COMMISSION 9: INSTRUMENTS AND TECHNIQUES (INSTRUMENTS ET TECHNIQUES)

PRESIDENT: J. Davis VICE-PRESIDENT: J.C. Bhattacharyya

Summaries of the business and scientific sessions held by Commission 9 during the 21st IAU General Assembly in Buenos Aires are given in this report. As part of the General Assembly program Commission 9 also co-sponsored two Joint Commission Meetings and joined with Commission 25 in a joint meeting on "Contributions of Polarimetry to Stellar Astrophysics". JCM II, on "Automated Telescopes for Photometry and Imaging" and "Performance and Results with IR Arrays", was co-sponsored with Commission 25 and the report can be found in Highlights of Astronomy (Volume 9). JCM IV, on "The Development of Antarctic Astronomy", was co-sponsored with Commissions 40 and 50 and its report will also appear in Highlights of Astronomy. The report on "Contributions of Polarimetry to Stellar Astrophysics" appears in the contribution from Commission 25 to this volume.

BUSINESS

Business Meeting: 30 July 1991

Chair: J. Davis

The business session opened with brief reports from the Commission's three Working Groups. The future of the Working Groups was discussed and it was agreed that the Working Groups on "Detectors" and on "High Angular Resolution Interferometry" should both continue unchanged. Both represented active and developing areas of great interest to the Commission and were playing significant roles in the Commission's program. The Working Group on "Photography" was the subject of some concern. Although it had been active between General Assemblies, with a meeting held in Garching, Germany, in October 1990, it had no organised program in Buenos Aires due to illness of the Chair of the Working Group. G. Westerhout proposed that an informal group of astronomers interested in large area plate measuring instruments merge with the Working Group on Photography. After discussion it was suggested and accepted that the Working Group should widen its scope to include large area plate measuring instruments and large area electronic detectors as well as photography. The Commission agreed to change the name of the Working Group from "Photography" to "Wide Field Imaging". R.M. West was elected by the Commission to chair the Working Group for the period 1991-94. Further details are given in the Working Group report.

The Commission discussed two resolutions and agreed to support both. The first sought the establishment of an ad-hoc Joint Working Group on Natural Near-Earth Objects with the participation of Commissions 4, 7, 9, 15, 16, 21 and 22. The Commission nominated G. Lelièvre to be its representative on the Working Group. The second resolution "Encouraging International Development of Antarctic Astronomy" also sought the establishment of a Working Group. Its role would be to "encourage international cooperation in site testing and in designing and constructing new Antarctica astronomical facilities". This resolution was supported by Commission's 9, 40, 44 and 50. P. Gillingham was nominated as Commission 9's representative for this Working Group.

The President reported on the IAU Colloquia and Symposia that the Commission had proposed or co-sponsored in the period 1988-91 and on meetings currently being planned or proposed. Future meetings with which Commission 9 is associated are:

Colloquium 136: "Stellar Photometry - Current Techniques and Future Developments" (jointly with Commission 25), Dublin, Ireland, 4-7 August, 1992.

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Meetings currently proposed by Commission 9 and under consideration by the IAU Executive are:

A Symposium on "Very High Angular Resolution Imaging" to be held in Sydney, Australia in January 1993 (jointly with Commission 40).
A Colloquium on "Schmidt Telescopes" to be held in Indonesia in 1993.

The President reminded the members of the need to support the incoming President and his Organising Committee. In particular, it is important to respond to requests for information, suggestions for meetings, or for views on Commission and IAU matters in general. Often it is has proved necessary to respond to the General Secretary or Executive without the benefit of the views of the membership, or even the Organising Committee, because so few people respond to requests.

The following were nominated and elected as officers of the Commission for the period 1991-94: President: J.C. Bhattacharyya; Vice-President: G. Lelièvre; Organising Committee: M. Cullum, J. Davis, C.M. Humphries, I.S. McLean, F. Merkle, W.J. Tango, R.M. West.

The following were welcomed as new members of the Commission: P.Alvarez, C. Baffia, A. Barcia, D.M. Gibson, P. Grosbøl, Li, Z-g., P.J. McGregor, Qiu P., M.H. Slovak, Wang, Z-m., and Zhang, X-z.

The Commission also noted the resignations of: B. Campbell, P. Fellgett, J. Jelley and G. Zambon. The members present at the meeting stood in silence in memory of past member P. Charvin.

It was agreed that the Commission Newsletter, commenced in 1990, should be continued. The President urged members to assist by submitting items of news and interest to the incoming President for inclusion in forthcoming issues.

The incoming President, J.C. Bhattacharyya, addressed the meeting, thanked the members for their support and, on behalf of the Commission, thanked the outgoing President for his work for the Commission.

