

## 4th Annual Report



**OPTICON**

***Optical Infrared Co-ordination Network for Astronomy***

**Integrating Activity**

implemented as

**Integrated Infrastructure Initiative**

Contract number: *RII3-CT-2004-001566*

Project Co-ordinator: *The Chancellor, Masters and Scholars of the University of Cambridge.*

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Project website: *[www.astro-Opticon.org](http://www.astro-Opticon.org)*

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# A. ACTIVITY REPORT

## 1. PROGRESS REPORT

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## ANNEXES

## **1. Progress report**

### **1.1 Summary of the activities and major achievements**

After four years Opticon activities continue to deliver at the optimistic upper limits of ambition. This year included our Mid Term review, an opportunity for all the many and varied participants and activities to consider what has been achieved. The process was rewarding and educational, allowing astronomers and engineers from all the (nearly) 80 laboratories involved to discover the range of success which has been delivered. The review report was pleasingly positive, highlighting considerable success, but also establishing continuing high standards and ambitions to which Opticon will aspire in future. These new challenges form the basis of the communities' ambitions for FP7.

In addition to the formal EC mid-term review, the Opticon executive and Project Office undertook our annual very detailed financial analysis of all activities, leading to some minor rebalancing to ensure optimum use of resources, and optimum value for previous investments.

The technical development activities, the JRAs, continue to deliver excellence, and exciting new opportunities for European astronomy. The biggest activity, JRA1, is developing aspects of adaptive optics technologies. These are being implemented on all of Europe's largest new astronomical telescopes, ESO's VLT, the Spanish GranteCan, and the Italy-German-US Large Binocular Telescope. The VLT has been in operation for several years: with these new technologies its accepted global leadership will continue. GTC and LBT are both coming into use at present, with their adaptive optics capabilities making them immediately world-leading. Adaptive optics technologies are extremely sophisticated, pushing the limits of real-time control, precision opto-mechanical systems. The delivered systems, illustrated in this report, are truly impressive achievements.

A particularly pleasing outcome is to see some of this technology, for large adaptive mirrors, developed under Opticon contract in industry, now winning orders to supply new US telescopes, ahead of domestic US industry. This spin-off, while always hard to predict in basic research, adds considerable value to this science investment.

In addition to this, the next developments in adaptive optics require laser-generated artificial 'guide' stars, and near perfect near single-photon detectors. Both these are under active development in Opticon. The laser guide stars exist, though adequate high-power affordable lasers are still a few years ahead. Present systems are being used on-sky, to deliver real experience, real science now, and improved next-generation system designs. All aspects of these are involved in Opticon, from technical developments (JRA1), real on-sky experience (MAD at VLT, WHT testbed), necessary improvements in observatory-wide control systems (N2), to improved detector developments (JRA2, JRA3), and new designs of focal plane instrumentation which can utilise the vastly improved information content delivered (JRA5, JRA6).

The other branch of innovative technology under community development is interferometry, which can deliver the highest-possible spatial resolution information. JRA4 has helped develop the set of concepts for next-generation instrumentation in interferometry, specifically



for the VLTI facility. Those developments have this year led to concept selection, leading on to detailed design, construction, and application, delivering better science. Correspondingly, through associated JRA network activities, the essential software tools to support science users are being developed, and new user communities are being trained in their use.

More generally, improved technologies for the instrumentation which records the photons, and allows the science, is the focus of both strategic planning (Key Technologies Network), prototyping to prove viability (JRA5 – Smart Focal Planes) and direct developments (eg JRA6). Many of these activities involve small high-tech industrial partners, and lead to future development opportunities outside astronomy. Some of the new materials – light sensitive polymers – developed and tested into real systems in JRA6 are simply revolutionary, and beyond imagination a few years ago. On sky tests of some of the new fast detectors and simple but clever instrument concepts developed in Opticon – eg, the ‘Lucky Imaging’ concept has delivered dramatic results. The movie of the pulsar in the Crab nebula is dramatic, while the delivery of the highest resolution blue image ever taken from the ground is quite an achievement (JRA3).

In terms of community development, the science-subject specific networks devoted to high time resolution astrophysics and to UltraViolet astrophysics have both completed their strategic plans, presented them to the community through large public conferences, and published corresponding books. The forward planning European Extremely Large Telescope Science Case development similarly has delivered community-wide involvement and support, so that there is now a joint Opticon-ESO project science team. This ensures wide European support for and ownership of this project. At a more technical but no less important level, Opticon supports European participation in a global programme to define software standards for future data processing systems (FASE).

The general success of these networking activities has led by example to establishment of a similar community (EAST) in solar astronomy, with plans for future partnership inside Opticon.

The Opticon access programme is dramatically successful, but we have even higher ambitions. Activities to date are a huge success, not least in establishing for the first time that European astronomy exists at a Europe-wide level, with genuine open science-based access and requisite support. Nonetheless, we have begun discussions with our eastern European colleagues, and the relevant coordinating bodies (eg SREAC, the South Regional European Astronomical Community ) to try to do even better. We are also working with telescope owners and operators to develop viable long-term strategies for European astronomy which is affordable, science-based, and open to all.

## 1.2 NA1: Management Activity

<b>Participant number</b>	1a	2b	
<b>Participant short name</b>	UCAM - IoA	STFC - UKATC	<b>Total</b>
<b>Person-months</b>	18	15	<b>33</b>

As explained in previous reports, OPTICON operates a distributed management structure. The Co-ordinator (G.Gilmore) is based at the Institute for Astronomy, Cambridge where he is supported by administrative and financial staff. The Project Scientist (J.Davies) and his assistant are based at the UKATC, Edinburgh, while the Trans-National Access Office operates from the IAC in La Laguna, Tenerife. In addition the larger JRA and networks have their own local activity leaders with responsibility to ensure progress according to the defined work plan and deliverables. Tasks are clearly divided between these various elements and regular e-mail and telephone communications, supplemented by face to face meetings as needed, have ensured the smooth running of the project.

The primary management activity remains the co-ordination of the six JRA projects, the six complex and multi-activity networking activities, and the trans-national access programme which includes every modern 2-4m optical-infrared telescope worldwide with even partial European ownership, as well as several more specialist facilities for solar astronomy. These activities are spread across 47 full OPTICON partners, and involving some 70 laboratories and organisations.

Two management meetings were held, one of the OPTICON board, the overarching management body, and one of the smaller executive committee. The Board meeting was combined with the EC mandated Mid-term review, the outcome of which was extremely positive. These meetings are detailed in the table below, with links to the minutes. Notable achievements included a full revision of the finance projections, some re-alignments carried out by the executive, and an agreed development strategy defined at the board meeting. The project office, distributed between contractors nos. 1 and 2, provided support for these meetings, produced and circulated minutes, and made available considerable documentation for the Mid-term review.

The technical sections of the 3<sup>rd</sup> annual report were collated at Edinburgh and delivered in a timely manner to the Co-ordinator. The Co-ordinator and his support team was then responsible for the integration of the financial information and the final delivery of the report. As in the previous year, this time consuming process included resolving open questions, correcting errors and misunderstandings, obtaining adequate audit certificates and minor corrections of the report. Once the final issues were resolved, the management team calculated the correct payments to be made to each contractor, including, for multi-activity and multi-lab partners, supplying them with detailed information on how the amounts were calculated and how the delivered funds were to be allocated between work packages within each contractor.

OPTICON was represented at the 2007 JENAM meeting in Armenia. A summary of OPTICON progress was presented by the Project Scientist at the half day session on

European Activities organised by the EAS. In addition some posters were displayed and most of the remainder of our publicity material (handouts, pens etc) was distributed. Special efforts were made to promote the trans-national access programme at this meeting, which included many astronomers from central Europe.

The Project Scientist participated in meetings of N2, N3.1, N3.2, N5, N6.1, JRA-1 and JRA-5. Planned involvement in an N6.3 meeting was cancelled due to bereavement. He was in regular telephone and e-mail contact with the leaders of all the other activities as required.

The project office continued to maintain the OPTICON web site. The series of paper handouts explaining Opticon activity were revised and distributed at appropriate events, such as the JENAM meeting mentioned above. Articles on progress with the project have appeared regularly in the newsletter of the European Astronomical Society.

The Project Scientist and Scientific Coordinator were in frequent contact with their counterparts in RadioNet, and AstroNet. They both participated in meetings of the I3NET forum to share information and discuss common issues. The project Scientist and the Co-ordinator attended the AstroNet symposium in Potiers, France in January 2007.

### **Milestones and Deliverables**

<b>Deliverable/ Milestone No</b>	<b>Name of deliverable/milestone</b>	<b>Work- package /Task No</b>	<b>Lead Contractor(s)</b>	<b>Planned (in months)</b>	<b>Achieved (in months)</b>
M14	Executive meeting. Venice	WP1	UCAM, STFC	39	40
M15	Complete Annual report to EU	WP1	UCAM, STFC	39	40
M18	OPTICON Board meeting. Autumn	WP1	UCAM, STFC	45	46

### **Meetings and Workshops**

<b>Date</b>	<b>Title/subject of meeting</b>	<b>Location</b>	<b>Number of attendees</b>	<b>Website address</b>
5 March 2007	7th Executive Committee meeting	Venice, I	15	<a href="http://www.astro-Opticon.org/agendas_minutes/Final-mins-exec8.pdf">http://www.astro-Opticon.org/agendas_minutes/Final-mins-exec8.pdf</a>
10-11 September 2007	4 <sup>th</sup> Board meeting	Corfu, Gr	30	<a href="http://www.astro-Opticon.org/mtr.html">http://www.astro-Opticon.org/mtr.html</a>

There has been no general meeting of the entire consortium. It is too large, and its activities too diverse, to make such a meeting productive. Central N1 management funds Board member travel when no alternative exists.

No specific consortium management problems have been encountered

### 1.3 NETWORKING ACTIVITIES (other than Management)

#### 1.3.1 NA2: Coordination and Integration of ENO facilities

##### Contractors:

Participant number	Participant short name	Department/faculty/institute/laboratory involved. SHORT NAME	Person-months
7	IAC	IAC	40 (6)
2	STFC	ING: WHT/INT	6 (0)
27	IOA-KUL	IOA-KUL	0 <sup>1</sup>
8	INAF	TNG	0 <sup>4</sup>
25	THEMIS	THEMIS	0 <sup>4</sup>
43	IFAE	IFAE	0 <sup>4</sup>
17	KIS	KIS	0 <sup>4</sup>
20	RSAS	RSAS-ISP	0 <sup>4</sup>
22	Utrecht Univ	Utrecht University	0 <sup>4</sup>
13	NOTSA	NOT / NOTSA	0 <sup>4</sup>
24	Uni-Graz	IGAM	5 (4)
1	UCAM	CAV	0 <sup>4</sup>
4	ESO	ESO	0
3	ESA	ESO	0
15	RDS/RUB	RDS/RUB	0
12	NOVA	NOVA	0
6	INSU/CNRS	INSU/CNRS	0

##### *Other participants:*

- ✓ Laboratoire Universitaire d'Astrophysique de Nice (LUAN), France
- ✓ Jodrell Bank Observatory, United Kingdom

##### **Summary of Objectives and progress made:**

##### *WP1.: Co-ordination of scientific communities at ENO:*

##### *WP1.1.: Dissemination of good practices:*

One general NA2 meeting was organized in 2007, after the OPTICON mid term review held in Corfu. Assessment was focussed in main achievements and plans for 2008.

##### *WP1.2.: Laser Traffic Control System (LTCS) for ORM:*

All the deliverables expected under this work package have already been accomplished. The

LTCS system is installed on the WHT telescope and is fully operational.

***WP2.: Site Characterisation of the Canary Islands' Observatories:***

Continuous site-testing campaign of night-time at the Degollada del Hoyo Verde at the ORM based on seeing and meteorological characterization has continued. An automatic software to obtain the atmospheric turbulence profiles in quasi real time from G-SCIDAR observations has been developed. This software has been successfully tested and it will be installed at the Cute-SCIDAR instrument installed in the Roque de los Muchachos observatory (ORM). DIMMA installation has been completed at both observatories (ORM & OT) and efforts are being focussed in its calibration.

The working group has participated in the main forums related to the separately funded E-ELT Design Study and the organization of SUCOSIP in November 2007.

***WP3.: Joint Information System and Transfer of Knowledge:***

***WP3.1.: Development of a Joint Information System for Solar Physics (JIS):***

The main efforts have been focussed in the promotion of this tool among the international solar physics community at appropriate forums/meetings. As a consequence, the Joint Information System has registered a considerable number of solar physicists across Europe, and has become widely used.

***WP3.2.: Co-ordinated actions on transfer of knowledge and public outreach:***

One meeting was organized in 2007. Among the ongoing actions we emphasize the following ones: publishing of 16 short audiovisuals for the promotion of facilities at ORM & OT, collection of the material for a joint Public Outreach Website in order to improve the exchange and distribution of information related to the ENO facilities, Participation in the 2007 Communicating Astronomy Conference (Athens 2007), Open Days at ORM & OT during the summer, the installation of permanent panels at Roque de Los Muchachos Observatory and the edition of a new digital publication (*astroNewsletter*) available in English and Spanish.

## **WP1: Co-ordination of scientific communities at ENO**

### **WP 1.1 Dissemination of good practices:**

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The assessment of the different work packages has continued being addressed by the group in 2007, with particular attention to the ongoing activities on Public Outreach, the promotion of the Joint Information System for Solar Physics (JIS), the assessment of the different Site Testing actions at both observatories and the latest news on the Laser Traffic Control System (LTCS) developments.

Spanish funding opportunities were identified at the request of the Public Outreach working group to support additional actions for which EC funding was considered as not enough. Special efforts were focussed in the preparation of a proposal that was finally approved. With this complementary support, the Public Outreach working group plans to carry out an additional set of actions that would not be affordable with solely OPTICON support.



VI NA2-ENO meeting. Tenerife September 2006

The last NA2-ENO meeting took place in Tenerife (September 2006). In May 2007 a progress report on the ongoing activities was distributed to the members of the working group, postponing the VII NA2-ENO meeting until winter 2007.

In September 2007 the OPTICON Mid Term review meeting took place in Corfu, Greece. The progress made under NA2 was presented. The EC auditors remarked positively on the efforts for interdisciplinary collaborations and the excellent public outreach activities (audit report available on <http://www.astro-Opticon.org/download/Opticon-mtr-mk-0907-final.pdf>). Likewise, during this meeting the plans/visions for FP7 were described. In the particular case of plans beyond NA2, the establishment of a network on the topic of Site Characterization (already proposed in the OPTICON planning meeting, Edinburgh June 2006) was mentioned. The proposed network: Exchange of Best practices for Site Characterization was evaluated by the OPTICON Executive Committee and included in the OPTICON proposal.

Last November, the SUCOSIP meeting was held in Madrid, where all the progress under the NA2-Site Characterization work packages was presented.

## WP1.2.: Laser Traffic Control System (LTCS) for ORM .:

All the deliverables expected under this work package have been already accomplished. The LTCS system is installed on the WHT telescope and is fully operational.

The system has been tested successfully during daytime, firstly by simulating the telescopes movements, and later by using the WHT and INT telescopes. In both cases the system was monitoring the potential for interference of the laser to the other telescopes and it was shuttering it correctly to protect the observations on site.

The LTCS has also been tested during night time, during the commissioning nights of the GLAS. During these nights the LTCS system was operating and it was protecting the observations of the other telescopes that already provide their pointing information.

There was also one case where the LTCS shuttered the laser to protect an observation happening on the INT telescope.

This OPTICON-funded development has now been implemented in a new generation laser traffic control system that will be put in use at a number of observatories around the world.

From the results of the tests done with INT and MAGIC telescopes, it became clear that the WHT laser can interfere with observations of other telescopes and affect their results. This stressed the importance of the Laser Traffic Control System.

Finally the LTCS is designed to support a site with more than one laser operating simultaneously, and if in the future another telescope will be equipped with a laser, it will be easy to be integrated in the existing system.

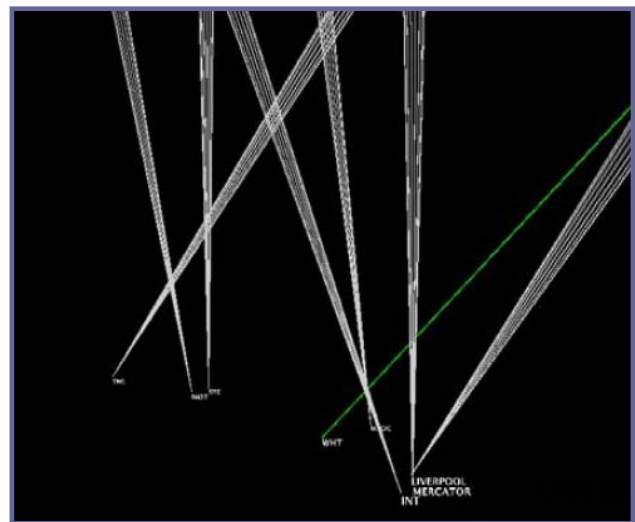
The complete final report can be downloaded as paper 06/07 at the following Web address:  
[http://www.otri.iac.es/na2/ver\\_meeting.php?id=27&id\\_proyecto=1](http://www.otri.iac.es/na2/ver_meeting.php?id=27&id_proyecto=1)

## WP2: Site Characterisation of the Canary Islands' Observatories

Following the internal work plan established for the Site Characterization activity, several action lines are being carried out by the different working groups, focusing in the achievement of the milestones and deliverables established for the first stage of the Project.

Observatories				Lasers				
		URL	OVR	Laser	Laser State		Shutter Event (site,duration)	Predictions (number, site list)
		State	State	Impacted	WHT	Shuttered	INT , 1043 (secs)	None
Collisions								
		INT	OK	NO	YES			
		NOT	OK	NO	NO			
		WHT	OK	NO	NO			
		Laser		Scope	Started	Ends	Priority	
		WHT	INT	15:42:40	16:00:30	SCOPE		
Laser "ON" Preview (Predictions & Collisions)								
		Laser		Scope	Starts	Ends	Priority	
Heartbeat Status :				Collector		GA_Engine		Status_Mgr

LTCS Web interface: status & alarm summary page



## WP2.1 Co-ordination of night-time seeing measurements with DIMMs:

A continuous optical and meteorological site-testing campaign has been performed during the first semester of 2007 with the IAC DIMM at the Degollada del Hoyo Verde (ORM). In July 2007 the IAC DIMM was dismounted and installed on ground near the JKT site in order to start a calibration campaign with the MASS-DIMM, a hybrid instrument consisting on a MASS (Multi Aperture Scintillation Sensor) and a DIMM. The MASS-DIMM will work for the E-ELT site selection (FP6 project) and will provide atmospheric turbulence parameters including integrated seeing.

Night time seeing and meteorological data and statistics are now also available from the project web page <http://www.iac.es/project/sitestesting/site.html> under “Statistics and Data”. Meteorological data in real time are also provided from the project webpage <http://www.iac.es/project/sitestesting/onlinepro/wstation.html> (Fig1).



Fig 1

Main conclusions with regard to the seeing are the following:

- The DHV delivers the excellent optical conditions obtained at other sites of the Observatory in past years.
- Seeing distribution obtained in some months shows a peak function that is associated to a drastic change of the wind regimes. The main symptoms are the large standard deviation of the mean values and therefore the large difference between the mean and the median seeing values obtained in this month.

Statistical results obtained at the DHV in 2007 (includes January, February, March and June) show mean and median seeing values of order of 0.81'' and 0.65'' respectively. (No data between April-May: new staff recruitment procedure).

### DIMMA

The DIMMA installation at the ORM at Las Lajitas started in June 2006. The DIMMA has been mounted on a 5m tower avoiding the surface layer effect on the seeing measurements. Next to the tower we have installed an Automatic Weather Station consisting of a Data Acquisition Unit (DAU) and a lattice tower equipped with standard meteorological sensors. The weather parameters will be stored for climatological analysis and will be also provided on-line for telescope operation control. The DIMMA area has been fenced in order to guarantee the security of the station.

In Figure 2 (top) we show the DIMMA station at the ORM. Figure 2 (bottom) shows the DIMMA interface. There are two web cameras installed at the meteorological mast and the other one inside the dome. The centre window shows the seeing profiles along the night.

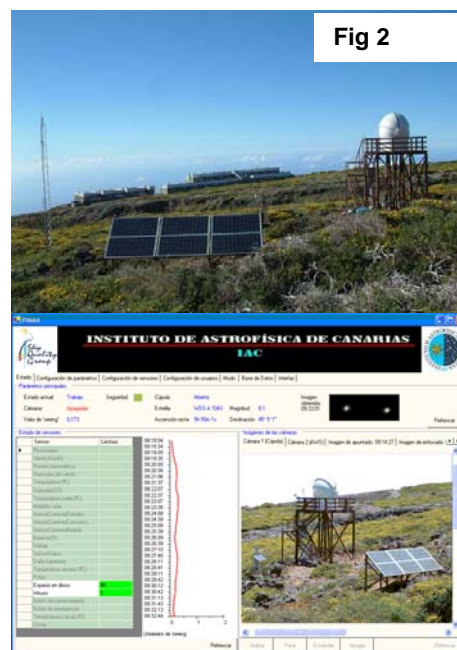
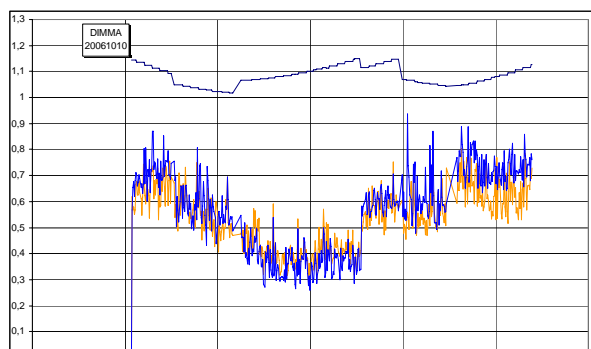


Fig 2



Sensor and operation status information, observed stars, statistical seeing values, etc. are also included.



**Fig 3** Example of the seeing profiles (fwhm and fwhmt) provided by the ORM DIMMA.

The ORM DIMMS could have been operative in spring 2007, but more batteries and solar panels have been required for fully automatic operation. We have bought this additional equipment which will be provided in January 2008.

### WP2.3 Joint actions for meteorology, dust, extinction and Sky Background:

ING, NOT, TNG, MAGIC, and IAC weather stations at the ORM and IAC, GONG and BRT weather stations at the OT remain in operation providing continuous meteorological data. Likewise, the new meteorological station of Mercator put in operation during 2006 has joined to the common platform which provides direct access to current weather conditions (real time) at the Canary Islands Observatories ([http://www.otri.iac.es/na2/weather\\_conditions.html](http://www.otri.iac.es/na2/weather_conditions.html)). A total of nine weather stations are included in this new website.



**Fig 3:** Joint meteor webs at both observatories

### *Local Dust:*

The airborne particle counter (Fig4) was installed at the NOT telescope and it is operating with a sample rate of 1 data set every minute. Main properties:

6 channels: 0,3 – 0,5 -1 –3 – 5- 10 $\mu$ m

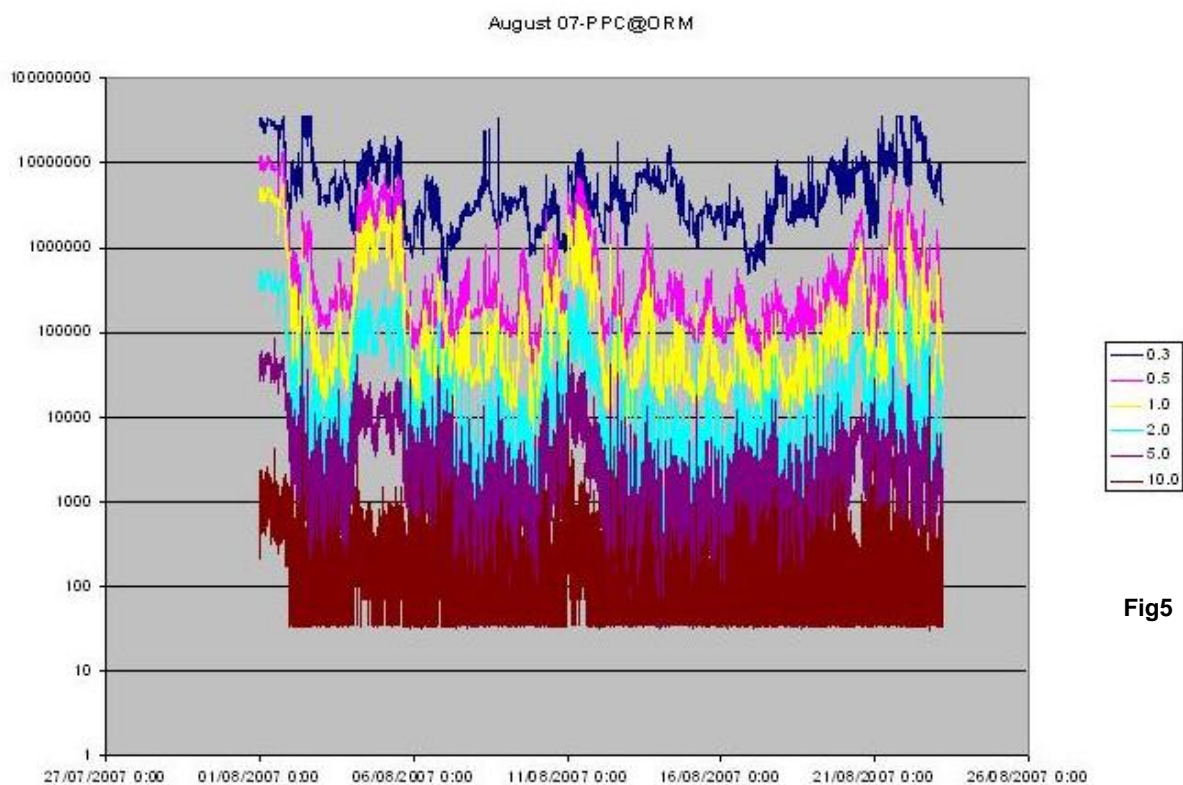
Light source: laser diode

The sensitivity of an airborne particle counter is determined by the size of the smallest particle the unit can detect. This one has sensitivity of 0,3microns with 95% percentage.

In Fig.5 we show the number of particles on six channels measured at the ORM in August 2007.



**Fig 4: Airborne particle counter at NOT telescope**



The IAC dust meter is similar to the Airborne Aerosols Counter at Paranal <http://www.eso.org/gen-fac/pubs/astclim/paranal/aerosol/>. It has been calibrated against the TNG dust counter. (Cross calibration between particle counters operating at the Roque de los Muchachos Observatory. TNG Newsletter A.M. Varela & A. Ghedina. April 2005). It has been installed at the NOT service area since February 2007 and has a sample rate of 1 data every minute.

New software has been prepared by the NOT staff in order to gather and provide data in real time. Access to data is via <http://www.not.iac.es/weather/dust.php> (still not public).

#### **Atmospheric extinction:**

The atmospheric extinction can be measured by using in situ techniques (airborne particle counters, telescopes, etc) or satellite data. However the usefulness of satellite data for characterizing the aerosol content above the atmosphere of an astronomical observatory is determined by the correlation between the aerosol index (or aerosol optical thickness) and the atmospheric extinction.

In previous work we concluded that aerosol parameters provided by TOMS was not an adequate tool for site characterization due to its low resolution and inadequate channels. This led to a joint action started on April 2006 between the Sky Quality Group of the IAC and the Padova University (Dr. S. Ortolani and C. Bertolin).

This project consists of exploring the usefulness of data provided by different spectrographs onboard NASA and ESA satellites with better spatial and temporal resolutions than TOMS and centered on channels of astronomical interest. Data analysis will be complemented with those provided by "in situ" instruments (telescopes and particle counters). We conclude that for the moment, AI and AOD provided by NASA satellites are not an useful tool for aerosol site characterization and in situ data are required, in particular in those astronomical sites with abrupt orography (ORM, Mauna Kea or San Pedro M'artir). Spatial resolution of the order of the Observatory area will be required in these cases.

In addition, from this satellite data it is possible to go back and examine the cloud coverage, the climatic trend or the atmospheric turbulence from troposphere winds. The main problem in using these values is their interpretation and their quantitative calibration. (see SPIE Florence September 2007).

#### **Meteorological common database:**

All ORM meteorological data are all provided in real time in a common webpage. A future action is to agree with other institutions involved how to store all data in a common database.

## **WP 2.4 Joint actions for Measurement of turbulence and wind vertical profiles.**

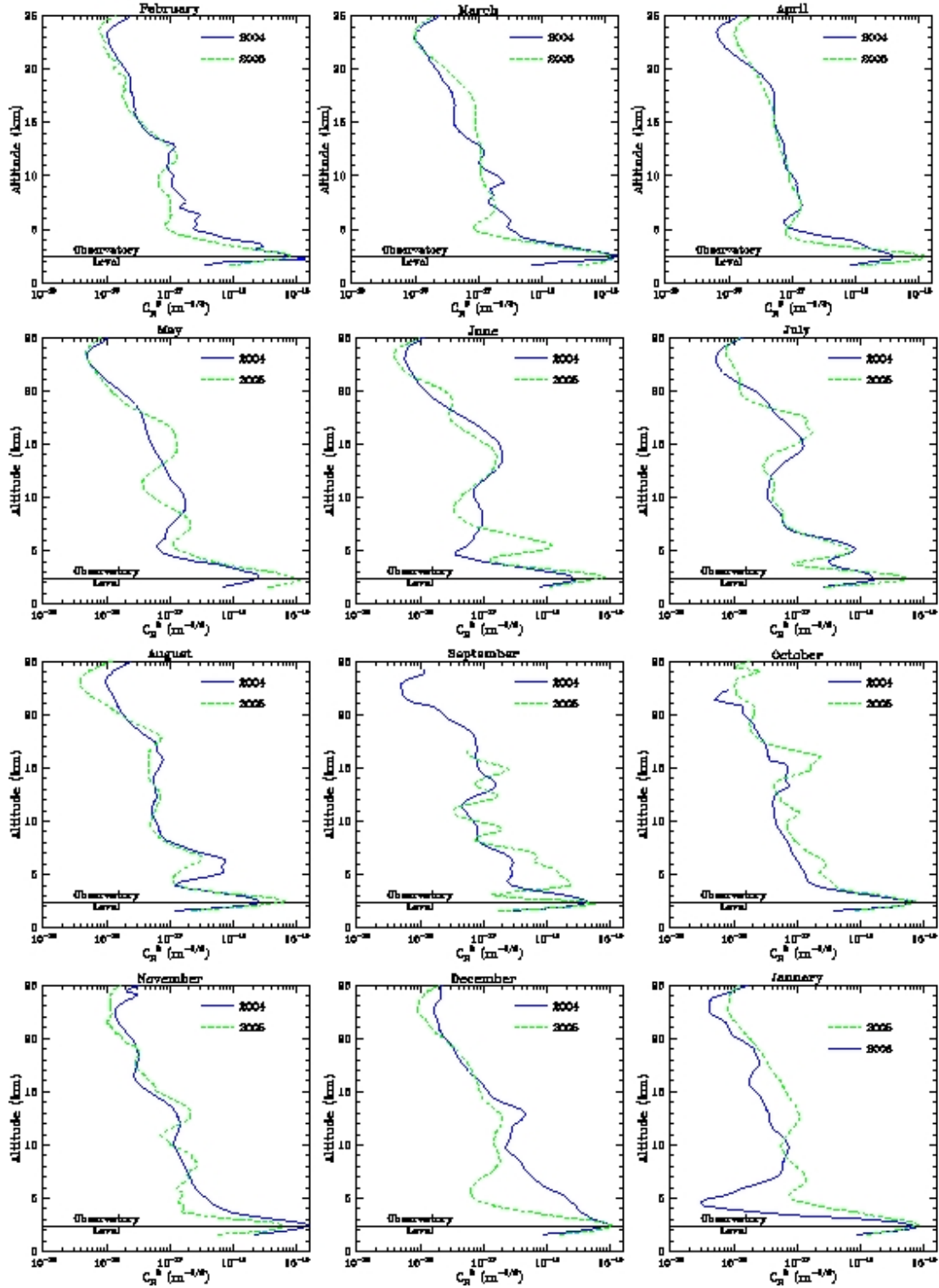
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Participants in this work package have developed software to obtain the atmospheric turbulence profiles in quasi real time from G-SCIDAR observations. This software has been successfully tested and it will be installed at the Cute-SCIDAR instrument installed in the Roque de los Muchachos observatory (ORM) next January 2008. This is the first software package anywhere allowing the retrieval of the information on the turbulence structure from G-SCIDAR observations on line.

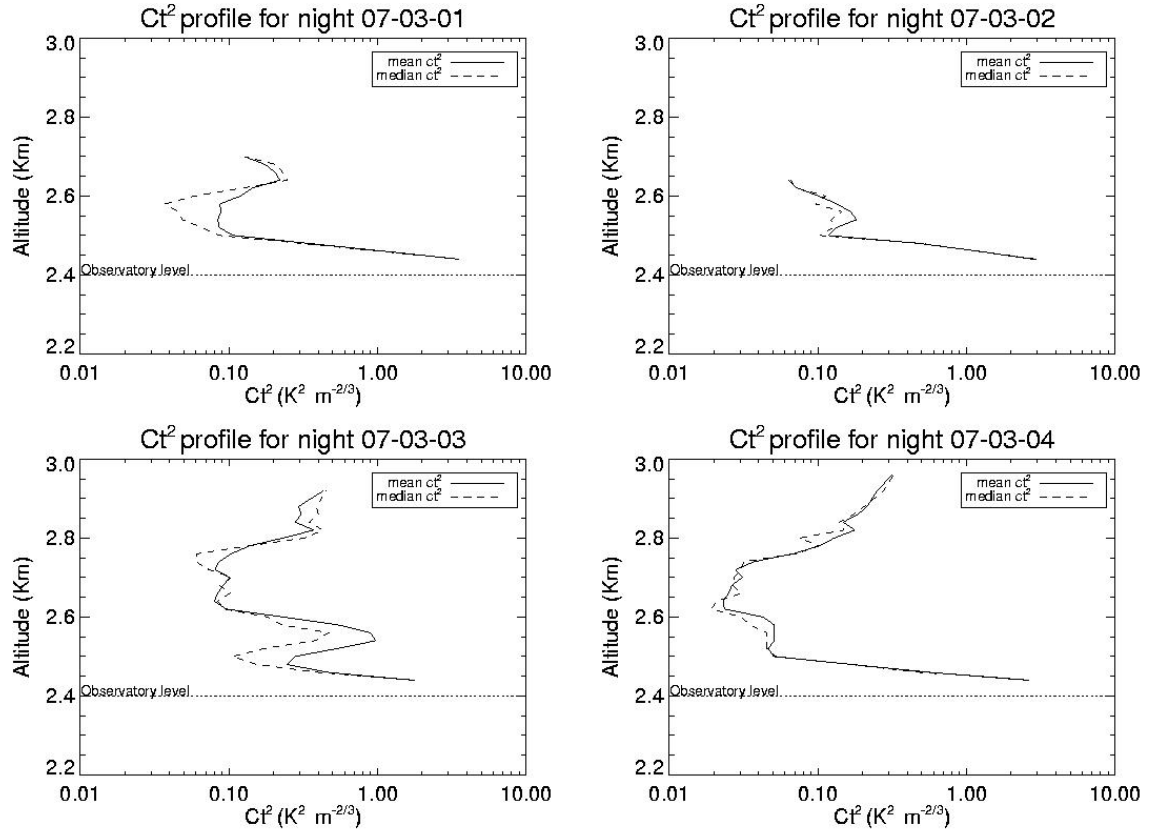
We have presented the statistical seasonal evolution of the optical-turbulence profiles (see Fig. 6) at the Roque de los Muchachos observatory (ORM) in the SPIE meeting Remote Sensing Europe, held in Florence last September (García-Lorenzo, Fuensalida, & Rodríguez-Hernández, 2007, SPIE, 6747, in print, “Statistical turbulence vertical profiles at the Roque de los Muchachos Observatory and Teide Observatory”). Statistical results are based on 68 nights in 2004 and 38 nights in 2005 of G-SCIDAR measurements at the ORM. The comparison of the monthly CN2 profiles along 2004 and 2005 at this site reveals the presence of stable turbulence layers in the atmospheric structure, showing an evolution in altitude and time in a slightly different behaviour during 2004 and 2005. The statistical study performed reveals the excellent conditions at the ORM for the implementation of adaptive optics systems.

The hybrid instrument (G-SCIDAR plus Shack-Hartmann) is monitoring the turbulence structure at the Teide observatory (OT). We are testing the Shack-Hartmann branch and we are improving the software to retrieve the turbulence information from Shack-Hartmann data. We have presented the instrument in the SPIE meeting Remote Sensing Europe, held in Florence last September (Rodríguez-Hernández, Fuensalida, García-Lorenzo, Delgado, Hernández, Hoegemann, Vázquez Ramió 2007, SPIE, 6747, in print, “The hybrid Shack-Hartmann/G-SCIDAR instrument”)

A SODAR (Sonic Detection And Ranging) instrument was tentatively installed at the Teide Observatory in order to check automatically the lower layers of the atmosphere. We started a package of activities tending to evaluate the characteristics of SODAR technique in calibration with G-SCIDAR measurements. The preliminary results of such cross-comparison were presented at the SPIE meeting Remote Sensing Europe, held in Florence last September (del la Nuez, García-Lorenzo, Fuensalida, & Rodríguez-Hernández 2007, SPIE, 6747, in print, “Atmospheric turbulence profiling at the Teide observatory: comparison and calibration of SODAR and SCIDAR measurements”). Figure 7 shows the statistical temperature profiles at the Teide observatory.



**Fig 6:** Monthly average profiles of CN2 for 2004 (solid black line) and 2005 (dashed green line) obtained from G-SCIDAR measurements at the ORM. The horizontal axis represents the CN2 strength in logarithmic scale in units of  $m^{-2/3}$ . The vertical axis corresponds to the altitude above the sea level. The horizontal line indicates the observatory altitude (2400 meters). Dome seeing was removed from the individual profiles following the procedure proposed in Fuensalida, García-Lorenzo & Hoegemann, SPIE, 6747, in press.



**Fig 7:** Daily statistical profiles of the structure constant of temperature ( $CT_2$ ) for four consecutive nights at the Teide observatory during March 2007. Solid line corresponds to the mean and dashed line is the median of individual  $CT_2$  profiles. The vertical axis corresponds to the altitude above the site level. The horizontal dotted line indicates the observatory altitude (2400 meters). The horizontal axis represents the  $CT_2$  in logarithmic scale.

## **WP 2.5 Distribution and discussion of results and participation at the scientific forums.**

Representatives of the working group have participated in the following forums in the last months of 2006 and first four-month period of 2007:

<b>Name of Meeting</b>	<b>Date and Location</b>	<b>Web address</b>
European ELT - WP12000 Progress Meeting	Marseille , 30 Nov. 2006,	<a href="http://www.otri.iac.es/na2/">http://www.otri.iac.es/na2/</a>
OSC meeting	La Palma 2007	<a href="http://www.otri.iac.es/na2/">http://www.otri.iac.es/na2/</a>
Workshop on Astronomical Site Evaluation	S.Pedro Mártir, México 13-15 March 2007	<ul style="list-style-type: none"><li>• Recent results at the Canarian Observatories. C. Muñoz-Tuñón et al. WP2.1</li><li>• Site Selection for the european ELT. C. Muñoz-Tuñón, Vernin &amp; Sarazin. WP.5</li><li>• In situ Calibration using Satellite data results. A.M. Varela et al. WP.2.3</li></ul> <a href="http://www.otri.iac.es/na2/">http://www.otri.iac.es/na2/</a>
Seeing Symposium	Hawaii, 20-22 March 2007	<ul style="list-style-type: none"><li>• Climatology at the Roque de los Muchachos Observatory: tropospheric and ground level regimes. A.M. Varela &amp; C. Muñoz-Tuñón. WP2.3</li><li>• DIMMA: the first unmanned Differential Image Motion Monitor. A.M. Varela et al. WP2.1</li><li>• On the Use of Satellite Data for Atmospheric Extinction Studies. A.M. Varela et al. WP.2.3</li></ul> <a href="http://www.otri.iac.es/na2/">http://www.otri.iac.es/na2/</a>
Telescope and instrumentation robotization at Dome C	Puerto Santiago, Tenerife, 26-29 March 2007	DIMMA: a completely unmanned Differential Image Motion Monitor. A.M. Varela et al. <a href="http://www.otri.iac.es/na2/">http://www.otri.iac.es/na2/</a>
SUCOSIP	26 November 07 Madrid	<a href="http://www.otri.iac.es/na2/">http://www.otri.iac.es/na2/</a>
SPIE: Remote Sensing	17-20 September, Florence	<a href="http://www.otri.iac.es/na2/">http://www.otri.iac.es/na2/</a>



## WP3: Joint Information System and Transfer of Knowledge

### WP3.1.: Development of a Joint Information System for Solar Physics (JIS):

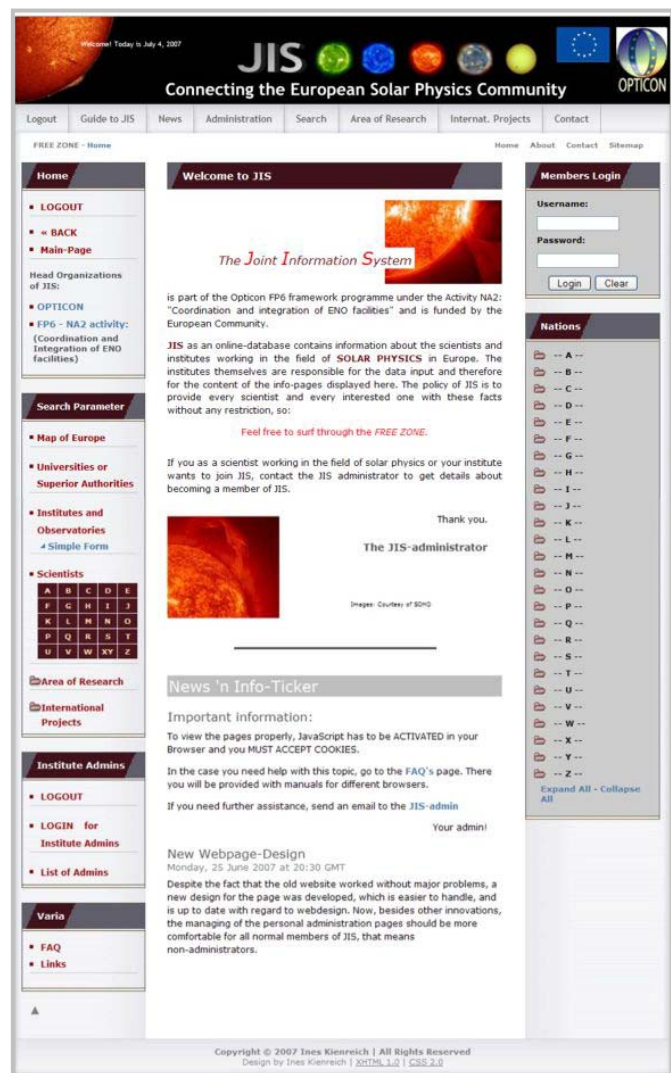
The Joint Information System (JIS) is a fully operational computing tool, which is a combination of a database and interactive web pages, reachable under the web address <http://www.solarJIS.com>. Over the last year the working group has concentrated efforts in promotional and maintenance activities of this tool. Future promotional events/seminars are expected in France, Austria and Germany.

JIS as an online-database contains information about the scientists and institutes working in the field of SOLAR PHYSICS in Europe. The institutes themselves are responsible for the data input and therefore for the content of the info-pages displayed here. The policy of JIS is to provide every scientist and everyone interested with these facts without any restriction.

It should ease the life of a scientist, because he/she doesn't need to search the internet any more to find other scientists/institutes working in a special field of work. He/she simply logs into the page and can find all information he/she needs.