SCIENTIFIC SESSIONS AND WORKING GROUP MEETINGS

New Instruments and Techniques: 24 July 1991

Chair: J. Davis

In this double session invited reports were presented on a number of major new astronomical instruments, on adaptive optics, and on the Steward Observatory Mirror Laboratory program. Reports were also presented on areas covered by two of the Commission's Working Groups, namely Detectors and High Angular Resolution Interferometry. The following summaries follow the order in which the reports were presented except for the report on "Adaptive Optics" which was given on 30 July prior to the Commission's business meeting.

Detectors - G. Lelièvre (Chair, Working Group on Detectors)
The new generation of large format Charge Coupled Devices (CCDs) now appearing on the commercial market is starting a general revolution for observations at optical wavelengths in all observatories. The evolution of CCDs and their applications in astronomy can be traced through the proceedings of various dedicated conferences (for a list see Commision 9's report for the period 1987-90 in Transactions of the IAU, XXIA, pp.48-9). The notable features are the increased range of CCDs available, their increased use in observatories, and the improved performance through lower readout

noise, improved quantum efficiency, UV coatings, thinning, etc. CCDs are now available in a form that allows them to be butted together (edge-buttable) opening up the possibility of achieving very large CCD arrays. These developments have had an impact on many fields of astronomy. For example, CCDs are now used for high precision photometry and spectrophotometry. They are used for deep imaging and high resolution imaging and have found applications using small to medium sized telescopes. In spectroscopy, large two-dimensional detectors with low readout noise have enabled high spectral resolution combined with high signal to noise ratio to be obtained on echelle spectrographs and with image slicers. CCD detectors are also being used in Fabry-Perot and Fourier Transform Spectrometers. Fundamental astrometry is also being enhanced by the use of CCDs, notably at the United States Naval Observatory's Flagstaff Station. In addition, new CCD controllers are being considered in most observatories with several under development.

Recent developments in photoelectric detectors include the use of a GaAs cathode in a Ranicon detector (Space Telescope Science Institute), the development of an improved CP40 photon counting detector (Observatoire de Paris and Observatoire de la Côte d'Azur), the development of a second generation Image Photon Counting System (IPCS) (European Space Agency), improved coding and arrays in MAMA detectors for Space missions (Stanford University), and the successful use of an electron bombarded CCD (EBCCD) as a wavefront sensor detector in the COME-ON adaptive optics experiment (see the contribution on adaptive optics in this report).

In conclusion, there is still a need for fast, high quantum efficiency detectors for applications in adaptive optics, wavefront sensors, and interferometry. At present CP40, PAPA and EBCCD detectors are used for this purpose but there is room for significant improvement.

High Angular Resolution Interferometry - W.J. Tango (Chair, Working Group on High Angular Resolution Interferometry)
In high angular resolution stellar interferometry the light from two or more widely separated apertures is brought together and coherently combined. The angular resolution of an interferometer depends on the separation of the apertures and the operating wavelength. Typically it will be in the range 10^{-2} to 10^{-5} arcseconds. The technique enables fundamental properties of stars such as surface fluxes, effective temperature, radius, and mass to be determined, and it opens up a wide range of stellar studies many of which cannot be tackled in any other way.

Stellar interferometry poses major instrumental and technical challenges, as the tolerances on the optical paths within the instrument are of the order of a wavelength of light and the effects of atmospheric "seeing" are more deleterious than in conventional astronomical imaging. Significant developments in the key areas of active/adaptive optics, detector technology, thin film coatings, metrology and computing/control have had a major impact and there are now a number of interferometers either operating, or in an advanced planning stage, which incorporate these new technologies.

Some of these projects and their current status will be highlighted very briefly; details of individual programs will be given at the Working Group session on 31 August:

The Center for High Angular Resolution (CHARA) Project (Georgia State University): The CHARA project is to build a multiple telescope array capable of submilliarcsecond resolution at optical wavelengths. The project has reached the detailed planning stage and a funding application is under consideration.

The Cambridge Optical Aperture Synthesis Telescope (COAST) (University of Cambridge): COAST is currently operating as a two aperture interferometer, but it is planned to expand the instrument into a four aperture array with baselines of the order of 100 m.

The Infrared Spatial Interferometer (ISI) (University of California, Berkeley): ISI is a two aperture infared heterodyne interferometer located on Mt. Wilson. It is being used to observe the dust envelopes around cool stars. There is an ongoing program to upgrade and extend the capabilities of the instrument.

The Infrared-Optical Telescope Array(IOTA): IOTA is a collaborative project involving a number of US institutions and the instrument is currently under construction at the Whipple Observatory (Mt. Hopkins, Arizona). It will have two 0.45 m telescopes initially and baselines up to the order of 100 m.