During 2007 the following documents have been updated or elaborated:

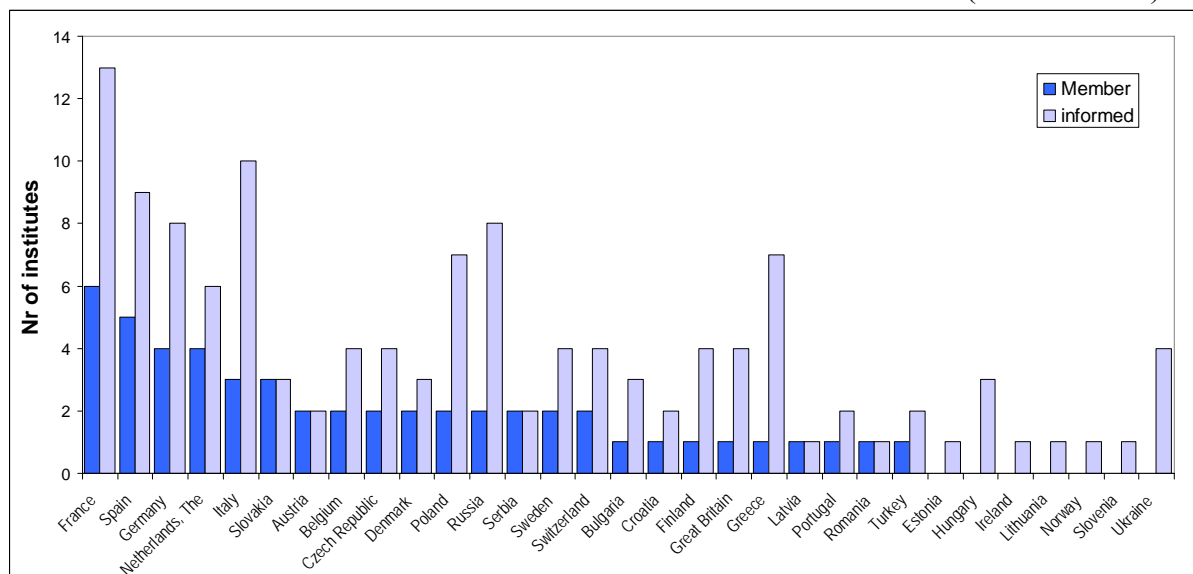
- Guide for Administrators: contains information for handling the data input
- Duties of an Administrator
- Questionnaire for institutes/observatories joining JIS:



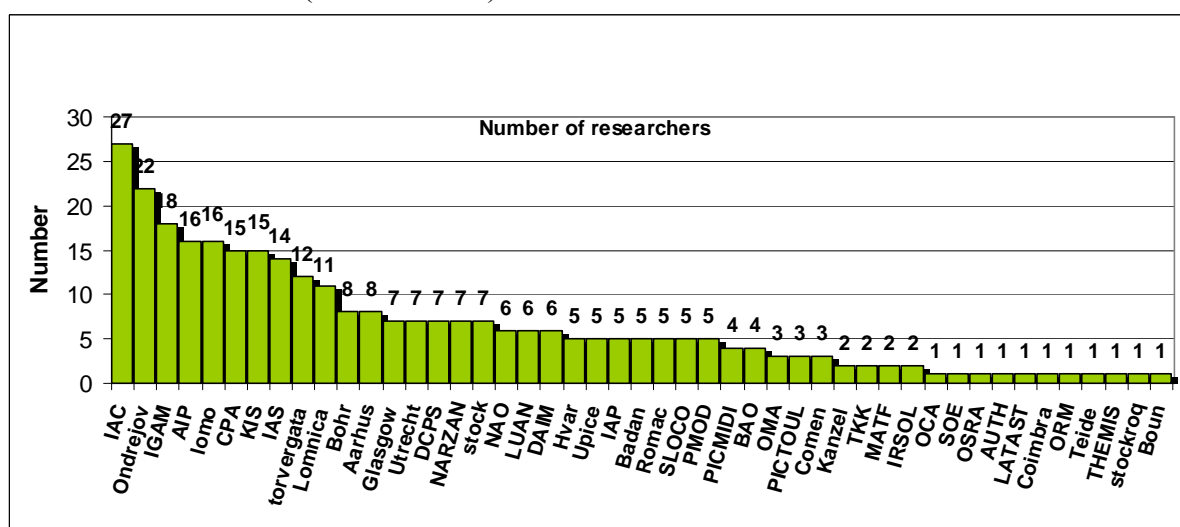
New layout of the JIS Website



A total of 125 institutions have been properly notified about the JIS tool and how to proceed to register their institutions and researchers. As a result of this promotional action a total of 57 institutions from 25 different countries have been included in our database (see next table)



Around 306 researchers have been already registered from 47 different institutes/observatories (see next table).



### WP3.2.: Co-ordinated actions on transfer of knowledge and public outreach:

Two coordination meetings have been organized over the last year (November 2006 and March 2007).

Among the ongoing actions we emphasize the following ones: reinforcement of the Public Outreach Website, organization of Open Days at ORM & OT together with the International Heliophysics Year 2007 (on June the 10th), Airport touring exhibition, distribution of the Audiovisual of the Astronomical Observatories in the Canary Islands and filming of specific audiovisuals for each facility.



VI Public Outreach coordination meeting

During the Starlight 2007 Conference, the Spanish representative of the UNAWE2 International Initiative and A. Sosa, as representative of the Public Outreach WG, organized a meeting to foster the exchange of astronomical outreach material and to promote a durable collaboration between both initiatives.

A pilot activity consisting of several lesson plans for children, teenagers and aged will be carried out in different secondary schools and associations of the Canary Islands. The class activities will be followed by a guided visit to the Canary Islands' astronomical observatories and Planetariums.



Poster presented at the Starlight Conference. La Palma (April 2007)

### Public Outreach Website: [www.eno.iac.es](http://www.eno.iac.es)

New sections for the joint ENO Website are being implemented, including new promotional material, an online agenda as well as relevant news related to the Canary Islands' astronomical observatories.

As proposed by the working group, the website includes a detailed list of links to the different facilities of the Canary Islands' Astronomical Observatories. The idea is to keep this website quite independent of a daily maintenance.

Contents are available in Spanish and English. There are several sections that require special collaboration by members of the working groups: Highlights and science carried out at both observatories

## Audiovisual of the Astronomical observatories in the Canary Islands

The working group has already delivered an entertaining audiovisual science show of the ENO facilities, focussed on Science Communication for general public. The audiovisual is available in five languages (Spanish, English, Italian, German and French) and also can be downloaded through the Public Outreach Website.

Apart from the audiovisual, the DVD contains an "extra section" with detailed information about the facilities as well as an astro-gallery and the Sky Law documentary.



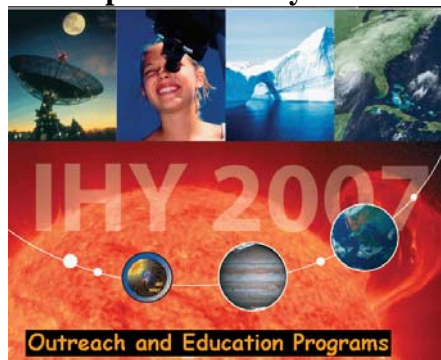
DVD Cover pages

## Short audiovisuals of the facilities installed at both observatories



As part of the new national proposal for outreach activities, members of the facilities at both observatories have been invited to participate in the production of shorts audiovisuals of their telescopes. The IAC has collected the contributions (script, proposed shots, etc.) provided by all the participants involved in this initiative. The filming has taken place during last summer and draft version of the audiovisual will be distributed shortly.

## 2007 Open-doors Day



During the last Public Outreach meeting it was agreed to organize the Open-doors Day at both observatories together with the proposed "Open Doors" Day at IHY3 Observatories and Museums (on June the 10th)

In this way, the Open-doors Day will concentrate part of the activity in the communication of solar

physics, although there will be also visits to several night-time telescopes.

As part of the promotional material financed by the Public Outreach working group, a "Solar Wind" DVD will be distributed, together with the aforementioned audiovisual of the observatories.



Solar Wind DVD covers

## Participation in the CAP 2007 Conference

3 To mark the 50th anniversary of the highly successful International Geophysical Year (IGY) of 1957, the International Heliophysical Year (IHY) began in February 2007 and runs to February 2009.



A poster was presented with the set of public outreach activities scheduled for 2007. Also some contacts were made with people of other institutions that are involved on public outreach activities.

A major theme of CAP2007 was the preparations for the International Year of Astronomy 2009.

The vast majority of IYA2009 activities will take place on several levels: locally, regionally and nationally. Several countries have already formed National Nodes to prepare activities for 2009. These Nodes are collaborations between professional and amateur astronomers, science centres and science communicators. The Spanish node has requested our collaboration to coordinate our activities and promotional material during 2008.

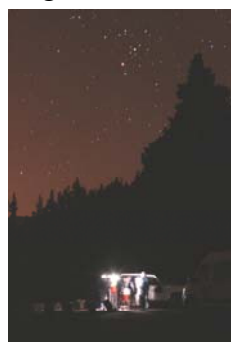


At the top: group photo; at the bottom: A. Sosa distributing the Public Outreach

astroNewsletter of the Observatories in the Canary Islands



This publication is available on the ENO website and contains news, articles and events related to the Observatories. The idea is to foster the dissemination of the science carried out at ENO among the general public. The astroNewsletter can be downloaded in Spanish and English. It can be easily distributed through mailing lists (no printed version is expected)



### Specifics visits to the Observatories

Last November a thematic visit to the Teide Observatory was organised for students of the UNED University studying astronomy. The visit was organized by M<sup>a</sup> Antonia Varela, who guided the group throughout their stay at the observatory. Several talks by telescope operators and astronomers as well as an introductory observation of the sky contributed to this pilot experience. This initiative takes part of the set of activities planned under the national approved proposal. The idea is to organize more thematic visits at both observatories during the first four-month

period of 2008.

### **Milestones and Deliverables achieved:**

<b>Deliverable/ Milestone No</b>	<b>Deliverable/Milestone name</b>	<b>Work-package /Task No.</b>	<b>Delivered by Contractor(s)</b>	<b>Planned (in months)</b>	<b>Achieved (in months)</b>
D1	Updated Progress report and revised roadmap	WP1.1	IAC	48	47
M1	Regular ENO meetings	WP1.1	IAC, IOA-KUL, INAF, NOTSA, THEMIS, IF AE, UCAM, Jodrell Bank.	45	47
D5	Final report	WP1.2	STFC	36	47
D1	Mounting automatic DIMM at OT	WP2.1	IAC	42	43
M1	Open-doors days at OT and ORM	WP3.2	IAC, STFC, INAF, IOA-KUL, IF AE	42 -43	42 -43
D1	New editions of outreach material	WP3.2	IAC, STFC, INAF, IOA-KUL, IF AE	40	40
D2	ENO website. Updated version	WP3.2	IAC, STFC, INAF, IOA-KUL, IF AE	47	47
D6	Participation in major events	WP3.2	IAC, STFC, INAF, IOA-KUL, IF AE	45	45

## Meetings and Workshops Table:

### WP1.1 Dissemination of good practices

Name of Meeting	Date and Location	Web address
Seventh ENO meeting	La Palma, 13 <sup>th</sup> December 2007	<a href="http://www.otri.iac.es/na2/">http://www.otri.iac.es/na2/</a>
OPTICON Mid term review	Corfu, 10 <sup>th</sup> September 2007	<a href="http://www.astro-Opticon.org/mtr.html">http://www.astro-Opticon.org/mtr.html</a>

### WP2 Site Characterisation of the Canaries Observatories

Name of Meeting	Date and Location	Web address
European ELT - WP12000 Progress Meeting	Marseille , 30 Nov. 2006,	<a href="http://www.otri.iac.es/na2/">http://www.otri.iac.es/na2/</a>
OSC meeting	La Palma 2007	<a href="http://www.otri.iac.es/na2/">http://www.otri.iac.es/na2/</a>
Workshop on Astronomical Site Evaluation	S.Pedro Mártir, México 13-15 March 2007	<a href="http://www.otri.iac.es/na2/">http://www.otri.iac.es/na2/</a>
Seeing Symposium	Hawaii, 20-22 March 2007	<a href="http://www.otri.iac.es/na2/">http://www.otri.iac.es/na2/</a>
Telescope and instrumentation robotization at Dome C	Puerto Santiago, Tenerife, 26-29 March 2007	<a href="http://www.otri.iac.es/na2/">http://www.otri.iac.es/na2/</a>
SUCOSIP	26 November 07 Madrid	<a href="http://www.otri.iac.es/na2/">http://www.otri.iac.es/na2/</a>
SPIE: Remote Sensing	17-20 September, Florence	<a href="http://www.otri.iac.es/na2/">http://www.otri.iac.es/na2/</a>

### WP3.1 Development of a Joint Information System (JIS) on European Solar Physics Facilities

Name of Meeting	Date and Location	Web address
JIS presentation	Bangalore Indian Institute of Astrophysics Dec 14 – Dec 16	<a href="http://www.solarjis.com">http://www.solarjis.com</a>
JIS presentation	Observatoire Pic du Midi, France, 29 Mai – 9 June	<a href="http://www.solarjis.com">http://www.solarjis.com</a>
JIS presentation	Zagreb, Univ. Geod. Fakultet, Cro, 29.-30. Nov.	<a href="http://www.joso-info.org">http://www.joso-info.org</a>
Central European Solar Physics Meeting,	Austria, Oct 10-12	<a href="http://www.solarjis.com">http://www.solarjis.com</a>

### WP 3.2 Co-ordinated actions on transfer of knowledge and public outreach

Name of Meeting	Date and Location	Web address
8 <sup>th</sup> Coordination meeting	Tenerife, 23 <sup>rd</sup> March, 2007	<a href="http://www.otri.iac.es/na2/">http://www.otri.iac.es/na2/</a>

### 1.3.2 NA3: Structuring European Astronomy

Participant number	2	2b	
Participant short name	STFC	UKATC	<b>Total</b>
Person-months	6	2	8

#### WP1: ELT

The objective of N3.1 is to develop the science case for an Extremely Large Telescope (ELT). The activity involves over 100 astronomers from around Europe.

In previous years we have held a series of meetings, including annual meetings on the ELT science case, the most recent of which was the Conference "Towards the European ELT", Marseilles, France, Nov 27-Dec 01 2006. Over 250 people attended the conference (see <http://www.elt2006.org>). Other highlights include production in 2005 of a science case brochure, documents and CDs to support ELT development in Europe.

In April 2006 the OPTICON science case activity merged with the newly-formed ESO ELT Science Working Group. The resulting joint SWG continues to provide close scientific guidance to the project, and the OPTICON ELT project scientist (I. Hook) is joint Chair of the SWG.

#### Progress

Since the 2006 annual report the following activities have been carried out or are underway.

The SWG has held four face-to-face meetings and two telecons in 2007. The Information about the SWG activities, meetings and resolutions can be found at <http://www-astro.physics.ox.ac.uk/~imh/ELT/SWG/>

The main activity in 2007 has been development of the Design Reference Mission, involving production of observing proposals that are used as input to simulations. The SWG has also had important discussions on instrument priorities. These have fed into the specifications of instrument phase-A design studies that are currently being launched by the E-ELT project office.

Some staff effort has been used to develop the 'Specsim' tool to ELT applications. This tool will be helpful in developing the ELT science case in the future by producing quantitative estimates of expected ELT instrument performance. The software models the operation of Integral Field Unit (IFU) spectrometers, generating synthetic data frames which approximate those which will be taken by actual instruments. These frames can then be used to illustrate and inform a range of activities, including refining instrument design, developing calibration strategies and the development and testing of data reduction pipelines. OPTICON-funded effort on the Specsim spectrometer simulator began in June 2007. An E-ELT simulation module has been developed which currently allows the user to produce synthetic white-light images of the instrument's field of view, using user-defined levels of adaptive optics correction. Additionally, a simple model of the E-ELT EAGLE spectrometer has been developed, which produces spectrometer images of the modelled field of view.

The SWG web site and the OPTICON ELT mailing list continue to be maintained. It is

planned to migrate the web pages to ESO within the next few months so that they are fully integrated into the E-ELT project pages.

Preparation for the next major community meeting has begun. This will be held in Vienna in September 2008, as a 2-day session connected with the JENAM.

In August 2007 we announced the opportunity to fund European astronomers to attend conferences & promote the ELT.

## **WP2: Network for UV Astronomy (NUVA)**

The Network for UltraViolet Astronomy objectives are to:

- Formulate and operate a UV astronomy Network
- Plan and execute a road mapping activity
- Exploratory analysis to define scientific requirements for the future and critical assessment of the publicly available information in various archives.

Progress towards the planned milestones in summarised below:

M1: An instrumentation meeting was held in Madrid 17-18 of November to discuss/summarize the characteristics of the instrumentation required from the science case articles. The article summarizing the results of the meeting is being prepared under the coordination of Norbert Kappellmann (IAAT, Tuebingen) and will be included in the White book of UV astronomy.

M2: The UV science case book is published: "Fundamental problems in astrophysics: Guideline for future UV observatories" by Astrophysics Space Science/Kluwer-Springer (Vol 302). This book represents the draft of the "White book" for UV astronomy.

M3 – The science case has been discussed during the "Joint Discussion" on "The Ultraviolet Universe: stars from birth to death" held at the IAU General Assembly in August 2006.

A summary of the main aspects discussed during the session is published in the proceeding of the IAU GA "The Ultraviolet Universe: stars from birth to death" and are published in the NUVA web.

M4: NUVA web site has been established ([www.ucm.es/info/nuva](http://www.ucm.es/info/nuva)). The web is handled by a contents manager so it works like an instrument for publication/interaction among the dispersed UV community.

M5: An international meeting about UV astronomy was held from May 28th to June 1<sup>st</sup> 2007 in the grounds of the UCM summer campus at El Escorial. The conference was entitled: "Space Astronomy: the UV window to the Universe". There were 117 attendees from all projects (agencies) developing UV instrumentation or UV missions.

The editing of the proceedings is ongoing (expected publication before June 2008).

## **WP3: High Time Resolution Astrophysics (HTRA)**

In early 2007, a Scientific Organising Committee (SOC) was formed to prepare the programme for the High Time Resolution Astrophysics Conference titled "The Universe at sub-second timescales" that was held in Royal Observatory Edinburgh Scotland from the 11th -13th September 2007. The SOC consisted of Martin Cullum (ESO), Vik Dhillon (Sheffield), Dainis Dravins (Lund), Tom Marsh (Warwick), Kieran O'Brien (ESO), Don Phelan (Chair,



NUI, Galway), Oliver Ryan (NUI, Galway), Oswald Seigmund (Berkeley), Andrew Shearer (NUI, Galway), and Barry Welsh (Berkeley). To meet our goals, the SOC selected ten major topics: X-ray Binaries and Cataclysmic Variables; Pulsars; Transients and Asteroseismology; Transits and Occultations; New Detectors and Instrumentation; and Future Topics.

Following a major publicity campaign of posters, emails and website updates, the papers started to flood in. These were reviewed by the SOC, and a programme was formally developed. Along with the submitted papers, the SOC selected invited speakers to attend, which completed an exciting program. Additional sponsorship from companies Hamamatsu, Andor and ICOS provided additional financial support and endorsement for the conference. The communication amongst the HTRA community building up to the conference was immense, with regular updates and discussions through mailing lists, and a HTRA "blog" on our website at <http://www.htra.ie>, providing a lively platform for discussion amongst the HTRA community.

Three days were devoted to these sessions and more than 60 delegates attended from over 13 countries, with 40 papers presented. Following a very successful conference, the feedback received from the delegates was very positive. Many photos of the event are available to download from our website.

In October 2007, the HTRA contributed volume was published by Springer as part of the Astrophysics & Space Science Library (ASSL) - "High Time Resolution Astrophysics", eds. D Phelan, O. Ryan. A. Shearer, Astrophysics and Space Science Library, Springer, 2007, ISBN-10: 1402065175. This represented the culmination of 18 months work, following the Galway Workshop in 2006.

In early November 2007, all the papers from the conference had been collected and reviewed by the editors of the proceedings. These were submitted to the American Institute of Physics and have been published - "The Universe at sub second timescales", eds. D Phelan, O. Ryan. A. Shearer, AIP Conference Proceedings, 984, ISBN 978-0-7354-0503-5.

As set out in last year's plan, the deliverables "D1- Publication of High Time Resolution Astrophysics Book as part of the Astrophysics & Space Science Library", "D2- International conference at the Royal Observatory Edinburgh, Scotland" and "D3- Publication of conference proceedings" have all been successfully achieved. This completes the programme of work that was set out for the HTRA Network in FP6.

#### **WP4: Astrophysical Virtual Observatory (AVO)**

This activity is complete.

#### **WP5: Key Technologies Network**

The major activities of the Key Technologies Network have focussed on developing teams and proposals towards future funding, in particular within the FP7 programmes. Support has been given to Workshop/Planning meetings focussed on the William Herschel Telescope (WHT) Laser Guide Star Adaptive Optics Test bed, Astrophotonics, Smart Focal Planes and Fast Detectors.

The initiative to develop the WHT as a test bed to enable on-sky verification of European

cooperative adaptive optics research programmes is seen as an important addition to the infrastructure available to European astronomy technology institutes, which will be very important in maintaining and enhancing competitiveness with the USA, especially in the field of laser guide stars and multi-object adaptive optics.

Developing photonics technologies for application in astronomy is seen to have potential to revolutionise the way instruments are built, especially for ELTs where conventional spectrometer designs result in severe challenges of mass and size. AstroPhotonica Europa is a partnership to exploit photonic principles for astronomy, using and enriching the existing research and industrial infrastructure. The primary goal is to make instruments for Extremely Large Telescopes affordable and practicable by exploiting photonic principles. Telecommunications has been the main driver for photonic innovation so far.

Although the potential of photonics has been demonstrated, much is still needed to develop practical, efficient devices. The proposed programme will build on the lead in instrument innovation already established by Europe and its strategic partners. There are opportunities for synergy with the life sciences and earth observation. Benefits from this programme will flow back to industry to enhance European expertise in a strategically-important sector

Through technology roadmapping associated with ELT instrument concepts, a major weakness in provision of infrared detectors in Europe was identified. Discussions have been held with UK and French industry and with ESA, and a plan for a joint industrial/academic workshop on IR detectors developed, to be held in the Netherlands. This activity has helped develop links with ESA, which we intend to expand towards stronger cooperation in FP7.

On the 19th Nov 2007 Colin Cunningham gave an invited talk at NASA Goddard on Technology Planning, based on the work of the Opticon KTN. He was also invited to give a similar talk at a technology festival in India (Techkriti '08 at IIT Kanpur).

## **WP6: Future Astronomical Software Environment**

The main objectives of WP6 are, as defined in 2004, to discuss the needs for 'Future Astronomical Software Environments' and identify high-level requirements and architectural concepts for such systems. A more detailed discussion of scope and objectives for WP6 is available on the TWiki based Web site at URL: <http://archive.eso.org/Opticon/twiki/bin/view/Main> which is also used for exchange of ideas and proposals. Monthly phone meetings were held to ensure that all members are updated on discussions (minutes can be found on the TWiki).

A broad Internet review of the high-level requirements was conducted. It was an important step to ensure wide circulation of the document in the astronomical community but it took significantly longer than expected. Full answers to the written comments were first available in the summer of 2007 so that a final approval of the revised version had to be postponed to the face-to-face meeting in January 2008. The document now includes a total of 204 explicit requirements at three priority levels.

During the face-to-face meeting March 2007, options for implementation of prototypes to test features of the architectural concept, parameter passing, and interfaces were considered.

A collaboration between institutes in Milan and Marseilles was formed. This prototype used D-bus for internal communication and executed tasks written in the C language through either Python scripts or directly from the command line. First results were available in the fall of

2007 and will be used to reassess the architectural concept and interfaces required. The delay caused by the wide review of requirements meant that the finalization of both the architectural concept document and the list of software interfaces required had to be postponed till the spring of 2008.

The work of the Network was presented at the OPTICON mid-term review. Further, the Network activities were discussed during the ADASS 2007 meeting in London.

The milestone M4 was achieved at the sixth face-to-face meeting (2007-03-01/P2D) where general plans for implementation of prototypes were discussed. The full Internet review of the high-level requirements took significant longer time than expected and was first concluded in the summer of 2007. This has delayed the milestones M3b and M5 which will be concluded in the first part of 2008.

### **Description:**

The sixth face-to-face meeting was mostly devoted to two topics, namely: a final discussion on the detailed high-level requirement based on the comments received through the written review, and considerations on prototypes which could demonstrate feasibility of the architectural concept and help specifying interfaces. A short seventh face-to-face meeting was held during the ADASS 2007 meeting in London, UK, as several of the Network members also participated in this conference.

Minutes of the meetings are available at the URL's:

<http://archive.eso.org/Opticon/twiki/bin/view/Main/FaceToFaceMeeting20070301> and  
<http://archive.eso.org/Opticon/twiki/bin/view/Main/FaceToFaceMeeting20070924>

It is essential to have wide agreement on the high-level requirements for a future astronomical software environment. With the extended effort on a wide Internet review, this has been completed and will serve as a solid foundation for the final work on architecture and software interfaces.

A first prototype was created by a collaboration between Milan and Marseilles. It displays several important features of the architecture and possible interface. This prototype is an important step to a better understanding of the individual parts of a future environment.

### **Milestones and Deliverables achieved:**

Deliverable/ Milestone No	Name of deliverable/milestone	Work- package /Task No	Lead Contractor(s)	Planned (in months)	Achieved (in months)
M2	UV Science Case Book/ Roadmap	WP2	STFC	18	26 *
M3	International UV astronomy meeting	WP2	STFC	41	41
D1	Publication of High Time Resolution Astrophysics Book as part of the Astrophysics & Space Science Library	WP3	NUIG	48	48
D2	International conference at the Royal Observatory Edinburgh, Scotland	WP3	NUIG	45	45
D3	Publication of conference proceedings	WP3	NUIG	52	52
M4	Implementation project plan	WP6	ESO	42	39

\* Actually published in 2007 with a 2006 date

## Major Meetings And Workshops Organised During The Reporting Period:

Date	Title/subject of meeting/workshop	Location	Number of attendees	Website address
19/01/07	SWG meeting	Munich	18	<a href="http://www-astro.physics.ox.ac.uk/~imh/ELT/SWG/">http://www-astro.physics.ox.ac.uk/~imh/ELT/SWG/</a>
2-3/04/07	SWG meeting	Munich	20	<a href="http://www-astro.physics.ox.ac.uk/~imh/ELT/SWG">http://www-astro.physics.ox.ac.uk/~imh/ELT/SWG</a>
29-30/05/07	SWG DRM workshop	Munich	25	<a href="http://www-astro.physics.ox.ac.uk/~imh/ELT/SWG">http://www-astro.physics.ox.ac.uk/~imh/ELT/SWG</a>
09/10/07 (followed by telecom 19/10/07)	SWG meeting	Munich	18	<a href="http://www-astro.physics.ox.ac.uk/~imh/ELT/SWG">http://www-astro.physics.ox.ac.uk/~imh/ELT/SWG</a>
28/5/07-01/06/07	“Space Astronomy: the UV window to the Universe”	Madrid	117	
26/2/2007	WHT Test bed Meeting	Leiden	15	
2-4/10/2007	Astro-Photonica Europa Consortium Meeting	Grenoble	13	
28/3/2007	Smart Focal Planes Consortium & roadmap meeting	Leiden	13 + 2 by teleconf	
17/7/2007	WHT Test bed detailed planning meeting	ESO, Garching	6	
19/11/2007	Talk on Technology Planning	NASA Goddard, Maryland	80	
01/03/07	Sixth face-to-face meeting	Tenerife	10	<a href="http://archive.eso.org/Opticon/twiki/bin/view/Main/FaceToFaceMeeting20070301">http://archive.eso.org/Opticon/twiki/bin/view/Main/FaceToFaceMeeting20070301</a>
24/09/07	Seventh face-to-face meeting	London, UK	8	<a href="http://archive.eso.org/Opticon/twiki/bin/view/Main/FaceToFaceMeeting20070924">http://archive.eso.org/Opticon/twiki/bin/view/Main/FaceToFaceMeeting20070924</a>

### 1.3.3 NA4: Mechanisms for synergy in space-ground coordination

This activity is complete.

### 1.3.4 NA5: Interferometry forum

Participant number	Participant name short	Person-months
12	NOVA	1 (0.5)
21b	ULg	1 (0.5)
34	NCU/UMK	0.5

**Table N5.1: Effort of participants' personnel in network.**

Although the group has been very active, no staff efforts (Table N5.1) have been charged to the project. Only travel and material cost have been charged to the project.

The flyer on the Network activities, which had been produced in 2005, was again distributed at a number of venues.

The European Interferometry Web-site that contains the most up to date information about the European Interferometry Initiative (EII) activities and the Network Activities ([www.strw.leidenuniv.nl/~eurinterf](http://www.strw.leidenuniv.nl/~eurinterf)) has been updated. Migration of the web page to a server in Heidelberg had to be postponed because of organizational difficulties. However, with a change of the chairmanship of the EII due the web site will soon be relocated to a new institution.

#### 1.5.1.1 Fizeau exchange visitors program

New announcements of the Fizeau Exchange Visitors Program have been widely distributed through relevant mailing lists, web-pages (<http://www.strw.leidenuniv.nl/~eurinterf>), and direct mailing. A poster with the announcement was mailed to a long list of astronomical institutions in Europe.

On 15 March (call 2007A) and 15 September (call 2007B) 2007 two new application rounds for the Fizeau Exchange Visitors Program were closed. The applications were reviewed by the Network Board, suitable candidates were identified, and travel funds awarded. Most exchange visits involve scientists from institutions that do not have much expertise in interferometry; many of these are from central European countries. Several participants in previous exchanges have applied again; this means that longer-term collaborations between institutions with little expertise in interferometry and expert institutions are being established. Awards were as follows:

2007/1

- B. Valat (France) to visit MPIfR (900 Euro)
- T. Laczkowski (Poland) to visit OCA (1800 Euro)
- M. Filho (Portugal) to visit (1490 Euro)
- F. Reynauld (France) to visit CAUP (1500 Euro)
- D. Defrere (Belgium) to visit LAOG (3000 Euro)
- I. Spaleniak (Poland) to visit ESO/Garching (3380 Euro)

2007/2

X. Hanbois (France) to visit Grenoble (1.000 Euro)  
T. Laczkowski (Poland) to visit OCA (1.825 Euro)  
M. Netolicki (Czech Republic) to visit OCA (1.050 Euro)  
N. Sipos (Hungary) to visit MPIA (2.700 Euro)  
T. Eisenbeis (Germany) to visit TCfA (1.250 Euro)  
F. Lykou (UK) to visit OCA (2.500 Euro)  
A. Saglam (Belgium) to visit INAF/Torino (1.270 Euro)  
M. Kraus (Czech Republic) to visit OCA (2.150 Euro)  
I. Karivikova (Czech Republic) to visit LUAN (3.000 Euro)

### 1.5.1.2: Working groups

Three working groups had been established in 2004. These were: “Interferometric scientific council”, “Radiative transfer”, and “Atmospheric modelling”. The latter two groups were merged at the request of the group members in 2005. Following an initial meeting in Paris in June 2006, this group held a focused workshop near Lyon in May 2007. Proceedings from this workshop have been written up and will be published in 2008. A new working group on “Interferometry and asteroseismology” was established in 2005 and met for the first time in November 2005 in Porto. The report from this workshop was finalized in 2007 and has appeared as a review article in “Astronomy and Astrophysics Reviews” (Cunha et al. A&AR 14, 217-360).

### Scientific Council

The “Scientific Council” met several times by teleconference, and in person in Heidelberg in May 2007. The main focus of this meeting was a review of EII activities and included, as a minor item, the preparation of the OPTICON FP7 proposal. The representatives (one for each participating country and the two international organisations ESO and ESA), who were elected in 2004, continued to serve on the Scientific Council. Minutes of the meetings have been compiled and distributed.

Country	Member	Status
Austria	Josef Hron	
Belgium	Jean Surdej	
Switzerland	Didier Queloz	
Czech Republic	Pavel Koubsky	
Germany	Thomas Henning	President
Spain	Carlos Eiroa	
France	Christian Perrier	
United Kingdom	David Buscher	
Hungary	Lajos Balazs	
Italy	Mario Gai	
Israel	Erez Ribak	
Netherlands	Eric J. Bakker	Deputy-president
Poland	Andrzej Niedzielski	
Portugal	Paulo Garcia	
ESO	Guy Monnet	
ESA	Malcolm Fridlund	Observer

**Table: N5.3: participants of working group “EII scientific council”.**

### 1.5.1.3 Next-generation interferometric infrastructure

A proposal for a design study for a kilometric optical interferometer (KOI) was prepared by many participants in the working group on “Next-generation interferometric infrastructure” and submitted for the FP7 deadline on May 2, 2007. The proposal received excellent marks by the referees, but has not been funded. (A formal response by the EU commission has not yet been received, but informal correspondence indicates that the available funding was insufficient to fund the KOI proposal.)

#### Meetings and workshops

	Date	Title/subject of meeting /workshop	Location	Nr of attendees
1	05-06 Feb 07	Working Group “Scientific Council”	Heidelberg	28
2	14-16 May 07	Working Group “Radiative Transfer”	Morgon	22

**Table N5.6: overview of meetings**



### 1.3.5 NA6: OPTICON Telescope Network

<b>Participant number</b>	7	
<b>Participant short name</b>	IAC	<b>Total</b>
<b>Person-months</b>	18 (18)	18 (18)

#### **WP1 : Telescope Directors Forum**

The telescope directors' forum comprises the directors of all those telescopes in the Trans-national access programme, and hence represents all modern 2-4m telescopes with European involvement. The primary responsibilities of the group are oversight of the trans-national access programme, planning for future co-operation and preparing for future opportunities. The group is chaired by the Project Scientist whose time is accounted to management effort.

The annual directors meeting was held in Athens, and provided an opportunity to visit the new Aristachos telescope at Helmos.

Highlights of the year's activities included:

- Implementation of the Northstar software package for common telescope submission software at the French TBL and OHP telescopes.. This has further confirmed the potential for developing the system and then adopting it at several of the OPTICON supported telescopes.
- A review of the allocations under the access programme was made and an agreement reached to plan a smooth spend profile reaching ~100% by mid 2008. The rationale for this was to allow further uptake in late 2008 if funds were available after savings in the NA6 network or elsewhere.
- The TDF chairman (the project Scientist) visited Vilnius and the Moletai observatory in Lithuania. He promoted the access programme and had discussions with the director on expanding the uptake by astronomers from the Baltic states
- OPTICON sponsored several observatory staff members to attend a meeting of the Northstar consortium in Bologna (Italy) to enhance their ability to adopt this system at their own observatories

There was extensive discussion of our FP7 plans, and agreement in principle to adopt a single pool/common TAC process

#### **WP2: Operation of the Trans-national Access Office**

In 2007 the Access Office has devoted a total human effort of 18 person-months. During this year its two main objectives (management of the Trans-national Access

Programme and interface between the bodies and communities involved) have been accomplished. Its role as a reference node between telescope operators, the OPTICON Project Office, the Telescope Directors' Forum, and users continues being highly appreciated.

The Access Office has implemented the following actions during 2007:

- *Maintenance of the database powered website of the Access Programme*

The Access Office staff has periodically updated the contents of this key interface with users for sharing relevant information, application forms, reports, documents, statistics, etc.

- *Publicity of the Trans-national Access Programme*

As a complement of the publicity made through the website of the Access Programme (and through the OPTICON site), our team has sent announcements of opportunity by email and standard mail.

- *Trans-national Access Programme. Impact, progress and output*

Beyond the daily operation and promotion of the Access Programme, the Access Office is carrying out an important effort to accomplish EC requirements (annual reports, etc.) and to analyse the impact and progress of this activity, by assessing the scientific output, user questionnaires and feedback, identifying new users, analyzing the procedure of awarding time, etc.

- *Progress reports to be delivered in accordance to Annex I of the contract*

Each four-month period, the Access Office has delivered standard progress reports by collecting and providing to the Telescope Directors' Forum detailed statistics about type and characteristics of observing runs supported under the Access Programme (see table with such deliverables).

- *User questionnaires and feedbacks*

User groups awarded telescope time under this Access Programme have been invited to complete a user questionnaire.

Information from these questionnaires and feedback tells us more about the various users of the Access Programme. This information helps us to understand our users' needs and their opinion about the services provided. It enables us to meet those needs by making the Access Programme as useful as possible.

- *International partnership. Analysis of current situation and trends*

The Access Programme provides opportunities for international partnerships that contribute to implement an effective, efficient, and focused international astronomical research.

As part of the analysis carried out by the Access Office to monitor the impact of the Access Programme among the Astronomical Community, we have analyzed the establishment of such international partnership in those observing projects submitted for telescope time, with special attention to those with awarded time under this Trans-national Access Programme.

- *Scientific fields addressed by OPTICON user teams*

The astronomical research carried out under the OPTICON Access Programme is focussed in optical and infrared observing projects as well as in solar physics observations. As part of the progress and outputs of the Access Programme in this period, the Access Office has collected all the projects summary reports of such observing projects asking astronomers for their corresponding scientific fields

Milestones for this WP, as defined by the implementation plan, have been successfully achieved.

### **WP3: Enhancement**

The N6.3 activity (Enhancing the efficiency of research) developed in 2007 according to the initial planning.

A two weeks NEON observing school was held in September at the Asiago Observatory (Italy) and gathered 20 students from 14 different nationalities. Over a dozen lecturers and tutors, mainly sponsored by OPTICON, provided the necessary background for observations (lectures on Telescope Optics, Spectroscopy, Photometry, etc...) and the small research topics for the five groups of students. Special emphasis was put on Polarimetry, which is one of the strengths of the Asiago group. A novelty was also introduced in this year's school, namely the simultaneous use of archival data, principally from the Sloan Digital Sky Survey, with specific tutorials prepared for the students. This way, the young observer learns that it is good practice to first check what is available in the archives before going to the telescope to obtain fresh data. The observing programmes dealt with polarisation in galaxies, elemental abundances in stars, detection of clusters of galaxies, investigation of fossile groups of galaxies, and the search for and characterisation of, Novae in our closeby galaxy M31. New results have been obtained, leading to at least two publications in preparation, including the discovery of one new, and confirmation of several other novae in M31.

A short visit was paid to Potsdam by the chair of this group, to prepare the organisation of a new type of workshop/schools, devoted to some specific instrumentation of new interest in the field of observational astrophysics. As a result, a school on Integral Field Unit spectroscopy will be held in Potsdam in May 2008, open not only to young researchers, but also to more senior people wishing to get acquainted with such new instrumentation.

Some OPTICON support (in the form of lecturers) was also provided to the spectroscopy school held in Rozhen observatory (Bulgaria) in October this year. This event gathered about 20 students mainly from south-eastern Europe, and adjacent countries (Turkey, Armenia, Ukraine). It was the prototype of some more regular schools to be organised in the future by SREAC (the South Regional European Astronomical Community) with the help of OPTICON.

The most important organisational event of 2007 was a meeting in Bucharest (Roumania) which gathered the Opticon "Enhancement" WG, representatives of Radionet, the Interferometry network and SREAC, and staff from the National Observatory and the University of Bucharest. The goal was to discuss present activities in training young researchers, possible trans-disciplinary coordination, and specific needs from the new- or future-members of the EU. Among many interesting

facts and ideas which emerged, the details of which can be read in the minutes of the meeting (available on the Opticon Web page), it clearly appeared that special efforts need to be made towards European eastern countries, to better integrate them into the present activities like the Access programme; to raise their awareness of new or developing scientific and instrumental topics in Astrophysics, which constitute the basis for their participation in the next generation of large scale facilities; and more generally to attract young and talented people to sciences in general. Activities towards achieving these goals will constitute the basis of the FP7 proposal.

### Milestones and Deliverables

Deliverable/ Milestone No	Deliverable/Milestone Name	Workpackage /Task No	Lead Contractor(s)	Planned (in months)	Achieved (in months)
M2	Annual Directors' Meeting	WP1	STFC	46	46
M4A	Peer review of Aristarchos telescope	WP1	STFC	46	46
D1	Promote Access programme at Jenam meeting in Yerevan	WP2	IAC	32	32
M2	4 <sup>th</sup> Report to Directors forum	WP2	IAC	48	48
M3a	Working group Meeting	WP3	CNRS,IAP	29	44

### Meetings and workshops

Date	Title/subject of meeting /workshop	Location	No of attendees	Website address
22 June 2007	WP3: Enhancement WG	Bucharest, Romania	5	<a href="http://www.astro-Opticon.org/meetings.html">http://www.astro-Opticon.org/meetings.html</a>
3 October 2007	WP1: Telescope Directors Forum meeting	Athens, Greece	25	<a href="http://www.astro-Opticon.org/meetings.html">http://www.astro-Opticon.org/meetings.html</a>

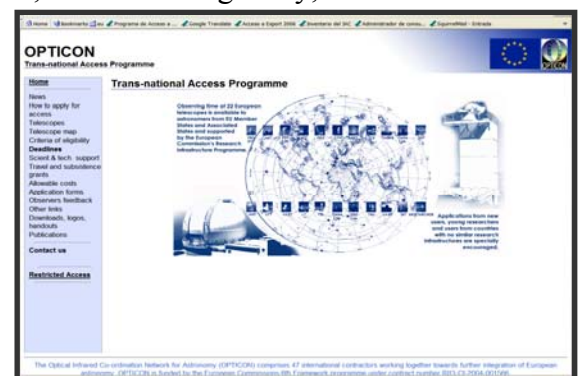
## 1.4 TRANSNATIONAL ACCESS ACTIVITIES

### 1.4.1 OPTICON Trans-national Access Programme

#### 1.4.1.1 Description of the publicity concerning the new opportunities for access

The Trans-national Access Programme Website (OPTICON Access Website: <http://www.otri.iac.es/Opticon/>) is the main tool available to publicise the new opportunities for access to the telescopes involved in the OPTICON Access Programme. After four years of this programme, most of the international scientific community is aware of the advantages offered under this initiative, especially for new users and European young researchers. The oversubscription of eligible teams in most of the OPTICON telescopes provides clear evidence that the appropriate dissemination is being achieved. The Trans-national Access Programme web page is a key reference to keep oneself updated about deadlines of each telescope. In addition, a complete contact list of scientific and technical support is at the reader's disposal, guaranteeing the most suitable advice level for users.

The brief descriptions of each telescope (location, instruments, full address, funding sources, etc.), a guideline on how to apply for access, criteria of eligibility, travel and subsistence grants, information on allowable expenses, etc, have been updated. As a complement of the information available in the Public Area, this website provides users with a list of useful links to Observatories, Survey data / Catalogues, Literature / Directories, astronomical and physics links, as well as a section of the OPTICON facilities' newsletter and a download section of the Access Office with promotional material about the Access Programme.



OPTICON Access Website: <http://www.otri.iac.es/Opticon/>

#### ***Promotion of the Trans-national Access Programme at other Websites:***

Similarly, information about the Access Programme can be found on the corresponding web sites of each of the 22 participant telescopes. Each observing campaign is widely advertised there. Announcements of Opportunity are normally published twice a year via the Internet as well as via extensive distribution to the international astronomical community.

As a complement to these methods, the Trans-national Access Office has sent by post a general advertisement of the Programme to the international astronomical community.

#### 1.4.1.2 Description of the selection procedure

Observing time is awarded following standard selection procedures at each telescope or group of telescopes, which are based on scientific merits and feasibility.

Since 22 medium-sized telescopes are offered under the contract, and they are operated by different legal entities / countries, specific criteria of eligibility differ from one telescope to another. The procedure to apply for telescope time under this EC contract is to do it in response to the different Announcements of Opportunity for observing time at each telescope. Once the deadline for submission of proposals has been closed, Time Allocation Committees (TACs)<sup>4</sup>, composed of experts of international reputation, evaluate the proposals received and approve a ranked list for distributing the observing time available among the best proposals. The prime consideration of these TACs in making awards is scientific merit and technical feasibility, taking into account the interests of the astronomical community as well as scientific output from previous time awards. Teams compete on the basis of equal opportunity. However, new users, young researchers and users from countries with no similar research infrastructures are especially encouraged to apply for observing time.

Following EC guidelines, criteria of eligibility of the astronomers who want to benefit from this Access Programme are mainly based on the country of origin of the user group (as defined below), and the ownership of the telescope for which observing time is applied to (or country of the entity/ies responsible for its operation). These criteria apply separately to each telescope.

To be eligible to benefit from access to a particular telescope under the contract, a user group<sup>5</sup> must satisfy the following conditions:

- both the user group leader and the majority of the users must come from Member States or Associated States;
- both the user group leader and the majority of the users must come from a country other than the country(ies) where the legal entity(ies) operating the infrastructure is(are) established;

In order to prioritize applications from actual external users (especially new users), i.e. users not having access by right to these telescopes because of any formal agreement signed between their institutions and the telescope operator, two other additional criteria were considered when awarding time under the EC contract:

- ⇒ the institution of affiliation of the user group leader and the majority of the users shall not have access by right to the facility being applied to.
- ⇒ in no case shall a user be eligible for travel and subsistence support to access his/her own facility through this programme.

User groups meeting EC criteria of eligibility, and awarded telescope time by these TACs, are informed by the Trans-national Access Office (located at Instituto de Astrofísica de Canarias, Spain) about this funding opportunity. They receive full information about how to apply for travel and subsistence grants, how to get scientific and technical support to carry out their observations, application forms, etc. Application forms and reports can be completed on-line.

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<sup>4</sup> See Annex 2: Selection Panel members list.

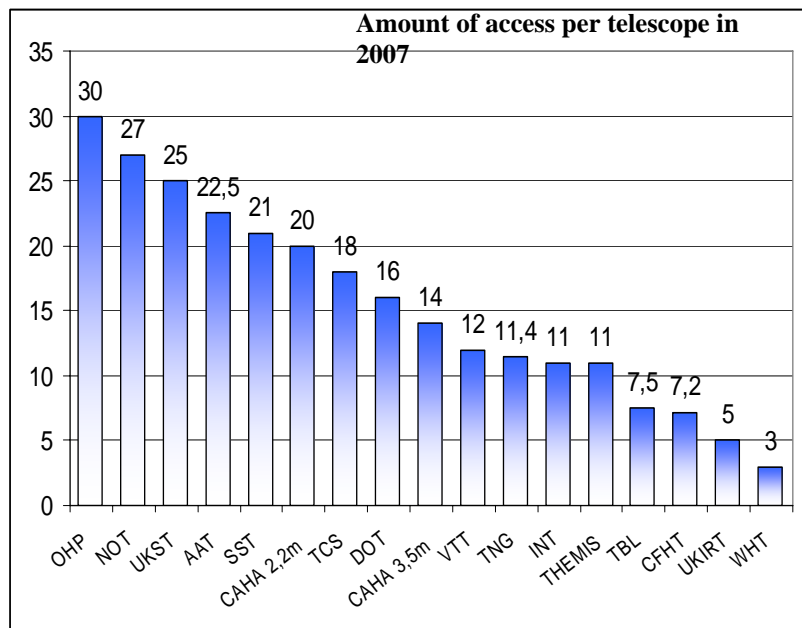
<sup>5</sup> **User:** means a researcher within a user group, including the user group leader. **User group:** means a research team of one or more researchers given access to the infrastructure under the project. Each user group is led by a user group leader.