CHARON and GI2T (Observatoire de la Côte d'Azur): CHARON is a development of the Interferomètre à deux Télescopes (I2T) and it is planned to become a multiple aperture, imaging instrument. The Grand Interferomètre à deux Télescopes (GI2T) is in operation.

The Sydney University Stellar Interferometer (SUSI): SUSI is a two aperture interferometer with baselines up to 640 m. It is undergoing commissioning tests and is expected to commence a regular observing program in 1992.

The Mark III Astrometric Interferometer (US Naval Research Laboratory, Smithsonian Astrophysical Observatory, US Naval Observatory, Massachusetts Institute of Technology): The Mark III instrument is engaged in an extensive observational program. The USNO is developing plans for a dedicated astrometric instrument while the USNRL is developing plans for the Big Optical Array (BOA).

Optical Fiber Spectrograph Feeds - P. Gray (given by P. Gillingham) (Anglo-Australian Observatory)
The use of optical fibres in astronomical instrumentation continues to grow. The technology to efficiently use them as light guides, and successfully employ them in specific applications, has been developing steadily over the past 10 years. In addition, new applications are being found for their use. The use of fibres in astronomy can be broadly divided into two main areas.

Firstly, they are being employed in applications which enhance the capability and performance of existing instruments. These applications are usually relatively small budget projects and demonstrate that fibre feeds are a cost effective way of utilising existing instruments in new ways. Some examples of these systems include: simple plug-plate multi-object fibre spectroscopy systems feeding existing Cassegrain spectrographs; long fibre feeds to Coudé instruments; and two-dimensional area spectroscopy using short fibre arrays.

Secondly, several ambitious new projects are underway, or are being proposed, in which a major new telescope facility is being based solely on the use of optical fibres. The majority of these projects involve multi-object spectroscopy of large numbers of objects (400-600). Some involve a major upgrade to an existing telescope. For example, the two degree field (2dF) project at the Anglo-Australian Observatory which will involve a new prime focus with a large field corrector, multi-fibre robotic positioner and dedicated fibre spectrographs. Other projects have been proposed which involve the construction of a dedicated 2-3m class telescope built specifically for multi-fibre spectroscopy. An example is the 2.5m digital survey telescope (DSS) which has been proposed by the ARC consortium in the USA.

Other areas of development of fibre feed instrumentation include the use of mono-mode fibres for interferometric links between telescopes and the use of infrared transmitting fibres to feed infrared instrumentation.

The ESO New Technology Telescope (NTT) and Very Large Telescope (VLT) - M. Tarenghi (European Southern Observatory)
The principal new technology features of the NTT are the active optical control system and the telescope building design. The NTT is an alt-az mounted telescope with a 3.58 m diameter primary

and actively controlled mirrors. Its housing rotates with the telescope but is open at both ends to allow maximum natural ventilation. The first direct images of astronomical objects with the optics of the NTT in an optimised state were obtained in March 1989. Images of 0.33 arcsecond FWHM have been obtained and the contribution of the telescope enclosure to the seeing has been shown to be negligible. The first regular astronomical observations commenced in January 1990 and the inauguration of the telescope took place on 6 February 1990.

The VLT will have four 8 m aperture telescopes giving it the equivalent collecting area of a 16 m telescope. It is to be located on Cerro Paranal, an isolated, 2664 m high mountain in the central part of Chile's Atacama desert. The telescopes may be used alone, in combined mode, or in a combined interferometric mode. The four telescopes will be positioned in a two-dimensional array which gives good (u,v) plane cover for the interferometric mode and also preserves the best seeing for each of the individual telescopes. Some details of the interferometric mode are given in the report to the Working Group on High Angular Resolution Interferometry and tests of the COME-ON prototype adaptive optics system for the VLT are given in the following report. A range of instruments is planned for the VLT and a review article on them has been published (Journal of Optics, 1991, **22**, p.85).

A contract has been signed for the levelling of the top of the Paranal mountain so that it can accommodate the entire array of 8 m and auxilliary telescopes, as well as associated buildings that together make up the VLT Observatory. This work should be completed by March 1992. A contract has also been signed for an in-depth engineering design study of all the structures and buildings to be erected at Paranal as well as the optimal layout of the access roads. Actual construction is expected to commence on site in the second half of 1992.

Details of the VLT and progress reports appear regularly in the ESO publication "The Messenger".

<u>Adaptive Optics</u> - Fritz Merkle (European Southern Observatory)
Since the IAU General Assembly in 1988 significant progress has been achieved in the area of adaptive optics. At that time several projects were under way but a demonstration of the feasibility and gain which could be obtained for high resolution imaging in astronomy was still missing.

The adaptive optics program of the European Southern Observatory will be summarised after a brief review of worldwide activity in the field.

The adaptive optics project of the University of Hawaii, USA, is now working in the laboratory and will go to the telescope in the fourth quarter of 1991. This system, which is based on wavefront curvature sensing and a bimorph mirror, will be operated at visible wavelengths.

Another approach has been used by the Steward Observatory in collaboration with the Thermo Electron Corporation, USA. A neural network is used to determine directly the correction values for the mirror from image information. The first tests to phase the Multiple Mirror Telescope mirrors demonstrated the feasibility of this method.

The Martini system of the University of Durham, UK, which allows the coalignment of six masked subapertures for the 4 m William Herschel Telescope, La Palma, using tip/tilt mirrors, now regularly produces sharpened images.

A test of an adaptive optics system has been carried out on an astronomical telescope at Yunnan Observatory, People's Republic of China. The system was developed at the Institute of Optics and Electronics, Chengdu, but it was not designed specifically for astronomical applications and it suffers from severe sensitivity problems. Some results for very bright object can be expected.

There are adaptive optics projects in progress at the Johns Hopkins University and the University of Illinois in the USA.

A quite significant input to adaptive optics came in May 1991 from American groups at the MIT Lincoln Laboratory and Philips Laboratory who are working on defence oriented applications. Both teams made public experiments which successfully demonstrated that the principle of artificial reference stars for wavefront sensing, created by scattering of a laser beam, works and will be applicable to full sky coverage from infrared to visible wavelengths. Some of these tests date back to 1983, two years before it was proposed by Foy and Labeyrie in France. These results will give impetus to further developments and it is already obvious that very large telescope projects, like Gemini, the ESO-VLT and others, will include this technique in their adaptive optics programs.

In fact, adaptive optics is already one of the main features of the ESO - Very Large Telescope (VLT) program. First results with the so-called COME-ON prototype system developed for the VLT demonstrated the feasibility and the significant gain of this technology for astronomical imaging. This system gave the first diffraction limited images with adaptive optics in the near infrared for wavelengths between 2.2 and 4.8 microns at the Observatoire de Haute-Provence 1.52 meter telescope in October 1989. Between April 1990 and May 1991 five successful observing runs took place with the ESO 3.6 meter telescope at La Silla, two of these exclusively for scientific programs. For objects like Eta Carinae, Ceres, NGC 1068, Titan, and others, diffraction limited near infrared images have been obtained and the reduction and interpretation are under way.

The COME-ON prototype system, developed as a collaboration between the European Southern Observatory, the Observatoire de Paris-Meudon, ONERA, and the French company Laserdot, is based on a 19 actuator deformable mirror with discrete piezoelectric actuators. The stroke of each actuator is ± 7.5 micrometers. Global wavefront tilt correction is separated from the higher orders of aberration by using an additional tip/tilt mirror. The wavefront sensor is of the Shack-Hartmann type with 5 by 5 subapertures. An electron bombarded CCD makes it photon noise limited. The computing power for the control system comes from a dedicated hardware device with a 68020 processor based host computer. A bandwidth of 25 Hz has been reached. The system is currently equipped with a 32 x 32 IR-array camera.

Presently the system is being upgraded with a deformable mirror with 52 piezoelectric actuators and an improved control system to achieve 40 Hz bandwidth. In a second phase it is planned to transform the system into a standard user instrument for the La Silla observatory. For this purpose it is anticipated that it will be equipped with an expert system to assist the astronomer in finding the best operational parameters based on seeing, brightness and type of object and/or reference source, wavelength, etc. The infrared camera will be equipped with a 128 x 128 and/or 256 x 256 sensor array. The first tests with the upgraded system are expected for mid 1992.

The final definition of the adaptive systems for the 8 meter telescopes has started, including the possible implementation of artificial guide stars.

In conclusion, it can be stated that during the last three years it has been demonstrated that adaptive optics is feasible, that it is important for astronomy, and that new technologies will make it even more powerful and applicable to nearly all high resolution imaging problems from the ground and, in particular, to long baseline interferometry.

<u>The LEST Project</u> - O. Engvold (LEST Foundation)
The Large Earth-based Solar Telescope (LEST), which is run jointly by Germany, Israel, Italy, Norway, Spain, Switzerland and the USA, will be a powerful, next-generation solar telescope with

unprecedented angular resolution and high accuracy polarimetry. The very promising development of techniques for controlling telescope aberrations ("live optics") and seeing ("adaptive optics") and the access to very good sites, means that spatial resolution close to 0.1 arcseconds can in the near future be obtained with ground-based solar observations in the visible and near-infrared.