### 1.4.1.3 Trans-national Access activity

#### Amount of Access delivered:

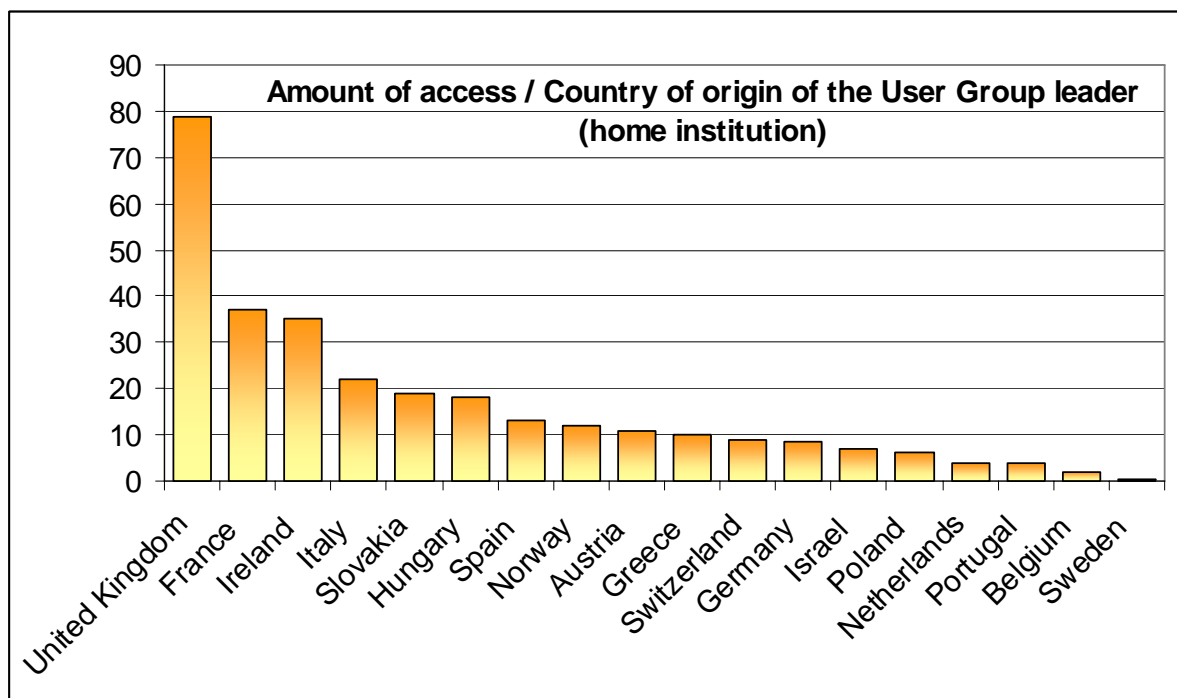
20,60 % of the total amount of access to be provided under this five-year contract was delivered in 2007. This means 296,6 units of access (days/nights/hours) in 2007 plus a total of 1035,2 days/nights/hours during the first three years of the contract (71,7 %).

The OHP 1.93m Telescope (Observatoire de Haute Provence), the Nordic Optical Telescope (NOT) and the United Kingdom Schmidt Telescope, 1.2m (UKST) have been those telescopes which have delivered most observing time during 2006 (30, 27 and 25 nights respectively).



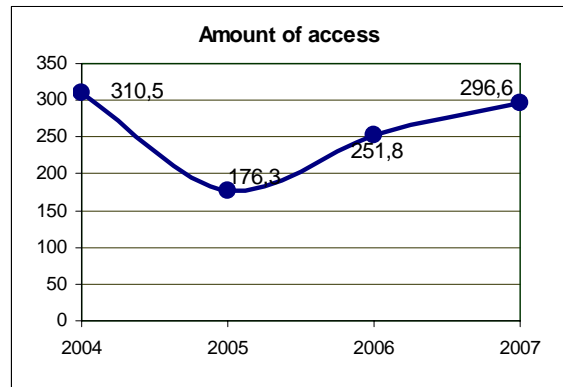
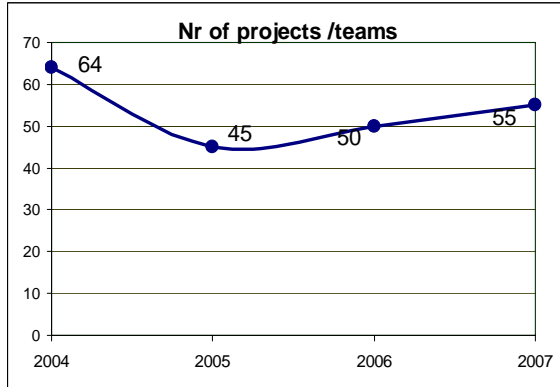
#### Statistics on users awarded with telescope time:

Most of the telescopes have allocated observing OPTICON time under the contract during 2007. With regard to the P.I.s home institutions, the group leaders from United Kingdom clearly lead the allocation of time in 2007, followed by French and Irish P.I.s

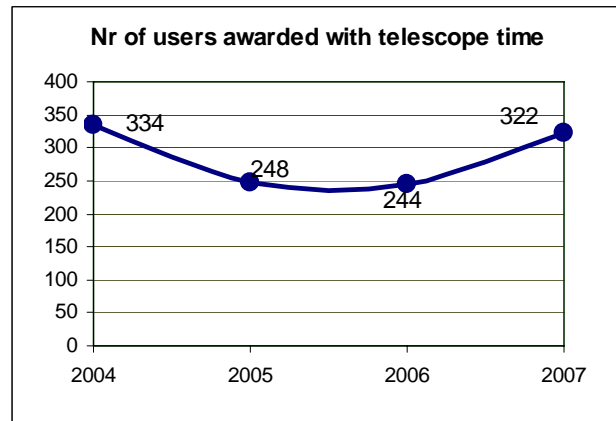




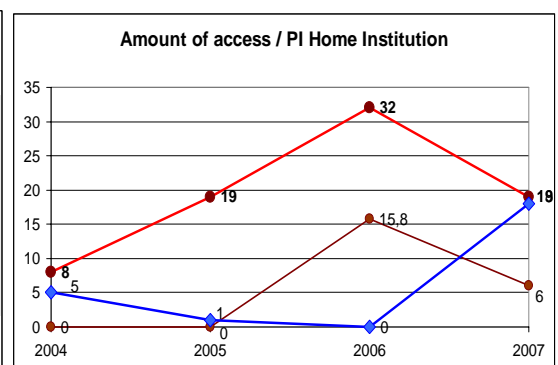
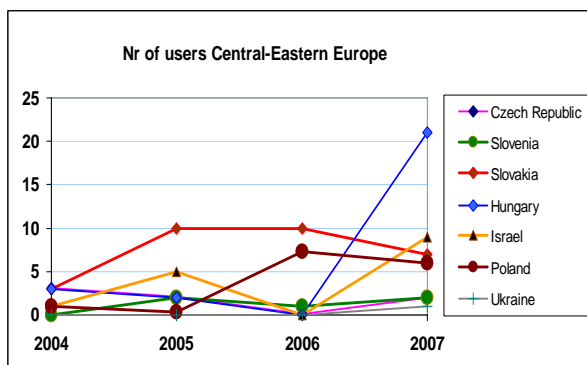
*Projects and access:* 2007 shows a positive trend of these two parameters, only surpassed by the results achieved during the first year of the contract, where a spending profile plan had not been fixed yet. The maximum quota fixed for the 2005, 2006 and 2007 has forced a reduction in the allocation of time in order to guarantee a regular allocation during the five-year contract.



- *User groups:* The number of users in 2007 is the highest value since 2005, with a similar trend of previous parameters. The rate of users per project in 2007 is the highest one since the beginning of the contract with an average of 5.8 users/project. The estimated number of users to take advantage of the Access Programme expected for the whole contract, has been clearly surpassed with almost 190% of the expected value.

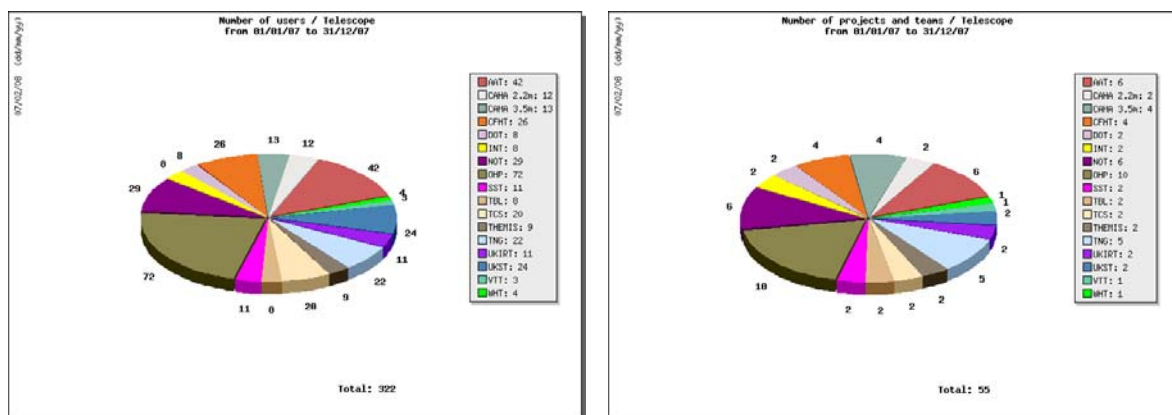


- *Observing time for astronomers from Central-Eastern Europe:* The Access Office promotes the participation of new users, young researchers and specially, users from Central and Eastern Europe. In this way, it should be remarked that Slovakia and Hungary maintain a good take up of OPTICON time, followed by Poland. The following figures show the take up for the different Central-Eastern European astronomers as well as the trends for Slovakia, Hungary and Poland. Slovakia has been awarded time for a total of 74 observing periods until now, Hungary 23 and Poland 21,8.

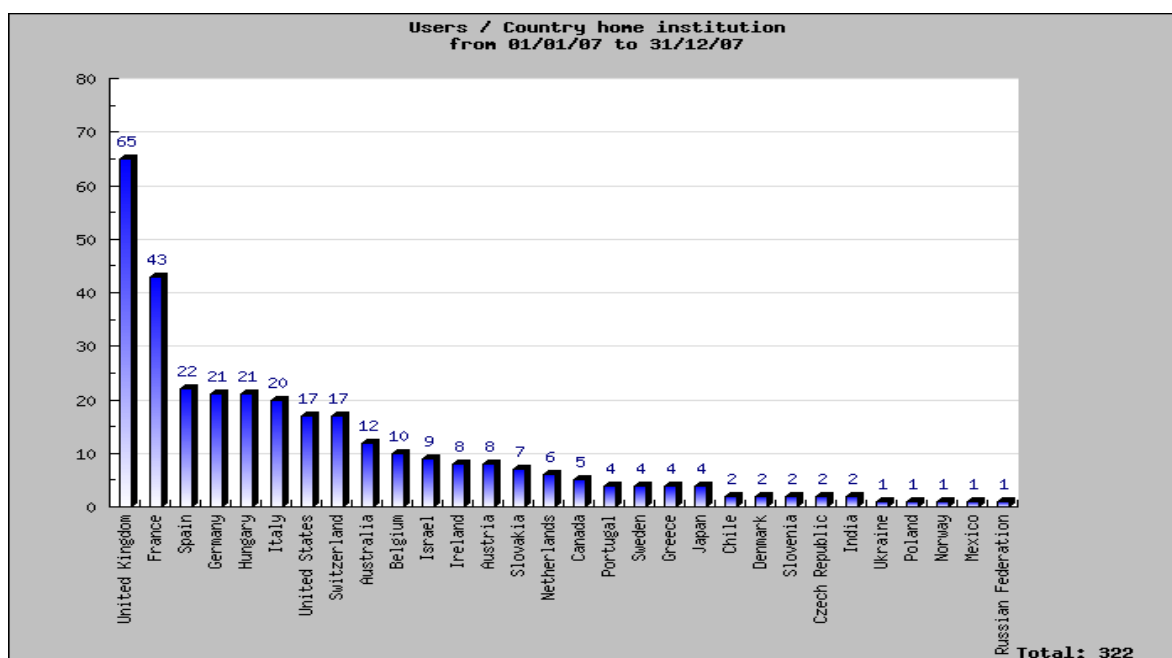


### ***Impact of the Access provided by telescope:***

322 users from 30 different countries have benefited from this Access Programme during this period (members of the user groups). 35 % of these users were awarded observing time at two telescopes: OHP and AAT.



United Kingdom and France were those EU countries involving more users. (*see next figure*). The important take up of users from Hungary (21) should be remarked upon.

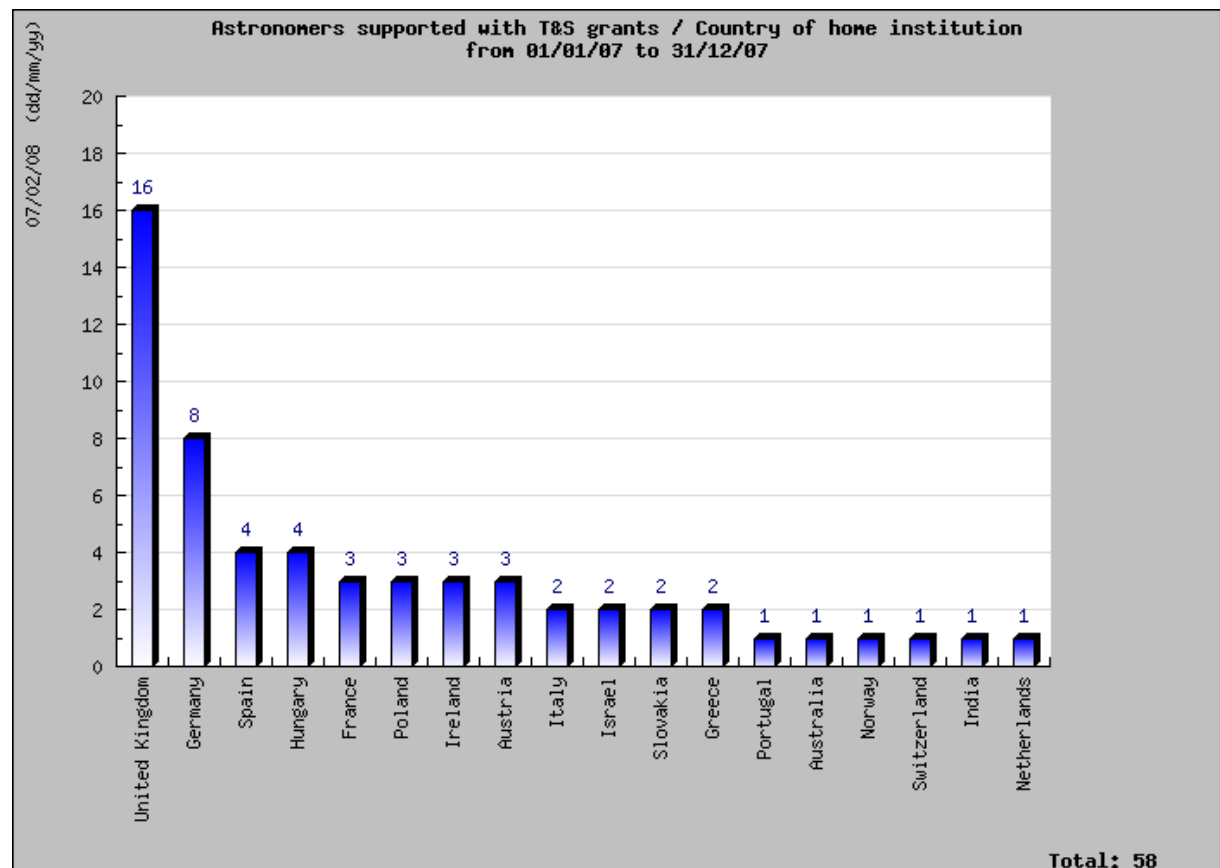


NOTE: Servicing mode: 11,6 units of the access provided in 2007 are under servicing mode. This value does not seem high but involves eight different projects (11,54%).

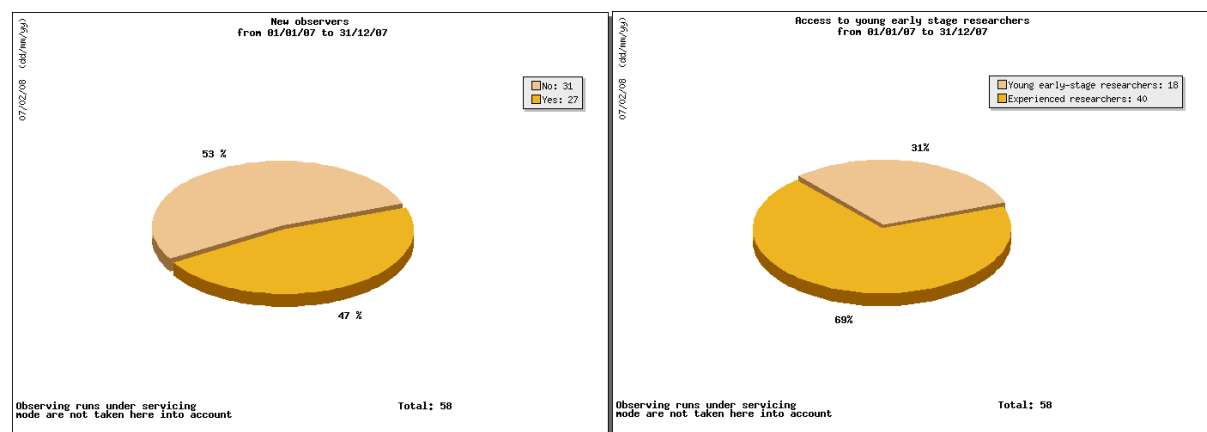
### ***Travel and subsistence grants:***

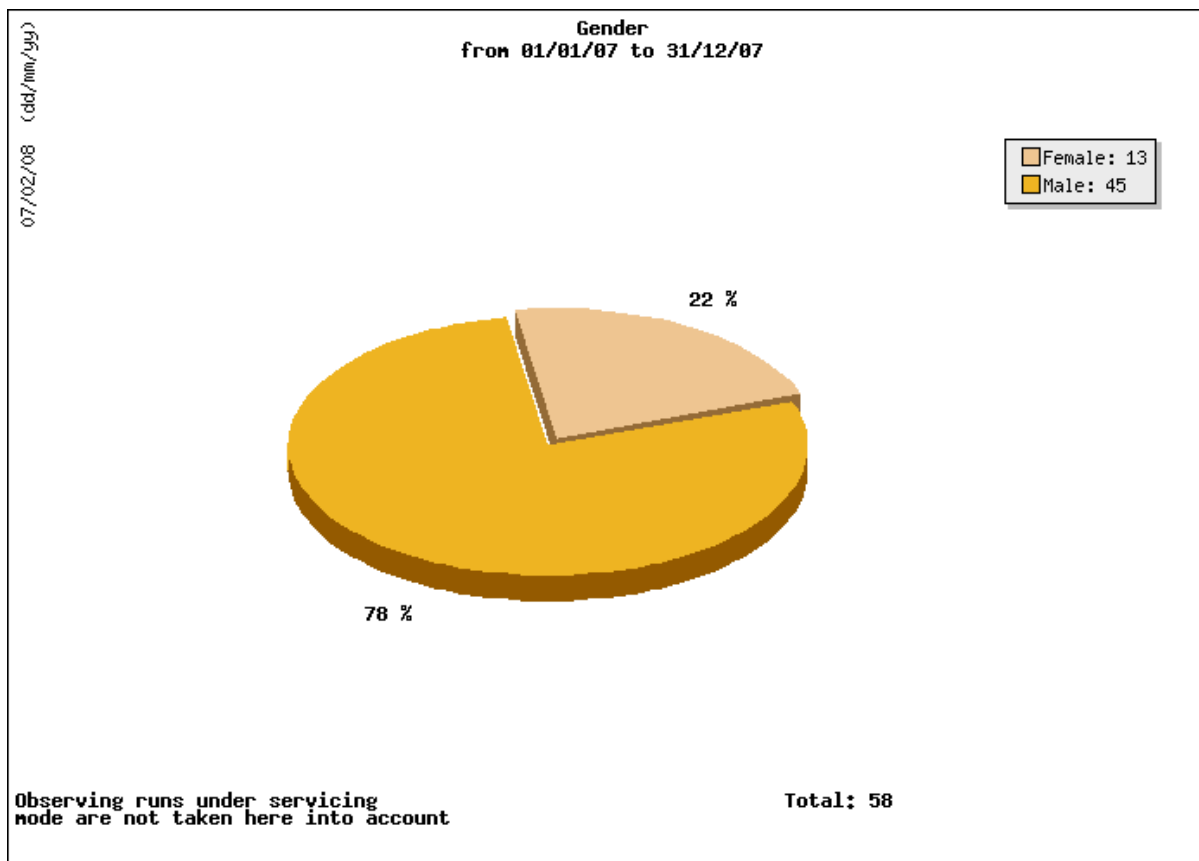
58 of these 322 users have been granted for Travel and Subsistence (T&S) support when visiting the facility to carry out the observations (basically one observer per project, apart from those special cases in which two grants were needed and awarded). See Annex 4.

Following charts offer more information about these travel and subsistence grants:



**New Observers:** Over 53% of those astronomers supported with T&S grants in 2007 are new users. This result is quite positive since the OPTICON Access programme has been run for four years and we still receive a high percentage of new users. On the other hand 31 % were young-early stage researchers. The gender ratio among users with T&S grants is 22% female and 78% male.





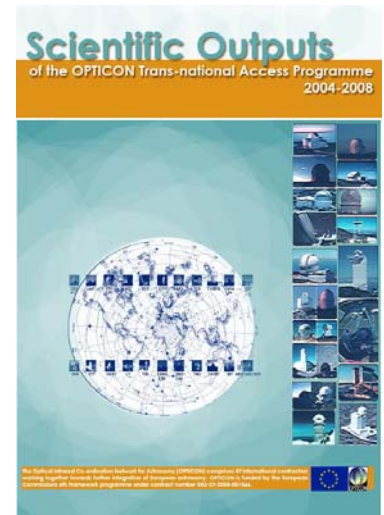
#### 1.4.1.4 Scientific output of the users at the facilities.

During this year the Access Office has gathered ten publications related to observations based on results of observing projects carried out with the OPTICON Trans-national Access Programme support, mainly in 2005 and 2006.

As expected for our science field, feedbacks rate provided by users suggest that gathering all theses scientific outputs arising from the first years of the contract will take a couple of year from now onward.

The Access Office is facing up to this challenge by half-yearly surveys to our users as well as by tracking possible acknowledgement of our Access Programme in papers (ASTRONOMICAL JOURNAL, ASTRONOMY & ASTROPHYSICS, ASTROPHYSICAL JOURNAL, etc).

Moreover, we have uploaded to our website an online-form to compile these scientific outputs (<http://www.otri.iac.es/Opticon/frame.php?pagina=output>). Users can easily fill out this form, collaborating with the Access Office to elaborate a Scientific Output report by the end of 2008.



#### **1.4.1.5 User meetings**

No user meetings during the whole contract are expected to be organised.

## 1.5 JOINT RESEARCH ACTIVITIES

### 1.5.1 JRA1: Adaptive Optics

The Total human effort deployed during this reporting period for JRA1 is summarized in the following table (in parenthesis additional manpower only for AC cost model):

<b>Participant number</b>	4	6	8b	11a	12	19	31	35	
<b>Participant short name</b>	ESO	INSU/CNRS	INAF-Arcetri	MPIA	NOVA	GRANT ECAN	ONERA	Univ Durham	<b>Total</b>
<b>Person-months</b>	73.69	53.94	10.17	30,96 (17,16)	12	5,8	4.55	1.5	<b>192,61 (17,16)</b>

#### WP 1: Coordination of JRA1

##### **Past years:**

JRA1, managed by ESO, was launched in March 2004. ESO created a dedicated web page to disseminate the information and reports produced by JRA1 (<http://www.eso.org/projects/aot/jra1/>). Some documents are password protected. General meetings have been organised every 9 months as planned (see meeting table). Dedicated meetings or video-conferences have allowed accurate monitoring of the individual WPs. Strong interactions between JRA1 & 2 have been maintained since the beginning of the contract as JRA2 R&D (Adaptive Optics CCD detector) is one of the key element of the projects developed within JRA1.

The management (ESO) of the JRA1 has been active since the beginning of OPTICON to prepare the subcontract technical specifications/Statement of Works, to negotiate the contracts and to monitor the progress of the Adaptive Optics key components (1370 actuators piezo deformable mirror, Thin Zerodur glass shell, 1170 actuators Adaptive secondary design, piezo DM Drive electronics, micro and mini deformable mirrors, wavefront sensor CCD). Four general meetings have been organised.

In 2007, one General meeting 5 (deliverables M1 of this WP 1) was organised by ESO: November 15<sup>th</sup> & 17<sup>th</sup> at University of Leiden. ESO has continued the monitoring of the JRA1 FTE and HW expenditures.

ESO has also presented the JRA1 results at the OPTICON Mid-term Review in Corfu Sept. 10 & 11<sup>th</sup>.

The last subcontract for the development of 50x50 actuator Mini deformable mirror has been placed to CILAS on May 4<sup>th</sup> 2007. Monitoring of other subcontracts has continued.

#### WP 2: System design

##### **WP2.1: XAO system Study**

##### **Past years:**

Following two competitive feasibility and conceptual design studies of the VLT XAO system achieved by INSU and MPIA-INAF and reviewed by ESO in the fall of 2004, the ESO Scientific and Technical Committee (STC) recommended in April 2005 to

establish a collaboration of both teams under the lead of INSU-LAOG as the P.I. institute. The main goal of this collaboration was to enhance Planet Finder's scientific capabilities by the inclusion of the science instruments (integral field spectrograph and differential polarimeter) proposed by the former MPIA led consortium. To support this merging, ESO launched a Post-phase A contract in 2005 with the aim of providing enough resource to perform the R&D activities between the end of the phase A and the start of the VLT Planet Finder design and construction phase.

The newly merged Consortium submitted a consolidated instrument concept and a strong coherent system and project management plan to the ESO Scientific and Technical Committee (STC) in October 2005. Documentation presenting the efforts of the two former Consortia towards these goals (including an executive summary) has been produced. STC recommended to the ESO Council that this project should be continued. The new Consortium consists of: INSU-LAOG, INSU-LAM, ONERA, INSU-LESIA, MPIA, ETH Zurich, INAF-Padova, Geneva Observatory, University of Amsterdam, Utrecht University, ASTRON, and ESO. The newly named VLT SPHERE project (standing for Spectro-Polarimetric High-Contrast Exoplanet Research) has successfully been able to accrete several new European Institutes outside the original JRA1 partners. This interest is due to the potential high scientific return of this future facility i.e. the direct detection of Extrasolar Planets. In June 2006, ESO Council decided to proceed with and fund the full development of SPHERE as part of the 2<sup>nd</sup> Generation instrument program of the Very Large Telescope and to allocate 260 Guaranteed Observing nights to the Consortium building this facility. These observing nights on the VLT will actually be used to start a large scale survey for the direct detection of exoplanets.

### **In 2007:**

In 2007, the Consortium has passed the SPHERE Optical Preliminary Design Review March 6<sup>th</sup> and completed the Preliminary design documentation (Final delivery D1 of WP 2.1). The Design Review took place on Sept. 20 & 21<sup>st</sup>. Several key prototypes and demonstration experiments crucial for SPHERE have been achieved: Apodised Lyot coronagraph, four quadrant phase mask coronagraph, low crosstalk lenslet array for high contrast 3D Spectroscopy, low aberration differential filters etc...

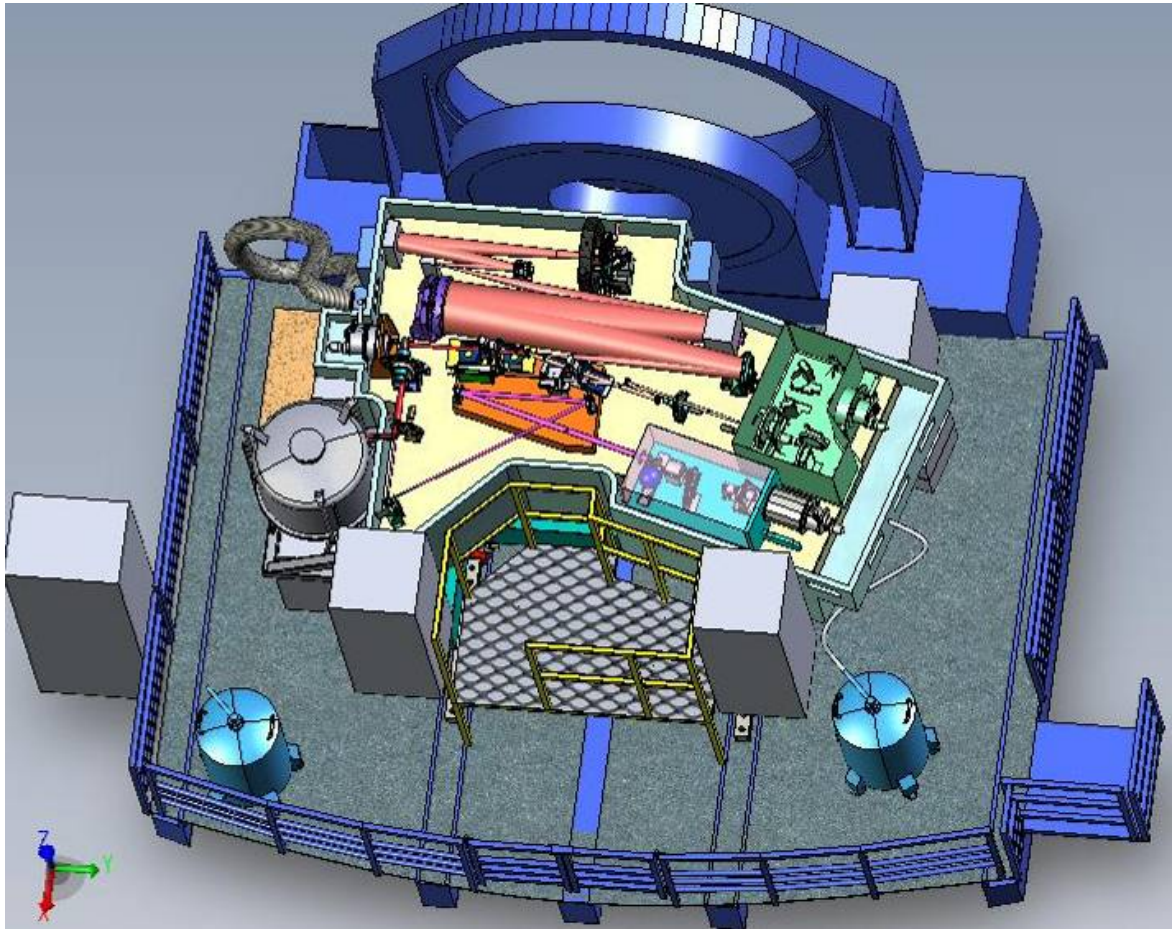
Apart from the preliminary design activities, the OPTICON funded activities directly related to SPHERE have been pursued in particular:

- ESO follow-up and acceptance July 5<sup>th</sup> 2007 of the 1370 actuator deformable mirror from CILAS (France) related to WP3.3.
- ESO follow-up of the development of the 240x240 pixels CCD detector (from E2V, UK) for wavefront sensing equipped with 8 outputs and based on L3CCD technology with 0.2 e RON (JRA2). Science grade chips are expected to be delivered 1<sup>st</sup> half 2008.
- ESO follow-up of the development of the piezo Deformable mirror drive electronics WP 3.4 (from SHAKTIWARE (France)). Delivery of the unit is expected in 1Q 2008.
- Real Time Computer Platform (SPARTA) WP 3.1 design has been completed by ESO and Durham 4Q 2007.

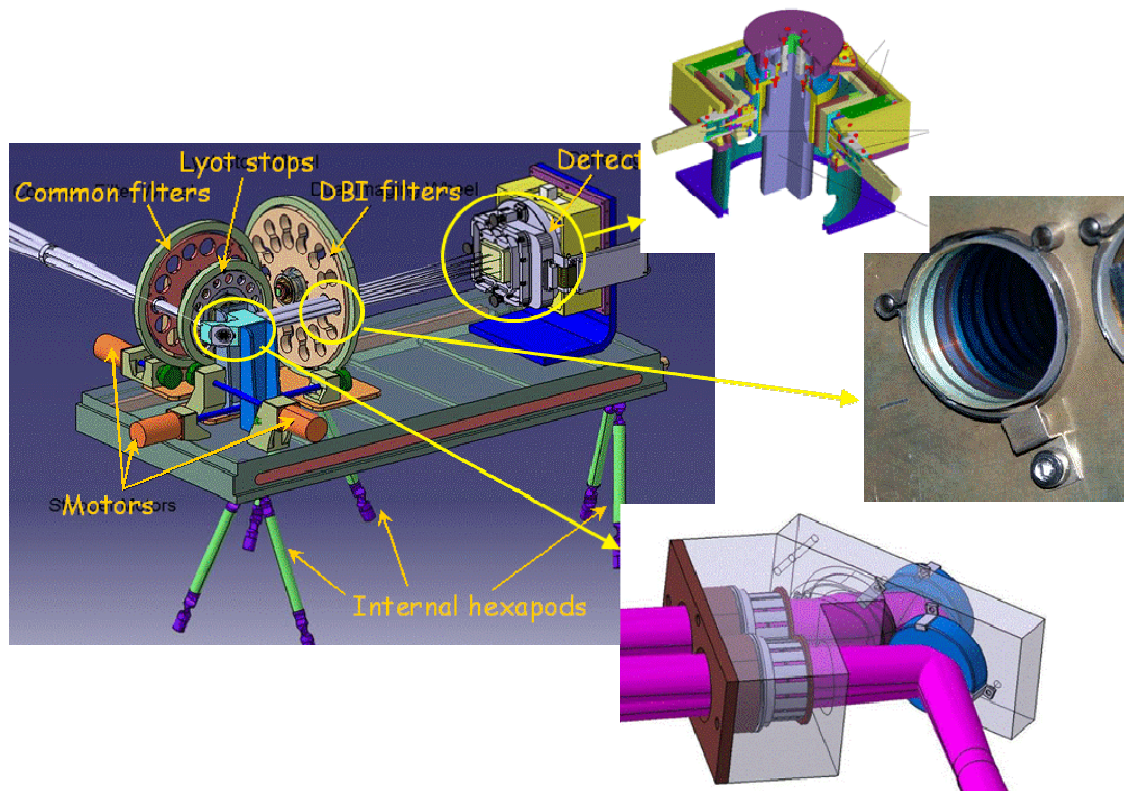
SPHERE, as a planet hunter machine to be installed on the VLT, is considered as an important pathfinder for the European Extremely Large Telescope, E-ELT (a new European facility included in the ESFRI roadmap). Research efforts which have been



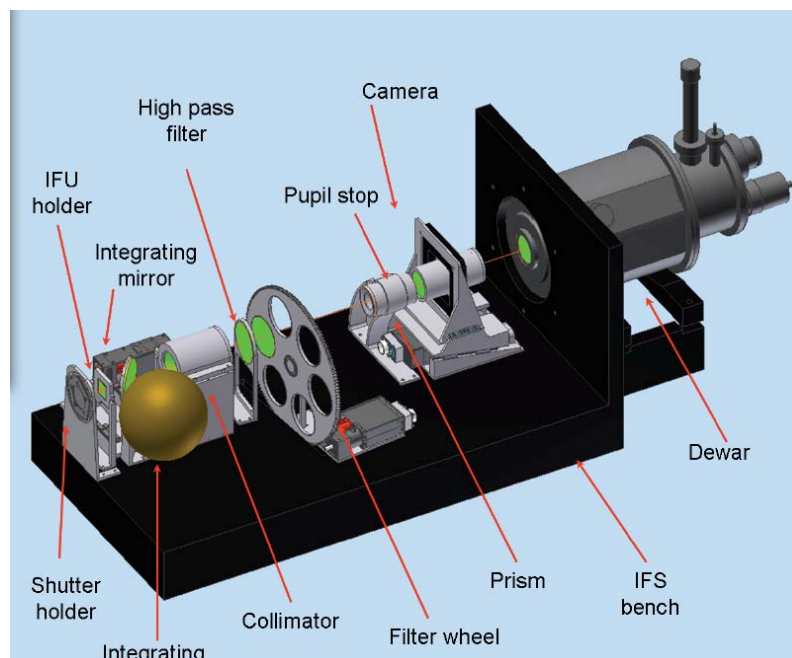
invested on SPHERE are crucial for the development of the high contrast instrument required to meet the challenging scientific objectives of the E-ELT: detection of cold Jupiters or rocky planets.



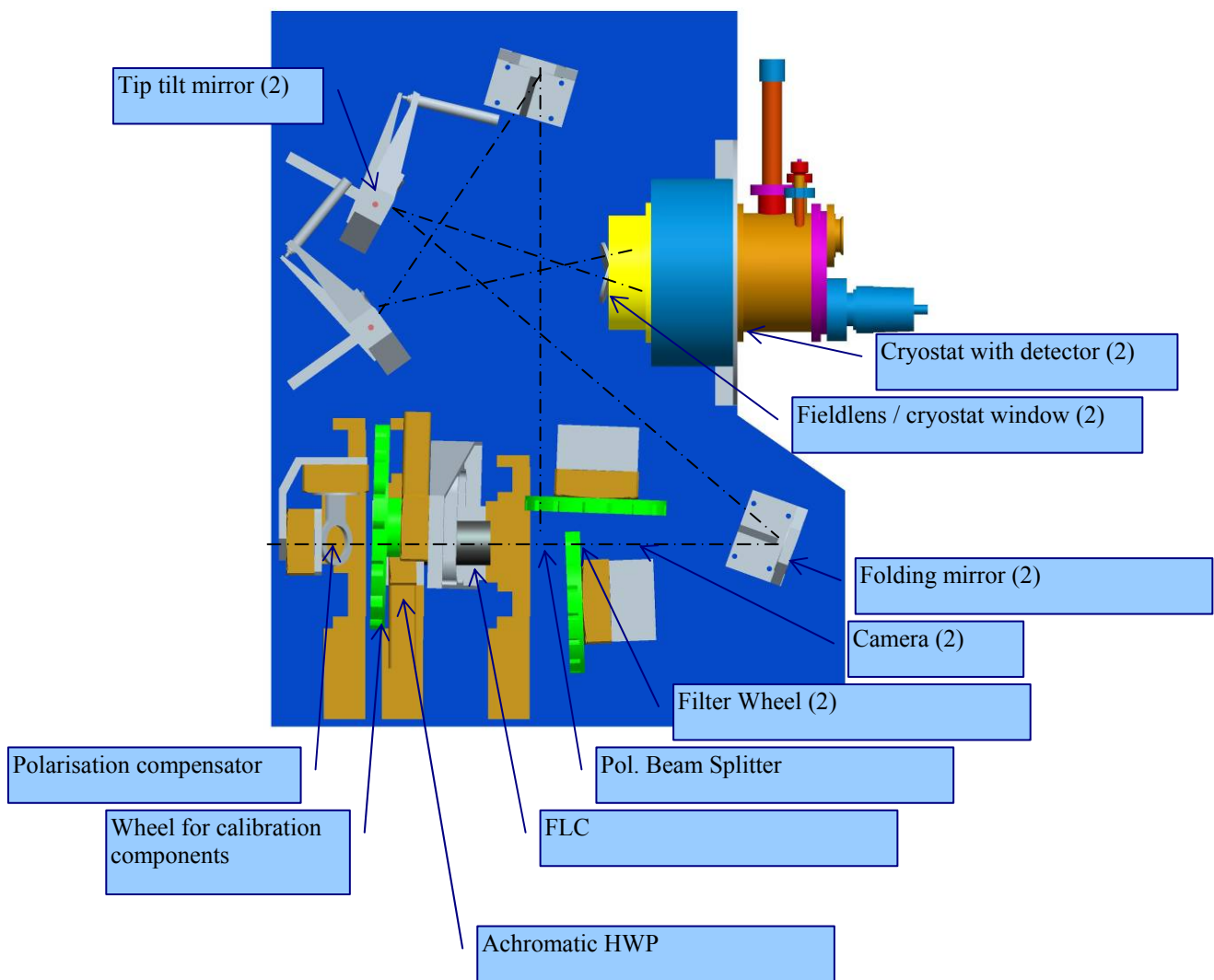
**Implementation of SPHERE on the VLT Nasmyth platform**



**Left: Design of the differential imager (IRDIS); Top: cryogenic detector jitter system;**  
**Right: <1nm rms IR filter prototype; Bottom: differential imaging optomechanical design.**



**Design of the NIR 3 D Spectrograph (IFS)**



### Design of the differential polarimeter: ZIMPOL

4 meetings have been organized in the period including the Optical Preliminary Design review March 6<sup>th</sup> and the SPHERE Design review.

The documents produced by this WP are provided in CD-ROM JRA1/WP2.1.

#### **WP2.2: GLAO System Study**

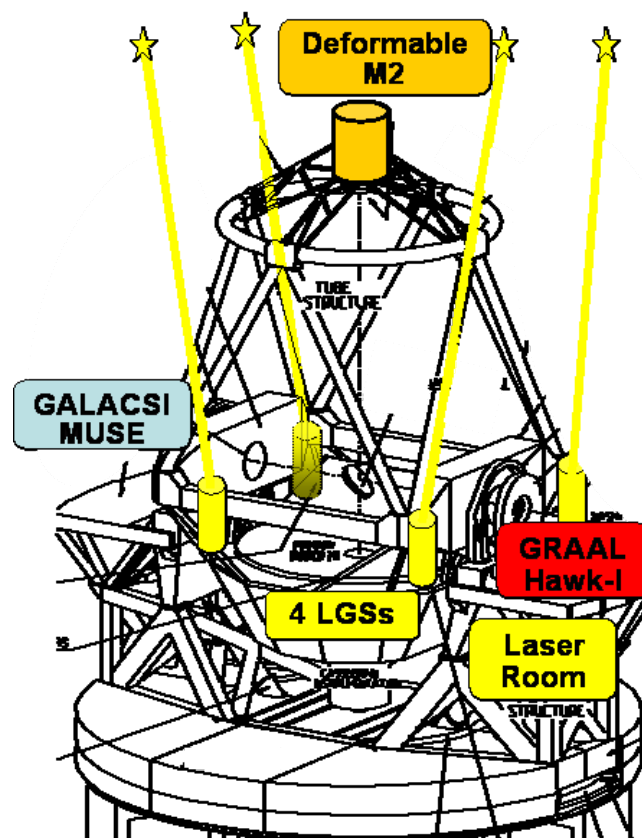
##### **Past years:**

Following the two GLAO conceptual designs (GALACSI and GRAAL) performed in 2004 and the work started on the feasibility of the VLT Deformable Secondary Mirror (DSM), WP3.5, the ESO-INAF-NOVA/Leiden project team was requested to provide the design of a fully integrated VLT Adaptive Optics Facility (AOF) consisting of GALACSI, GRAAL, DSM as a full secondary unit, the laboratory test facility (ASSIST) and the Laser Guide Star Facility with 4 laser projectors. The goal was to have a better understanding of the whole project and a better estimate of the cost to completion of this new European Facility in view of its approval by the ESO committees.

In 2005 the new Adaptive Optics Facility conceptual design has been performed and the design documentation package was produced by ESO-INAF-NOVA/Leiden. A conceptual design review involving ESO and international reviewers was conducted on September 29<sup>th</sup>-30<sup>th</sup>. The outcome of this design review was that AOF was technically feasible and scientifically worthwhile while risks were considered acceptable and controlled. Following this recommendation from the review board, ESO Scientific and Technical Committee and ESO Council (respectively in October & December 2005) have decided to proceed with the development and construction of this new facility. In 2006, NOVA/Leiden and INAF have worked on the Preliminary design of this facility: NOVA/Leiden has focused its effort on the design of the required test facility ASSIST while ESO has worked on the design of the Ground layer AO modules (GRAAL and GALACSI) and on the 4 Laser Guide Star Facility (4LGSF). Deformable Secondary Mirror design activities are included in WP 3.5 and have been supported partially by INAF.

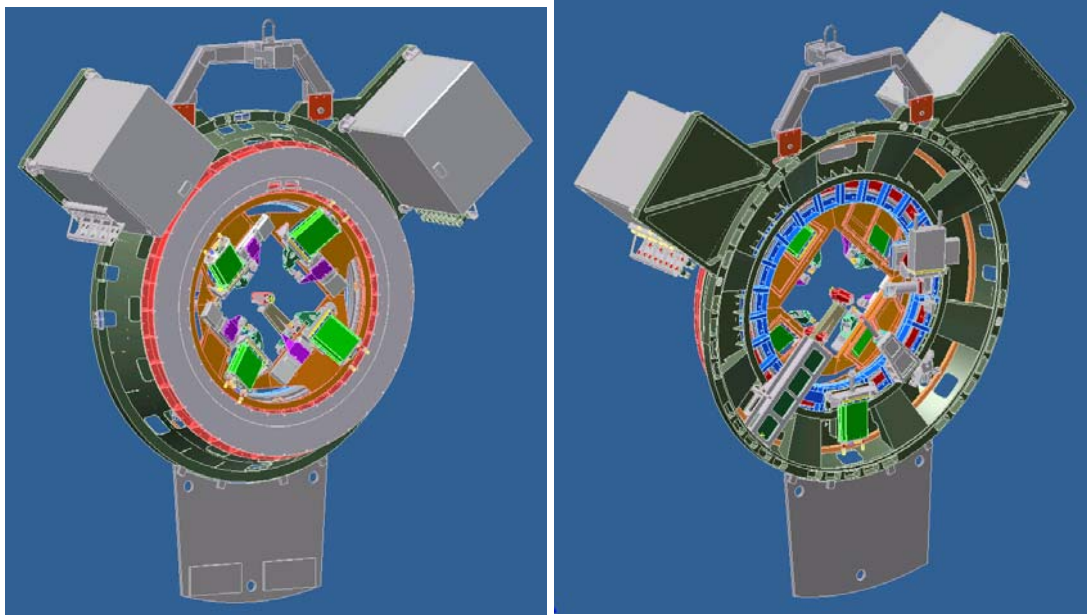
### **In 2007:**

GRAAL Preliminary design was passed March 12<sup>th</sup> 2007 (Final delivery of WP 2.2), Deformable Secondary Mirror Preliminary design was passed March 5<sup>th</sup> 2007, Final design Dec 18<sup>th</sup>. The laboratory test bench ASSIST had its Design review in October 30<sup>th</sup>. (CD-ROM JRA1/WP2.2). These reviews complete the activities covered by WP 2.2.

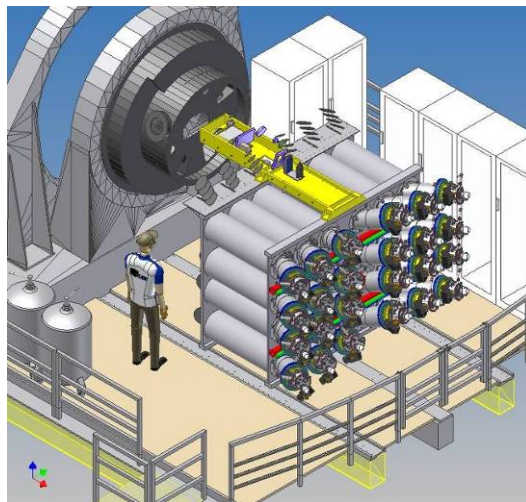


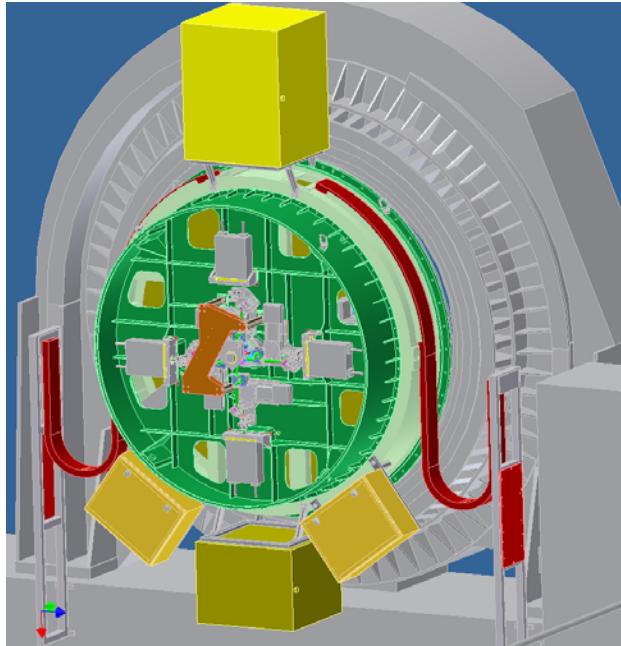
**Overview of the VLT Adaptive Optics Facility included the two Ground Layer Adaptive Optics systems: GRAAL, and GALACSI (WP2.2), the Deformable Secondary Mirror (WP3.5) and the 4Laser Guide Stars.**



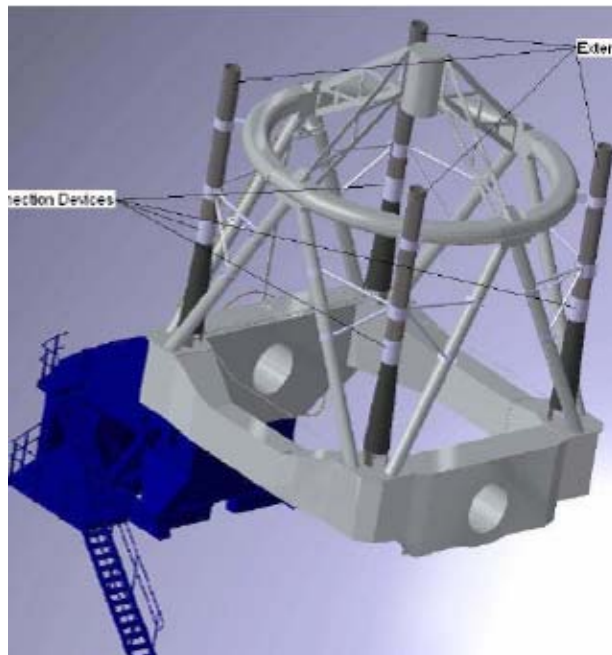


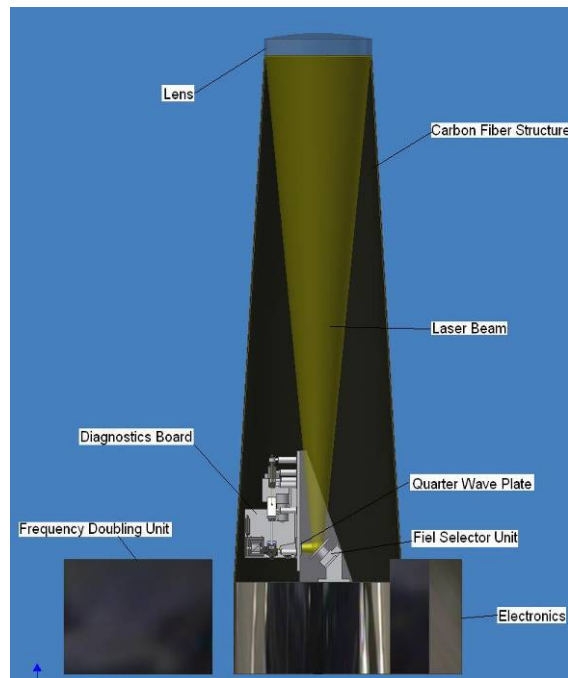
**Front & back views of the GRAAL, Ground Layer Adaptive Optics for the VLT.**



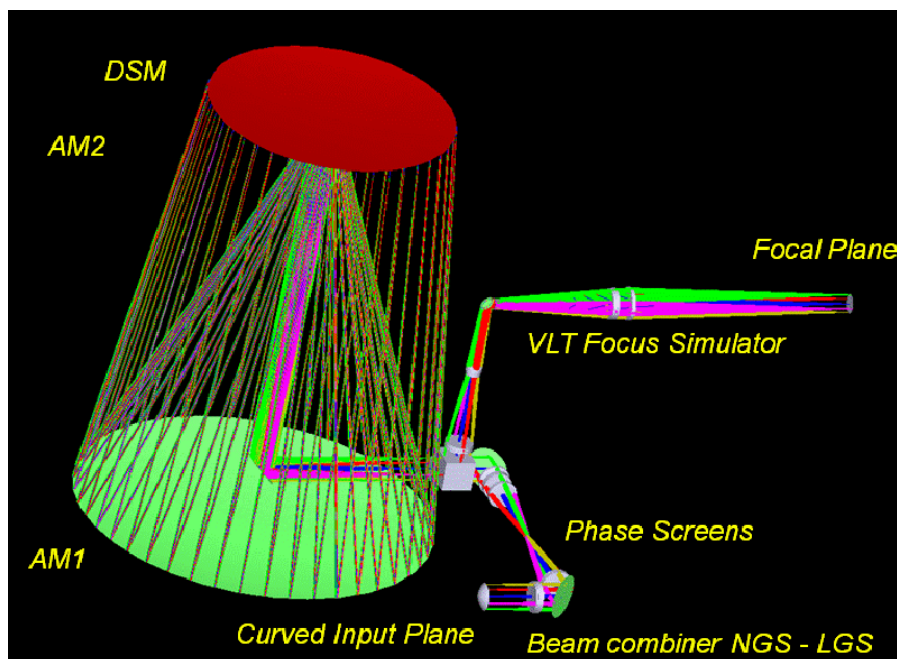


**Overview of the GALACSI, Ground Layer Adaptive Optics for the VLT. On the left: MUSE visible 3D spectrograph, in dark grey GALACSI attached to the Adapter-Rotator. On the right: GALACSI design overview.**



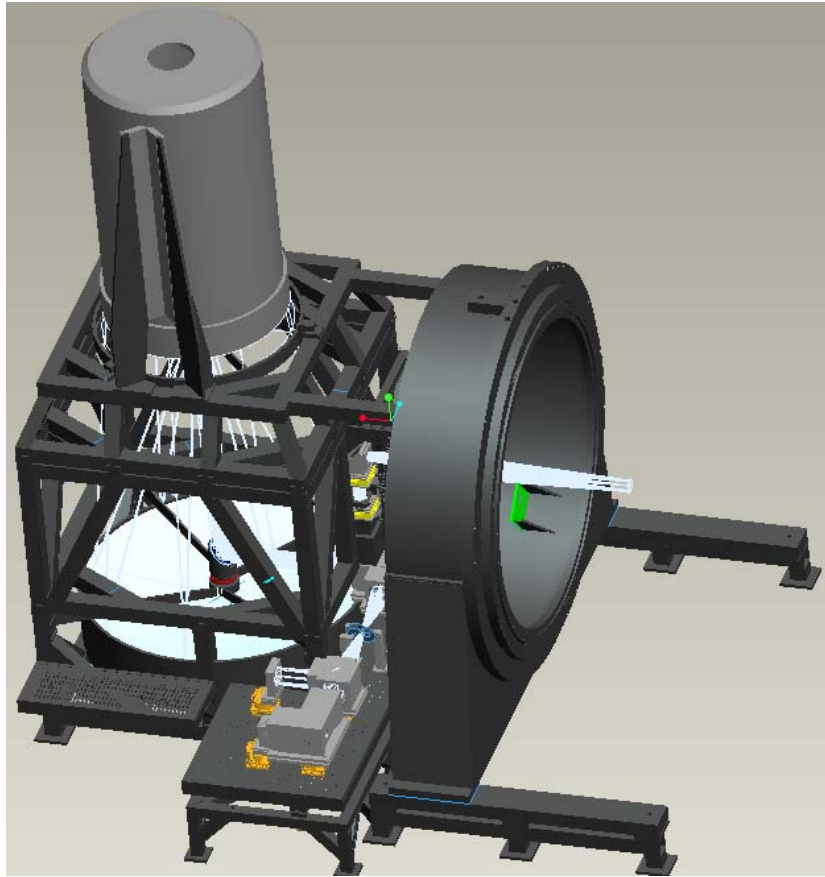


**Overview of the Laser Guide Star Facility at the VLT. Right: The four tubes are the launched telescopes for the laser beams; Left: Design of the individual launch telescope**



**Optical Design of ASSIST**





**Overview of the Adaptive Optics test facility (ASSIST): on top the Deformable Secondary mirror, on the right the mounting flange for GRAAL or GALACSI. On the bottom: the turbulence generator.**

The documents produced by this WP are provided in **CD-ROM JRA1/WP2.2**.

### ***WP2.3: Multi-Object WFS for GTC***

#### **Past years:**

The original proposal of the GTC Project Office (GTC PO) consisted of the conceptual study, design and fabrication of a multi-object wavefront sensor based on the concept of curvature wavefront sensing. In 2004, GTC carried out the simulation software development to test the conceptual feasibility of the multi-object curvature wavefront sensor concept.

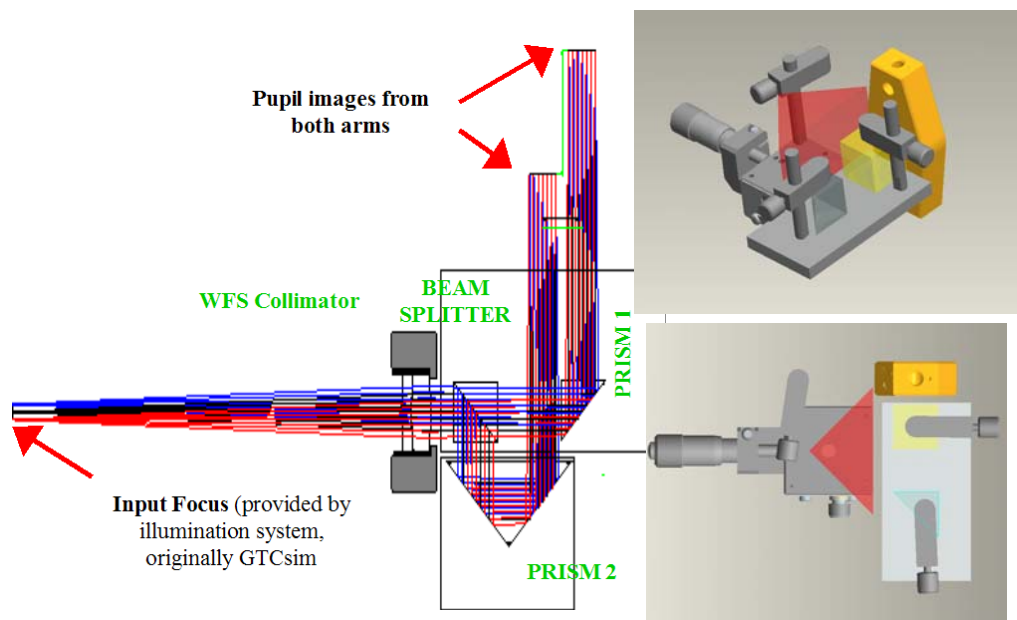
Simulations conducted at the beginning of 2005 showed that multi-object curvature wavefront reconstruction using several randomly distributed objects in the Field of View (FoV) with noise-free measurements was not good enough. The interpretation is that a better sampling of the recorded images will greatly improve the reconstruction (i.e. deconvolution) of the defocused pupil images which constitute the input to the wavefront reconstruction algorithm. In addition, the defocused pupil images reconstruction algorithm is based on a least square minimization algorithm which might benefit from a more sophisticated constrained linear least squares minimization where the “non-negativeness” of images is explicitly imposed.

Based on the results obtained so far, it is essential to address the reasons leading to the degradation of the reconstruction with a laboratory single object curvature

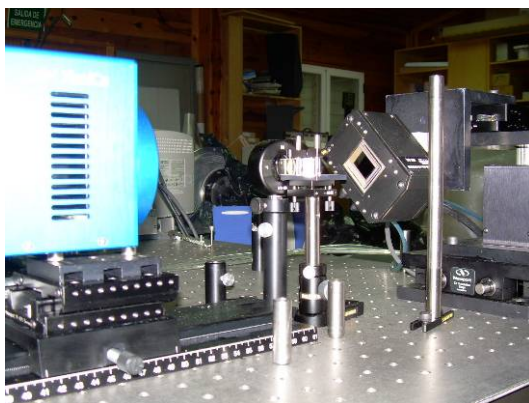
wavefront sensor in which the problem is similar to the multi-object wavefront sensor. In addition, this approach fits better the plans and the needs of the GTC Adaptive Optics Facility. In 2006, the GTC team developed the design of the GTCsim system.

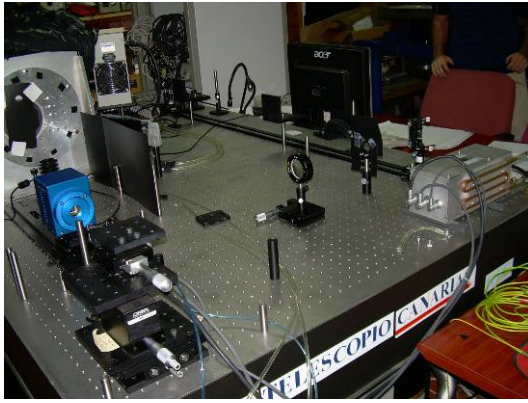
#### **In 2007:**

Following the design activities performed in 2006, the telescope + turbulence simulator and Curvature WFS was developed based on commercial optics and phase screens able to produce the required atmospheric-like turbulence. The mechanical design for the Curvature WFS was completed in March-April 2007. Components were delivered to GTC in late June 2007. In parallel, procurement of a Near-Infrared commercial camera was launched. We selected and acquired a Xenics XEVA 503 camera that arrived at GTC in August 2007. Final integration and alignment of the complete prototype using CCD47-20 in the Curvature WFS was achieved by October 2007. Due to problems encountered with the CCD47-20 head which have since been fixed, the prototype testing has been delayed to 2008.



**Optical design for Curvature WFS (left); 3D model with components selected (right)**





**Left, close-up showing NIR camera (blue box), CCD47-20 head (black box) and in between, the collimator and optics assembly for the Curvature WFS. On the right a general view of the whole prototype before closing to avoid light scattering.**

#### ***WP2.4: Multiple FOV System with NGS***

The objective of this WP is to develop a Multiple Field of View AO wavefront sensor (MFoV-WFS) prototype to be tested on the AO system of LINC-NIRVANA: a Fizeau Interferometer for the Large Binocular Telescope (LBT). The prototype system consists of a Ground Layer Wavefront Sensor (GWS), a High Layer Wavefront sensor, de-rotation units for the sensors (bearing and K-mirror), one deformable mirror, collimation and imaging optics (Collimator, FP20) for the High Layer wavefront sensor (HWS) and a patrol camera for monitoring the acquisition field of the HWS.

#### **Past years:**

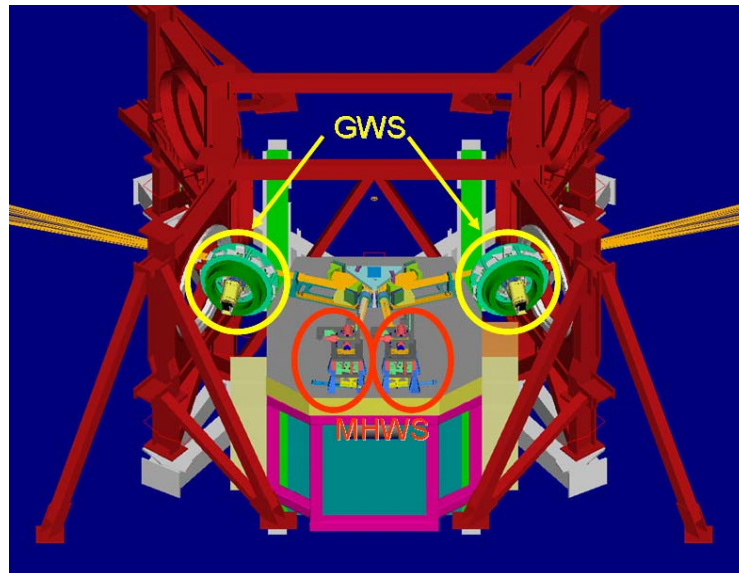
In 2004, the LBT team worked on sky coverage and performance simulation. In parallel, the team received a 349 actuator deformable mirror which was tested and characterized. At the end of 2004 the GWS design report (M1) was delivered and the CCD and control electronics was ordered. In 2005, the Final Design Review of the complete LINC-NIRVANA instrument including the MFoV-WFS systems was completed. The High order wavefront sensor translation stages were tested and found to be out of specification. The manufacturer started to re-work the stages to fix the problem. In parallel a re-evaluation of the sensor performance was conducted. In 2006, the re-work of the stages by the manufacturer was evaluated, but were not satisfactory. The high order wavefront sensor was however integrated in Bologna with the existing translation stages while the Ground layer wavefront sensor, more sensitive to the translation stage accuracy, integration was delayed. It was decided to explore an alternative translation stage design. In parallel to the opto-mechanical activities, development of instrument control software was conducted in the framework of the overall LINC-NIRVANA instrument.

#### **In 2007:**

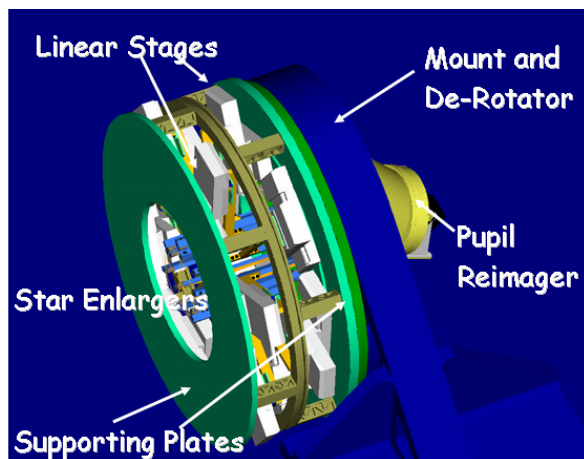
Assembly, integration and testing of the High Order wavefront sensor, assembly of the Ground layer wavefront sensor bearing was performed. Mounting of the relay optics and Patrol camera is on-going. The High Order wavefront sensor integrated at INAF will be delivered to MPIA for closed loop testing in February 2008. MPIA is currently preparing for these tests. The K-mirror is awaiting acceptance at the company. The Patrol Camera Splitter Unit did show flexure and requires mechanical stiffening. Ground Layer wavefront sensor optics and electronics have been delivered

to INAF Padova. The Pyramids have already been tested. Prototype stages from two different companies (Tomelleri, PI) have been delivered and have been extensively tested for accuracy under different temperature and flexure conditions. The stage by Tomelleri was selected and a few changes proposed to fit weight and flexure requirements. Currently, the GWS mechanics and positioning stages are outstanding; they should be delivered in spring 2008.

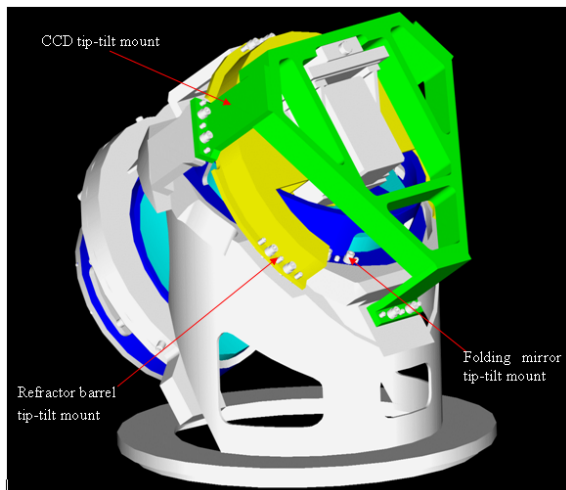
The documents produced by this WP are provided in CD-ROM JRA1/WP2.4.



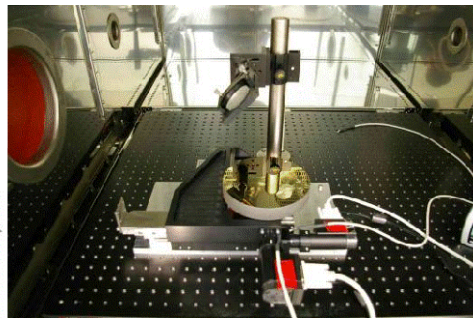
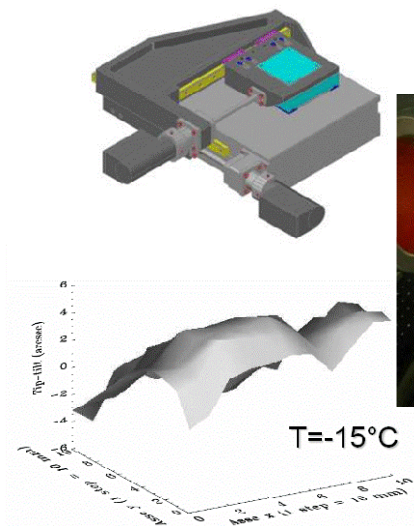
**Overview of the LINC-NIRVANA Multi-Conjugate Adaptive Optics system: In yellow the Ground layer wavefront sensor to be delivered by JRA1**





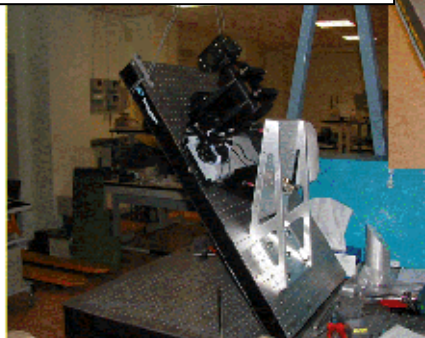


**Left: design of the Ground layer Wavefront sensor; Right: Detailed view of the pupil re-imager of the Ground Layer WFS.**



**Design & prototype (Tomelleri) testing of the Ground Layer wavefront sensor stage**

AIT at INAF – Rome  
Flexure tests have been out specification



**Testing of the of the wavefront sensor patrol camera**

### **WP 3: ENABLING TECHNOLOGY FOR 2<sup>nd</sup> GENERATION/ELT AO SYSTEM**

#### **WP3.1: 2<sup>nd</sup> Generation RTC Platform**

##### **Past years:**

SPARTA (Standard Platform for Adaptive optics Real Time Applications) went through different phases of evolution in which ESO and Durham tried different solutions of various complexity. With the guidelines of using only COTS components and keeping the development of the platform as simple as possible, SPARTA started off in 2004 with an all-CPU solution. The participation of Durham into the WP brought expertise of FPGAs (Field Programmable Gate Array), which were included into the design through available commercial products. Given the difficulty of programming an FPGA, the choice was to assign to Durham the development of well-known process like the “input machinery” (later called WPU for Wavefront Processing Unit) and statistical machinery.

The first concept presented in 2004 included all these features, but an issue with board-to-board latency had already been identified.

In the course of 2004 and 2005 we performed all the foreseen benchmarks and we realized that the architecture could not meet the requirements for two reasons: computing power of the CPU did not meet the expectations and the measured communication latency was too high. Results were shown in 2005 at the JRA-1 general meeting where the shift to the second architecture was announced.

The second SPARTA concept addressed the concerns of computing power and communication latency by increasing the use of FPGAs. We proposed a 2-layer architecture with FPGAs running all the real-time part and CPUs supervising their functions. A suitable commercial product had not been identified yet, but the concept was very similar to the forthcoming VMETRO VPF1. We ran an internal conceptual design review between Durham and ESO to consolidate the architecture.

However the architecture seemed too biased towards FPGAs: the difficulty of their programming and the long development cycle raised concerns about their wide use.

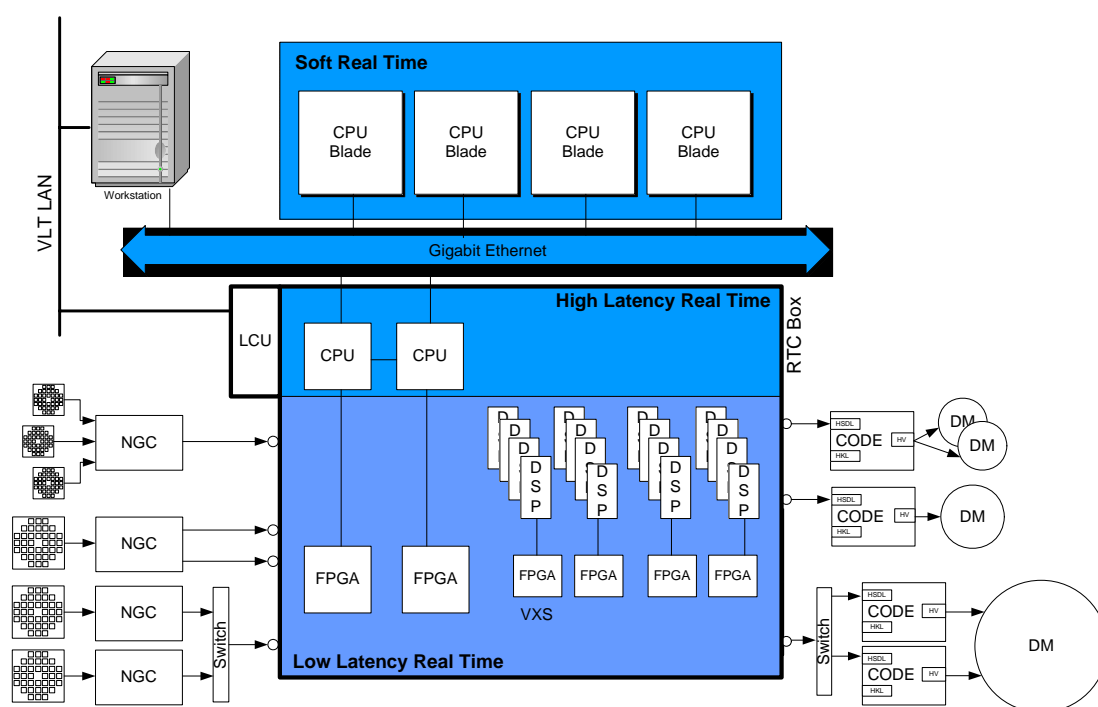
Towards the end of 2005, ESO and Durham developed a third concept for SPARTA based on a hybrid architecture that uses three different technologies for different purposes. FPGAs are used to pre-process the large incoming data stream to more manageable sizes (i.e.: from pixels to gradients, developed by Durham) and to implement the high-speed communication infrastructure that runs serial FPDP. DSPs (Digital Signal Processors) are in charge of the main mathematical operations and general-purpose CPUs (Central Processing Unit) perform more complex tasks or high level operations developed by ESO. Each technology is employed where it is best suited. These computing elements are organized within two types of SBC (Single Board Computer) boards. The first features 2 CPUs and 2 FPGAs (VMETRO VPF1) and it is used as front-end and back-end of the processing chain. The second features 8 DSPs and 2 FPGAs (Bittware T2V6). The same type of FPGA is present on both boards and this enables board-to-board communications. The high-speed communication layer runs over a VXS bus, a follow-on of the VME standard. The rack is completed by an ESO-standard LCU used to monitor the rack and control the T2V6 boards and a Zero-Latency-Switch (CSW1 from VMETRO) that connects the VXS slots with each other and also features several optical transceivers that can be directly routed to any VXS slot. We have called this part the Real-Time Box, since

only the core of the application runs here, the high-speed, low-latency, high-throughput hard real-time computation.

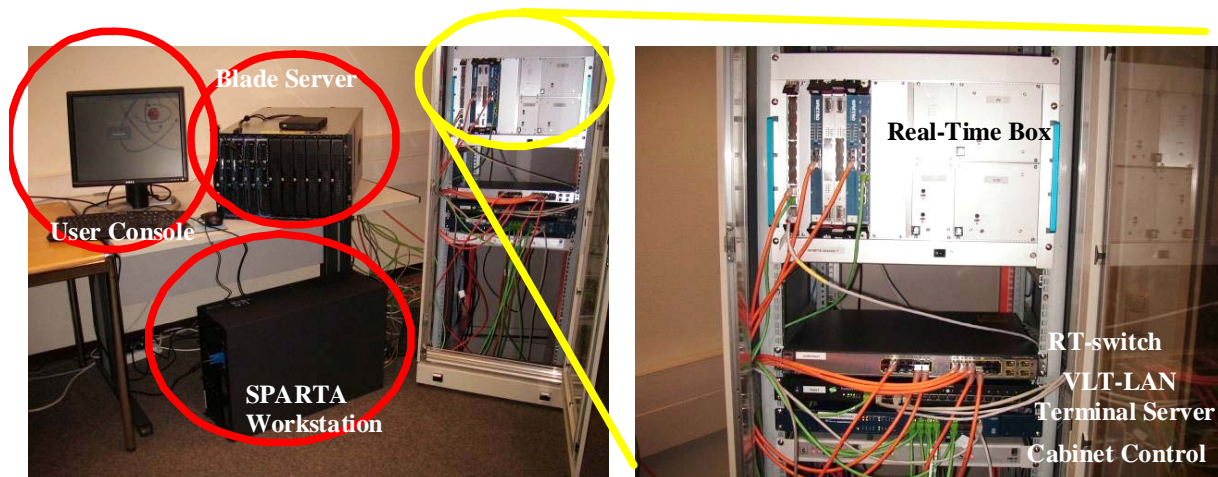
This new concept was presented to an external board of reviewers, who approved it in May 2006. Hardware procurement and definition of all the interfaces were also completed.

#### In 2007:

A working WPU (Wavefront Processing Unit) prototype that runs on the FPGA and converts pixels to gradients has been developed and partially tested on one test platform. All other unit benchmarks have been completed. The SPARTA architecture design, the benchmark results as well as the results obtained on the prototypes were reviewed at the Preliminary Design Review July 6<sup>th</sup> (Deliverable M2 of WP 3.1). This review completes the work on this WP 3.1.



**SPARTA concept.** The platform is scalable in the number of computing elements. The computing elements are divided into three areas: a low-latency real-time domain mainly populated with FPGAs and DSP, a high latency real-time domain mainly populated by general purpose CPUs and a soft real-time domain populated by CPUs. The low-latency real-time domain is connected directly to the external world where it receives detector data from and sends mirror commands to. The FPGAs constitute the communication framework, while implementing also part of the processing pipeline. DSPs complement the FPGAs for floating point mathematical operations. The internal communications run over an electrical VXS backplane, while the external interfaces are fibre-based. The upper level, soft real time domain, is in charge of statistical analysis and loop monitoring, all computational intensive but with lower real-time requirements. The two top levels are connected together through a gigabit Ethernet interface. A standard LCU is provided to control each crate and a standard Instrument Workstation is provided to offer a CCS-standard interface.



**Overall SPARTA system (left) and closed-up for the Real-Time box (right). In the picture the SPHERE prototype is shown. On the left side one can see the Blade server the SPARTA Supervisor), the SPARTA Instrument Control Workstation and a User Console. On the right side one can see the real-time rack with, from left, one ESO-standard LCU, one front-end VPF1, two T2V6, one back-end VPF1 and the Zero-Latency-Switch. Below the rack one can see the real-time network switch (a Cisco Catalyst), a standard switch simulating the VLT LAN, a terminal server and the Rittal cabinet control system.**

The documents produced by this WP are provided in CD-ROM JRA1/WP3.1.

#### **List of papers:**

1. R. Myers et al. FPGA Developments for the SPARTA project - Part 3, SPIE-07

### **WP3.2: Optimal Control Methods for MCAO Systems**

#### **Past years**

The activity of 2004, 2005 and 2006 for WP 3.2 performed by ONERA consisted of the following:

- Optimal Control Methods for Multi Conjugate Adaptive Optics using Kalman approach. Off-axis Adaptive Optics control using this method has been numerically and experimentally demonstrated on the BOA bench at ONERA. From this successful experimental work, ONERA developed the specifications and the algorithms of this optimal control method for the ESO Multi Conjugate Adaptive Optics demonstrator (MAD).
- Theoretical studies on high performance wavefront sensor in Multi Conjugate AO have been performed. In particular, Sky coverage, comparison and optimisation of wavefront sensor measurement concepts (based on Star Oriented and Layer Oriented approaches) have been studied.

#### **In 2007:**

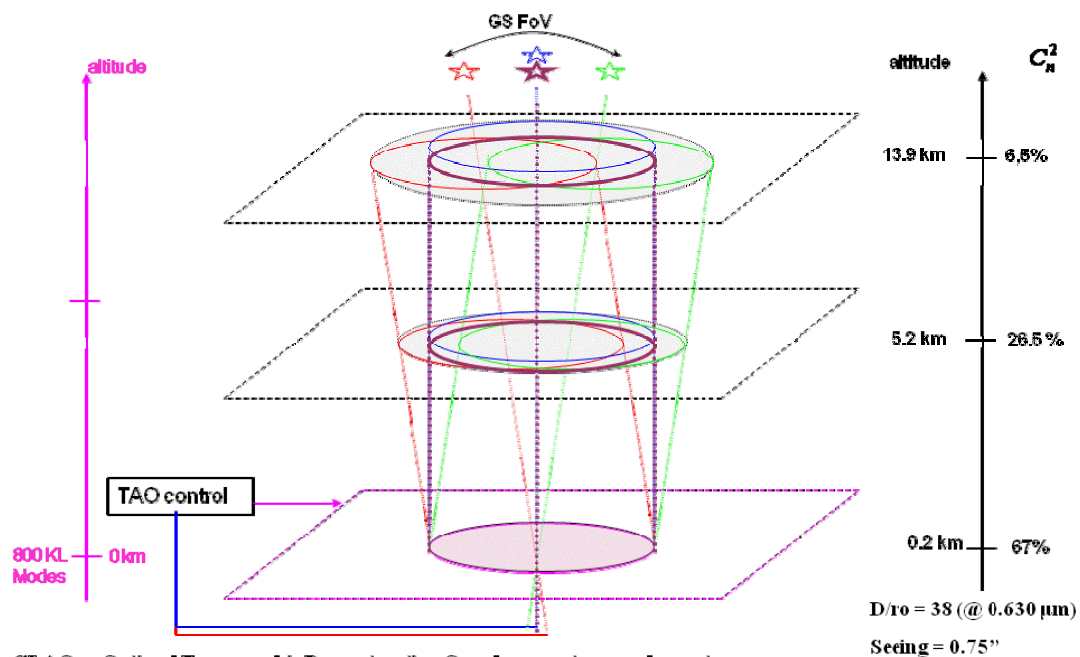
As expected in last year's annual report, the VLT Multi-Conjugate Adaptive Optics demonstrator has been shipped to the Paranal Observatory before the implementation of the ONERA optimal control method developed in earlier years. In addition, due to



the technical success of MAD on-sky, the astronomical community has asked to keep MAD at the Paranal observatory to perform Multi-Conjugate AO observations. Therefore MAD will not be back to ESO-Garching before end of 2008 (end of JRA1). It was proposed last year to replace this activity by VLT-like LTAO and Tomographic AO simulations with the optimal tomographic reconstruction to demonstrate its interest. This study was performed and results compared with a simple Ground Layer AO. This issue is of particular interest for the so-called VLT MUSE visible 3D spectrograph narrow field mode. The simulation parameters therefore correspond to a VLT case with typical Paranal turbulence conditions. As a first approximation the simulation is performed in open loop which is sufficient to obtain general trends. The Strehl Ratio is estimated at the centre of the field of view with various Guide Star (GS) configurations: four to nine GSs on a circle of variable FoV diameter, with or without a central GS. The GS are Sodium Laser Guide Stars (LGS), accounting only for the cone effect, but we also give for comparison the Natural Guide Star (NGS) case. This study is also part of a PhD work.

The optimal tomographic reconstruction brings a very significant gain in performance both in the NGS and LGS cases (several tens of SR percent). However performance and global behaviour with respect to GS FoV is quite different with NGS and LGS due to the cone effect.

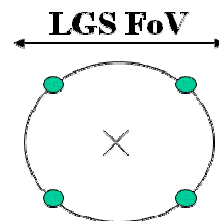
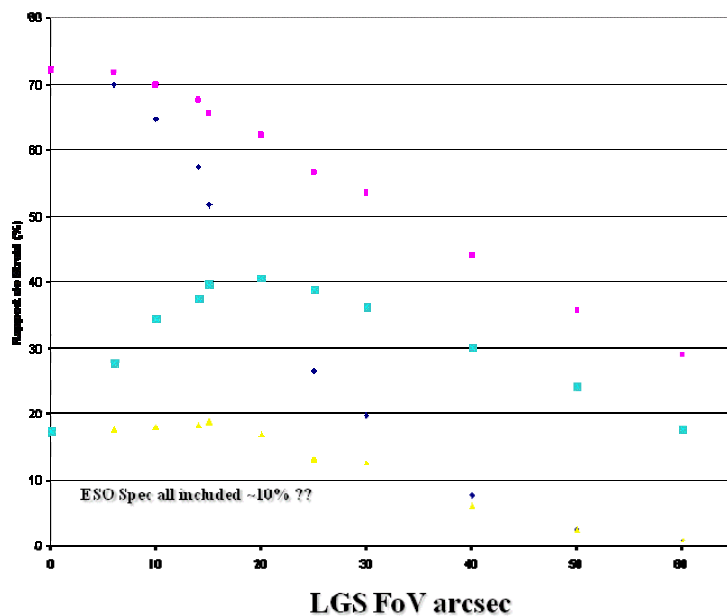
For the case of interest here, that is LGS, a clear optimum is found as a function of GS separation (near a 20 arcsec LGS FoV): the tomographic reconstruction allows to partially solving for cone effect provided that the LGS give a good probing of the turbulence volume. Having more LGS improves the performance at the optimum but also clearly allows moving the LGS further apart: the performance stays rather constant between 20 and 60 arcsec LGS FoV. The natural way for implementing this tomographic optimal reconstruction in practice that is in a closed loop scenario, is to use the optimal LQG control (based on Kalman filtering) studied and validated in the present JRA1 WP3.2. It would guarantee optimal performance and ensure stability. Other techniques are also investigated at ESO ("virtual DM").



GLAO or Optimal Tomographic Reconstruction Openloop, no temporal aspects

## Muse Narrow Field mode context for the ONERA simulations

Comparison des performances GLAO/LTAO avec 4 NGS/LGS (matrices sur 256 pixels)



- 4 LGS
- LGS = only cone effect
- GLAO versus Optimal Tomographic Reconstruction

## Performance versus Guide Star separation for Natural & Laser Guide Stars in Ground Layer and Laser Tomography Adaptive Optics modes

A report was produced and is provided in CD-ROM JRA1/WP3.2 (deliverable M3 of WP 3.2). This report complete the activities planned in this WP 3.2

WP3.3: 2<sup>nd</sup> Generation Piezo DM

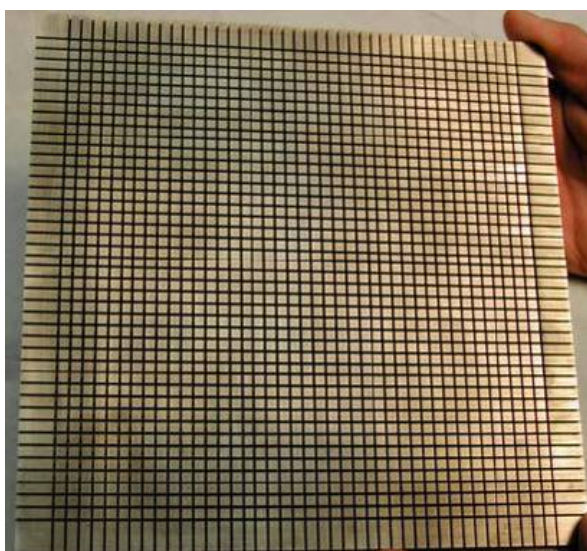
**Past years:**

Following the VLT Planet phase A studies (WP 2.1), top level specifications for the development of the 1370 actuator piezo deformable mirror prototype was produced by the SPHERE Consortium in 2004. These top level requirements have been integrated into a Technical specifications and Statement of Work by ESO. In 2005 a Call for Tender was issued by ESO, and two proposals were received and evaluated. After difficult negotiations the contract was granted and signed with CILAS (France) in March 2005. The Kick-off meeting took place in April 2005. CILAS has developed the design of the 1377 actuator piezo-deformable mirror and a design review was organized by ESO in November 2005 (deliverable D1 of WP 3.3). In 2006, CILAS has developed a 57 actuator mockup to validate design parameters of the final unit. This mockup has been extensively tested to check the actuator stroke and inter-actuator stroke, the coupling between actuators, the optical quality of the best flat, hysteresis and dynamic characteristics. Results obtained on the mockup have shown that the performances were conformed to the ESO technical specifications.

**In 2007:**

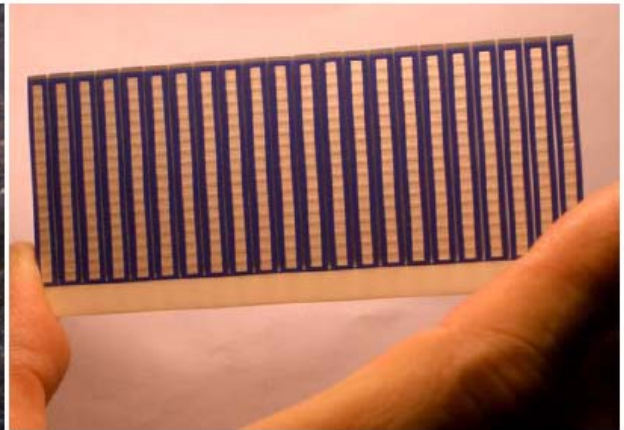
Manufacturing, Assembly, Integration and testing of the 1377 actuators has been completed in 2007 and Acceptance of the deformable Mirror was achieved July 5<sup>th</sup> at CILAS. Test report was delivered in October (deliverable M1 of WP 3.3). This completes the activities foreseen in the WP 3.3.

Pictures are provided below to show the deformable mirror key elements as well as of the final unit. The successful development of this 1377 actuator deformable mirror is a world first from the number of actuators view point. This success has already led CILAS to negotiate with the Thirty Meter Telescope project for the manufacturing of two 60x60 actuator deformable mirrors and with the New Solar Telescope (40x40 actuator cooled deformable mirror). This is a good demonstration of European Research funding impact helping industry to capture new contracts outside Europe.