LEST will be sited on La Palma, Canary Islands, near the Caldera rim on the Roque de los Muchachos observatory. This site offers superb seeing conditions which will enable LEST to reach its ambitious scientific goals.

The conceptual LEST design was completed in 1990. The telescope is a 2.4 m aperture, "polarization-free" concept based on a modified Gregorian optical system. A fast polarization modulator will be located close to the secondary focus of the system. An actively controlled NTT-type main mirror, a high precision pointing and tracking system, a helium-filled light path and thin entrance window, together with an integrated adaptive optics system, will provide near diffraction-limited performance of the telescope.

The construction of LEST will begin in early 1993, and the telescope will be ready for "first light" in 1996.

<u>The Steward Observatory Mirror Lab Program</u> - R. Thompson (Steward Observatory)
The Steward Observatory Mirror Laboratory has the fabrication of mirrors for 8 m class telescopes, including three in which the University of Arizona is a partner, as its primary goal. The mirror design is a honeycomb sandwich which has the properties of being stiff, light and thermally responsive combined with short focal length. The technical innovations that have made the fabrication of such mirrors possible include spin-casting of the monolithic honeycomb sandwiches to give structural efficiency, and rapid tracking of ambient temperature. This process results in a saving of some 20 tons of glass and 9 months of annealing time for an 8 m mirror. The technique of polishing with actively stressed laps has also been developed to allow the production of high quality aspheric surfaces as fast as F/1.

The Mirror Lab successfully cast three 3.5 m mirrors in 1988 and 1989. Preparations are under way to cast a 6.5 m mirror to convert the Multiple Mirror Telescope to a single 6.5 m aperture, doubling its aperture. This casting is scheduled for January 1992 and will be followed by a series of mirrors of 8 to 8.4 m diameter.

The stressed-lap polishing process has been developed to finish fast mirrors to an accuracy consistent with the very best telescope sites. Projects currently under way are the polishing of a 1.8 m F/1 primary mirror for the Vatican Advanced Technology Telescope, and a 3.5 m F/1.5 primary mirror for a US Air Force telescope. Polishing of the Vatican mirror is nearly complete. The specification is to produce images better than 1/8 arcsecond FWHM.

A polishing facility large enough for simultaneous polishing and testing of two 8 m mirrors is in place together with a 24 m vibration isolated test tower. Stressed laps up to 1.2 m diameter have been built and a 2.5 m diameter lap is being designed for use on the large mirrors.

<u>The Keck Telescope</u> - S.G. Djorgovski (California Institute of Technology)
The Keck 10-meter telescope, a joint venture of the University of California, the California Institute of Technology and the University of Hawaii, is now nearing completion at the summit of Mauna Kea. The telescope is still undergoing engineering tests, and the first scientific observations are anticipated in late 1991 or early 1992. The construction of the second 10-meter telescope, Keck-2, is expected to start shortly, and to be complete by 1996. The two telescopes are expected to be used for optical/IR

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interferometry for at least a fraction of the time. Plans are also being developed for a subsidiary array of 1.5 m telescopes (Side-Kecks!) to be used as an independent interferometric array but also with the capability of working with the two 10 m telescopes in a combined interferometric mode.

Working Group on Photography: 26 July 1991

Due to the illness of the Chair of the Working Group, J-L Heudier, no scientific program was held. The President of the Commission chaired the session in which the future of the Working Group was discussed. It was clear that there was a strong feeling that the WG should continue but that its area of interest should be broadened and that its name should possibly be changed to reflect this. G. Westerhout proposed that a group of astronomers, which had held informal meetings to discuss large area measuring instruments, should merge with the Working Group. It was agreed that further discussions should take place prior to the Commission's business session on 30 July and that proposals for the future of the WG should be put to the Commission for consideration. This was done and the outcome is reported briefly in the report of the business session given earlier. Details of the plans for the WG's immediate future follow.

The Working Group will have the title "Wide Field Imaging" and its main areas of concern will be : 1. Sky Surveys and Patrols; 2. Photographic Techniques; 3. Digitization Techniques; and 4. Archiving and Retrieval of Wide-Field Data. Membership will be established by merging members of the former Working Group on "Photography" and the informal digitization groups. For the period 1991-4 the Chair will be R.M. West and the Organising Committee will include (to be confirmed): J. Guibert, R. Humphreys, K. Ishida, B. Lasker, H. Lorenz, H. McGillivray, D. Malin, N. Reid, and M. Tsvetkov. A meeting of the re-formed WG is being considered for autumn 1992 and a newsletter is also under consideration.