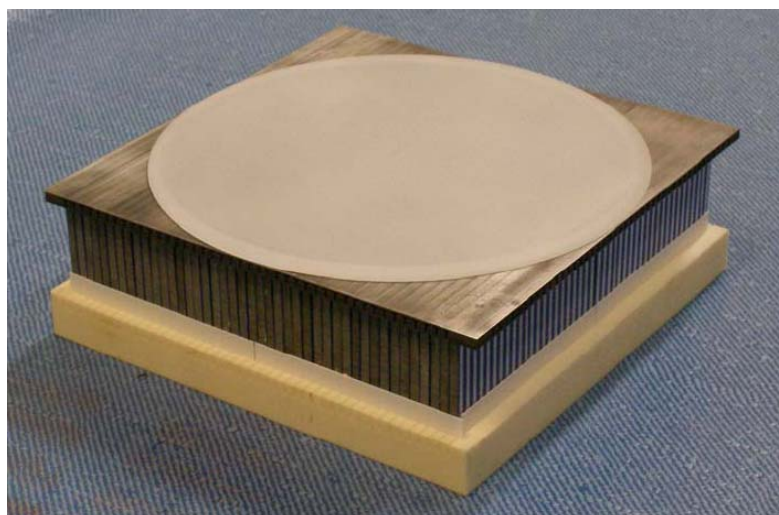




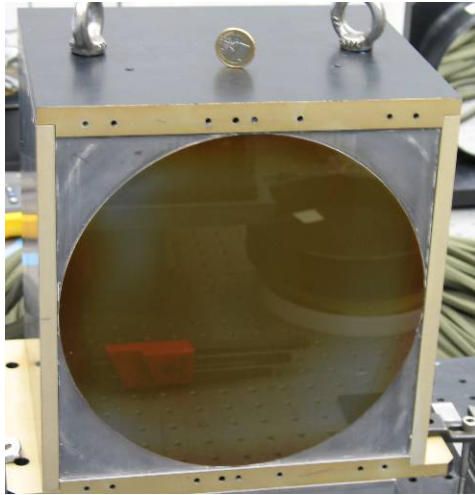
**Left: 41x41 deformable mirror head; Right: housing**



**Base plate and line of actuators**



**Preassembly of the 41x41 actuator piezo DM**



**1377 actuator deformable mirror (before coating)**



**From ~900 k€contract signature to deformable mirror acceptance**

The documents produced by this WP are provided in **CD-ROM JRA1/WP3.3**.

#### ***WP3.4: 2<sup>nd</sup> Generation Piezo DM drive Electronic***

##### **Past years:**

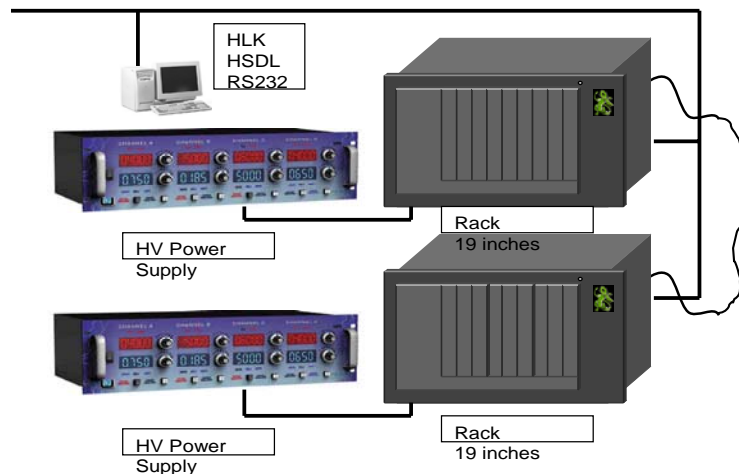
Following the design review of the piezo Deformable Mirror (WP3.3) and the corresponding interface definition (November 2005), ESO finalised the technical specifications and Statement of Work for the design and development of the Corrective Optics Drive Electronics (CODE) with 1500 channel and launched a fixed price (230k€) Call for Tender (17 companies contacted in Europe and in US). Two offers were received, the Shaktiware offer based on innovative technology that should achieve goal specifications in the critical areas of power dissipation and latency was



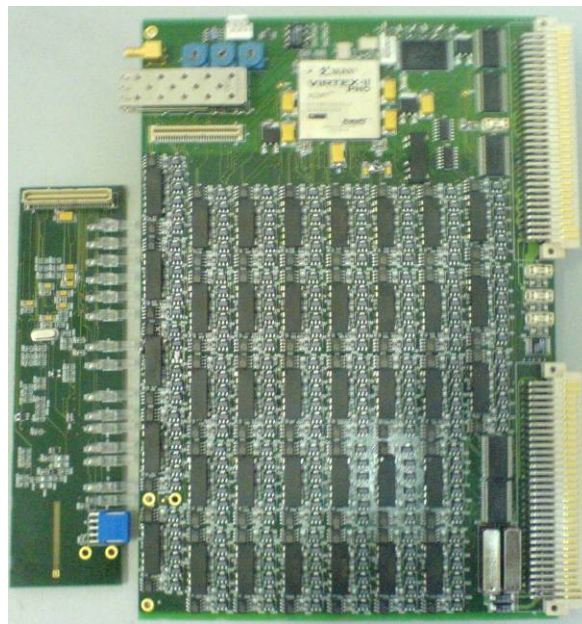
selected and contract was signed in October 2006. A design review was successfully conducted in December 2006.

**In 2007:**

Manufacturing of the Corrective Optics Drive Electronics is closed to completion and will be accepted 1<sup>st</sup> Quarter 2008. (Deliverable M2 of WP 3.4). This will complete the activity of this WP 3.4.



**1500 channels piezo DM drive electronic architecture`**



**One high voltage amplifier board of CODE**

**WP3.5: VLT Adaptive Secondary**

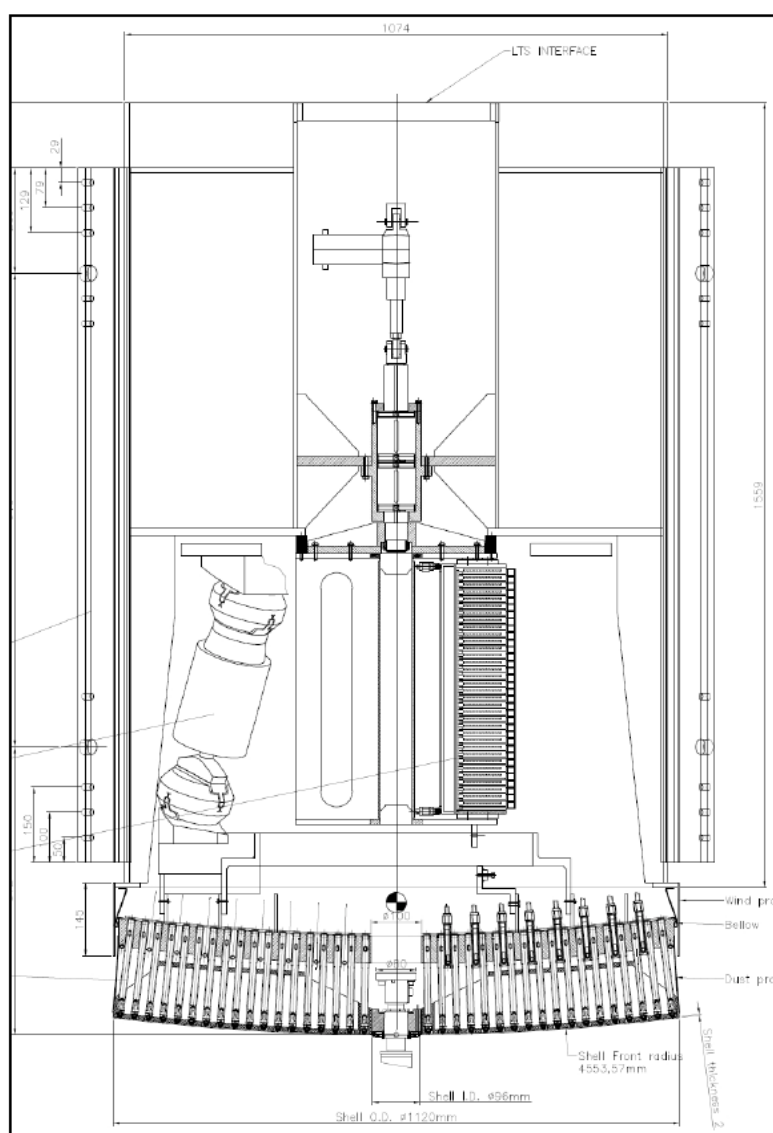
**Past years:**

In 2004, ESO in collaboration with INAF, prepared the detailed technical specification and Statement of Work for the development of the VLT Adaptive

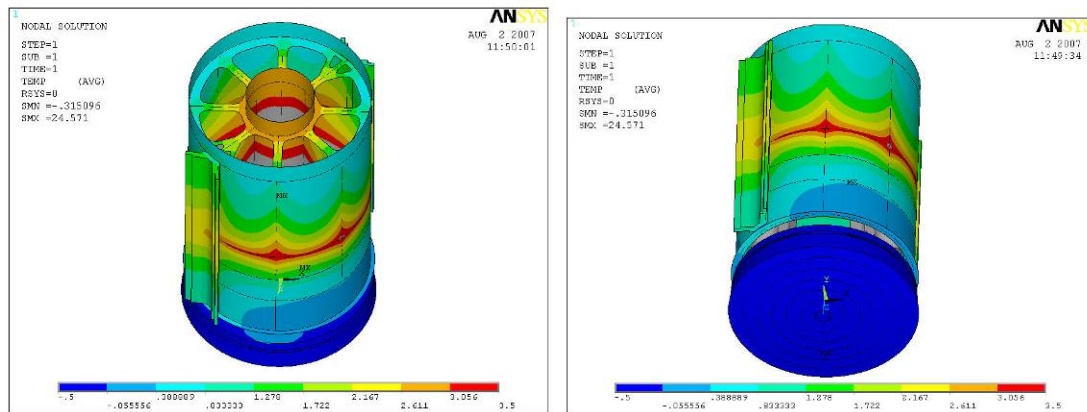
Secondary. The contract (s) for the feasibility and conceptual design study part of this development was signed with Microgate (Italy) in July 04. Microgate has delivered a straw man design report including review of the critical interfaces and the corresponding design review has taken place. INAF has produced the preliminary evaluation of the performance of the VLT adaptive secondary for this straw man design phase. In March 2005 the consortium of Microgate, ADS and INAF Arcetri presented a straw-man design for a complete VLT Deformable Secondary Mirror (DSM). In August 2005, the conceptual design of the VLT Adaptive Secondary was presented to ESO. The feasibility study was concluded as having demonstrated the feasibility of the VLT DSM. Early 2006, the preliminary and final design phases were kicked-off.

In 2007: The preliminary design review was successfully passed March 5<sup>th</sup> 2007. Important prototyping activities have been on-going until 3Q 2007 to ensure control electronic low power consumption demonstration, hexapod flexible joints and shell lateral restraint. The final design review has been successfully passed in December 18<sup>th</sup> (Delivery of WP 3.5). The later complete the activities of WP 3.5.

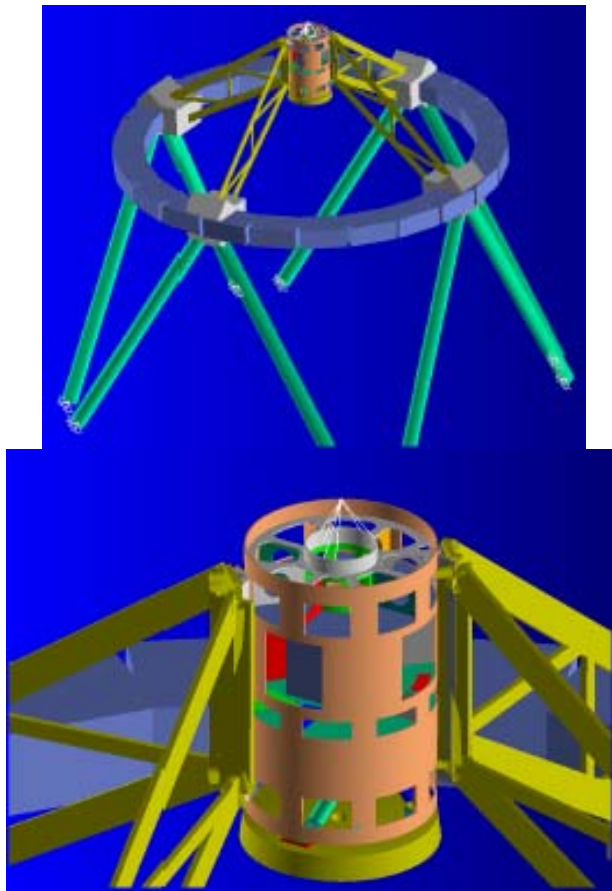
Documentation of WP 3.5 is included in CD-ROM JRA1/WP3.5



## VLT Deformable Secondary mirror components layout into the M2 hub

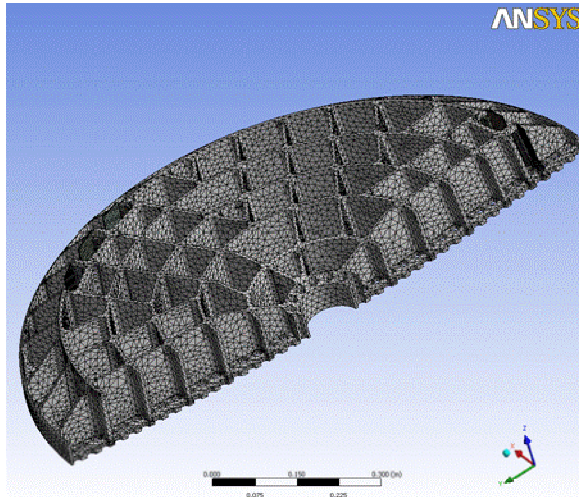


## Thermal Analysis of the Deformable Secondary Mirror

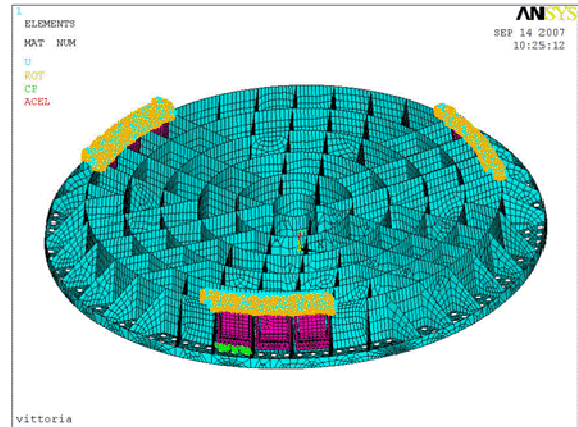


## Deformable secondary Mirror mounted on the VLT



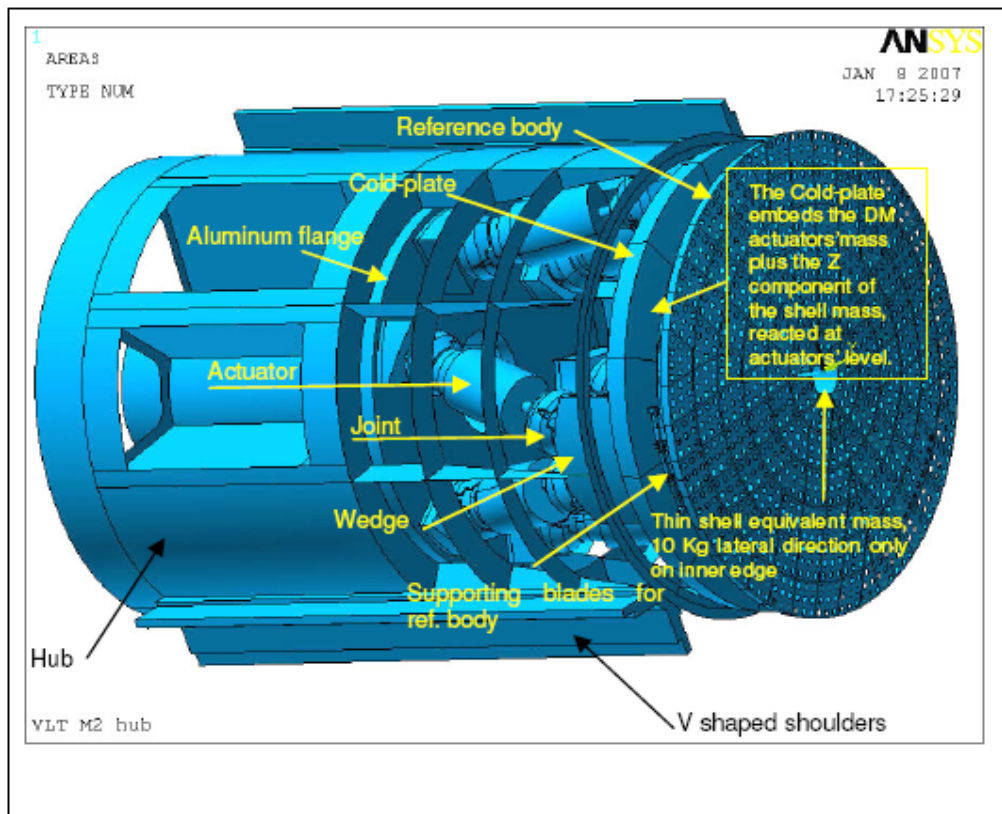


Detailed FE model of the zerodur back-plate with only brick elements



simplified FE model of the back-plate (shell elements) used for the analysis of the entire DSM unit.

### Back Plate final design Finite Element Analysis

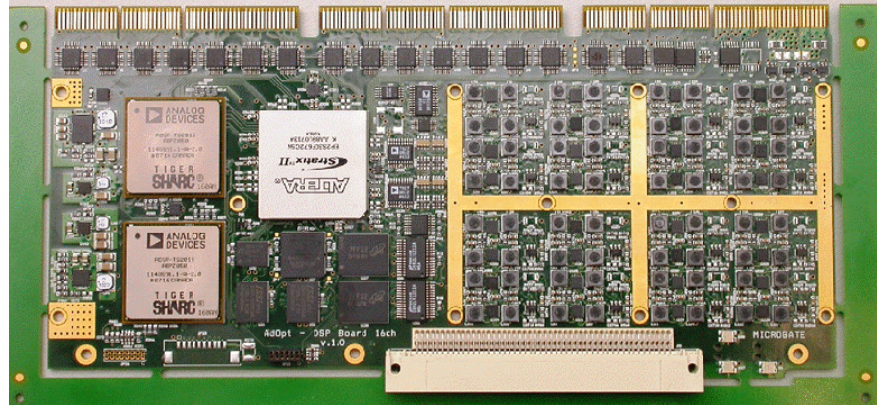


Geometrical solid model of the entire M2 unit. The main subsystems are highlighted

### DSP – Board Technology

- 16 Layers on 1.6mm board thickness
- Tracks: Controlled Impedance, transmission lines; 100  $\mu\text{m}$  routing and spacing
- 1341 components (9 BGA)
- 6122 connections

→ *State of the Art, but even consolidated and established technology*



### Digital Signal Processing board prototype for the VLT Deformable Secondary Mirror



### Deformable Secondary Mirror Hexapod flex joint prototype

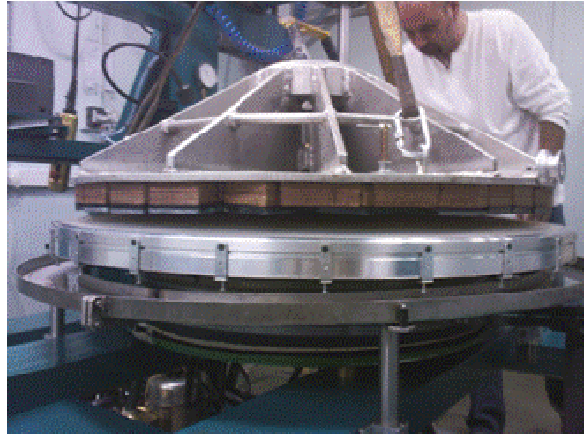
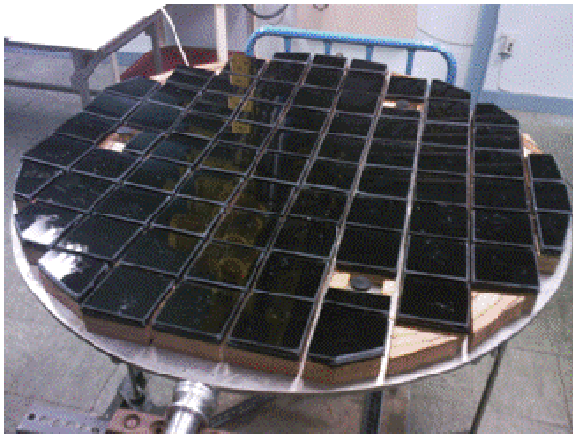
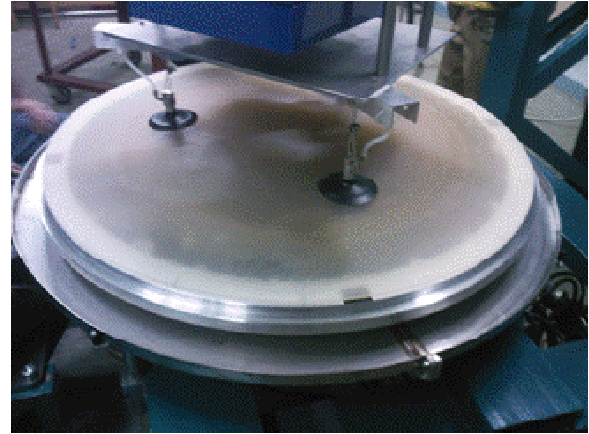
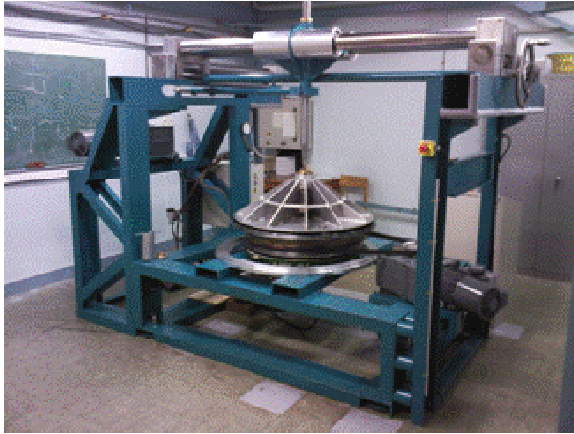
#### WP3.6 Manufacturing and Demonstration of a large convex glass shell

##### Past years:

In 2005 ESO issued a Call for Tender for the “Manufacturing, Testing and Delivery of one 1.1m Glass Thin Shell at a firm price of EUR 300.000”. Two (2) answers were received but were considered non-compliant. The tender was closed and negotiations were conducted with both potential suppliers to identify areas of compromise. ESO issued an updated CfT in December 2005 to the 2 above mentioned suppliers. The compromises are that ESO will provide a supplementary blank (funded outside OPTICON funds) and the surface errors versus linear scale requirements have been relaxed. Answers to the second CFT were received in January 2006; ESO Finance Committee approved the selection of the SESO (France) for the manufacturing of the 1.1m thin shell in collaboration with LAM. A kick-off meeting took place at SESO in April 06, final design review was in September 2006. The first Zerodur blank was delivered to SESO at the end of 2006.

##### In 2007:

Following the delivery of the Zerodur blank, the blank was prepared by SESO. INSU-LAM integrated the 1.5 m polishing machine, manufactured the 1 m polishing tools, manufactured the support ring on the tabletop of the polishing machine. After the installation of the blank meniscus from SESO, INSU-LAM installed the meniscus on the polishing machine and tested the depressurization system (see pictures below). The polishing process actually started in September 2007 due to the late delivery of pieces for the polishing tool and machine. Fine spherical grinding was completed in December. The delivery of the final polished shell tested is now foreseen 4Q 2008.



**Top left: 1.3 m polishing machine at INSU-LAM, Top right: Zerodur meniscus installed on polishing machine using a dedicated handling tool; Bottom left: polishing tool; Bottom right: polishing tool in contact with the Zerodur shell.**





**Polishing of the shell at INSU-LAM**



**1.1 m VLT M2 test matrix in a dedicated mechanical mount and handling tool delivered by ESO to SESO for the thin shell testing.**

ESO has delivered the test matrix mounted in a newly designed mechanical mount matching the polishing machine mechanical interfaces early 2007.

ESO has received a 2<sup>nd</sup> Zerodur blank (spare).

### ***WP3.7 2k Actuator & low order Micro-Deformable Mirrors (MDM) R&D***

#### **Past years:**

The first activity of work-package 3.7 was the development of a prototype magnetic deformable mirror. This prototype was delivered in 2005 by LAOG, and we received a lot of requests for this device from the adaptive optics community (both astrophysics and ophthalmology). LAOG had to quickly find a solution to manufacture and commercialize these deformable mirrors, and in 2005 we decided to create a business unit called ALPAO within FLORALIS, a subsidiary company from the Grenoble University dedicated to technology transfer. ALPAO will become a stand-alone company in June 2007 and is now employing 3 people. A second patent license was granted to the Imagine Eyes Company for non-astrophysics applications.

The second activity of work-package 3.7 is the development of a MEMS-based 2k actuator deformable mirror. A call for tender was issued (JRA1-SPE-LAO-0003) and sent to 23 companies and research centres selected with the help of a private consulting company (Yole Development). But due to the lack of satisfactory answers and the late availability of funding, we decided to adapt our strategy to both the available cash-flow and to the technical capabilities of possible subcontractors. After discussions with LETI, ALPAO and OKO/IPMS we decided to launch 2 smaller contracts in 2006. These are:

- One with LETI for the development of a smaller MEMS-based deformable mirror. The kick-off meeting took place in September 2006 and a first progress report was delivered end of 2006.
- One with ALPAO for the development of an improved magnetic deformable mirror. The kick-off meeting of the feasibility study took place in August 2006 and a 1<sup>st</sup> progress report was delivered in December 2006.

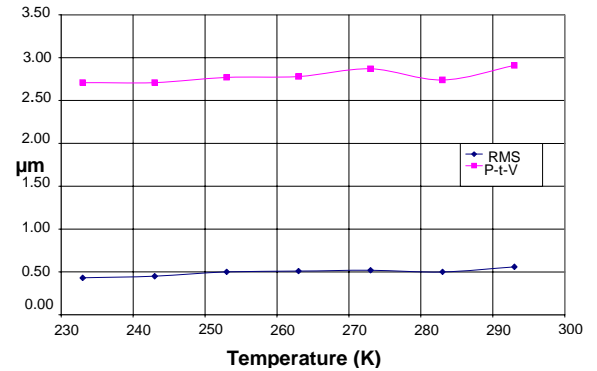
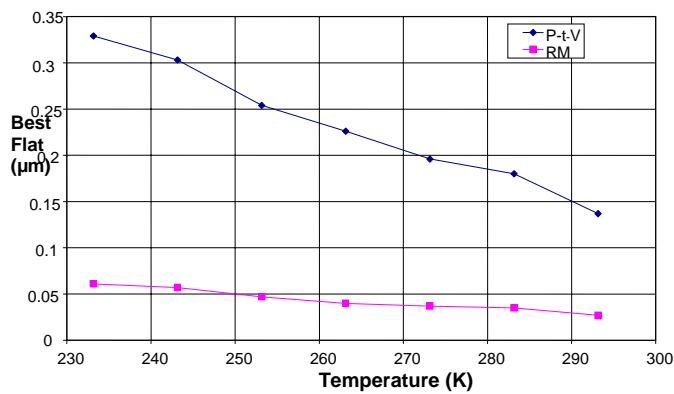
The third activity of work-package 3.7 was the development of drive-electronics for the MEMS prototype (deliverable M3). A contract was signed in 2005 with SHAKTIWARE for the development of 1024 channel drive electronics (CNRS contract N° M051104). This prototype was delivered in 2006 and is now fully operational at INSU-LAM. We managed to keep the requirements and the design compatible with other MEMS devices, and the Shaktiware electronics is now used at ESO to drive a MEMS device manufactured by Boston-Micromachine.

#### **In 2007:**

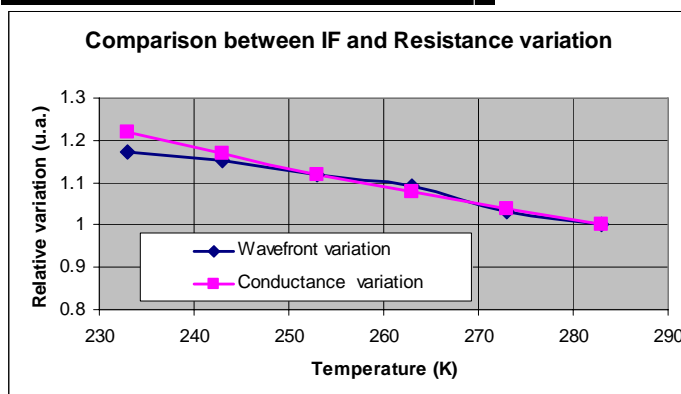
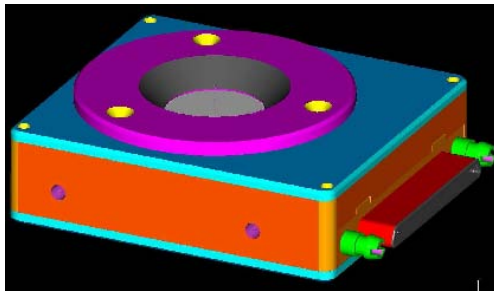
##### ***Magnetic Deformable Mirror***

The feasibility study has continued. The design phase of an 11x11 magnetic deformable mirror has been successfully conducted this year. The final design report was delivered in October 2007. A complete thermal analysis has shown the capability of such mirror to withstand temperatures down to -40 degree and provide the required flatness, stroke and power consumption. The print-through is not increased. ALPAO demonstrated all the characteristics by testing directly on a prototype. The only requirement not reached was the bandwidth. A new contract was signed for the next phase: prototyping of a magnetic deformable mirror with high bandwidth. The KOM took place in January 2008. The final prototype should be delivered in July 2008.

**Wavefront deformation (μm)**



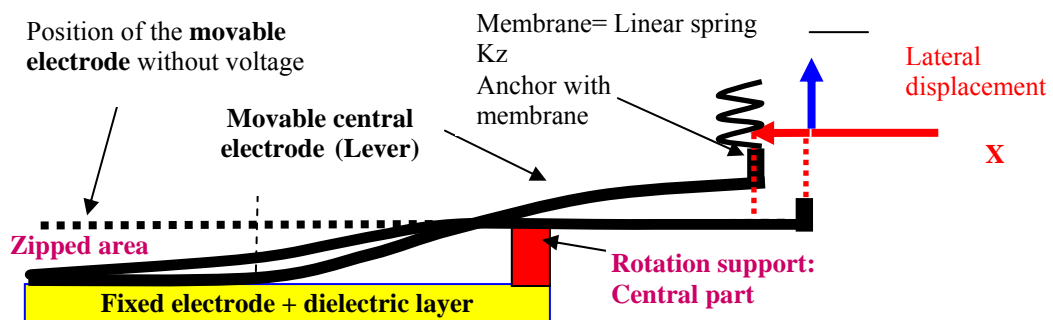
**Left: Best flat evolution with temperature- Right: Wavefront deformation as a function of temperature**



**Left: DM prototype design - Right: Conductance variation as a function of temperature**

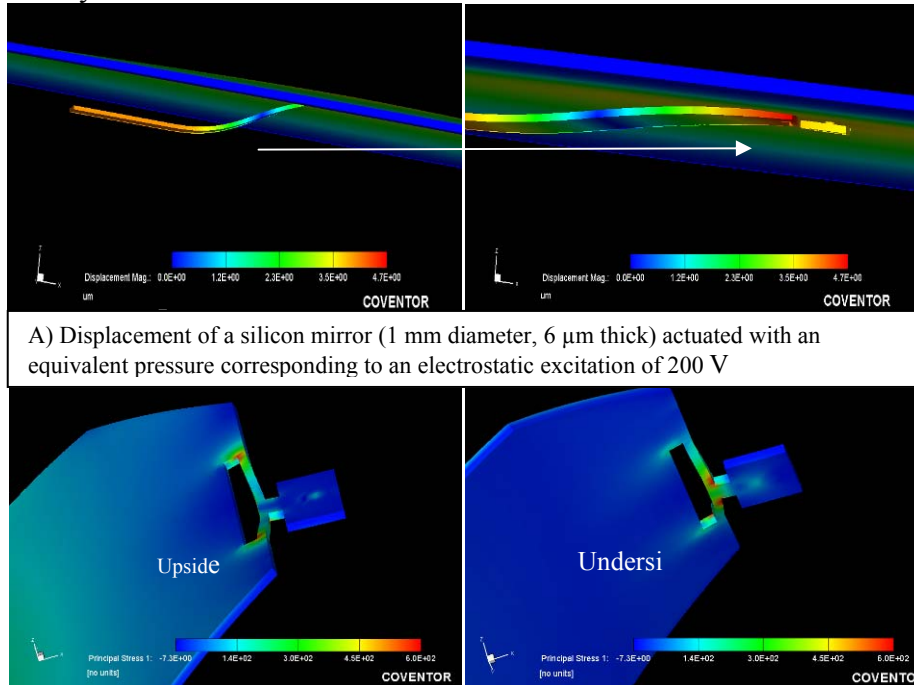
### ***MEMS Deformable Mirror***

As already stated in the report of 2006, the work done by LETI did not reach the expected level. The design review took place in October 2007 after a 10 month delay. The "Final Design Report" delivered by LETI still contains many open issues. In particular, the concept of zipping actuator (see figure below) has not been validated.



### *Working principle of a zipping actuator*

Several simulations of the actuator have been done using the Coventor software (below) but the ability of the proposed actuator to meet the requirements has not been clearly demonstrated.

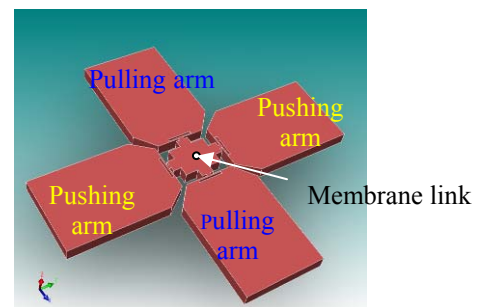


A) Displacement of a silicon mirror (1 mm diameter, 6  $\mu\text{m}$  thick) actuated with an equivalent pressure corresponding to an electrostatic excitation of 200 V

(B) Principal Internal stress in the movable part of the actuator

*Coventor simulation of one push actuator. Excessive stress is visible at the anchor points*

A detailed design of the complete device (including addressing different variants, tests patterns,...) was also missing. A sketch of pull push actuator was proposed but no real complete simulation was provided.



*Left part: Circular silicon membranes (20  $\mu\text{m}$  thick) with 20 mm diameter processed in 200 mm. Right part: Proposed actuator composed of 2 pushing and 2 pulling arms*

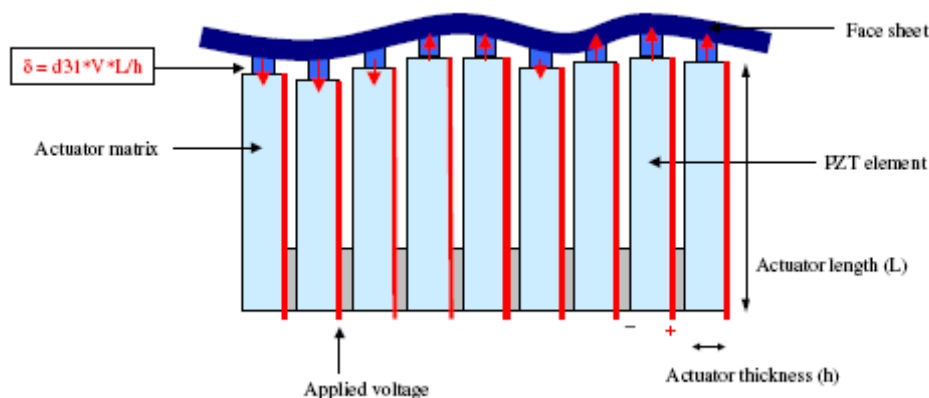
LETI reported some runs on DRIE process for the realization of silicon membranes in 200 mm technology but with thicker membranes than the one foreseen in the design (20 microns instead of 6 microns). LETI only studied the zipping actuator and offered no alternative while it had been explicitly requested at the mid-term review that they

analyze alternative solutions. Considering that, according to LETI, the budget required to obtain a working device is now an order of magnitude larger than what was discussed before this contract. It was decided to not pursue this path with LETI.

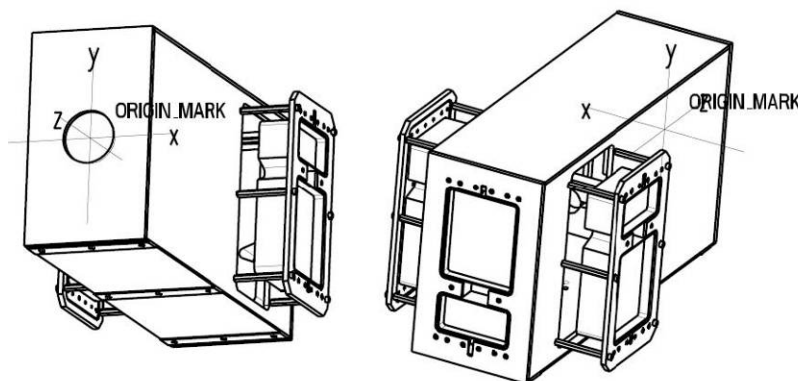
### Mini deformable mirror based on Piezo material

As demonstrated in the past three years, the two technologies explored so far will not meet the original goal of the WP which is to develop a high density deformable mirror with 2K actuators, at least within the available JRA1 budget. For that reason, the piezo technology, usually limited to 5 mm actuator pitch was re-discussed with suppliers. After some iterations we have identified one possible way to overcome this limitation making use of the transverse effect of the piezo material. The mechanical stroke potentially possible with such concept is inversely proportional to the actuator thickness. First order computation shows that 1mm actuator pitch should provide 3 micron mechanical stroke, in principle sufficient for Extreme Adaptive Optics applications after a first stage of correction with a low order large stroke DM (an electromagnetic DM for instance). Extrapolation of this technology to larger degrees of freedom (for instance for the future European ELT Extreme adaptive Optics with 200x200 actuators) looks a priori straightforward. The electronics required to drive such mini deformable mirror is identical to the one developed in the WP 3.4.

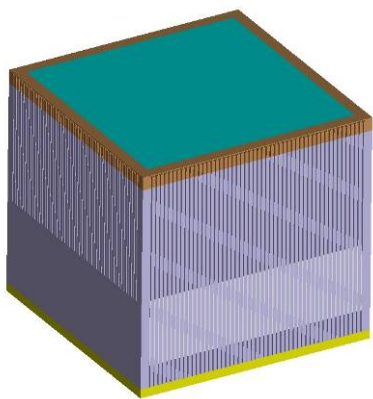
To explore this technology further, a contract was given to CILAS to develop a 50x50 actuator mini deformable mirror based on transverse piezo electric forces. The KOM meeting took place in May 2007 (**Milestone M1 of WP 3.7**), preliminary and final design review was held in November 2007 (**Milestone M2 and M4 of WP 3.7**). Next step is the assembly of the mini DM and the tests. The prototype should be delivered beginning of June 2008.



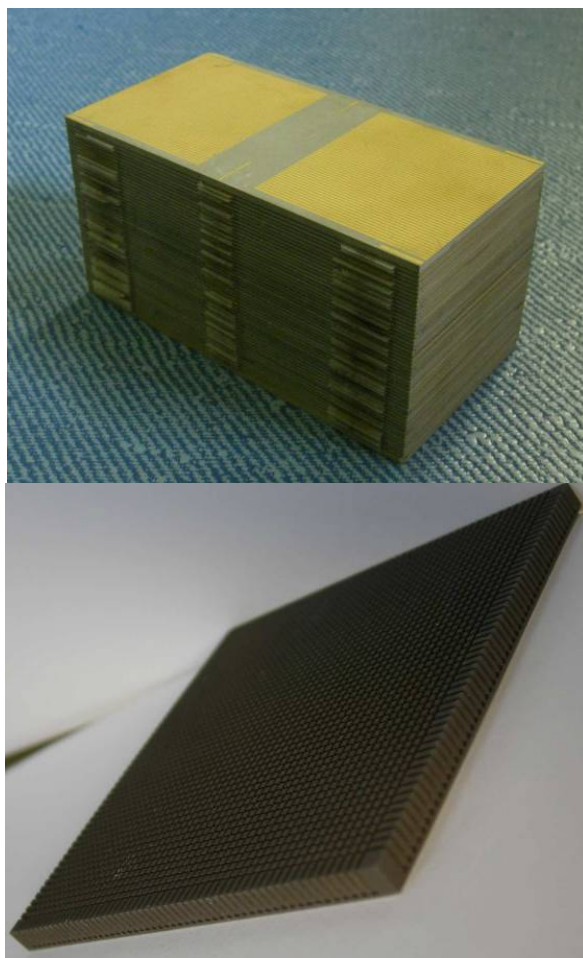
### Mini deformable mirror concept with use of transverse piezo electrical effect







*Left: Mini DM external box mechanical layout – Right: Mini DM Design*



*Left: Min DM proto-body (2 units) – Right: Mini DM head*

The documents produced by this WP are provided in CD-ROM JRA1/WP3.7.

### ***WP3.8 High Order wavefront sensor experimental study***

#### **Past years:**

In 2004 & 2005, a theoretical study was performed by ONERA comparing the Shack Hartmann and the pyramid wavefront sensors for high order adaptive optics.

The top-Level requirements of the High Order Test bench (HOT) document was finalized by ESO in collaboration with Durham and INAF-Arcetri. The design of the HOT bench was developed by ESO, Durham and INAF-Arcetri, although some tunings were necessary during integration to cope with interface issues between the different subsystems. A survey of coronagraph was done in order to determine which coronagraph could be implemented in the future.

Key components were ordered: the 1K actuator Micro Deformable Mirror from Boston Micromachine and the CCD cameras for the Shack Hartmann and Pyramid WFSs from ANDOR, the micro-deformable mirror drive electronics from Shaktiware.

In 2006, the design of the whole system was finalized and review organised, all components have been ordered, the Shack-Hartmann (from Durham) and the Pyramid (from INAF Arcetri) wavefront sensors were delivered to ESO as well as the 2<sup>nd</sup> Boston micromachine DM. All sub-systems were characterized.

### **In 2007:**

#### **Detailed characterization of Deformable Mirrors:**

The influence functions of the 60 elements, large stroke (so called woofer), bimorph mirror of MACAO were measured using a Hadamard voltage matrix technique.

The BMM-MEMS mirror (tweeter) has been characterized in detail by interferometric measurements of the influence functions, the voltage-stroke behavior and the inter-actuator coupling.

The correct mapping between control electronics channels and actuators was identified and implemented in the mirror drive electronics.

#### **Final opto-mechanical alignment:**

The precise alignment of the Shack-Hartmann sensor arm was carried out and the major alignment steps and metrics (pupil size, conjugate planes, homogeneity illumination, F number, collimation,...) were recorded and documented in the SHS alignment report.

Remaining optical aberrations were compensated by applying a correcting shape to the MACAO bimorph DM.

A cube beamsplitter has been installed to split the light into the wavefront sensor and the coronagraphic imaging channels.

New pupil masks were designed and installed in front of the bimorph DM. These pupil masks now precisely mimic the VLT pupil in terms of spider thickness and also mask a small area near the edge of the pupil where the MEMS DM has two non-moving actuators by design.

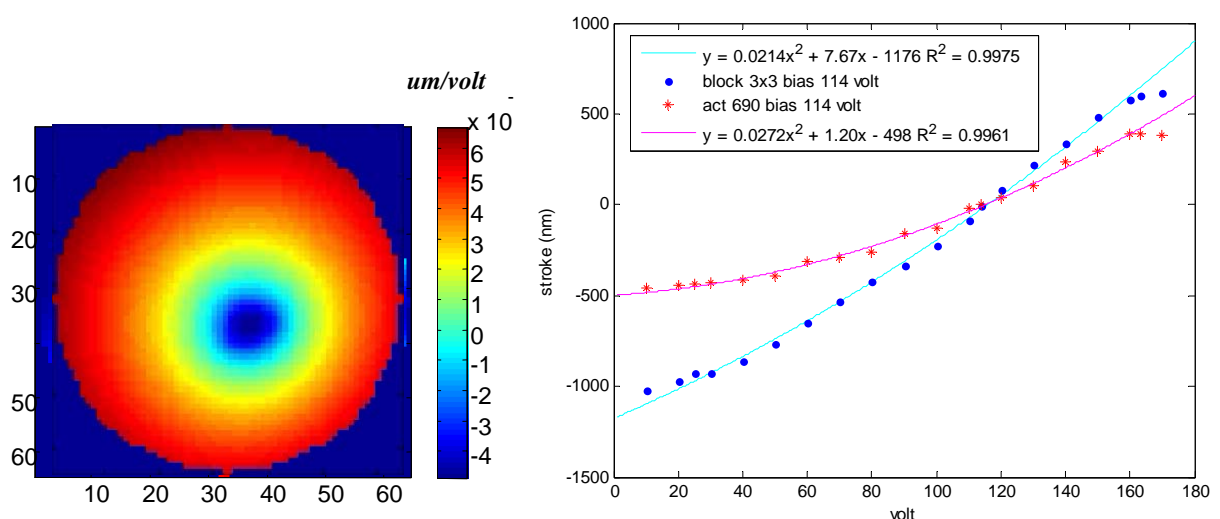
#### **Closed loop control using Pyramid and Shack-Hartmann wave-front sensors:**

The installation of both WFS (Pyramid WFS and Shack-Hartmann WFS) was completed.