Working Group on Detectors: 30 July 1991

Chair: G. Lelièvre

CCDs at the Flagstaff Station - M.H. Ables (US Naval Observatory, Flagstaff):
Astrometric results obtained with CCD detectors have given accuracies equal to or better than 0.0010 arcseconds. Developments for astrometry include the advanced astrometric mosaic array with 6 CCDs and a large format (5 cm x 5 cm) Tektronic 2048 x 2048 CCD.

A transputer-based CCD controller - I.S. Glass(South African Astronomical Observatory):
A compact CCD controller has been developed by groups at the Royal Greenwich Observatory and the South African Astronomical Observatory. It occupies a small Eurocard crate attached to the side of a dewar containing the detector. It offers the possibility of extension to multiple readout devices, control of filter wheels, etc. and fiber-optic communication with the control computer. Ten examples are being constructed for the control of infrared and optical CCDs as well as for CCD-based acquisition cameras.

Astronomical detectors at ESO - M. Cullum (given by F. Merkle) (European Southern Observatory):
Since the last IAU General Assembly in Baltimore, several new large format optical CCDs have been commissioned at ESO's La Silla Observatory. These include several 2048 x 2048 chips from Loral, and 1024 x 1024 chips from both Thomson and Tektronix. The Loral and Thomson CCDs are front illuminated and most have been coated to enhance their UV response. The Tektronix chips are thinned and exhibit a RQE of between 10-12% at 350 nm. Readout noise figures have also evolved

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with the current record being held by Thompson CCDs with values down to 2.8 e^- rms measured on the telescope.

The development of infrared array detectors has been rapid. Current arrays in service include Philips Components 64 x 64 *MCT* and a Santa Barbara 62 x 58 *InSb* detector. A Cincinatti 64 x 64 *InSb* detector is currently being evaluated in ESO's Garching laboratories and looks extremely promising in terms of large full-well capacity and low dark current. ESO also has a Rockwell 256 x 256 *MCT* detector under test which should be ready for installation at La Silla during the first half of 1992.

Electronic developments related to CCDs have centred on a new VME-based controller. ESO currently has about seven VME controllers of an earlier design in service at La Silla. The new design is necessary to meet the rather special requirements of the VLT project. These include a reduction in the unit production costs and make the system more amenable to larger-scale production methods, the possibility of setting all analogue clock and bias voltages remotely, and a reduction in the size and heat dissipation of the CCD head.

ESO's MAMA photon-counting detector has only been used for UV spectroscopy to date. Due to a lack of a recording system for time-tagged events, it has not been possible so far to make use of the system for time-resolved applications. With the help of outside collaboration, it is hoped that some initial experiments in this direction can be started within the next 6 months.

Review of work at the Observatoire de Paris - G. Lelièvre (Observatoire de Paris)
Work relating to wavefront sensors, adaptive optics, and interferometry by P. Lena, J-M. Mariotti, R. Foy et al. was reviewed. It was noted that fast and efficient detectors are still required in order to obtain the high temporal resolution of a few milliseconds necessary to avoid the effects of phase smearing due to atmospheric turbulence during an observational sample time.

An electron bombarded CCD (EBCCD) has been provided by Laboratoire d'Electronique Philips (LEP) and successfully tested as a detector for the wavefront sensor in the COME-ON experiment at the Observatoire de Haute-Provence and the European Southern Observatory. This device allows discrimination against multi-electron impacts, an advantage over classical photon counting cameras.

An improved CP40 camera (a photon counting camera with 3200 x 2400 pixels) has been completed at Paris Observatory.

Speckle and direct imaging using deconvolution techniques based on reconstruction of the wavefront is under development for the visible domain (R. Foy and G. Lelièvre).

In the ATLAS Experiment a laser made artificial star has been tested (M. Tallon and ONERA) at the Lunar Laser Station (CERGA) and has been shown to provide a 6 arcsecond artificial star image at an altitude of 15 km.

G. Lelièvre summarised reports received from groups unable to attend the General Assembly:

From P.R. Jorden (Royal Greenwich Observatory): The Royal Greenwich Observatory has been particularly active in recent years since the William Herschel 4.2 m Telescope saw "first light" in 1987. Detectors include integrated TV for field-viewing, CCD-based autoguiders, Image Photon Counting System (IPCS), cryogenic CCD cameras, an embedded CCD for a faint object spectrograph, and the main grating spectrograph (ISIS) uses separate CCDs in its red and blue arms. EEV CCD-05-30 chips are used. They provide excellent performance including 3e^- readout noise, 50% peak quantum efficiency and no defective columns in a super-grade 1280 x 1180 format array. A new integrated CCD controller was designed to give high performance, compact, multi-chip CCD operation. A development program for thinned CCD by EEV and financed by the AAT is also complete. Development plans include multi-chip mosaics and lower readout noise devices.