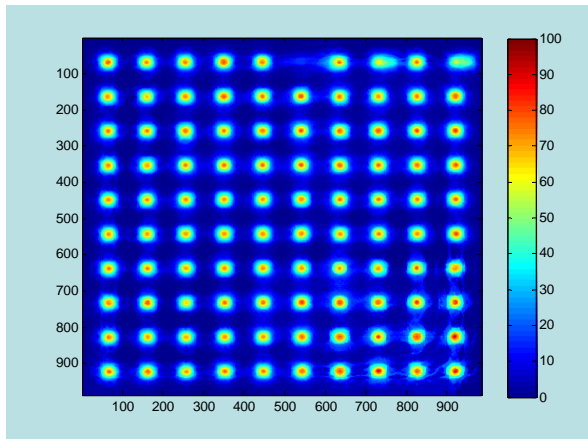
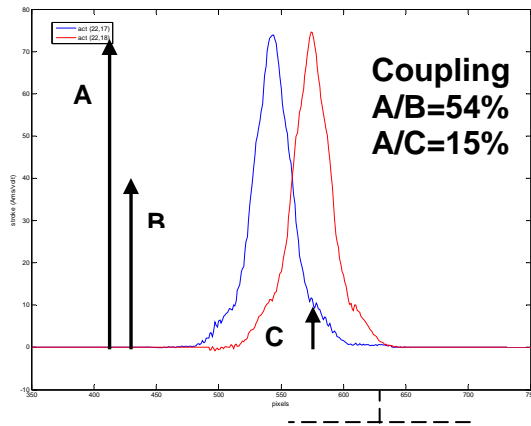
The Pyramid WFS has been calibrated using a pre-calculated basis resembling the least-squares fit of the MEMS DM to the 400 lowest order Karhunen-Loeve modes of Kolmogorov atmospheric turbulence. The control loop could be closed using this modal basis set and aberrations introduced by the MEMS DM were corrected. The results of these initial PWS tests were presented at the JRA1 progress meeting in Leiden.

The Shack-Hartmann sensor (SHS) was accurately aligned with respect to rotation between the CCD camera and the lenslet array and rotation and translation between the lenslet array and the MEMS DM. With the precisely measured influence functions, a modal basis set consisting of the Karhunen-Loeve modes of atmospheric turbulence within the control space of the MEMS DM has been calculated. Software has been developed under Matlab to calculate the SHS interaction matrix using the Hadamard matrix technique and to calculate either zonal or modal control matrices using SVD filtering techniques. Closed loop control was achieved under Matlab using either a zonal reconstructor (~600 modes) or the K-L modal reconstructor. The residual image quality on the visible CCD installed in the imaging channel is ~85 nm rms wavefront error, corresponding to PSF around 60% Strehl ratio at the 750 nm wavelength or 95% in K-band).

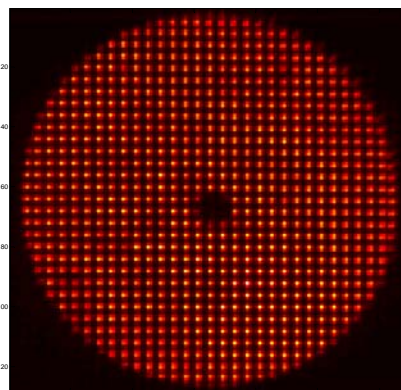
Preceding closed loop operation, considerable real-time computer software had to be developed under C++ and Matlab, such as the interface between the CCD and the RTC, wavefront processing unit (WPU) which calculates the slopes from the SHS images, and the closed loop control. The software WPU is supposed to be replaced by an FPGA-based WPU which is currently being developed by Durham University and has initially been tested on HOT.



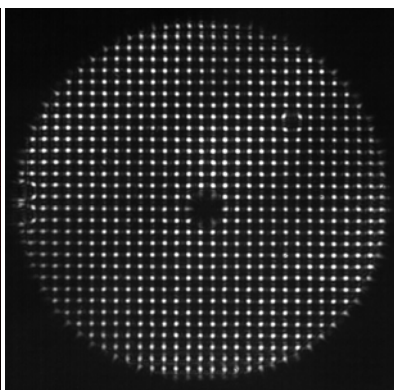
**Left: Influence function of the MACAO bimorph DM; Right: Stroke as a function of voltage for the MEMS DM.**



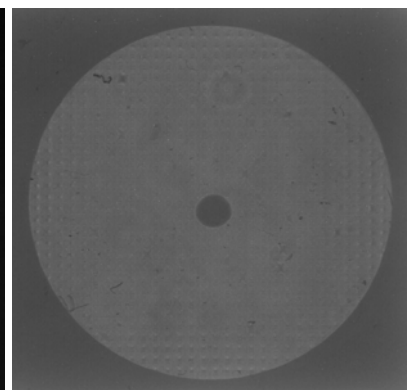
Left: 1-D cut of an influence function showing the coupling between adjacent actuators;  
 Right: Set of MEMS DM influence functions.



CCD 124x124 SHS image

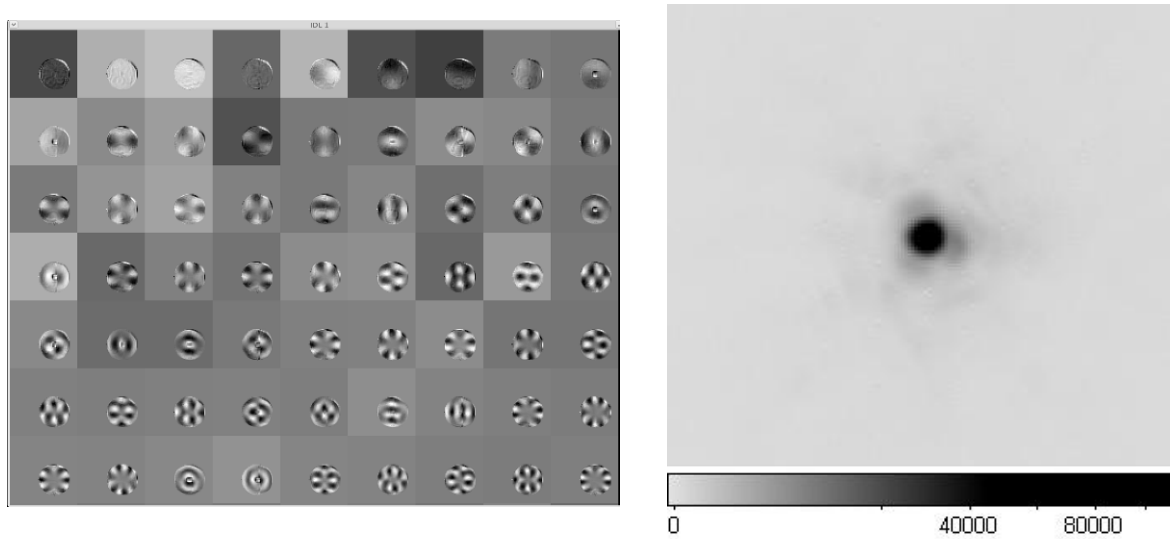


LA focal plane

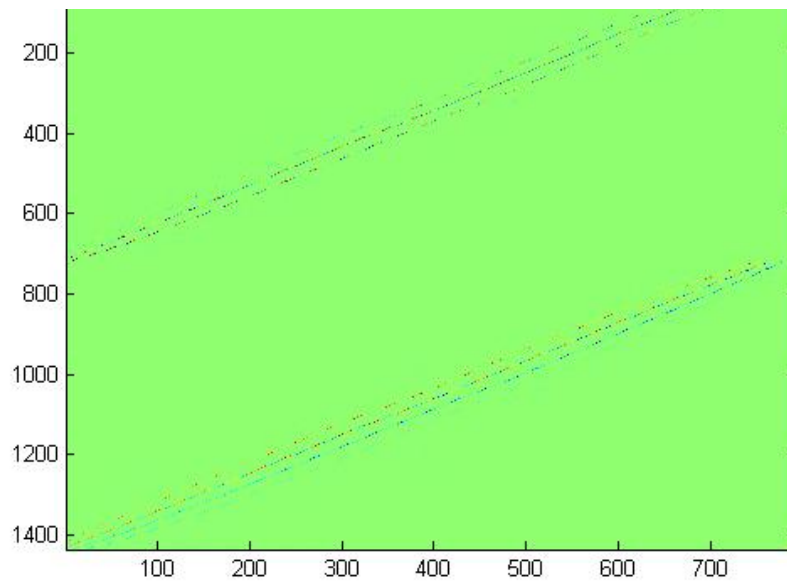


Pupil Plane

Shack-Hartmann spot pattern using a lab CCD (left) and the ANDOR CCD60 (middle). The slightly off-pupil plane image on the right shows the high spatial frequency ripples introduced by the MEMS DM.



*Left: Low order K-L modes used to control the MEMS DM; Right: HOT SHS closed loop PSF at ~750nm.*



*SHS interaction matrix recorded with HOT (~800 active actuators on X-axis and ~700 active subapertures X and Y slopes on Y-axis).*

All documents produced by this WP are included in CD-ROM JRA1/WP 3.8/.

The following table summarises the Milestones and deliverables achieved during the 2007 reporting period by JRA1:

<b>Deliverable/ Milestone No</b>	<b>Deliverable/Milestone Name</b>	<b>Workpackage /Task No</b>	<b>Lead Contractor(s)</b>	<b>Planned (in months)</b>	<b>Achieved (in months)</b>
M1	JRA1 General Meeting 5	WP1	ESO	9	11
MTR	Mid Term Review	WP 1	OPTICON	9	9
D1	Design of SPHERE	WP 2.1	INSU-ESO	6	9
D2	Design of the VLT multi-LGS GLAO facility (DSM+GRAAL +ASSIST)	WP 2.2	ESO	12	12
M2	Design review & Complete development of the Real Time Computer Platform and performance testing	WP 3.1	ESO	12	10
M2	Laser Tomography simulations and optimal reconstruction study report	WP 3.2	ONERA	6	12
M1	Delivery and testing of a 1377 actuators piezo deformable mirror	WP 3.3	ESO	12	10
M2	Complete final design of the VLT Adaptive secondary design	WP 3.5	ESO	6	12
New	Design of the 100 actuators electromagnetic deformable mirror	WP 3.7	INSU/ESO	6	9
New	Design of the 100 actuators electrostatic deformable mirror	WP 3.7	INSU/ESO	6	9
M2/M4	Preliminary & Final design of a 50x50 actuators mini piezo deformable mirror	WP 3.7	INSU/ESO	9	11

The table below summarises the major JRA1 meetings:

<b>Date (2007)</b>	<b>Title/subject of meeting /workshop</b>	<b>Location</b>	<b>Number of attendees</b>	<b>Website address</b>
Nov. 15 <sup>th</sup> & 17 <sup>th</sup>	General Meeting 5 JRA1	Leiden	20	<a href="http://www.eso.org/projects/aot/jra1/">http://www.eso.org/projects/aot/jra1/</a>
Sept. 10-11 <sup>th</sup>	Opticon Mid Term Review	Corfu	20	
Weekly	Weekly telecon WP 2.1	Telecon	8	

March 6 <sup>th</sup>	SPHERE Optical Design review	Garching	20	CD-ROM
March 7 <sup>th</sup>	SPHERE progress meeting 3 (WP2.1)	Paris	20	CR-ROM
April 27 <sup>th</sup>	SPHERE progress meeting 4 (WP2.1)	Padova	20	CDROM
Dec 19 & 20 <sup>th</sup>	SPHERE progress meeting 5 (WP2.1)	Paris	20	CDROM
Sept. 20 & 21 <sup>st</sup>	SPHERE Design Review (WP2.1)	Garching	20	CDROM
Weekly	Weekly internal progress meeting (WP2.2)	Garching	8	CDROM
March 12 <sup>th</sup>	Ground Layer AO (GRAAL) design review (WP2.2)	Garching	20	CDROM
Oct 30 <sup>th</sup>	ASSIST test bench design review (WP2.2)	Garching	10	CDROM
March 28&29 <sup>th</sup>	LINC-NIRVANA Progress meeting (WP 2.4)	Heidelberg	10	CDROM
July 11 & 13 <sup>th</sup>	LINC-NIRVANA AIT & Technical meeting (WP2.4)	Heidelberg	10	CDROM
Oct. 16&17 <sup>th</sup>	LINC-NIRVANA Progress meeting (WP 2.4)	Heidelberg	10	CDROM
July 6 <sup>th</sup>	Real Time Computer Platform (SPARTA) design review (WP 3.1)	Garching	15	CDROM
Dec 21 <sup>st</sup>	Progress meeting WP 3.1	Durham	6	CDROM
June 11 <sup>th</sup>	Progress meeting (WP 3.2)	Telecon	6	CDROM
July 3 <sup>rd</sup>	Progress meeting (WP 3.2)	Telecon	6	CDROM
July 5 <sup>th</sup>	Acceptance test at CILAS of the 1370 actuator piezo DM (WP 3.3)	Orleans	5	CDROM
Nov 13 <sup>th</sup>	Progress meeting 5 WP 3.4	Telecon	5	CDROM
Dec 17 <sup>th</sup>	Progress meeting 6 WP 3.4	Telecon	5	CDROM
March 5 <sup>th</sup>	VLT Deformable Secondary Mirror preliminary design review (WP 3.5)	Garching	15	CDROM
Dec 12 <sup>th</sup>	VLT Deformable secondary Mirror Final Design review (WP 3.5)	Garching	15	CDROM
May 22 <sup>nd</sup>	VLT DSM Progress meeting (WP 3.5)	Bolzano	10	CDROM
Sept 25 <sup>th</sup>	VLT DSM Progress meeting (WP 3.5)	Bolzano	10	CDROM
Every two months	<u>Zerodur thin Shell progress meeting (WP 3.6)</u>	Telecon	5	CDROM
March 26 <sup>th</sup>	ALPAO: electromagnetic deformable mirror progress meeting (WP 3.7)	Videoconf.	5	CDROM
Oct. 10 <sup>th</sup>	ALPAO: electromagnetic deformable mirror design review (WP3.7)	Videoconf.	5	CDROM
January 8 <sup>th</sup>	ALPAO: electromagnetic deformable mirror Kick-off 2 <sup>nd</sup> phase (WP 3.7)	Videoconf.	5	CDROM
June 29 <sup>th</sup>	LETI: electrostatic MEMs feasibility study progress meeting (WP 3.7)	Vidoeconf.	6	CDROM
October	LETI: electrostatic MEMs feasibility study	Videcon	6	CDROM



12 <sup>th</sup>	design meeting (WP 3.7)			
May 04 <sup>th</sup>	CILAS: Mini piezo DM Kick-off meeting (WP 3.7)	Orleans	5	CDROM
Nov. 11 <sup>th</sup>	CILAS: mini piezo DM preliminary & final design review (WP 3.7)	Telecon	6	CD-ROM
Feb. 21 <sup>st</sup>	HOT Progress meeting (WP3.8)	Telecon	8	CD-ROM
Oct 26 <sup>th</sup>	HOT Progress meeting WP 3.8	Telecon	8	CD-ROM

### 1.5.2 JRA2: Fast detectors for AO – 2007 report

<b>Participant number</b>	40	4	7	31	
<b>Participant short name</b>	INSU/C NRS	ESO- INS	IAC	ONERA	<b>Total</b>
<b>Person-months</b>	45.6	4.94	1	0	<b>51.54</b>

#### Context of the JRA2

ESO and OPTICON have funded e2v technologies to develop a compact packaged Peltier cooled 24  $\mu\text{m}$  square 240x240 pixels split frame transfer 8-output back-illuminated L3Vision CCD3 for Adaptive Optic Wave Front Sensor (AO WFS) applications. The device is designed to achieve sub-electron read noise at frame rates from 25 Hz to 1,500 Hz and dark current lower than 0.01 e-/pixel/frame. The development has many unique features. To obtain high frame rates, multi-output EMCCD gain registers and metal buttressing of row clock lines are used. The baseline device is built in standard silicon. In addition, a split wafer run has enabled two speculative variants to be built; deep depletion silicon devices to improve red response and devices with an electronic shutter to extend use to Rayleigh and Pulsed Laser Guide Star applications. These are all firsts for L3Vision CCDs.

This detector, called CCD220 and subcontracted to *e2v technologies* (UK), is being built as part of the JRA2 activities. This JRA also delivers:

- A detector controller: this is the main deliverable of WP3.
- A cryogenic system (to cool down the detector): this is the main deliverable of WP4.
- A full evaluation of the detector performances in the framework of WFS applications for the second generation of adaptive optics instruments in Europe. This is the main goal of WP5.

#### WP1: Management

One progress meeting was organised at ESO by end of 2007, allowing the organization of the last period of the OCam camera integration (WP3 and WP4). The JRA2 financial situation is still tight, but remains manageable.

Weekly teleconferences of the whole JRA2 team were held all year (except during summer holidays) to organize and follow the activity extremely closely, because this system integration period was extremely critical and we did not want to add delays to the activity in order to be able to achieve our main goals in 2008. Minutes of these teleconferences were distributed by e-mail to the participants. This was the remedial action we decided to use for stabilizing the overall delay of the JRA activity that was described in the last annual report.

#### WP2: Detector specification and fabrication work package.

On 9<sup>th</sup> August 2007, e2v provided a Delivery & Quality (D & Q) Verification Report for the custom Peltier cooler (photo Figure 1) and 64-pin package (photo Figure 2). The report concludes that e2v has sufficient peltier coolers and package bases of acceptable quality to fulfil the deliverables of the project.

During acceptance test of the package lid assemblies, optical inspection showed that the seal between the sapphire window and lid was not of acceptable quality and Schott (the manufacturer) was asked to provide replacements. Ten improved build Schott window assemblies were received on 29th January 2008. A further 15 were received on 4th February 2008. They are currently awaiting detailed inspection.

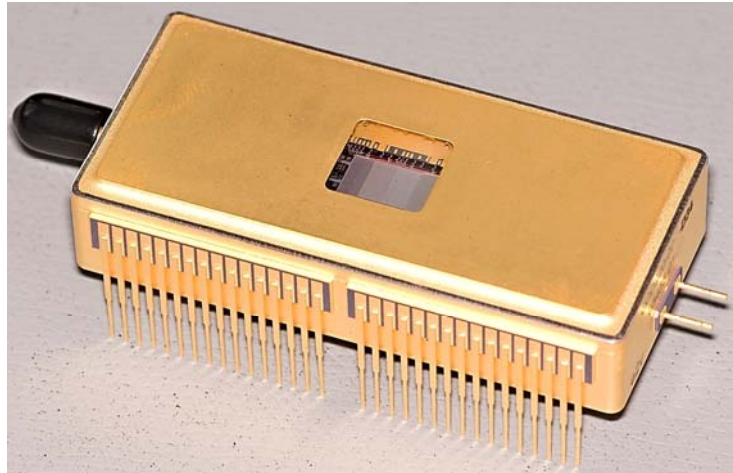


***Figure 1. Photograph of custom Peltier***



***Figure 2. Photograph of package base.***

The DC test facility for the packaged back-thinned devices has been successfully commissioned. Several CCD wafers have completed back-thinning, and a number of devices have been packaged or are in the process of being packaged minus their windows. These are on hold pending the acceptance of the new lot of Schott window assemblies. Four electrical grade devices (photo Figure 3) were completed using the old windows but with epoxy around the windows to improve the seal. These were delivered on the 30<sup>th</sup> January 2008 and are being used for final testing of the OCam camera.



*Figure 3. Photograph of one of the electrical grade CCD220.*

A number of wafers are being held in back-thinning as reserves pending the results of the cold testing with the OCam camera.

The QE test facility has been commissioned using back-thinned devices and is ready for device testing.

Delivery date of the final devices is dependent on the delivery of the OCam Test Camera. With the current expected delivery date of end of February 2008, the science devices will be delivered in August 2008.

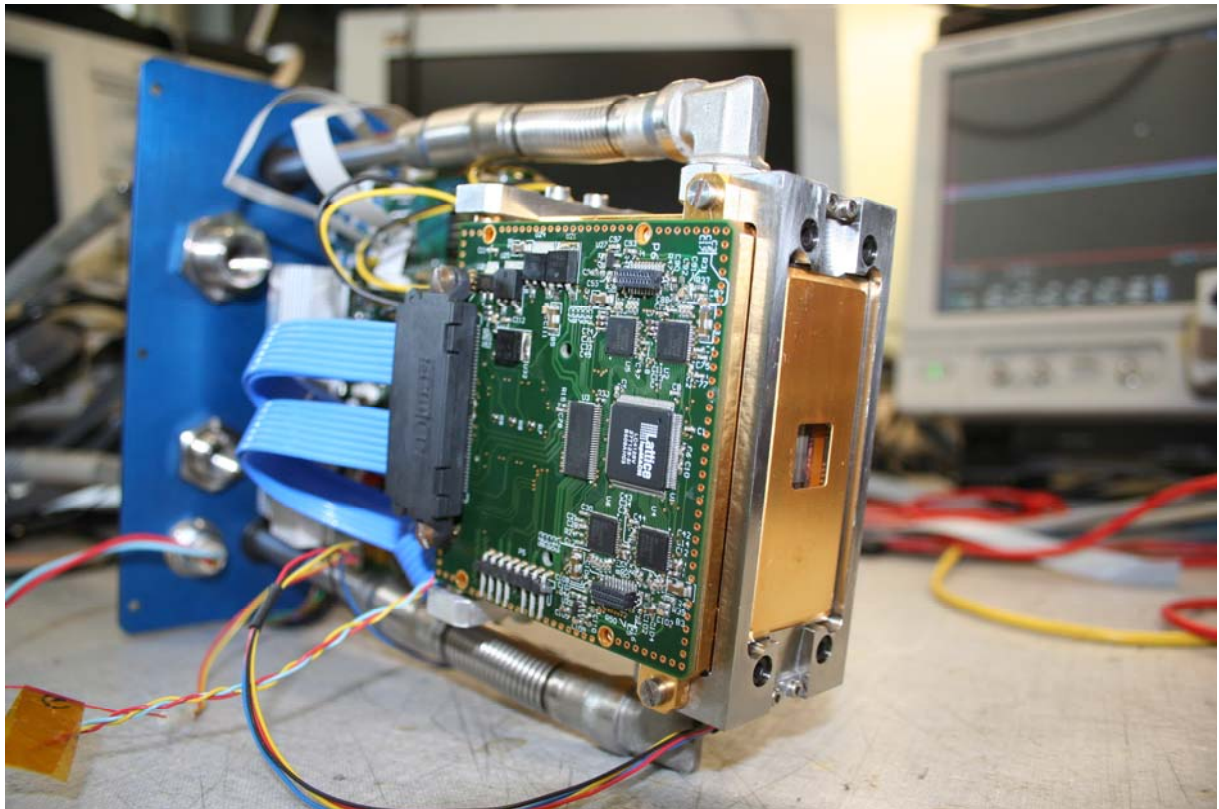
### **WP3: Detector control and software**

#### ***Fabrication***

All parts of the electronics have been built successfully, with spares.

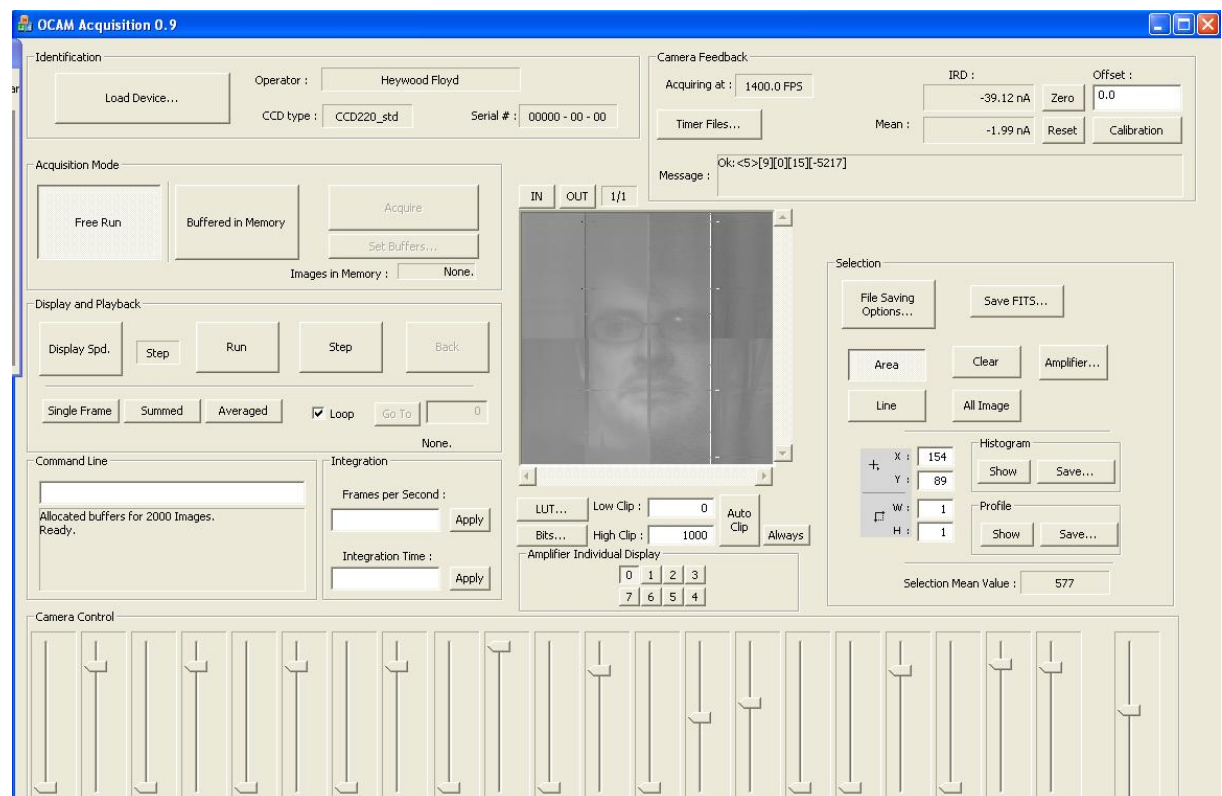
#### ***Integration and tests***

All the electronics boards have been successfully integrated into the OCAM mechanics. The whole system has been proven to meet the requirements of the CCD manufacturer and is functional. Figure 4 shows the whole system with an electrical grade CCD220 fitted in.



**Figure 4: OCAM electronics assembled into the mechanics (cover removed). The CCD 220 detector is fitted into the system (golden part in the front).**

All of the system is running now and a first image has been done (see Figure 5)





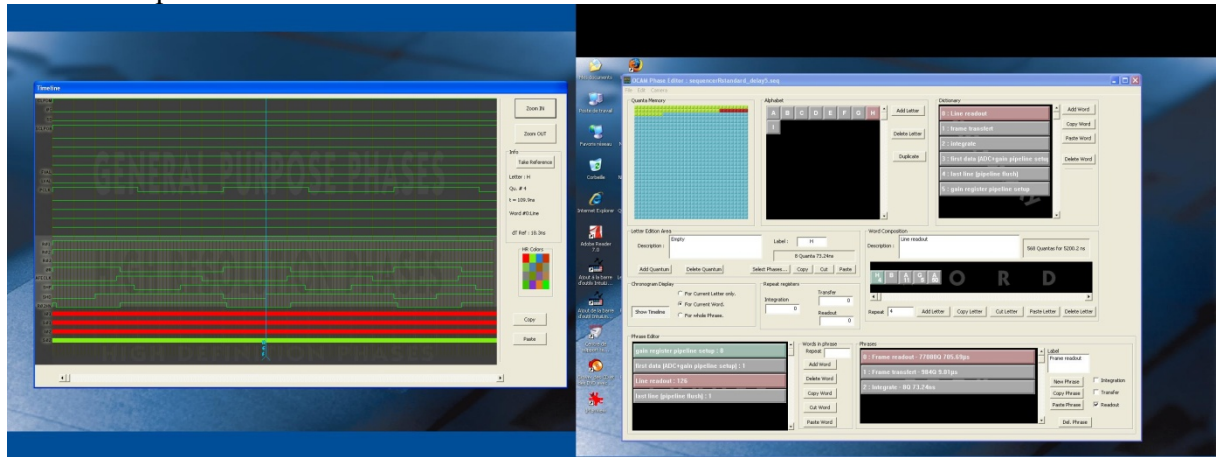
**Figure 5: first image obtained with OCAM. Note that this image was taken at 1400 frames per second. Note the vertical zones corresponding to one amplifier/output each.**

The whole system is now undergoing final tests.

### **Camera Firmware and Software**

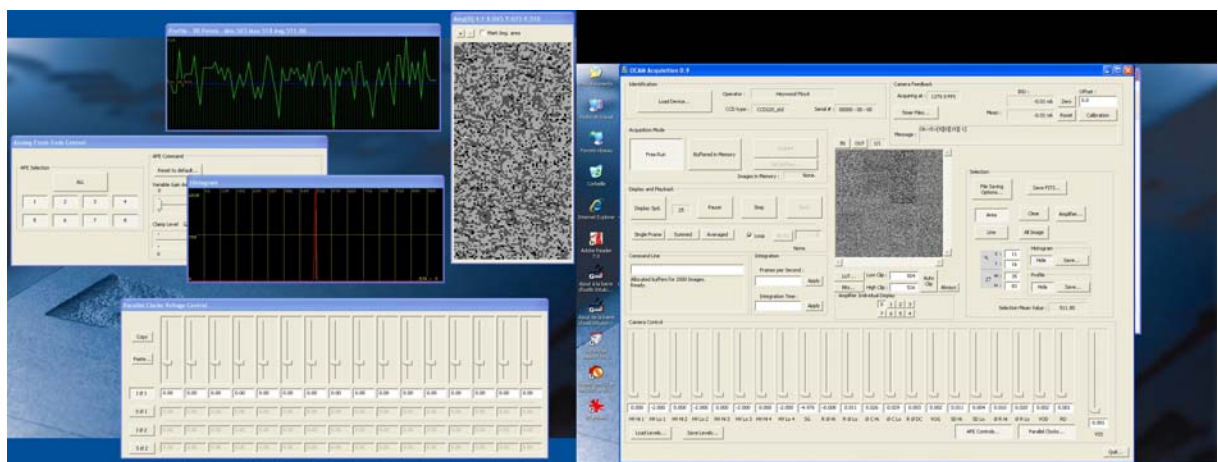
The Software development for OCAM has three distinct but connected parts : Camera Firmware, runs inside the Camera and provides control over the embedded, low-level camera operation (finished in late 2006), the sequencer editor (controls the CCD sequencing through the electronics see figure 6), and the acquisition software (see figure 7).

#### **Camera Sequencer Editor**



**Figure 6 : OCAM Sequencer Editor.**

An independent piece of software has been developed to provide a convenient means to design the CCD readout phases. Software has been fully debugged and is production ready.



**Figure 7: OCAM acquisition snapshot, showing all the software functionalities.**

**Conclusion for WP3:** OCAM controller is fully functional, we have demonstrated it



is capable of making images at 1400 frames/second, and is close to release (within weeks).

#### **WP4: Cryogenic system**

All milestones of this WP was achieved during this period. We now have to duplicate the cryogenic system, because detectors will be tested at 2 different locations: one first set of tests will be held at e2v in Chelmsford (UK), the other detector tests will be performed by IAC (see next WP activity). Therefore a second cryogenic system, duplicating the first one, is currently under production.

#### **WP5: detector testing activity**

The Detector test plan at the IAC is developed and was presented at the progress meeting held at ESO by November 6<sup>th</sup>, 2007. The testing lab is now ready as part of a more challenging activity to provide an Optical Detector Test facility at the IAC whose first objective is to test the CCD220 for Opticon. By mid 2008 it is planned to receive the first devices and the OCam test camera to start with the detector testing.

#### **Milestones and Deliverables**

During 2007, the JRA2 made good progress and the following deliverables and milestones were achieved:

<b>Deliverable/ Milestone No</b>	<b>Deliverable/Milestone Name</b>	<b>Workpackage /Task No</b>	<b>Lead Contractor(s)</b>	<b>Planned (in months)</b>	<b>Achieved (in months)</b>
M5	Frontside device test	WP2	ESO	24	36
M3	Delivery of detector controller	WP 3	INSU/CNRS	18	44
M4	Delivery of detector controller	WP3	INSU/CNRS	18	48
M2	Cryogenic system acceptance	WP4	INSU/CNRS	18	36

#### **Major meetings and workshops**

<b>Date</b>	<b>Title/subject of meeting /workshop</b>	<b>Location</b>	<b>Number of attendees</b>	<b>Website address</b>
6 Nov 2007	JRA2 progress meeting	ESO Garching	8	<a href="http://www-laog.obs.ujf-grenoble.fr/JRA2">http://www-laog.obs.ujf-grenoble.fr/JRA2</a>

#### **Conclusion**

The JRA2 schedule has a general slip of about one year; this slip was stabilized during the third year of the project.

We made excellent progress during this year and some major goals of the JRA2 were achieved:

- The first front side detectors have been produced by the sub-contractor and delivered to the JRA2.
- The test camera, called OCam and which is the result of the WP3 and WP4 of this activity, is now complete and will be formally delivered to the CCD manufacturer in March 2008, after a commissioning period of one month at e2v factory.
- We are now starting the exciting period of detector testing.

### 1.5.3 JRA3: Fast Readout High Performance Optical Detectors

#### A. Contractors:

<b>Participant number</b>	1	2	4	11d	11e	13	28	37	39	40	
<b>Participant short name</b>	UCAM	STFC	ESO	MPG MPA	MPG MPE	NOTSA	NUIG	LSW	USFD	War	<b>Total</b>
<b>Person-months</b>	14(12)	2.73(1.36)	0	0.5 (0.5)	13 (6)	0	7(0)	0	4 (0)	2(0)	<b>43 (20)</b>

#### WP1: Management

Progress of JRA3 during the reporting period has been excellent. Three contractors (STFC, USFD, Warwick) have nearly completed their contractual contributions to the individual work packages. Highlights are the progress in the two largest work packages, WP3 (L3 EMCCDs) and WP3 (avalanche amplified pn-CCDs), which have performed well beyond expectation (see technical reports below). One package (WP4, APDs) has lagged behind because of problems with the technology, but is still expected to complete its main deliverables in 2008. The main deliverable D1 of work package WP6 (common higher level software) has been deleted, as it has been replaced by availability of high level software from the individual work packages of JRA3. Management has reported other details of the work in JRA3 at the midterm review in July.

#### WP2: EMCCD developments

Most of the tasks for this work package have been completed with the acquisition, integration and test of the EMCCDs used in WPs 5 and 7. A small amount of remaining work is to be completed in early 2008.

Lab-based characterisation has continued in order to reduce the two limiting sources of noise in EMCCDs still further - clock-induced charge and dark current. Both have now been halved thanks to further improvements in the high-voltage clock driver board, the thermal contact of the EMCCD with the cryostat, and the design of the clock waveforms. Final on-sky characterisation of the device will be performed during January/February 2008 on the ESO 3.6m telescope.

A significant fraction of the data obtained during the first set of on-sky tests in December 2006 have now been reduced and analysed. The initial results were presented at the HTRA conference in Edinburgh in September 2007 and have been written up for publication in the proceedings. A brief article was also published in the March 2007 edition of the ESO Messenger.

## WP3: pn-sensor development

### Summary:

The design, fabrication and testing of new CCDs for highest frame rates and excellent sensitivity over a wide wavelength range made good progress in 2007. To achieve frame rates in the kHz regime, the devices are based on proven technology with column parallel readout. The CCDs are back illuminated, sensitive over their full thickness of 450  $\mu\text{m}$ , allowing a broad band quantum efficiency with a peak near 100 % at any chosen wavelength between 400 nm and 1,000 nm. Astronomical trials using available devices with on-chip JFET amplifiers were performed at Skinakas observatory in August 2007. These tests proved the viability of pnCCDs and the read-out electronics.

### Optimization of dark noise characteristics:

The level of bulk dark current in Si devices is directly related to defects in the material and dark rates may vary substantially depending upon the material quality, prefabrication processing, and device fabrication itself. Considerable effort has been spent in order to achieve rates as low as possible. Figure 1 shows the temperature dependence of dark current from three different pnCCDs. The squares are from a "conventional" (in the sense of device fabrication process) 75 x 75  $\mu\text{m}^2$  pixel size CCD. A significant improvement of more than one order of magnitude was achieved with a 36 x 51  $\mu\text{m}^2$  pixel geometry, in which a new optimized process sequence has been applied (plotted as triangles). The same procedure was also used in the fabrication of a third CCD of the same pixel size. The improvement resulted from selecting a bulk material from a different company with proprietary substrate treatment. A further lowering in the dark rate of at least a factor of two is clearly seen (plotted as diamonds).

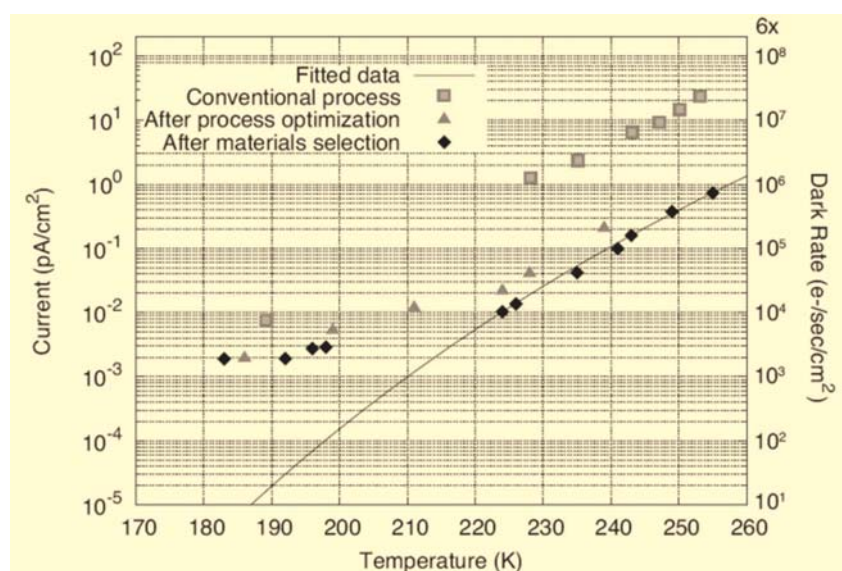


Fig 1.: Summary of CCD dark current characteristics showing improvements due to processing and material optimizations.

### High-speed astronomical observations with pnCCDs:

The capabilities for high-speed optical imaging of a pnCCD were tested at the 1.3 m telescope at Skinakas observatory, University of Crete, Heraklion in August 2007. A pnCCD detector with 51  $\mu\text{m}$  pixel-size and a sensitive area of 13 x 13  $\text{mm}^2$  was used. To allow high speed operations while maintaining the 2-dimensional imaging capabilities, the detector is designed to operate in a split-frame-transfer mode. The imaging area of 264 x 264 pixels, split into two halves for readout on opposite sides of the detector, is transferred in 50  $\mu\text{s}$  to the storage areas. During readout the imaging area is again sensitive for incident photons. For a readout time of 7  $\mu\text{s}$  per line, a frame repetition rate of nearly 1100 Hz was achieved with an electronic noise floor of less than three electrons ENC at an operating temperature of -55°C. To ensure a high quantum efficiency in the optical and near-infrared region, the radiation entrance window of the detector had an anti-reflective coating (ARC) with a quantum efficiency higher than 80 % between 500 nm and 1000 nm.

As a standard object for high-speed astronomical photometry the Crab nebula and pulsar was observed. Combining the fast variability of the pulsar (period approx. 33 msec.) with several stars of similar optical magnitudes and the high surface brightness of the nebula in one image, demonstrates the ability of a pnCCD to perform high-speed optical, differential photometry over a very large field of view. Fig. 2 shows an image of the nebula as well as a light curve and a time sequence of the pulsar. Both have been obtained after a preliminary analysis of the same data set with a total exposure time of about 30 seconds only. For this observation the pnCCD was operated with a speed of 600 frames per second.

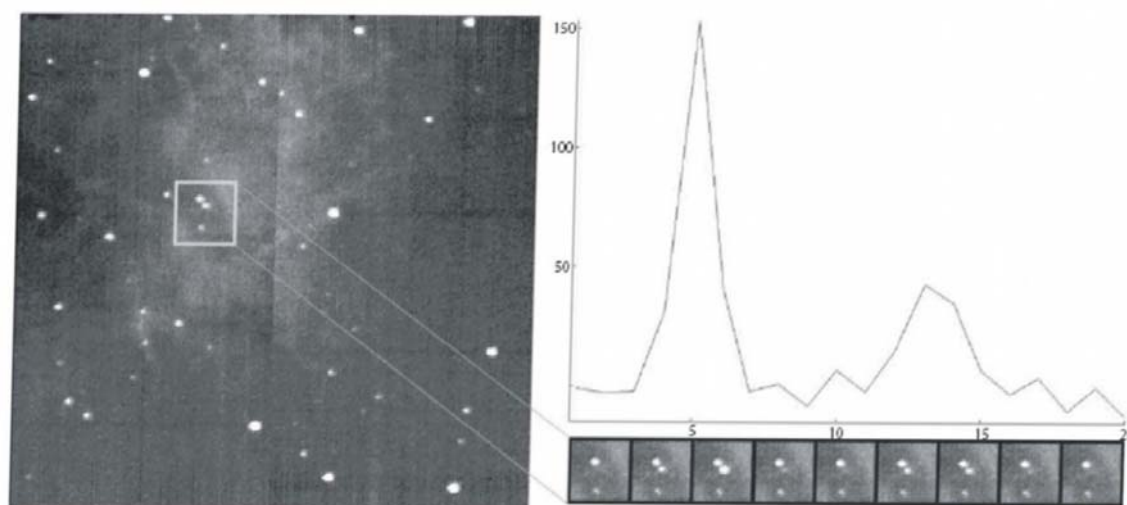
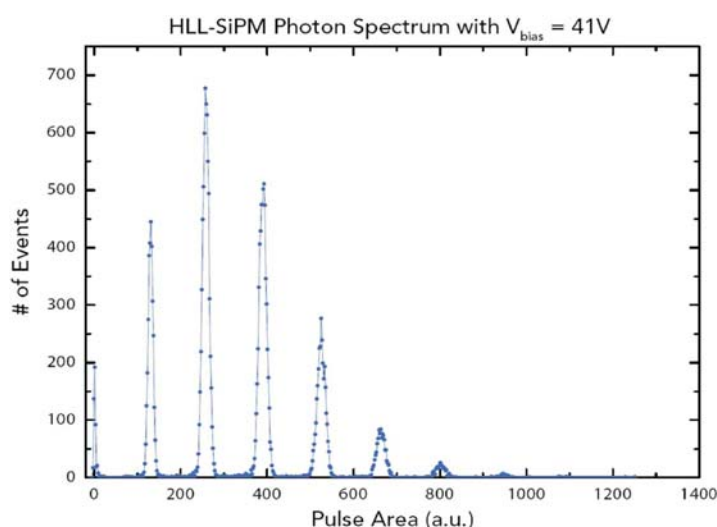


Fig 2: Image of the Crab nebula and pulsar taken with an exposure time of 30 sec at the 1.3m Skinakas telescope. On the right side, the folded light curve of the pulsar with a timing resolution of 1.6 ms is shown. The image sequence under the light-curve shows the pulsar and two constant neighbouring stars.

### Single photon performance of Avalanche Amplifier cells:

Avalanche cells with an avalanche region of diameter 10  $\mu\text{m}$  were fabricated with a design that will be used on the output amplifiers of the pnCCDs. The cells were arranged in test arrays of 20 x 25 sub-pixels. These arrays, also called silicon photo-multipliers (SiPM), were illuminated with femto-second pulses from a laser with very low intensity. The summed signal of the 500 cells in an array are shown in Figure 3.

Peaks corresponding to the detection of a certain number of photons are very well separated and demonstrate the excellent uniformity of the avalanche signals and the technology.



**Fig 3:** Photon spectrum recorded with SiPM test structures. The well separated peaks indicate events containing between one and seven photoelectrons. They are collected from 500 individual cells, demonstrating the excellent uniformity of the technology.

#### WP4: APD array development

The main objective for the APD array project was the development of a multi-pixel array of APD detectors, consisting of the design of individual APDs and fibre fed APD array, the design and fabrication of detector electronics, the design and fabrication of an integrated APD array, and a final technical report.

In collaboration with our colleagues in University College Cork, we have designed, fabricated and packaged new APD devices. The custom packaging of dies has also been made on ceramic hybrid boards. Further progress has also been made with the simulation of the APD active quench circuits. From these simulations, the hardware design of active and passive quench electronics for operating APDs in photon counting mode have been made. Following the fabrication of boards and implementation of design, along with a temperature control unit, a high speed digital I/O unit for the data collection system has been implemented. The design of the software and Labview platform for APD control systems has also been undertaken through this period.