From G.J. Monnet (Canada-France-Hawaii Telescope (CFHT)): A Ford 2048 x 2048 CCD is in general use by observers. A new generation controller with improved readout time is being designed for various chips and for an infrared array (256 x 256 from Rockwell).

The archiving of CFHT data will be handled by the Canadian Astronomical Data center at the Dominion Astrophysical Observatory.

An adaptive optics bonette is under construction to correct static effects on a 4 arcminute field and atmospheric turbulence on a small field (resolution better than 0.2 arcseconds in the 0.5 to 2.5 mm wavelength range). Future planned developments include the study of large CCD mosaics.

From Bartoletto (Padova): A CCD working group was formed to equip the new Galileo Telescope. A collaboration with the Cerro Tololo Inter-American Observatory (CTIO) was arranged for the development of a multiple CCD controller based on the CTIO transputer sequences and having the capability of reading various chips and mosaics (4 output CCD controller). The detectors are required for focal plane instrumentation, autoguiding and active optics systems.

From J.G. Timothy (Stanford University): Several MAMA detectors are under test for space experiments. For the latest, an array of 726 x 8096 pixels is proposed. Improvements have been made in the x-y coding of MAMA detectors.

The Organising Committee for the Working Group for 1991-4 is: M. Cullum (Chair), B. Fort, J. Geary, P.R. Jorden, G. Lelièvre and J.G. Timothy.

Working Group on High Angular Resolution Interferometry: 31 August 1991

Chair: W. J. Tango

Nine papers were submitted for the scientific program of the Working Group:

COAST - The Cambridge Optical Aperture Synthesis Telescope - D. Green (Cambridge University): COAST is planned to be an array of four 40 cm telescopes for imaging in the red and infrared, using baselines up to approximately 100 m. Two telescopes are currently operational, together with equipment for acquisition, guiding, and variable optical path delay compensation, all housed in a passive thermally stable building. Fringes are, weather permitting, currently being obtained over a wide range of declinations and hour angles.

The Infrared-Optical Telescope Array (IOTA) - N. Carleton, P. Horowitz, M. Lacasse, P. Nisenson, C. Papaliolios, M. Pearman, R. Reasenberg, W. Traub (Center for Astrophysics), R. Predmore, P. Schloerb, S. Strom (University of Massachusetts), D. Gibson (MIT Lincoln Lab), J. Benson, M. Dyck (University of Wyoming):
IOTA is planned to operate initially with two 0.45 m telescopes and baselines of the order of 100 m at visible and infrared wavelengths. The instrument will be sited at Mt. Hopkins and is scheduled to begin operating in the first half of 1992. Flat siderostat mirrors will feed light into fixed beam compression telescopes which will reduce the beam diameter by a factor of ten. The light is then

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transferred via relay optics to the delay lines and the beam combining optics. The relay optics and delay lines are all in vacuum. The visible light fringes will be detected using a grism spectrometer as described by Traub (JOSA A, 1990, 7, p.1779), while the infrared detection will be with two single element detectors operating in the spatio-spectral interferometric mode.

The Big Optical Array - K. Johnston (U. S. Naval Research Laboratory):
The U.S. Naval Research Laboratory is developing the design of a large optical interferometer known as the Big Optical Array (BOA). It will be a phase closure, imaging instrument with six 0.5 m siderostats moveable to various stations on a Y shaped array with available baselines from 4 m to 470 m. It will be a single r_0 instrument with a magnitude limit of the order of 9.5 for stellar angular diameter measurements and 4.5 for full image mapping. It is planned to site BOA on Anderson Mesa, near Flagstaff, Arizona.

Laser Reference Stars: first results of the ATLAS experiment - M. Tallon (Observatoire de Paris):
A bright reference star lying in the isoplanatic patch surrounding the observed object is needed to operate adaptive optics devices. The probability of finding a reference star in a given direction in the sky is low, particularly for fully correcting wavefronts at visible wavelengths. To operate adaptive optics in any direction in the sky, even in the visible, it is possible to create an "artificial reference star" by using the backscattered light of a laser beam, focused in the atmosphere. The ATLAS experiment is being carried out by ONERA, Observatoire de Paris, and CERGA. The first aim of the experiment is to create a laser reference star and to compare the wavefronts restored from simultaneous observations of a real bright star and the laser spot. An image of a reference star has been obtained.

Optimum Exposure Times for High Resolution Imaging - B. Lopez (European Southern Observatory):
It is important to be able to estimate the stability time for interference fringes since this affects the signal level that can be detected. A theory has been developed which relates this time to the standard deviation of the wind speed of the turbulent layers and Fried's r_0 parameter. This was tested at La Silla by monitoring the wavefront tilts at two separate positions on the wavefront. Values of the "speckle lifetime" were observed in the range 4 to 16 ms over seven nights.