In relation to the fibre fed APD, optical fibres have been aligned and proximity focused to individual APDs. The fibres were epoxied by UV curing to the APD devices and the crosstalk issue was eliminated due to the separation of the APD elements. The individual fibre bundles are then brought together to form an array. For testing and characterisation, key parameters have been measured and ascertained. The optimisation of these variable parameters ensures the optimum operating performance and parameters such as dark count rate, photon detection probability, operating temperature, after-pulsing probability, optimum hold-off time, timing resolution and many more have been determined.

For the design and fabrication of integrated APD array, a new mask set was designed, and the progression of process optimisation in fabrication procedure was undertaken by our colleagues at University College Cork. The numerous devices and layouts include a linear and 2-d array APD array, the largest of which is 10 x 10 array. The successful design and fabrication of individual APD devices, fibre fed array, and integrated APD array have been completed. The design of active quench circuits and operating



electronics, along with the testing, simulation and characterisation of devices have been successfully concluded. All key objectives and deliverables will be completed in 2008

## **WP5: Controller Development**

### *Work done at UCAM*

The experience of controller developers whose background is in astronomy very much puts the emphasis onto precision readout at relatively slow pixel rates. At the high pixel rates of EMCCDs, an entirely new technical approach is required in order to clock the charge efficiently and reliably at these high pixel rates without compromising other parameters such as the readout noise, dynamic range and the linearity of the CCDs. The areas that are technically rather difficult include the creation of a controller structure that allows not simply high pixel rates but can control the precise timing of the clock edges (and particularly those used by the analog to digital conversion circuitry) to a very small fraction of the pixel period. The clock drivers themselves need to be able to produce very fast clean waveforms and the signal processing system must allow the full dynamic range of the CCD even at the highest pixel rates.

The development of a controller dedicated to L3CCDs and to EMCCDs has been under development in the Institute of Astronomy, University of Cambridge for some while. Progress here was slow until we obtained a technician in Cambridge. We were very fortunate in having Keith Weller join the team in May, 2006 and will be with us until April 2008. He has an extensive background in electronic hardware design with considerable analogue electronics experience. Since then excellent progress has been made.

The basic specification of the controller is unchanged and we are progressively improving its performance and getting closer and closer to the goal performance. We are now using an ARM-based microcomputer with a USB interface to provide camera control from the computer. The on-board microprocessor manages a new high-speed sequencer ASIC from Kodak that allows sophisticated waveform generation at pixel rates up to 60 MHz. Using these components we now have a prototype camera taking pictures of reasonable quality at pixel rates in excess of 20 MHz. The present design needs a further refinement to improve a number of aspects of its performance but there is no doubt that we have already made very good progress in the year under report. Indeed in a number of areas we have already managed to exceed the performance specification of the controller and we can see plenty of scope for improving it further, particularly in respect of the general noise performance and immunity to interference. In particular pixel rates of up to 60 MHz now appear to be quite realistic as we have information that some devices will perform satisfactorily at these pixel rates.

The current specification of the camera system is:

*EMCCD Controller System: minimum performance (desirable goal performance):*

Must operate full frame, frame transfer and interline transfer CCDs with a high-voltage multiplication gate, and with up to four phase parallel clocks in both image and store registers.

High-voltage clocks must be able to provide 45 volt swing with 16MHz pixel rate (for E2V L3CCDs) and 25 volt swing for 35MHz pixel rate (Texas Instruments EMCCDs)

To operate at a pixel rate of at least 15MHz (35MHz). To provide clock drivers capable of working with at least 15 centimetres of track length between driver and CCD chip. To provide 14 bit digitisation at the maximum pixel rate with full double correlated sampling signal processing. To have the complete analog signal processing chain self calibrating and balancing to guarantee negligible fixed pattern noise.

The structure of the controller must allow it to be expanded to cope with significant numbers of detectors (of the order of 256) being operated in parallel and simultaneously.

The controller must be able to be operated via an industry standard ethernet/USB connection on both Windows and Linux. The data produced by the camera controller to be transmitted with high-speed LVDS drivers so that it may be attached to any industry standard frame grabber hardware that uses the AIA frame grabber interface standard.

#### *CCD Camera Postprocessing:*

Fast readout high-performance optical detectors need software at a number of different levels. At the lowest levels, the software that is required to set up and programme the controller has to be at a machine code level and closely integrated with the controller hardware development effort itself. Software at this level cannot be considered to be common in any useful sense although it is important to establish communication standards between the higher level software that needs to grab the camera resource and control it properly.

The EMCCDs are capable of producing very large amounts of data indeed. The sort of volume of data produced by a single Texas Instruments EMCCD is greater than can be handled by a PCI interface card and very quickly any real computer system will become overwhelmed. The consequence of this is that it is essential to integrate the hardware with some kind of high-speed processing system that can extract the information required from the images in real time and pass the results to the host computer with a greatly reduced data bandwidth requirement. JRA3 provided the funding in principle for two-man years of effort but the delay in the funds actually becoming available and then the delays in actually recruiting someone meant that we were unable to get anyone in post until November, 2004, when Frank Suess joined our group for a 2-year appointment which has just come to an end. Frank has considerable experience in writing software for CCD systems used in the physical and life sciences as well as having a lot of experience of dealing with digital signal processor systems such as will be important for some of the work with L3CCDs. Frank's initial work was on the software to download controlling microcode into the EMCCD controller. In addition, Frank Suess has made some progress in investigating a variety of commercially available DSP hardware solutions which have sophisticated development software packages as well. We are currently working with a promising board manufactured by Matrox called the Odyssey. This uses a custom FPGA on board to provide a good number of DSP elements within the chip. The overall processing power looks very promising and it is well integrated with a frame grabber part of the hardware which is important for these applications. It has a further advantage that the library sold with the board is very well developed and compatible

with other frame grabbers. This allows the camera to be used with either a standard frame grabber or with the DSP interchangeably. Although we have made good progress there is still a lot to be done. Unfortunately we have no further funding for this work beyond the end of 2006 so progress will be slow in this area.

We are using a commercially written software package for controlling the camera which runs under Windows quite satisfactorily at present. The overall common software development of a system that can control a wide range detectors is being handled elsewhere but it is important that whatever is done is able to operate both under Linux as well as under Windows since the most advanced technical solutions in DSP hardware and FPGA programming all require their development to be done under Windows, the environment in which all the development software operates.

### *Overall Hardware Design*

This has not changed significantly over the last year. The boards of the EMCCD controller are mounted on a third printed circuit board which is extended into the vacuum enclosure of the dewar (see figure below). It is important when designing high-speed camera electronics to minimise the distance between the clock drivers and the CCD, and also to minimise the distance between the CCD and the signal processing and electronics. This latter problem can be avoided by using a buffer transistor adjacent to the CCD and this is what we have chosen to do.

We can make a high-quality vacuum seal by bringing all the signal tracks through the wall of the dewar on an internal PCB layer and by using a gold plated copper area to provide a reliable vacuum seal. We have used this method successfully and found that it gives a good and reliable platform for driving the CCD as well as providing a structure that is easy to work with both when it is outside the dewar and when it is within it. It also appears to have good vacuum integrity and very low out-gassing rates.

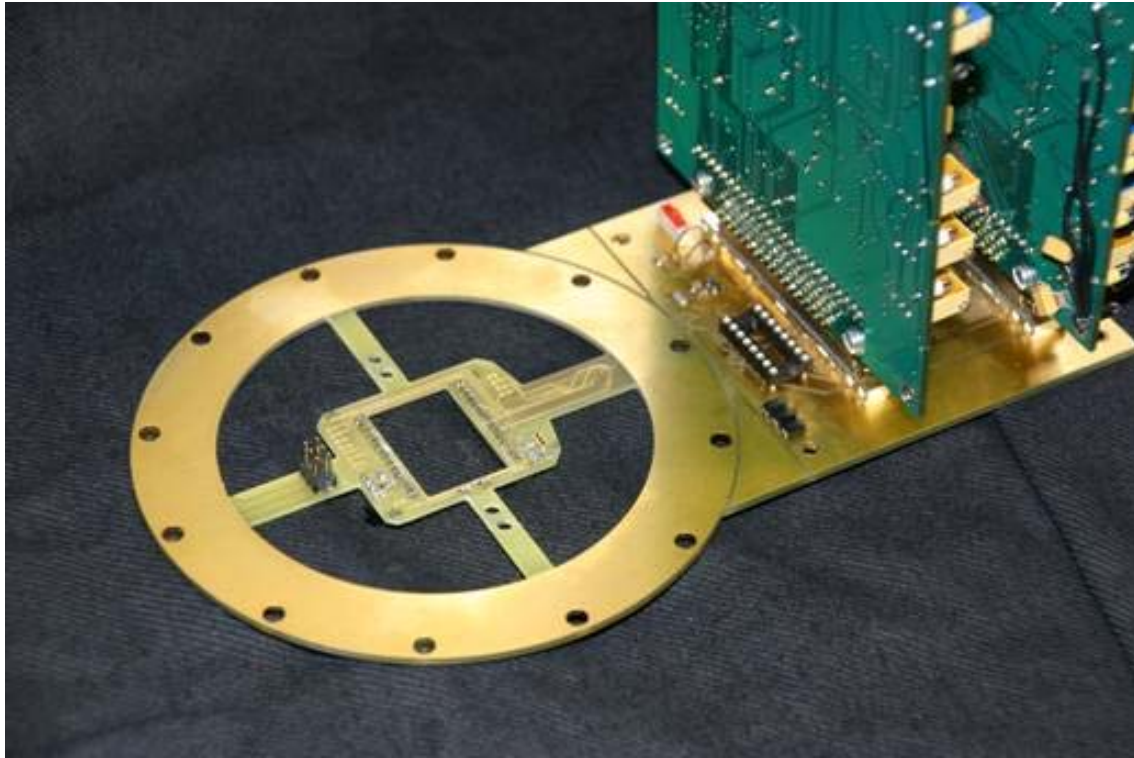


Fig: controller boards, detector support and vacuum interface.

### *Scientific Results 2007*

The camera system we have developed was used for a unique observing run on the Palomar 5 m (200 inch) telescope in June 2007. We knew that the lucky imaging techniques we had demonstrated on smaller telescopes would not work on larger ones because of the very low probability of getting a sharp image. However on the Palomar telescope they have a low order adaptive optics system (PALMAO) which we were able to use in front of our lucky imaging system. The idea was that if we could use the adaptive optics system to remove the largest scales of turbulence and therefore reduce the overall turbulent power then, notwithstanding the fact that we were using such a large aperture, we would be able to get an acceptable lucky imaging probability and be able to achieve high resolution.

We had six nights of reasonably good conditions and the results were excellent. The images below show the globular cluster M13 as it would be seen normally on that telescope together with the image that we took using our lucky camera behind the Palomar adaptive optic system.

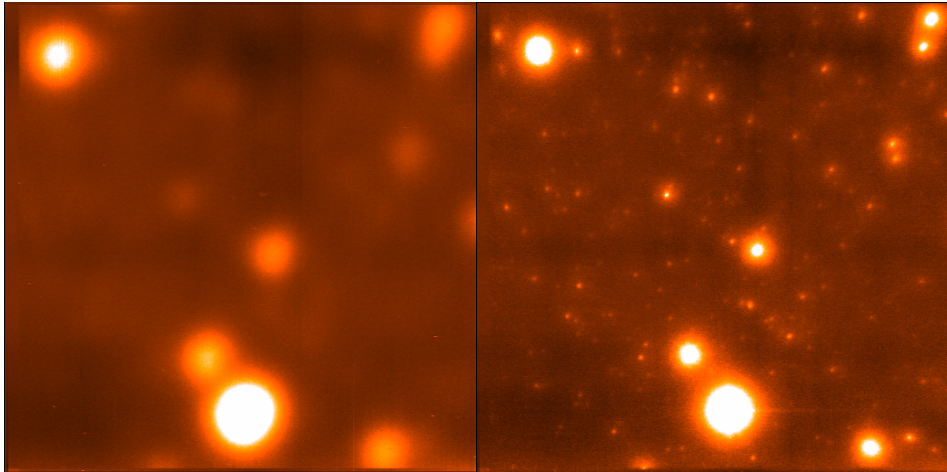


Figure 1: The Globular cluster M13 as imaged conventionally by the Palomar 200 inch telescope, and then as imaged with the Lucky Camera behind an adaptive optics system on the Palomar 200 inch telescope.

This image has a resolution of about 40 milliarcseconds and a peak Strehl ratio of about 17% in I band. The field of view is only 10 arc second square, but the resolution improvement from a natural seeing limit of about 0.65 arc seconds is dramatic. This picture is the highest resolution image ever taken in the visible or the infrared either from space or from the ground, and it demonstrates that the techniques being developed in Cambridge have enormous potential. Particularly when we bear in mind that the Palomar telescope is nearly 70 years old with a mirror that is significantly poorer than the present state of the art, and that their adaptive optics system is one of the earlier ones (there are only 12 actuators across the diameter of the telescope: these can be seen as faint images around figure 2 which shows a binary star of 0.6 arc second separation imaged again with 40 milliarcseconds resolution.

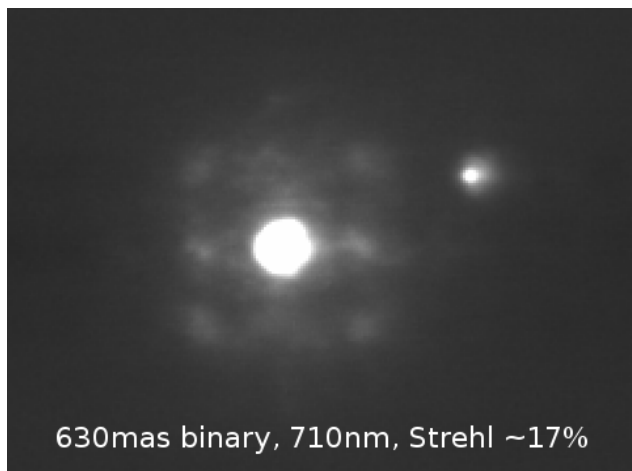


Figure 2: a binary star imaged on the Palomar 200 inch telescope with 40 milliarcseconds resolution, 17% Strehl ratio.

It is also the case that this technique seems to work well at even shorter wavelengths. Figure 3 shows an image of the Cat's Eye Nebula imaged in three colours (green is V-band, principally oxygen emission, red is R-band, principally hydrogen and blue is I band). In order to get the entire nebula on the field of view the resolution has been reduced and so this is about equal to that from the Hubble space telescope or approximately 110 milliarcseconds resolution.

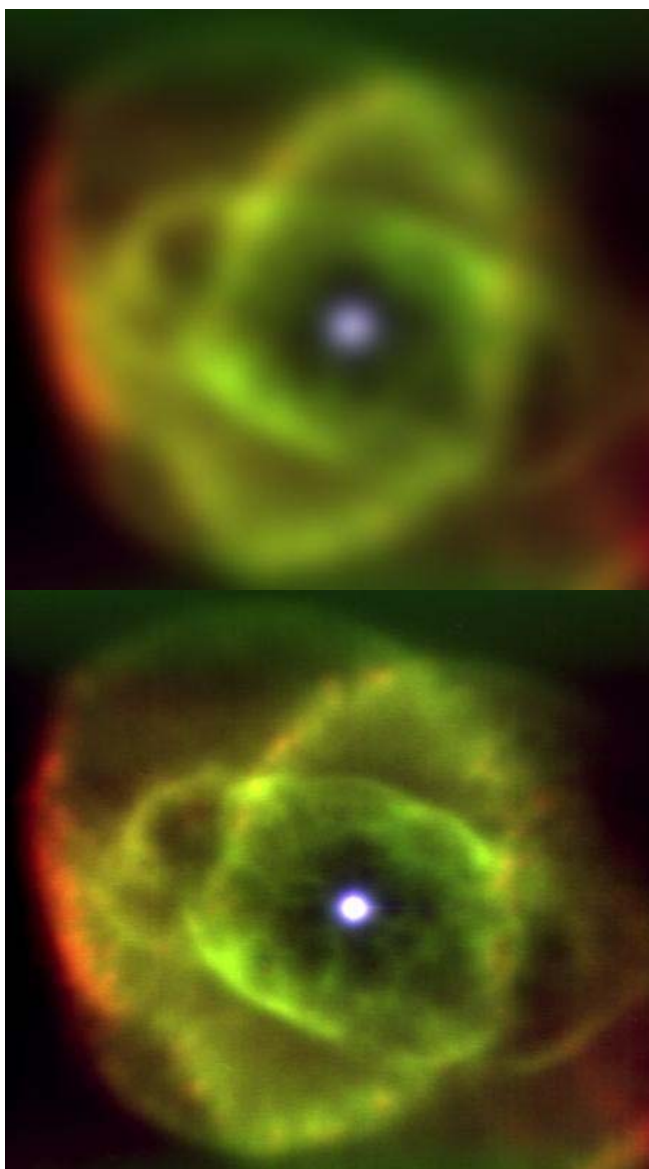


Figure 3: Left: the Cat's Eye Nebula (NGC6543) as imaged conventionally by the Palomar 200 inch telescope. The green light is oxygen emission, the red is hydrogen emission, and the blue is near-infrared radiation. Right: as imaged with the Lucky Camera behind an adaptive optics system on the Palomar 200 inch telescope.

### *Competitiveness of R&D Programme of WP5*

Although there is a lot of interest in the application of EMCCDs in astronomy, most of the work being undertaken is targeting relatively low pixel rates. There are now commercially available cameras able to work in a limited range of formats at pixel rates up to 10MHz but, to our knowledge, nobody is even close to contemplating building controllers that are really able to work at the maximum rate that these devices are capable of. In addition, all the commercial designs are only intended to be



capable of driving single detector systems and none are, to our knowledge, working on their integration with intelligent image processors. What is also clear is that the commercial offerings are very poor in terms of clock induced charge. Commercial cameras must operate with the internal gain turned off to be able to cope with the large signal levels that the CCD can transfer. This in turn forces the use of relatively high clock levels. When designing a camera for very low level operation the clock levels can be reduced and the waveforms tailored to minimise clock induced charge. In this way we find that we are running at levels that are typically 10-100 times lower than that obtained with commercial cameras. This difference is undoubtedly critical to the ability of these cameras to work effectively at the lowest light levels.

The conclusion is, therefore, that this work is highly competitive and is not being done by any other groups. In addition because of the novel properties of these detectors we are likely to continue to be in a world-leading position in respect of these technologies.

#### **WP6: Common Software Development**

As reported in Annual report 2006, the development of common software has been found impractical, since the experience delivered by the software developed in the individual work packages (especially WP5) has been found adequate for use in JRA3. The corresponding deliverable of WP6 has been deleted.

#### **WP7: Cooled Camera Head Development**

##### *Work done at IoA*

The work for WP7 that was to be undertaken at UCAM has been described in the report on WP5 under "overall hardware design". If we are to achieve photon counting performance with these detectors then it will be necessary to use liquid nitrogen cooling and the sort of structure that we are developing integrated with the controller looks to be a satisfactory way forward. For some applications it may be preferable to use thermoelectric cooling but we have no resources to allow us to pursue that possibility within JRA3. Another possibility of course would be to operate these detectors using mechanical refrigerators that achieve temperatures close to that of liquid nitrogen for situations where the use of liquid nitrogen would be unacceptable. This is a fairly straightforward and known technology and does not really merit any particular effort at this stage since it is principally a matter of straightforward engineering.

#### **WP8: Common Testbed**

As reported in 2006 and 2006, the tasks for this workpackage have been transferred to WP1, its deliverables will be subsumed under the final deliverable of WP1 (report on comparison of relative merits and prospects of the technologies tested).

## Milestones and Deliverables

Completed 2007 (contract months 37-48) and still pending for 2008:

Deliverable/ Milestone No	Deliverable/milestone name	Work- package /Task	Lead Contractor(s)	Planned/ revised (in months)	Achieved (in months)
D1	comparison of technologies report	WP1	MPA	60	60(expected)
D2	test report	WP2	STFC	48	52(expected)
D2	AA-pn-sensor device	WP3	MPE/MPG	60	54 (expected)
D3	Test report AA-pn-device	WP3	MPE/MPG	60	60 (expected)
M2	delivery APD array	WP4		12	60 (expected)
D1	AIT APD array	WP4	NUIG	12	54 (expected)
D1	Fast timing controller L3CCD	WP5	UCAM	45	45
D2	Fast timing controller AA-pn	WP5	MPE/MPG	48	54 (expected)
D1	Common higher level software	WP6	NOTSA	deleted (see WP1)	
D1	software testbed	WP8,WP1	LSW/MPA	48	60 (expected)
D1	prototype camera on testbed	WP7	STFC	48	52 (expected)

## Meetings

No meetings were held by JRA3, all communication has been effected by electronic means.

### 1.5.4 JRA4: Integrating optical Interferometry into mainstream astronomy

The total human effort deployed during the year 2007 for JRA4 is summarized in the following table:

Participant number	Participant short name	Person-months
6a	INSU/CNRS	50 (0)
1b	UCAM/CAV	6.5(2)
8e	INAF/OATo	11 (4)
11a	MPIA	0
11f	MPIfR	17 (6)
12	NOVA	0
21b	Ulg	1 (0)
30	Konkoly Observatory	6 (1.5)
31	ONERA	0 (0)
32	CAUP	29 (7.2)
33	Technion	3 (0)
34	NCU/UMK	24 (20)
36	UNIGE	3 (3)
38	OO	2.5 (1.3)
41	UNIVIE	5 (2.5)
<b>Total</b>		<b>155 (42.5)</b>

- **WP1.1: Concept to feasibility studies**

The Science and Technical Committee (STC) of ESO which has met in October 2007 recommended the projects MATISSE and VSI (and also GRAVITY) for the second generation instruments of the VLTI. The ESO Council in December 2007 has approved the STC recommendations.

The phase A of MATISSE started in June 2006 and has been achieved successfully (phase A review at ESO Garching, 3<sup>rd</sup> and 4<sup>th</sup> July 2007). The contract, engaging the consortium with ESO, towards the next important step which is the Final Design Review, is under preparation.

The VSI project has finished its phase A which has been reviewed on 29-30 August 2007 by an internal ESO review board. However, since the fringe tracker facility of VSI is of interest for the other two instruments and since the VSI study has not covered all aspects of fringe tracking, in particular the experience from existing VLTI fringe trackers like FINITO and the soon to be installed PRIMA FSU, the VSI consortium has proposed conducting an extension of the phase A study to investigate further the fringe tracking options. This should be performed between spring 2008 and spring 2009. We expect that ESO will launch the next phases of the VSI project under a formal contract in mid-2009.

Web pages : Information and documentation and publications can be found at

1. VSI: <http://www-laog.obs.ujf-grenoble.fr/twiki/bin/view/Laog/Projets/VSI/WebHome>
2. MATISSE: <http://www.obs-nice.fr/matisse>

- **WP1.2: Cophasing and Fringe Tracking**

The progress report on Work Package 1.2 - Cophasing and Fringe Tracking (CFT) describes the main activity advancements since the previous report (January, 2007), including the development of concepts for the VLTI second generation instruments (in particular VSI, the VLTI Spectro-Imager), the understanding of the instrumental limitations and environmental disturbances, and some recommendations for the future developments.

The minimum redundancy, bulk optics combination concept, developed in collaboration by the Turin and Cambridge teams, for the Fringe Tracker of the VSI instrument, is described. The study is restricted to photon limited performance, due to limited information on environment noise. The impact of internal disturbances on the performance of combined instruments is discussed, as well as possible mitigation strategies by means of auxiliary instrumentation (metrology) and proper design solutions within the science and fringe tracking combiners. The recommendations include further study of the VLTI conditions to improve them for the existing instruments and to define proper requirements for the future auxiliary and science instrumentation.

- **WP2: Off-line data reduction software**

WP2.1 (General Management and User Support): This activity (which consists in maintaining the Web services on <http://eii-jra4.ujf-grenoble.fr>, including documentation and reporting) is continuing.

WP2.2 (Common Software): See 2006 report for details. Package frozen in 2006 and available under (deliverable **WP2.2/D2**):

<http://www-laog.obs.ujfgrenoble.fr/twiki/bin/view/Laog/GRIL/Informatique/JmmcMcsInstallation>

WP2.3 (Model Fitting)

This software programme (deliverable **WP2.3/D2**) has been demonstrated at the 2006 Goutelas School, and is available "as is" at the address:

<cvs:ext:username@avae.univ-lyon1.fr:/home/cvsroot/yoga> (password available on request)

WP2.4 (Astrometry): Closed, see 2006 report. The user requirements (deliverable **WP2.4/D2**) are available at <http://eii-jra4.ujf-grenoble.fr/doc/approved/JRA4-SPE-2410-0001.pdf>

## WP 2.5 (Image reconstruction)

The Cambridge group has released a public version of its BSMEM software. The software (deliverable **WP2.5/D2**) is available at:

<http://www.mrao.cam.ac.uk/research/OAS/bsmem.html>

The JMMC is finalizing the distribution of the WISARD software, made by ONERA, which ends the JRA delivery.

### 1.4 Summary Tables

The Table below summarized the milestones and deliverables achieved by JRA4 during the year 2007:

<b>Deliverable/ Milestone</b>	<b>Name</b>	<b>Work Package</b>	<b>Lead contractor (s)</b>	<b>Planned (months)</b>	<b>Achieved (months)</b>
D5	ESO selection of second generation of VLTI instruments	1.1	ESO	48	48
D4	Third Progress Report on CFT	1.2	INAF/OATo	48	48
D2	Common software & User Manual	2.2	INSU/LAOG	42	48
D2	Model fitting software package & User manual	2.3	INSU/LAOG	48	48
D2	User requirements	2.4	UNIGE	42	48
D2	Image reconstruction software BSMEM & User Manual	2.5	UCAM/CAV	48	46

The Table below summarized the major JRA4 meetings for the year 2007:

<b>Date</b>	<b>Workshop/Meeting</b>	<b>Location</b>	<b>Number of attendees</b>	<b>Website address</b>
July 3-4	MATISSE ESO phase A review	Garching	20	<a href="http://www.obs-nice.fr/matisse">http://www.obs-nice.fr/matisse</a>
August 29-30	VSI ESO phase A review	Garching	20	<a href="http://www-laog.obs.ujf-grenoble.fr/twiki/bin/view/Laog/Projets/VSI/WebHome">http://www-laog.obs.ujf-grenoble.fr/twiki/bin/view/Laog/Projets/VSI/WebHome</a>

### 1.5.5 JRA5: Smart Focal Planes

#### Participating Contractors and Effort Deployed

Participant number	2b	5	6d	7a	8d
Participant short name	STFC	CSEM SA	LAM	IAC	Padua
Person-months	12.4	10	20.6	9 (6)	1.34
Participant number	10	45	47a		
Participant short name	ASTRON	TNO/TPD	AAO		Total
Person-months	4.06	4	1.5		?

#### Introduction

The project goal is the development of technologies to gain maximum scientific benefit from the information rich focal planes of current telescopes and future Extremely Large Telescopes by targeting the objects observed in the most effective manner. The strategy to achieve this has been to develop a Smart Focal Plane roadmap to identify which technologies to target, and to develop instrument concepts which link scientific goals with specific parameters for these technologies. This has required the bringing together of partners that have complementary expertise to progress these technologies and to focus on increasing the Technology Readiness Level (TRL) of all the technologies under development. The final stage of the Smart Focal Planes programme will be to hold a review workshop which will be used to evaluate TRLs of the technologies we have developed and revise the Technology Roadmap in order to define any further technology developments needed to ensure adoption in future instruments.

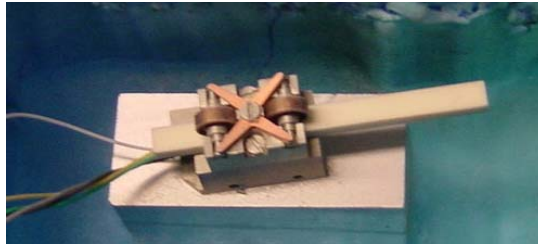
Following the consortium team meeting in Neuchatel at the end of 2006, a major team workshop was held in Leiden in March, which resulted in re-focussing of some efforts towards developing and reviewing cryogenic mechanism developments aimed at internal instrument active and adaptive optics requirements. It is proposed that this activity will lead on to a JRA on active instrument research in the OPTICON FP7 programme.

Meanwhile, the technologies developed in the Smart Focal Plane JRA formed the basis for two instrument proposals for the E-ELT. The EAGLE multi-Integral Field NIR spectrometer concept which is being developed as a Phase A study for the E-ELT is based round the pick-off devices and active mirror technologies. The SMOS concept is based on reconfigurable slit masks or MOEMs mirror arrays. As this concept is much less mature, two workshops were held within this JRA to define the science requirements, and hence define the technology specifications on the slit mechanisms.

#### WP 3.2 Cryo Mechanisms: Piezo Motors (ASTRON)

Previously this work package concentrated on a low cost commercial piezo motor, suitable for room temperature applications, which was modified to make it suitable for cryogenic applications down to temperatures of 77K.

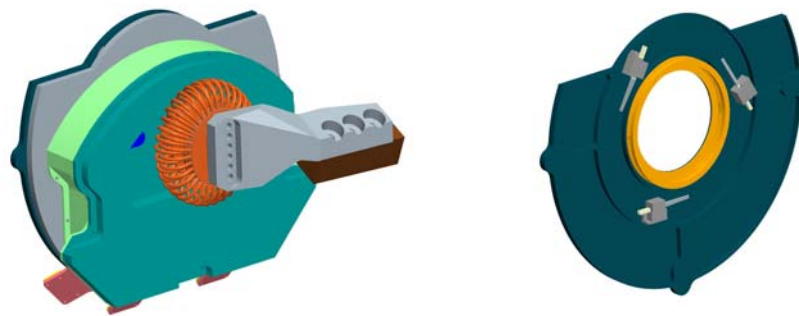




*Figure: Commercial low-cost piezo motor modified and tested at 77K [Motor dimensions 20x20x10 mm; displacement 40mm; resolution <100 nm]*

In 2007 this motor development work was combined with other OPTICON research towards a design of a cryogenic Tip/Tilt/Focus unit. The heart of this unit will be three piezo motors to drive a three point semi iso-static mount to adjust tip, tilt and focus. It is based on slide bearings with low friction cryogenic coatings and with the accurate piezo motor with 100nm resolution it will comprise high stiffness, accurate adjustments, simple construction and be very stable over time. It is primarily designed for adjusting a HAWAII-2RG detector at 77K, but is easily suitable for any other type of optical element which might need to be adjusted at low temperatures.

The main specifications for the Tip/Tilt/Focus unit are derived from the VLT XSHOOTER NIR spectrograph which is currently designed with a non-moving detector. The intention is to reduce commissioning time at cryogenic temperature by fitting an active Tip/Tilt/Focus unit. Applying one or more Tip/Tilt/Focus-units can reduce the design and testing time of complex cryogenic instruments significantly. Due to the possibility of small changes of alignment inside the cryostat, the tolerances of positioning of optics will be relaxed and the alignment of optics can be done cold within a few minutes without the need for extended cycling to room temperature. For such applications the unit needs to be extremely stiff and reliable over time. The Tip/Tilt/Focus unit is now at a preliminary design level.



*Figure 1: Overall view of the detector assembly (Hawaii 2RG) and a view inside with the three piezo motors*

In the first half year of 2008 the design will be detailed further towards final design, parts will be produced and the motors will be ordered, the unit will be assembled and the work package will be closed by testing in the May-June period.

### **WP 3.2 Cryo Mechanisms: Reconfigurable Slits and Masks (IAC)**

During 2007 we have continued the development work aimed at producing a fully functional reconfigurable cryogenic slit unit which can serve as a field selector for astronomical instruments, mainly operating at IR wavelengths. To this end, our activities have been focused mainly in two aspects:

- Establishment of a set of calibration and verification procedures working in cryogenic environments. This will permit the precise measurement of the different functional parameters defining the performance of high precision mechanisms used in astronomical instruments. This work has not being restricted to the theoretical definition of the procedures but has included the physical mounting and testing of the laboratory setup as well. We have concentrated most of our efforts in trying different solutions and gaining experience in using external optical equipment for the metrology of mechanisms mounted inside a cryostat. Differential interferometers have proven to be highly useful in this process, despite some difficulties encountered.
- Definition of a complete set of functional specifications for a reconfigurable cryogenic slit unit. This work has ended with the Call for Proposals for the procurement of that unit in EMIR for the GTC and the subsequent assignment of the contract. We have included in the contract an early delivery of a functional prototype which will permit the verification of the feasibility of the adopted solutions and which will be tested using the procedures and setup described in the above paragraph.

We are directly transferring the results of these activities to the conceptual definition of a large FOV NIR slit MOS with imaging capabilities, SMOS, to be proposed for an ELT. The instrument concept was developed by a team from IAC, UK ATC, CSEM and LAM. The concept was developed to incorporate the latest information about the instrument interface to the Basic Reference Design of the E-ELT, from the original OWL-based concept which was developed to drive the technology requirements for both reconfigurable slit mechanism and the MOEMS devices described under workpackage 3.3.

During 2008 we plan to characterise the first prototype of the EMIR cold slit unit, which may require the final fine tuning of the laboratory setup, and the completion of the SMOS proposal for the E-ELT.

### **WP 3.2 Cryo Mechanisms: Configurable Slit Mask Unit (CSEM)**

The CSEM work has concentrated on a feasibility study for the implementation of a Configurable Slit Mask Unit for the SMOS instrument on the E-ELT.

The CSU designed for the MOSFIRE instrument on the Keck telescope was modified to consider the possibility of integrating a slit mask unit in an instrument with a very large FOV. In order to minimise the development risk, it was decided to place two units side-by-side with a minimized interface thickness between the two. The actuators and indexing stage were split into two separate units, one on each side. The dead zone between the two units has been estimated to be approximately 60-80mm in

total. The design shown in the figures reflect a scaled up mechanism to the 416mmx416mm FOV. Each CSU could be equipped with 36 slits for a total of 72.

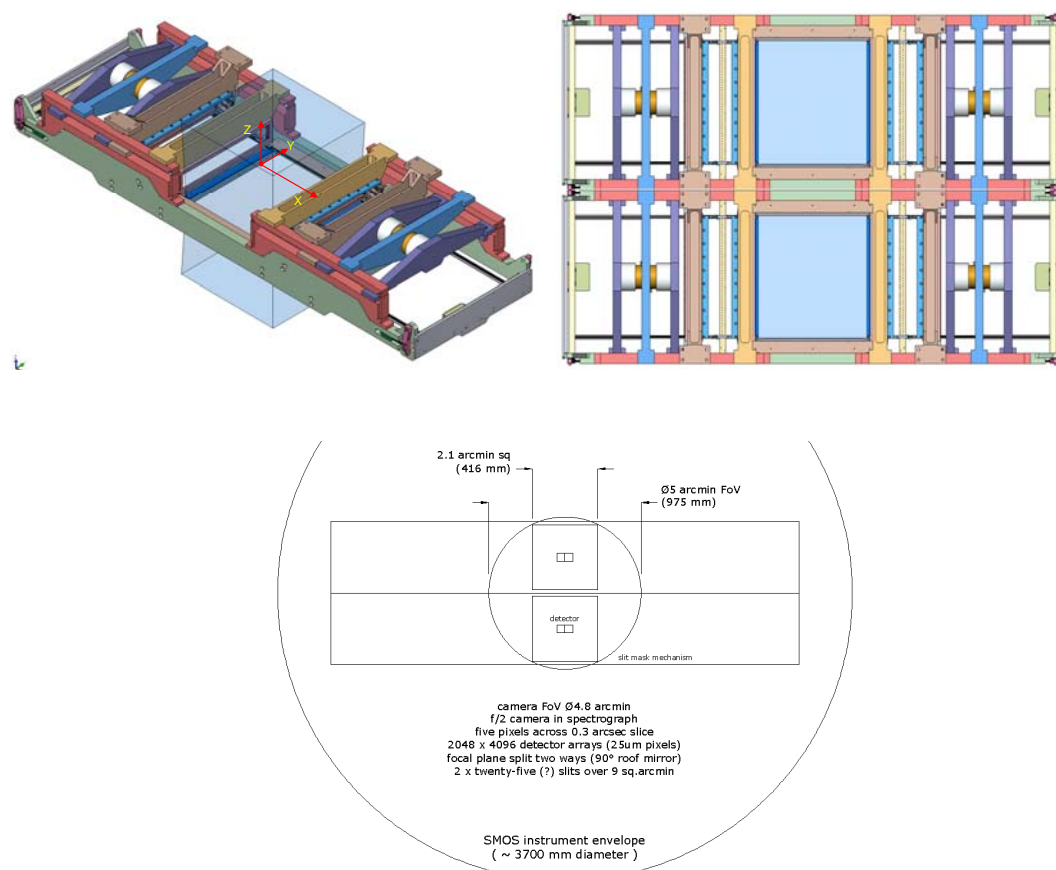


Figure 6: Extended field of view configurable slit mask aimed at SMOS requirements

### WP 3.3 - MOEMS Based Programmable Slit Masks (LAM)

We have engaged with Institut de Micro-Technologies of University of Neuchatel (Switzerland) a successful collaboration for the development of MOEMS-based programmable slit-masks. Micro-mirror arrays (MMA) have been designed for future generation infrared multi-object spectroscopy (MOS) requiring a cryogenic environment. Using a combination of surface and bulk micro-machining, we successfully realized small arrays of 5x5 single-crystalline silicon micro-mirrors. The 100µm x 200µm micro-mirrors show excellent surface quality and can be tilted by electrostatic actuation yielding 20° mechanical tilt-angle. An electromechanical locking mechanism has been demonstrated that provides uniform tilt-angle within one arc minute precision over the whole array.

Infrared MOS requires a cryogenic environment and coated mirrors, silicon being

transparent in the infrared. Influence of the reflective coating on the mirror quality has been investigated and the characterization of the MMA in a cryogenic environment has been performed.

The uncoated and un-actuated micro-mirrors showed a peak-to-valley deformation (PTV) of below 10nm. An evaporated 10nm chrome/50nm gold coating on the mirror increased the PTV to 35nm; by depositing the same layers on both sides of the mirrors the PTV was reduced down to 17nm.

Cryogenic characterization was carried out on a custom built interferometric characterization bench onto which a cryogenic chamber was mounted. The chamber pressure was at  $10^{-6}$  mbar and the temperature measured right next to the micro-mirror device was 92K. The micro-mirrors could be actuated before, during and after cryogenic testing. The PTV of the chrome/gold coated mirrors increased from 35nm to 50nm, still remaining in the requirements of  $< \lambda/20$  for  $\lambda=1\mu\text{m}$ . In conclusion the MMA is functional and remains within the specs at temperatures below 100K.

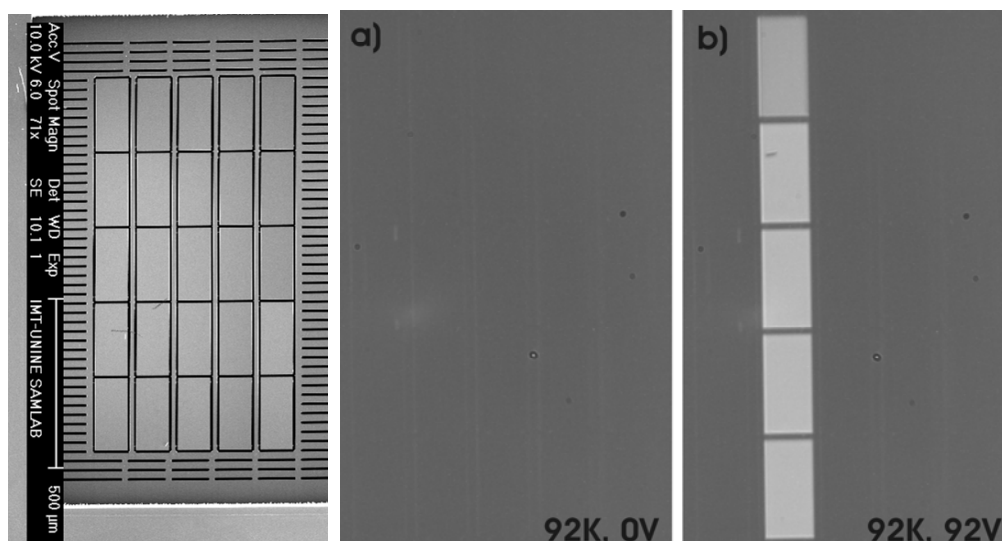


Figure 7: Scanning microscope image of the front surface of the micro-mirror array ( $100 \times 200 \mu\text{m}^2$  mirrors). Functional testing of the micro-mirror array in the cryogenic chamber at 92K: One line of micro-mirrors, initially in the OFF state (a) is switched into the ON state (b), with 90V applied.

## WP 5.0 Management and Systems Engineering (STFC)

A set of science requirements were developed from the sciences cases, and a systems engineering framework developed to flow these down to instrument requirements was developed. Areas considered include risk, technology readiness and maturity, and variables arising from the fluid state of E-ELT conceptual design and uncertainties in an organisational structure. Optical instrument concepts were modelled and investigated. An instrument Product Development Specification using the developments of this JRA has been developed for the potential ELT instruments EAGLE and SMOS.

The plan for this period included completing subsystem cryogenic testing for the

Starpicker rotation stages and gripper, and the active mirror and beam steering mechanism, followed by a complete systems test bringing them both together. A combination of delays in the cryogenic testing and re-evaluation of the gains to be obtained by an integrated test resulted in a decision to descope the programme in order to concentrate on ensuring subsystems could go through enough cycles of test and debugging.

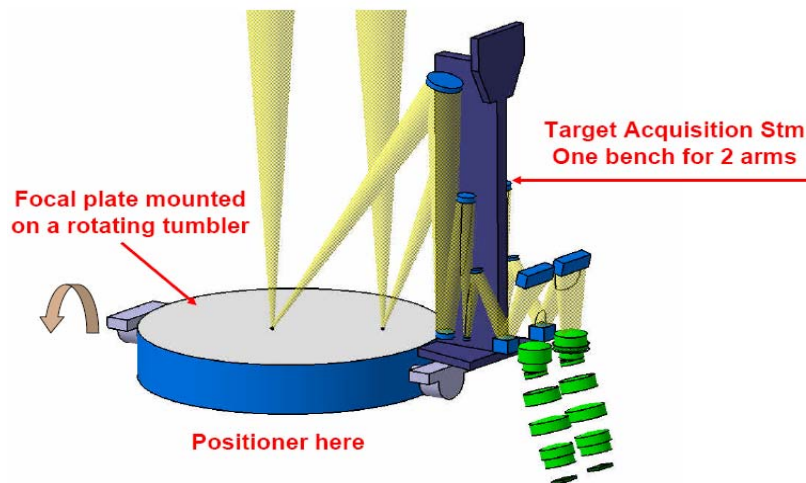


Figure 4: EAGLE concept based on Starpicker or Starbugs and active mirror systems developed in the Smart Focal Planes JRA

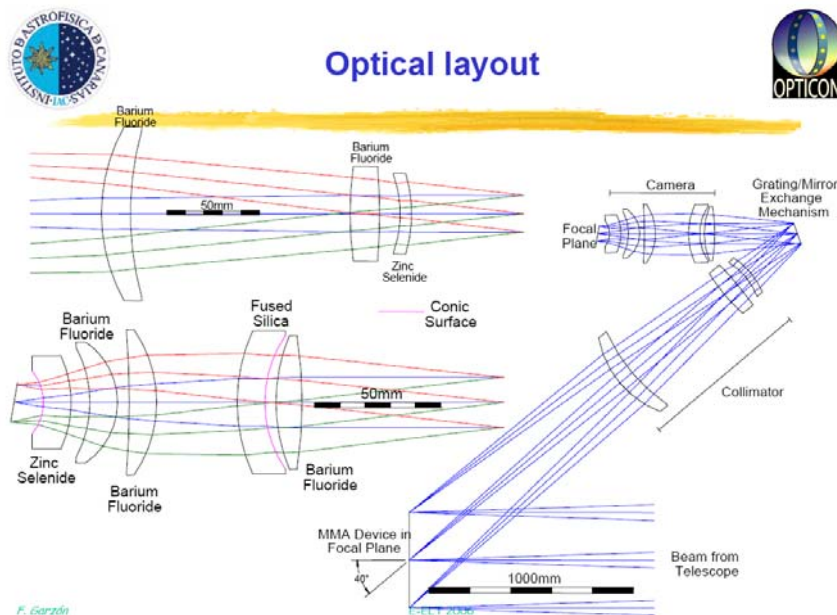


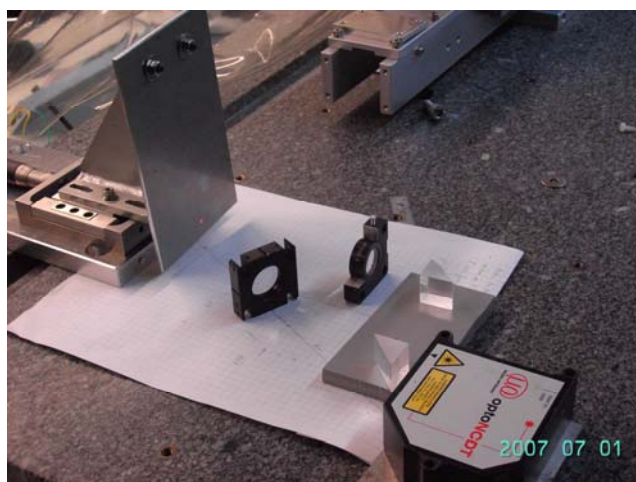
Figure 5: A SmartMOS (SMOS) concept based on MOEMs mirror arrays developed in the Smart Focal Planes JRA

## WP 6.2 Pick-off Prototype: Gripper (CSEM)

CSEM has supported the cryogenic test activities performed by the UK ATC on the Star Picker, in particular reviewing the measurements methods for precision positioning in vacuum cryostats at 77 K.