The Sydney University Stellar Interferometer (SUSI) - J. Davis (University of Sydney):
The Sydney University Stellar Interferometer (SUSI) is sited at the Paul Wild Observatory in northern New South Wales alongside the Australia Telescope. Construction commenced in October 1987 and all civil and building works were completed by early 1990. Since then an extensive installation, alignment, and commissioning program has been pursued. SUSI has 12 siderostat stations distributed along a North-South line to give baselines in the range 5 m to 640 m. Currently the inner baselines are being commissioned. Four stations are equipped with siderostats and the remaining siderostats are to be progressively installed over the next 12 months. Two stations have been fully commissioned along with an intensified CCD based acquisition system and wavefront tilt correcting servos. The beam-combining and visibility detection systems from the SUSI prototype have been installed. The optical path length compensation system, which will have two compensation carriages running on parallel tracks, will give a total compensation range of ±420 m. The fine control carriage has been installed and partialy commissioned along with the laser metrology system. The SUSI project is jointly funded by the Australian Research Council and the University of Sydney. At the time that this report was given, attempts to detect fringes had not been made. However, shortly after the General Assembly the first fringe detection with starlight was reported.

The CHARA Array Project - H. McAlister (Georgia State):
Astronomers from Georgia State University's Center for High Angular Resolution Astronomy (CHARA), in a collaboration with scientists and engineers from the Georgia Institute of Technology, have proposed the construction of a multiple telescope array capable of submilliarcsecond resolution at optical wavelengths. The CHARA Array will consist of seven 1 m aperture telescopes in a Y-shaped array contained within a 400 m diameter circle. The facility will be located at a site in the southwestern USA. Each collecting telescope will have an independent delay line, and thus, while the initial observations will be made by pairwise interferometry, the instrument will be developed into a fully imaging array using all apertures together. It is expected that start-up funds in the second half of 1991 will permit the initiation of detailed analysis and design of critical subsystems of the Array. This work was supported during a feasibility study phase by the US National Science Foundation.

The VLT Interferometer - F. Merkle (European Southern Observatory):
The VLT Interferometer (VLTI) consists of an array of four adaptive optics aided 8 m telescopes as well as two or more 1.8 m Auxiliary Telescopes. The array of smaller telescopes, also referred to as the VISA (the VLT Interferometric Sub-Array), will be 100% dedicated to interferometry, and will be used on its own when the sensitivity of the large 8 m telescopes is not needed. The VISA telescopes will be moveable, and it will be possible to combine them with the 8 m telescopes when so desired since all telescopes will share the same interferometric infrastructure. The maximum baseline between the VISA telescopes will be 190 m and, between the 8 m telescopes, 128 m. The VLTI design specifies a large co-phased/coherenced interferometric field of view (8 arcsec) and an ability to "coherence guide" on objects 15 arcmin away.

The USNO Astrometric Optical Interferometer - D. Hutter and J. Hughes (US Naval Observatory):
The US Naval Observatory Astrometric Optical Interferometer (AOI) will be a dedicated astrometric interferometer. It is currently being designed and is planned to be in operation at a site in the western USA in 1993. The AOI will be built upon the experience gained from the Mark III Optical Interferometer on Mt. Wilson, California, which has been a joint project involving the Naval Research Laboratory, the Smithsonian Astrophysical Observatory, the US Naval Observatory and the massachusetts Institute of Technology. The Mark III has demonstrated wide-angle astrometry with uncertainties of 5 to 10 milliarcseconds from observations repeated over several nights and systematic agreement with FK5 catalog positions with the (larger) quoted uncertainties of the catalog. The new AOI will consist of four elements in a fixed array, with baselines arranged for instantaneous position measurement in two dimensions. State-of-the-art delay lines as well as extensive laser metrology will be incorporated. Several beam combination techniques will be used to increase the precision of astrometric measurements. The USNO AOI will achieve unprecedented precision in the optical regime (450 to 900 nm wavelength), with statistical and systematic errors below 5 milliarcseconds for wide angle measurements and 1 milliarcsecond for narrow angle measurements (object separations less than one degree). This array will establish a catalog of the positions of over 1000 stars.

Working Group business: Due to the disruption of the day's program caused by the fire in the Centro San Martin, it was not possible to hold a formal business session. After informal discussion with the WG members who were present and the Commission President, the organising committee will have the following membership for the next three years: J.E. Baldwin (UK), P. Lena (France), H.A. McAlister (USA), F. Merkle (European Southern Observatory), S.T. Ridgway (USA), W. J. Tango (Australia) (Chair) and C. H. Townes (USA).

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