The work performed was part of the activities to develop and test a cryogenic compatible gripper system integrated in the Star Picker design to pick and place pick-off mirrors on a focal plane. The Star Picker is designed and built for operation in vacuum-cryogenic conditions down to a temperature of 77K. The gripper is a high-precision manipulator, the performance of which, particularly repeatability of positioning of a manipulated object, was tested using an industrial position sensor for the measurements performed in ambient conditions. The need to perform measurements in vacuum and low temperature conditions led to the review of measurement techniques to propose alternative test metrology methods. Potential measurements methods usable in cryogenic conditions, in particular across an enclosure window, were studied. The most promising techniques were documented and plans to develop the test set-ups proposed. Techniques explored were:

- Triangulation sensor extension
- Focus dispersion
- Auto-collimator with sphere target



*Figure 6: Evaluation of metrology concept using standard industrial sensor with extension optics*

## WP6.2 Pick-off Prototype: Starbugs (AAO)

The Starbug development in 2007 was tightly targeted at addressing two of the actuator requirements: improving the determinism of motion offered by “Rez-J”-type bugs, and simultaneous independent operation of multiple bugs. These goals were considered important in terms of demonstrating Starbug capabilities.

### *Improve Determinism*

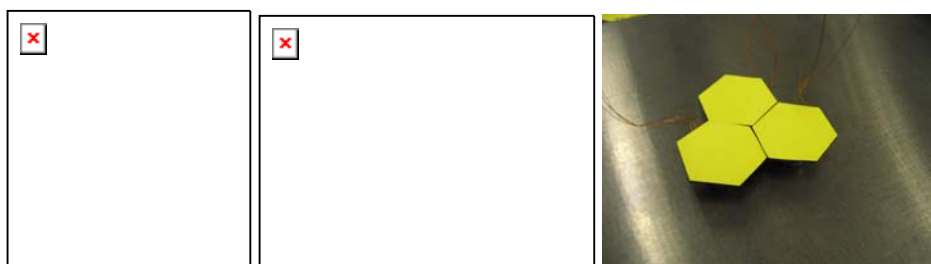
A new version of Rez-J built using a larger piezo element (10mm diameter) and stronger preload magnet, with the expectation that the larger dimensions would



improve repeatability of manufacture and larger forces should lead to better repeatability of motion. The initial bug performed successfully and two copies made allowing the demonstration of simultaneous operation of three bugs. This has also improved our understanding of the design parameters that impact the determinism of the bug.

### ***Simultaneous Operation***

Simultaneous operation of all three bugs was achieved without difficulty and the bugs had no detectable influence of one upon another until the separation became very small. The new bug design is shown in Figure 7. The hexagonal 'hats' notionally represents a hexagonal IFU lenslet arrays for a reconfigurable IFU application. It was necessary to tune the drive parameters to each of the bugs in order to optimise control over each of the bug's motion. Once tuned, it was possible to simultaneously drive the three bugs from one configuration to another, including into close-packed arrangements.



*Figure 7: Left: Rez-Jb inverted to show 'feet', and fitted with hexagonal 'hat' representing an IFU lenslet array. Middle: simultaneous operation of all three prototype bugs allowed movement between arbitrary configurations. Right: Close packed arrangements were readily achieved.*

### **Impact of work on future instrument design**

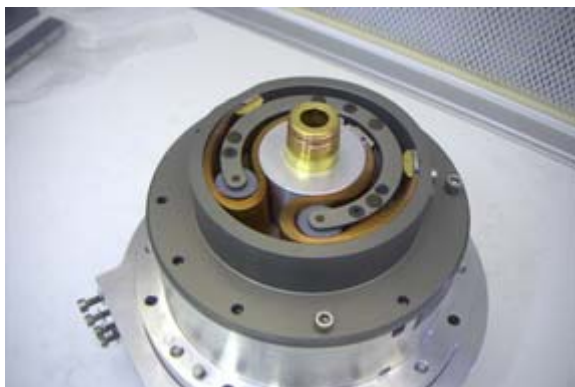
- 1) For the first time, we demonstrate simultaneous positioning of multiple bugs, a critical aspect of the Starbug concept.
- 2) The Starbug concept has been used in a preliminary system design for replacement to the 2dF positioner X-Y pick and place robot on AAT.

## WP 6.2 Pick-Off Prototype: Star-picker System Cold Tests (STFC)



*Figure 8: Star Picker and gripper assembly, showing dummy pick-off mirrors (POMs)*

Previous testing programmes at room temperature validated that the mechanism reliability and repeatability was well within requirements. Major work in 2007 included modifying the Star Picker for operation at cryogenic temperatures, and initiating a cryogenic testing programme. Modifications included incorporating a rotating thermal cooler strap to facilitate heat removal from the stepper motor on the rotating section (Figure 9), and changing the bearings to specialist dry-lubricated cryogenically compatible versions. The mechanism design was determined to be sound at LN<sub>2</sub> temperatures. However, an issue was identified where non-cryogenic-compatible cabling used was insufficiently flexible at these temperatures, resulting in limited motion of the gripper jaw while opening and closing, and reduced reliability of pick and place of the POMs.

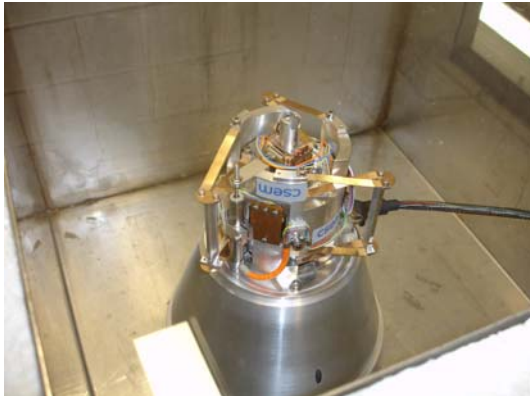


*Figure 9: Rotation stage thermal cooling strap*

Future work:

- Gripper cabling modifications: replacing existing cables with a type that

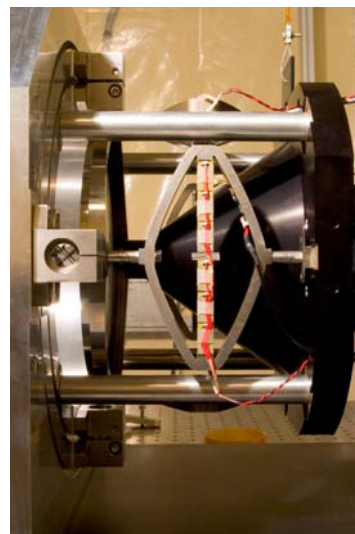
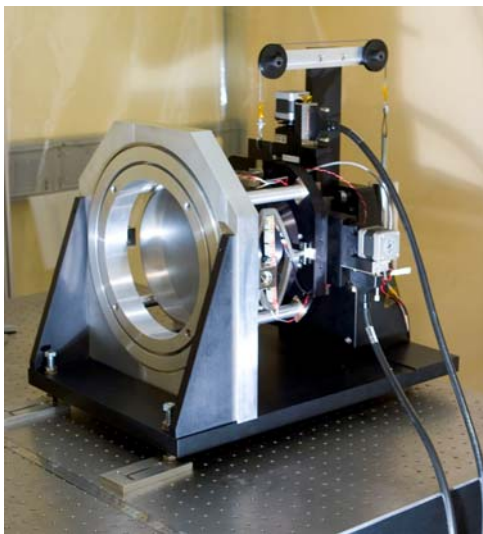
- retains flexibility at cryogenic temperatures;
- Gripper re-testing at cryogenic temperatures;
- Joint testing at cryogenic temperatures.



*Figure 10: Cryogenic testing of Star Picker Gripper*

### **WP 6.3 Beam Manipulator Prototype: Beam Steering Mirror (LAM)**

The aim of this workpackage is the development of an active Beam Steering Mirror, with specifications of this system based on past studies on the ELT WFSPEC and MOMFIS instrument concepts, but compatible with the new EAGLE concept. The system is used to generate a fixed pupil (where a Deformable Mirror can be located to enable Multi-Object Adaptive Optics) with the light coming from variable positions of the focal plane selected by the Star Picker or Starbugs. The mirror is able to correct the astigmatism and the focusing of the optical path. The actuators are amplified piezo devices (APA) from Cedrat<sup>®</sup>. Finally, the active mirror is mounted inside a tip-tilt stage that permits its orientation toward the observed subfield. The two figures below show the fully assembled prototype:



*Figure 11 Active Beam Steering Mirror Prototype*

The mirror was manufactured and ground to the required shape by November 2007. The first functional tests were carried out and the first measurements of its deformation made, showing good linearity and fit with predictions from FEA models. The instrumentation of system is underway, with to goal to get a fully controlled system by April 2008.

In parallel with this prototype, a set of two Variable Curvature Mirrors is under study. This system could allow the implementation of some zoom capability in the optical train. This system (which is less complex than the system shown above) should be ready and tested by May 2008. Then it will be combined with the previous active mirror on an optical bench. The goal here is to build a complete demonstrator of a Target Acquisition System for wide-field multi-object spectroscopy.

### **WP 6.3 Beam Manipulator Prototype: Small Deformable Mirrors (TNO)**

At the major review meeting held at Neuchatel in April 2007, it was identified that there was a requirement for highly linear cryogenic deformable mirrors in NIR multi-object spectroscopy to enable open-loop MOAO, and that this was also likely to be a requirement for a Mid-IR ELT instrument. TNO were asked to carry out a survey of technology readiness and develop a roadmap towards meeting the Smart Focal Focal Plane instrument requirements, such as those coming from the EAGLE study. The objective was to identify the most promising small deformable mirror technologies for use in next generation Smart Focal Plane Instruments. This also includes identifying potential companies and research centres in Europe that could realise or develop these technologies.

#### **Particular Aims:**

1. Identify the requirements of small deformable mirrors for next generation instrumentation, including E-ELT and VLT – 3<sup>rd</sup> generation. Attention should be paid to systems issues such as lifetime as well as optical performance. A requirement is likely to emerge for the ability of the mirrors to operate in a cryogenic or cooled environment.
2. Identify European expertise available to bring forward the development of these technologies, in particular parties involved in the OPTICON programme.
3. Summarise the generic technical approaches to addressing the requirements, and the broad advantages and disadvantages that they have.
4. Summarise the present state of technical readiness, including a numerical value for technology readiness level.
5. For technical approaches considered the most promising, present an outline of key technical milestones which must be achieved to increase technology readiness.
6. Produce a Technology Roadmap.

#### **Results:**

The final report will be issued in April 2008, but a summary of initial conclusions follows:

There are six types of AO systems for astronomy:

1. SCAO: Single Conjugate Adaptive Optics
2. GLAO: Ground-layer Adaptive Optics
3. LTAO: Laser Tomography Adaptive Optics
4. MCAO: Multi Conjugate Adaptive Optics
5. MOAO: Multi Object Adaptive Optics
6. XAO: eXtreme Adaptive Optics

The integrated AO capability of the telescope determines the need for additional AO for each of the basic AO systems. The future E-ELT for example will include a large deformable mirror which covers the requirements of SCAO, GLAO and LTAO. This mirror has been identified as M4 and is being developed at the moment. The focus of this study was therefore primarily on MCAO, MOAO and XAO systems where more stringent specifications are required for the deformable mirrors within an AO instrument, in particular an actuator pitch of typically 1mm. Cooled or cryogenic operation is a particular constraint for MOAO in the near infrared and AO built into a thermal IR instrument.

### **Smart Focal Plane JRA Conclusions**

We now have a full set of technologies available for incorporation into SFP instruments. Two ELT instrument concepts are under development, and depending on detailed trade-offs certain of these technologies will be adopted and developed to TRL 7-8 outside the Opticon programme. The configurable slit mechanisms are already being incorporated into instruments for the 10m Keck and GTC Telescopes.

**Table of Smart Focal Plane technologies and Technology Readiness Levels**

<b>Technology</b>	<b>TRL</b>	<b>Potential Instrument</b>	<b>Telescope</b>
Replicated Image Slicers	4	EAGLE	E-ELT
Star Picker	6	EAGLE	E-ELT
Star Bugs	4	2DF, EAGLE	AAT, E-ELT
Active Beam-steering Mirror	4	EAGLE	E-ELT
MOEMS Shutter	4	SMOS	E-ELT
Configurable Slit Mechanism	6	MOSFIRE, EMIR, SMOS	Keck, GTC, E-ELT
X/Y/Tip-Tilt Mechanism	4	X-Shooter, MIDIR	VLT, E-ELT

### Milestones and Deliverables achieved during the reporting period

Deliverable / Milestone No	Deliverable/Milestone Name	Work package / Task No.	Lead Contractor (s)	Planned (in months)	Achieved (in months)
D2	Report on tip-tilt cryogenic focal plane	3.2	ASTRON	48	-
D6	6 month report	5	STFC	42	-
D7	JRA5 Final Report		STFC	48	-
M2	Cryogenic tests of Gripper	6.2	STFC	42	44
M3	Cryogenic tests of Rotation Stages		STFC	42	-
M4	Cryogenic tests of StarPicker System		STFC	42	-
D2a	Report on warm tests from Active Mirror	6.3	LAM	39	-
D2b	Report on cryogenic tests from Active Mirror		LAM	42	-
D3	Report on Planar BS Mirror		LAM	42	-
D1	Report on cryogenic tests from MOEMs	6.4	LAM	42	
M2	2nd Generation MOEMs devices.		LAM	42	48
M1	Develop system for characterisation of integrated SFP system	6.5	STFC	42	-
D1	Report on performance of integrated SFP system		STFC	48	-

### Major Meetings and Workshops organised during the reporting period

Date	Title/subject of meeting /workshop	Location	Number of attendees	Website address
26/27 <sup>th</sup> March 2007	SMOS science requirements meeting	Madrid	20	SFP Twiki - restricted
28 <sup>th</sup> March 2007	Smart Focal Planes Consortium meeting	Leiden	13 + 2 by teleconf	SFP Twiki - restricted
5 <sup>th</sup> June 2007	SMOS Technology Evaluation meeting	Madrid	10	SFP Twiki - restricted



## 1.5.6 JRA6: Volume Phase Holographic Gratings (VPHG)

### Contractors:

Participant number	4a	7a	8c	21b	23	
Participant short name	ESO - INS	IAC	INAF – Brera	ULg – CSL- AOHL	POLIMI	Total
Person-months	1.2(0)	4(4)	8.1(0)	0(7.5)	7(0)	20.3(11.5)

### Summary of Objectives and progress made:

The JRA is organized in 5 main work packages (referred to also as *research lines*) which are:

1. Management
2. IR Volume Phase Holographic gratings development
3. Non-traditional VPHG-based configurations
4. Photochromic Polymers based VPHGs
5. UV Volume Phase Holographic gratings development

The general scheme followed in the JRA toward the final deliverables has followed the following phases

1. Theoretical studies aimed to the definition of a first set of prototypes.
2. Manufacturing of the first set of prototypes
3. Analysis and characterisation of the first set of prototypes
4. Definition of a second advanced set of prototypes and/or of the final devices
5. Manufacturing of the second set of prototypes and/or final devices
6. Characterisation of the second set of prototypes and/or final devices.

The present report describes the activity carried-out in the fourth year of the five year project, covering, with the exception of some left-over tasks detailed in the following sections, the phase 4 and 5 described above. The last year will be dedicated to phase 6 and final report preparation.

### WP 1 – Management

The activity of this Work Package concerned mainly leading the interconnection and intercommunication between the Work Packages. This is especially important in JRA6 because each of the contractors contributes to more than one Work Package offering its specific expertise to each research line in a transversal way. The coordination activity, e.g. making everyone aware of the expertise, infrastructure and facilities available in the team has been extremely important for the success of the research.

The interconnection and intercommunication has been managed via frequent bilateral conversations with WP leaders and a number of plenary progress meeting (at least one per year). In the year 2007 we had a plenary meeting on October 30 at Merate Observatory (Lecco, Italy). The minutes of the meeting are available on the [JRA6](#)

[Web-site.](#)

The management activity also concerned link between the JRA and the OPTICON authorities, the board and the executive board. This has been done via participation of the JRA leader to the relevant meetings and by assuring the preparation and delivery of the technical document in a timely manner. In the year 2007 the Board meeting coincided with the project mid-term review held in Corfu (Greece) in September 2007.

WP-1 also takes care of the dissemination of JRA-6 results. This is done via encouraging and coordinating the participation of the team members in congresses, conferences etc. The texts of the most relevant publications are available on the [JRA6 web-site](#).

## **WP 2 – IR VPHGs**

The general goal of WP2 within JRA6 is to enable the technology needed to manufacture Science grade VPHGs working at Near Infrared Wavelengths in cryogenic environments.

The activity has been scheduled in 3 main phases:

- a) Definition and fabrication of laboratory grade prototypes (18 months)
- b) Characterization of the prototypes and definition of the specifications for the science grade final device (24 months)
- c) Fabrication and characterization of the science grade prototype. (18 months)

The WP is currently in phase c. The final science grade prototypes have been defined, the substrates ordered and the fabrication process started. The WP is fully on schedule having achieved Milestone 6 on time.

A detailed description of the research carried out and achievements obtained can be found in the Annual report IV technical annex available from [JRA6 Web-site](#). The most important achievement of this work package in the reporting period is the **full characterization of the prototypes at cryogenic temperature**. This achievement has allowed us to move to the following step of definition and procurement of the science grade prototypes.

## **WP 3 – Non Traditional VPHG-based configurations**

Within the OPTICON JRA-6 activities the WP-3 is dedicated to the study and realisation of non-traditional configurations making use of VPHGs. The reason to have this research line in the JRA is that the use of existing VPHGs has not been pushed to the maximum. As a matter of fact, with few remarkable exceptions, they have only been used up to now as replacement for grisms in straight-through geometry spectrographs.

The activity has been scheduled along the duration of the project in 3 main phases:

- a) Trade off selection of possible representative non-traditional configuration (18 months).
- b) Demonstration of the feasibility via prototypes and characterization of a possibly innovative device at a laboratory level (24 months).
- c) Design, construction and characterization of a science grade device (18 months).

The WP is currently in phase c. The final prototypes are currently in production in the Merate Observatory Workshop and will soon be ready for characterisation. The WP is fully on schedule having achieved Milestone 6 on time.

A detailed description of the research carried out and achievements obtained can be found in the Annual report IV technical annex available from [JRA6 Web-site](#). The most important achievement of this Work Package in the reporting period is the starting of the manufacturing of parts for the final prototype.

#### ***WP 4 – Polymer based VPHGs***

WP 4 is to investigate possible alternatives to DCG as the photosensitive layer in the fabrication of VPHGs.

Due to limited resources that do not allow us to investigate all possible DCG alternatives, attention has been concentrated on a class of polymers, purposely synthesised in our laboratories, with linear and non-linear optical properties of already proven interest for astronomical instrumentation. These polymers are referred to by the general term of Photochromic polymers although many different species can be used for our purposes.

The above activity has been scheduled along the duration of the project in 3 main phases:

- a) Design, study and fabrication at laboratory level of the first VPHG based on photochromic polymers (24 months).
- b) Tests and characterization of the prototype with examination of critical fabrication points and feed back to technology enabling (24 months).
- c) Design, study and fabrication of a science grade photochromic VPHG (12 months).

The WP has recently concluded the phase b and is currently starting phase c. Materials and processes to be used have been selected and the phase of production of the final deliverable has started. The WP is fully on schedule having achieved Milestone 5 on time.

A detailed description of the research carried out and achievements obtained can be found in the Annual report IV technical annex available from [JRA6 Web-site](#). The most important achievement of this Work Package in the reporting period concerns the improvement of the photochromic polymer coating and the characterization of the film properties.

#### ***WP 5 – UV VPHGs***

The general goal of WP5 within JRA6 is to enable the technology needed to manufacture Science grade VPHGs working at UV Wavelengths with special attention to their use as cross dispersers in High Resolution Spectroscopy.

The above activity has been scheduled along the duration of the project in 3 main phases:

- a) Definition and fabrication of laboratory grade prototypes (18 months)
- b) Characterization of the prototypes and definition of the specifications for the science grade final device (24 months)
- c) Fabrication and characterization of the science grade prototype. (18 months)

The timeline of this WP diverged from the original scheme for a number of reasons. The first set of prototypes was manufactured earlier in the project and fully characterized. The result of the characterization immediately prompted the manufacturing of a second set of prototypes, nominally required later in the project. The second set has already been manufactured and awaits characterization. Such a characterization could have been carried out earlier but it has been delayed until now due to lack of manpower at ESO. Notwithstanding this the WP appears to be on schedule because the only activity left is the characterisation of the science grade prototypes.

A detailed description of the research carried out and achievements obtained can be found in the [Annual report III technical annex](#) available from [JRA6 Web-site](#).

### **Milestones and Deliverables achieved for JRA6**

Milestones and deliverables are in general agreement with the workplan. The following table report the milestones achieved and the reference to the document in which they are described (6MR – 6 months report, AR I,II,III,IV Annual report technical annex I,II,III, IV , 18MR 18 months report. All available from the [JRA6 Web-site](#)).

<b>Deliverable /Milestone No</b>	<b>Name of deliverable/milestone</b>	<b>Work-package /Task</b>	<b>Lead Contractor(s)</b>	<b>Planned (in months)</b>	<b>Achieved (in months)</b>	<b>Doc #</b>
M1	Material, Fabrication and test plan doc	WP2	ALL	6	6	6MR
M1	Preliminary design study report	WP3	ALL	6	6	6MR
M1	Theoretical and Experimental analysis report on the materials to be used	WP4	ALL	6	6	6MR
M1	Material, Fabrication and test plan doc	WP5	ALL	6	6	6MR
M2	Test Plan and test equipment procurement path document	WP2	ALL	12	12	ARI
M2	Industrial ready design report	WP3	ALL	12	12	ARI
M2	Production of small quantity of the selected material and analysis	WP4	ALL	12	12	ARI
M2	Test Plan and test equipment procurement path document	WP5	ALL	12	12	ARI
M3	Prototype manufacturing dossier and Test report	WP2	ALL	18	18	18MR
M3	Prototype manufacturing dossier and Test report	WP3	ALL	18	18	18MR
M3	Prototype manufacturing dossier and Test report	WP4	ALL	18	18	18MR

M3	Prototype manufacturing dossier and Test report	WP5	ALL	18	18	18MR
M4	Prototype Analysis Report Document	WP2	ALL	24	24	ARII
M4	Protoype Analysis Report Document	WP3	ALL	24	24	ARII
M4	Protoype Analysis Report Document	WP5	ALL	24	24	ARII
M4	Review of Prototype Critical Points	WP4	ALL	30	30	ARIII
M5	Science Grade Device Specifications	WP2	ALL	30	36	ARIII
M5	Construction Plan and Material trade-off selection	WP3	ALL	30	36	ARIII
M5	Science Grade Device Specificaions	WP5	ALL	30	36	ARIII
M5	Production of the material for final prot	WP4	ALL	36	42	ARIV
M6	Science Grade Manufacturing dossier	WP2	ALL	42	48	ARIV
M6	Assembly functional test dossier	WP3	ALL	42	48	ARIV
M6	Science Grade manufacturing dossier	WP5	ALL	42	48	ARIV
M6	Study of the Phys behaviourof material	WP4	ALL	48	48	ARIV

### Meetings and Workshop Table for JRA6

Date	Title/subject of meeting	Location	No of attendees	Website address
October 07	Progress Meeting	INAF-Merate	10	<a href="#">JRA6 Web-site</a>

## 2. List of deliverables

Activity	Deliverable No	Deliverable Name	Workpackage /Task No	Delivered by Contractor(s)	Planned (in months)	Achieved (in months)
NA1	M14	Executive meeting. Venice	WP1	IoA, STFC	39	40
NA1	M15	Complete Annual report to EU	WP1	IoA, STFC	39	40
NA1	M18	OPTICON Board meeting. Autumn 07	WP1	IoA, STFC	45	46
NA2	D1	Updated Progress report and revised roadmap	WP1.1	IAC	48	47
NA2	M1	Regular ENO meetings	WP1.1	IAC, IOA-KUL, INAF, NOTSA, THEMIS, IF AE, UCAM, Jodrell Bank	45	47
NA2	D5	Final report	WP1.2	STFC	36	47
NA2	D1	Mounting automatic DIMM at OT	WP2.1	IAC	42	43
NA2	M1	Open-doors days at OT and ORM	WP3.2	IAC, STFC, INAF, IOA-KUL, IF AE	42 -43	42 -43
NA2	D1	New editions of outreach material	WP3.2	IAC, STFC, INAF, IOA-KUL, IF AE	40	40
NA2	D2	ENO website. Updated version	WP3.2	IAC, STFC, INAF, IOA-KUL, IF AE	47	47
NA2	D6	Participation in major events	WP3.2	IAC, STFC, INAF, IOA-KUL, IF AE	45	45
NA3	M2	UV Science Case Book/ Roadmap	WP2	STFC	18	26
NA3	M3	International UV astronomy meeting	WP2	STFC	41	41
NA3	D1	Publication of High Time Resolution Astrophysics Book as part of the Astrophysics & Space Science Library	WP3	NUIG	48	48
NA3	D2	International conference at the Royal Observatory Edinburgh, Scotland	WP3	NUIG	45	45
NA3	D3	Publication of conference proceedings	WP3	NUIG	52	52
NA3	M4	Implementation project plan	WP6	ESO	42	39
NA4		<i>Activity complete</i>				
NA5	M2	Annual call for applications	WP1	NCU	39 & 45	40 & 46
NA5	M3	Collate list of applicants	WP1	NCU	39 & 45	40 & 46
NA5	M4	Selection of exchange visitors	WP1	NCU	40 & 46	40 & 48
<i>Milestone WP1.M2, WP1.M3 and WP1.M4 occur twice in the year 2007 since applications for the Fizeau Exchange Visitors Program were accepted every 6 months.</i>						
NA5	D1	Report from participants	WP1	NCU	48	48
NA6	M2	Annual Directors' Meeting	WP1	STFC	46	46



NA6	M4A	Peer review of Aristachos telescope	WP1	STFC	46	46
NA6	D1	Promote Access programme at Jenam meeting in Yerevan	WP2	IAC	32	32
NA6	M2	4 <sup>th</sup> Report to Directors forum	WP2	IAC	48	48
NA6	M3a	Working group Meeting	WP3	CNRS,IAP	29	44
JRA1	M1	JRA1 General Meeting 5	WP1	ESO	9	11
JRA1	MTR	Mid Term Review	WP1	OPTICON	9	9
JRA1	D1	Design of SPHERE	WP2.1	INSU-ESO	6	9
JRA1	D2	Design of the VLT multi-LGS GLAO facility (DSM+GRAAL +ASSIST)	WP2.2	ESO	12	12
JRA1	M2	Design review & Complete development of the Real Time Computer Platform and performance testing	WP3.1	ESO	12	10
JRA1	M2	Laser Tomography simulations and optimal reconstruction study report	WP3.2	ONERA	6	12
JRA1	M1	Delivery and testing of a 1377 actuators piezo deformable mirror	WP3.3	ESO	12	10
JRA1	M2	Complete final design of the VLT Adaptive secondary design	WP3.5	ESO	6	12
JRA1	New	Design of the 100 actuators electromagnetic deformable mirror	WP3.7	INSU/ESO	6	9
JRA1	New	Design of the 100 actuators electrostatic deformable mirror	WP3.7	INSU/ESO	6	9
JRA1	M2/M4	Preliminary & Final design of a 50x50 actuators mini piezo deformable mirror	WP 3.7	INSU/ESO	9	11
JRA2	M5	Frontside device test	WP2	ESO	24	36
JRA2	M3	Delivery of detector controller	3	INSU/CNRS	18	44
JRA2	M4	Delivery of detector controller	3	INSU/CNRS	18	48
JRA2	M2	Cryogenic system acceptance	4	INSU/CNRS	18	36
JRA3	D1	comparison of technologies report	WP1	MPA	60	60(expected)
JRA3	D2	test report	WP2	STFC	48	52(expected)
JRA3	D2	AA-pn-sensor device	WP3	MPE/MPG	60	54 (expected)
JRA3	D3	Test report AA-pn-device	WP3	MPE/MPG	60	60 (expected)
JRA3	M2	delivery APD array	WP4		12	60 (expected)
JRA3	D1	AIT APD array	WP4	NUIG	12	54 (expected)
JRA3	D1	Fast timing controller L3CCD	WP5	UCAM	45	45
JRA3	D2	Fast timing controller AA-pn	WP5	MPE/MPG	48	54 (expected)
JRA3	D1	copmmon higher level software	WP6	NOTSA	deleted (see WP1)	
JRA3	D1	software testbed	WP8, WP1	LSW/MPA	48	60 (expected)
JRA3	D1	prototype camera on testbed	WP7	STFC	48	52 (expected)
JRA4	D5	ESO selection of second generation of VLTI instruments	1.1	ESO	48	48
JRA4	D4	Third Progress Report on CFT	1.2	INAF/OATo	48	48

JRA4	D2	Common software & User Manual	2.2	INSU/LAOG	42	48
JRA4	D2	Model fitting software package & User manual	2.3	INSU/LAOG	48	48
JRA4	D2	User requirements	2.4	Geneva	42	48
JRA4	D2	Image reconstruction software BSMEM & User Manual	2.5	UCAM/CAV	48	46
JRA5	D2	Report on tip-tilt cryogenic focal plane	3.2	ASTRON	48	-
JRA5	D6	6 month report	5	STFC	42	-
JRA5	D7	JRA5 Final Report		STFC	48	-
JRA5	M2	Cryogenic tests of Gripper	6.2	STFC	42	44
JRA5	M3	Cryogenic tests of Rotation Stages		STFC	42	-
JRA5	M4	Cryogenic tests of StarPicker System		STFC	42	-
JRA5	D2a	Report on warm tests from Active Mirror	6.3	LAM	39	-
JRA5	D2b	Report on cryogenic tests from Active Mirror		LAM	42	-
JRA5	D3	Report on Planar BS Mirror		LAM	42	-
JRA5	D1	Report on cryogenic tests from MOEMs	6.4	LAM	42	
JRA5	M2	2nd Generation MOEMs devices.		LAM	42	48
JRA5	M1	Develop system for characterisation of integrated SFP system	6.5	STFC	42	-
JRA5	D1	Report on performance of integrated SFP system		STFC	48	-
JRA6	M1	Material, Fabrication and test plan doc	WP2	ESO-INS, IAC,INAF–Brera,ULg–CSL-AOHL,POLIMI	6	6
JRA6	M1	Preliminary design study report	WP3	ESO-INS, IAC,INAF–Brera,ULg–CSL-AOHL,POLIMI	6	6
JRA6	M1	Theoretical and Experimental analysis report on the materials to be used	WP4	ESO-INS, IAC,INAF–Brera,ULg–CSL-AOHL,POLIMI	6	6
JRA6	M1	Material, Fabrication and test plan doc	WP5	ESO-INS, IAC,INAF–Brera,ULg–CSL-AOHL,POLIMI	6	6
JRA6	M2	Test Plan and test equipment procurement path document	WP2	ESO-INS, IAC,INAF–Brera,ULg–CSL-AOHL,POLIMI	12	12
JRA6	M2	Industrial ready design report	WP3	ESO-INS, IAC,INAF–Brera,ULg–CSL-AOHL,POLIMI	12	12
JRA6	M2	Production of small quantity of the selected material and analysis	WP4	ESO-INS, IAC,INAF–Brera,ULg–CSL-AOHL,POLIMI	12	12

JRA6	M2	Test Plan and test equipment procurement path document	WP5	ESO-INS, IAC, INAF–Brera, ULg–CSL–AOHL, POLIMI	12	12
JRA6	M3	Prototype manufacturing dossier and Test report	WP2	ESO-INS, IAC, INAF–Brera, ULg–CSL–AOHL, POLIMI	18	18
JRA6	M3	Prototype manufacturing dossier and Test report	WP3	ESO-INS, IAC, INAF–Brera, ULg–CSL–AOHL, POLIMI	18	18
JRA6	M3	Prototype manufacturing dossier and Test report	WP4	ESO-INS, IAC, INAF–Brera, ULg–CSL–AOHL, POLIMI	18	18
JRA6	M3	Prototype manufacturing dossier and Test report	WP5	ESO-INS, IAC, INAF–Brera, ULg–CSL–AOHL, POLIMI	18	18
JRA6	M4	Prototype Analysis Report Document	WP2	ESO-INS, IAC, INAF–Brera, ULg–CSL–AOHL, POLIMI	24	24
JRA6	M4	Prototype Analysis Report Document	WP3	ESO-INS, IAC, INAF–Brera, ULg–CSL–AOHL, POLIMI	24	24
JRA6	M4	Prototype Analysis Report Document	WP5	ESO-INS, IAC, INAF–Brera, ULg–CSL–AOHL, POLIMI	24	24
JRA6	M4	Review of Prototype Critical Points	WP4	ESO-INS, IAC, INAF–Brera, ULg–CSL–AOHL, POLIMI	30	30
JRA6	M5	Science Grade Device Specifications	WP2	ESO-INS, IAC, INAF–Brera, ULg–CSL–AOHL, POLIMI	30	36
JRA6	M5	Construction Plan and Material trade-off selection	WP3	ESO-INS, IAC, INAF–Brera, ULg–CSL–AOHL, POLIMI	30	36
JRA6	M5	Science Grade Device Specifications	WP5	ESO-INS, IAC, INAF–Brera, ULg–CSL–AOHL, POLIMI	30	36
JRA6	M5	Production of the material for final prot	WP4	ESO-INS, IAC, INAF–Brera, ULg–CSL–AOHL, POLIMI	36	42
JRA6	M6	Science Grade Manufacturing dossier	WP2	ESO-INS, IAC, INAF–Brera, ULg–CSL–AOHL, POLIMI	42	48
JRA6	M6	Assembly functional test dossier	WP3	ESO-INS, IAC, INAF–Brera, ULg–CSL–AOHL, POLIMI	42	48

JRA6	M6	Science Grade manufacturing dossier	WP5	ESO-INS, IAC, INAF–Brera, ULg–CSL–AOHL, POLIMI	42	48
JRA6	M6	Study of the Phys behaviour of material	WP4	ESO-INS, IAC, INAF–Brera, ULg–CSL–AOHL, POLIMI	48	48

### **3. Use and dissemination of knowledge**

#### **NA 1. Management**

OPTICON was represented by posters and a talk at the 2007 JENAM meeting in Armenia.

The project office continued to maintain the OPTICON web site. The series of paper handouts were revised and distributed at appropriate events, such as the JENAM meeting.

Articles on progress with the project have appeared regularly in the newsletter of the European Astronomical Society.

#### **NA2: Coordination and Integration of ENO facilities**

##### **WP1.2 Laser Traffic Control System (LTCS) for ORM**

The complete final report can be downloaded as paper 06/07 at the following Web address:  
[http://www.otri.iac.es/na2/ver\\_meeting.php?id=27&id\\_proyecto=1](http://www.otri.iac.es/na2/ver_meeting.php?id=27&id_proyecto=1)

##### **WP2.1 Co-ordination of night-time seeing measurements with DIMMs:**

Night time seeing and meteorological data and statistics are now also available from the project web page <http://www.iac.es/project/sitesting/site.html> under “Statistics and Data”. Meteorological data in real time are also provided from the project webpage <http://www.iac.es/project/sitesting/onlinepro/wstation.html>

##### **WP 2.4 Joint actions for Measurement of turbulence and wind vertical profiles**

Statistical seasonal evolution of the optical-turbulence profiles (see Fig. 1) at the Roque de los Muchachos observatory (ORM) presented at the SPIE meeting Remote Sensing Europe, held in Florence last September (García-Lorenzo, Fuensalida, & Rodríguez-Hernández, 2007, SPIE, 6747, in print, “Statistical turbulence vertical profiles at the Roque de los Muchachos Observatory and Teide Observatory”).

The hybrid instrument (G-SCIDAR plus Shack-Hartmann) presented at the SPIE meeting Remote Sensing Europe, held in Florence last September (Rodríguez-Hernández, Fuensalida, García-Lorenzo, Delgado, Hernández, Hoegemann, Vázquez Ramió 2007, SPIE, 6747, in print, “The hybrid Shack-Hartmann/G-SCIDAR instrument”)

Package of activities to evaluate the characteristics of SODAR technique in calibration with G-SCIDAR measurements: preliminary results of such cross-comparison were presented at the SPIE meeting Remote Sensing Europe, held in Florence last September (del la Nuez, García-Lorenzo, Fuensalida, & Rodríguez-Hernández 2007, SPIE, 6747, in print, “Atmospheric turbulence profiling at the Teide observatory: comparison and calibration of SODAR and SCIDAR measurements”)

##### **WP 2.5 Distribution and discussion of results and participation at the scientific forums**

- Recent results at the Canarian Observatories. C. Muñoz-Tuñón et al. WP2.1
- Site Selection for the european ELT. C. Muñoz-Tuñón, Vernin & Sarazin. WP.5
- In situ Calibration using Satellite data results. A.M. Varela et al. WP.2.3.

<http://www.otri.iac.es/na2/>

- Climatology at the Roque de los Muchachos Observatory: tropospheric and ground level regimes. A.M. Varela & C. Muñoz-Tuñón. WP2.3
- DIMMA: the first unmanned Differential Image Motion Monitor. A.M. Varela et al. WP2.1
- On the Use of Satellite Data for Atmospheric Extinction Studies. A.M. Varela et al. WP.2.3. <http://www.otri.iac.es/na2/>

**Public Outreach Website: [www.eno.iac.es](http://www.eno.iac.es)**

### **NA3: Structuring European Astronomy**

#### **WP1: ELT**

Monnet, G., Hook, I., Cuby, J.-G., 2007, The Messenger (ESO), Reports on the Conference "Towards the European Extremely Large Telescope", 2007, 127, 20

Hook, I. and the OPTICON ELT Science Working Group, "Overview of the Science Case for a 50 100m Extremely Large Telescope", in proc. "Exploring the Cosmic Frontier: Astrophysical Instruments for the 21st Century". ESO Astrophysics Symposia, Edited by Andrei P. Lobanov, J. Anton Zensus, Catherine Cesarsky and Phillip J. Diamond. ISBN 978-3-540-39755-7. Published by Springer-Verlag, Berlin and Heidelberg, Germany, 2007, p.121

Hook, I. "Summary of the Science Case for an ELT", Proc 1st ARENA Conference on "Large Astronomical Infrastructures at CONCORDIA, prospects and constraints for Antarctic Optical/IR Astronomy" N. Epchtein and M. Candide (eds) EAS Publications Series, 25 (2007) 111-118 DOI: 10.1051/eas:2007081

#### **WP2: Network for UV Astronomy (NUVA)**

##### ***Summary of the Joint Discussion: "UV Astronomy: Stars from Birth to Death"***

Ana I. Gómez de Castro Martin A. Barstow

Highlights of Astronomy, Volume ??

XXVIth IAU General Assembly, August 2006

K.A. van der Hucht, ed., c ° 2006 International Astronomical Union

##### ***Fundamental problems in astrophysics: Guidelines for future UV observatories.***

Ana I. Gómez de Castro Willem Wamsteker, eds, 2006

Springer, ISBN 1-420-4836-6

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#### *Joint Discussion 4 UV astronomy: stars from birth to death*

Ana I. Gómez de Castro & Martin A. Barstow

Highlights of Astronomy, Vol. 14, as presented at the IAU XXVI General Assembly, 2006.  
Cambridge: Cambridge University Press, 2007., pp.169-194

*Space Astronomy: the UV window to the Universe* (eds. Ana I. Gómez de Castro Noah Brosch),  
to be published by Springer (and ApSS) in 2008

### **WP3: High Time Resolution Astrophysics (HTRA)**

In October 2007, the HTRA contributed volume was published by Springer as part of the Astrophysics & Space Science Library (ASSL) - "High Time Resolution Astrophysics", eds. D Phelan, O. Ryan. A. Shearer, Astrophysics and Space Science Library, Springer, 2007, ISBN-10: 1402065175. This represented the culmination of 18 months work, following the Galway Workshop in 2006.

In early November 2007, all the papers from the conference had been collected and reviewed by the editors of the proceedings. These were submitted to the American Institute of Physics and have been published - "The Universe at sub second timescales", eds. D Phelan, O. Ryan. A. Shearer, AIP Conference Proceedings, 984, ISBN 978-0-7354-0503-5.

### **NA5: Interferometry forum**

The report from this workshop was finalized in 2007 and has appeared as a review article in "Astronomy and Astrophysics Reviews" (Cunha et al. A&AR 14, 217-360).

### **NA6: OPTICON Telescope Network**

#### **WP3: Enhancement**

A full report on two NEON schools (which operate in conjunction with a Marie-Curie action) has been given in the ESO Messenger (n.126, Dec.2006 issue, p. 52)

## **JRA1: Adaptive Optics**

Large numbers of reports are provided in the CD-ROM.

## **WP3.1: 2<sup>nd</sup> Generation RTC Platform**

R. Myers et al. FPGA Developments for the SPARTA project - Part 3, SPIE-07

## **JRA2: Fast detectors for AO**

## **JRA3 : High Time Resolution Astronomy**

## **JRA4: Interferometry**

## **JRA5: Smart Focal Planes**

### **Proc. SPIE 6273 (2006)**

#### **A scalable pick-off technology for multi-object instruments**

Peter Hastings; Suzanne Ramsay Howat; Peter Spanoudakis; Raymond van den Brink; Callum Norrie; David Clarke; K. Laidlaw; S. McLay; Johan Pragt; Hermine Schnetler; L. Zago

#### **SMART-MOS: a NIR imager-MOS for the ELT**

Francisco Garzón; Eli Atad-Etchedgui; Peter Hammersley; David Henry; Callum Norrie; Pablo Redondo; Frederic Zamkotsian

#### **New beam steering mirror concept and metrology system for multi-IFU**

Fabrice Madec; Eric Prieto; Pierre-Eric Blanc; Emmanuel Hugot; Sébastien Vivès; Marc Ferrari; Jean-Gabriel Cuby

- [1] S. Waldis, F. Zamkotsian, P.-A. Clerc, W. Noell, M. Zickar, and N. de Rooij, "Arrays of High Tilt-Angle Micromirrors for Multi Object Spectroscopy", *IEEE Journal of Selected Topics in Quantum Electronics*, vol. 13, pp. 168–176, March-April 2007
- [2] S. Waldis, P.-A. Clerc, F. Zamkotsian, M. Zickar, W. Noell, N. F. de Rooij, "Uniform tilt-angle micromirror array for multi-object spectroscopy", *Proc. SPIE* 6466, San Jose, USA, January 2007
- [3] Frederic Zamkotsian, Arnaud Liotard, Patrick Lanzoni, Severin Waldis, Wilfried Noell, Nico de Rooij, Veronique Conedera, Norbert Fabre, "Optical MEMS for Future Instruments in Astronomy", Invited talk, Optical MEMS 2007 conference, Hualien, Taiwan, August 2007
- [4] S. Waldis, F. Zamkotsian, P. Ayyalasomayajula, W. Noell, N. F. de Rooij, "Micromirrors for Multiobject Spectroscopy: Large Array Actuation and Cryogenic Compatibility", Optical MEMS 2007 conference, Hualien, Taiwan, August 2007
- [5] Frederic Zamkotsian, Severin Waldis, Arnaud Liotard, Veronique Conedera, Patrick Lanzoni, "MOEMS for future astronomical instrumentation on ground and in space", JENAM 2007, Yerevan, Armenia, August 2007
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- [7] Frederic Zamkotsian, Emmanuel Grassi, Severin Waldis, Rudy Barette, Patrick Lanzoni, Christophe Fabron, Wilfried Noell, Nico de Rooij, "Cryogenic and interferometric characterization of MOEMS devices for astronomical instrumentation", ESA Micro and Nano Technologies Workshop, Noorwijk, Netherlands, October 2007
  - [8] Severin Waldis, Frederic Zamkotsian, Pierre-Andre Clerc, Michael Zickar, Wilfried Noell, Nico de Rooij, "Micromirror arrays for object selection", ISOT Conference, Lausanne, Switzerland, October 2007
  - [9] Severin Waldis, Frederic Zamkotsian, Patrick Lanzoni, Wilfried Noell, Nico de Rooij, "Packaged MEMS micro-mirrors for cryogenic environment", Conference MEMS 2008, Tucson, USA, January 2008
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1. Roger Haynes, Andrew McGrath, Scott Smedley, Rolf Muller, Stan Miziarski, Peter Gillingham, Gabriella Frost, David Correll and Jurek Brzeski: "It's alive: Performance and control of prototype Starbug actuators", SPIE Proc.6273, paper 69 (2006)
  2. Andrew McGrath and Roger Haynes: "Deployable payloads with Starbug", SPIE Proc.6273, paper 70 (2006)
  3. Roger Haynes and Andrew McGrath: "Wide field astronomy with Starbug", New Astronomy Reviews Vol.50 issue 4-5, p.329-331, 2006.
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## **JRA6: Volume Phase Holographic Gratings**