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COMMITTEE ON THE PEACEFUL
USES OF OUTER SPACE

REPORT ON THE UNITED NATIONS/INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS CONFERENCE ON OPTICS IN SPACE SCIENCE AND TECHNOLOGY

(20-24 November 1995, Trieste, Italy)

CONTENTS

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INTRODUCTION

A. Background and objectives

1. The General Assembly, in its resolution 37/90 of 10 December 1982, decided, upon the recommendation of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE 82),[1] that the United Nations Programme on Space Applications should, *inter alia*, stimulate the growth of indigenous nuclei and an autonomous technological base in space technology in developing countries and promote greater cooperation in space science and technology between developed and developing countries as well as among developing countries.

2. The Committee on the Peaceful Uses of Outer Space at its thirty-seventh session, held in June 1994, endorsed the programme of United Nations workshops, training courses and seminars proposed for 1995, as outlined by the Expert on Space Applications in his report (A/AC.105/555, paragraph 62).[2] Subsequently, the General Assembly, in its resolution 49/34 of 9 December 1994, endorsed the United Nations Programme on Space Applications for 1995.

3. In response to General Assembly resolution 49/34, and in accordance with the UNISPACE 82 recommendations, the organization of a Conference on Optics in Space Science and Technology was included as part of the activities for 1995 of the United Nations Programme on Space Applications. The Conference was jointly organized and sponsored by the Office for Outer Space Affairs of the Secretariat and the International Centre for Theoretical Physics (ICTP). It was held from 20 to 24 November 1995 at Trieste, Italy.

4. The Conference focused on the applications of optics in space science and technology, paying special attention to current and future developments in space-based optical instruments used in remote sensing, telecommunications, astronomy and astrophysics. Matters related to education in space science and technology and to the development of international cooperation between scientists working in those fields were considered by the Conference as well.

5. The present report, which covers the background, objectives, organization and recommendations of the Conference, as well as a summary of the papers presented, has been prepared for the Committee on the Peaceful Uses of Outer Space and its Scientific and Technical Subcommittee. Participants have reported to the appropriate authorities in their countries.

B. Organization and programme of the Conference

6. The Conference was attended by 52 experts, scientists and educators. The participants came from the following countries: Argentina, Belarus, China, Czech Republic, Egypt, Ethiopia, Germany, Ghana, Guinea, India, Israel, Italy, Jordan, Nigeria, Romania, Russian Federation, Sri Lanka, United States of America, Viet Nam, Zaire and Zimbabwe. The Office for Outer Space Affairs, the International Telecommunication Union (ITU) and ICTP were represented at the Conference.

7. Funds allocated by the United Nations for the organization of the Conference were used to defray the cost of international air travel of 15 participants from developing countries. Hotel accommodations and daily subsistence allowances for participants from developing countries, as well as conference facilities, technical support and documentation for the Conference, were provided by ICTP.

8. The programme of the Conference (see annex to the present report) was developed jointly by the United Nations and ICTP. Participants at the Conference discussed issues related to international cooperation in the development of optical instruments for applications in remote sensing, astronomy and space communications.

9. At the conclusion of the Conference, the participants expressed their appreciation of the scientific and technical quality of the programme and the presentations. In addition, they expressed their appreciation for the fellowships

that they had received from the co-sponsors, which had made their participation in the Conference possible, as well as for the cooperation and support that they had received from administrative and technical personnel of ICTP.

I. OBSERVATIONS AND RECOMMENDATIONS OF THE CONFERENCE

A. Observations of the Conference

10. The Conference discussion focused on the participation of developing countries in international scientific and technical exchange and cooperation. The Conference observed that international cooperation played a vital role in the development of space science and technology. It was noted that most space-based instruments for astronomical or astrophysical observations were designed, constructed, launched and maintained in orbit by cooperating groups of countries. In the field of Earth observation, regional and international programmes such as the International Geosphere-Biosphere Programme and Mission to Planet Earth provided the international research community with the opportunity to address effectively such issues as global warming and climate change, ozone layer depletion, global deforestation, land degradation and management of the coastal marine environment.

11. It was noted that the development of new space-based communications systems with a higher communication capacity and more compact, lighter equipment for future space activities also required cooperative efforts such as the technology demonstration experiment for optical inter-orbit communications planned by the National Space Development Agency (NASDA) of Japan and the European Space Agency. Two spacecraft - the Optical Inter-Orbit Communications Engineering Test Satellite and the geostationary satellite of the African Real-Time Environmental Monitoring using Imaging Satellites (ARTEMIS) system - would be involved in the experiment.

12. The Conference noted that the participation of scientists, researchers and educators from developing countries in international projects, as well as in international scientific information exchange, was extremely limited not only due to insufficient resources (both financial and human), but also because of inadequate access to scientific and technical information. The Conference noted that international efforts were required to bridge the gap between scientific communities in developing and developed countries.

13. The Conference emphasized the importance of efforts of the Office for Outer Space Affairs, within the framework of the United Nations Programme on Space Applications, aimed at establishing regional centres for space science and technology education in developing countries and at establishing a satellite-based information network system, the Cooperative Information Network Linking Scientists, Educators and Professionals in Africa (COPINE), which would link scientific, research and educational institutions in participating African countries to similar centres in Europe, as well as in Africa, with the initial aim of improving the exchange of scientific and technical information.

14. The Conference also noted with satisfaction the efforts of ICTP to support scientific and information exchange within the global scientific community. Through an intensive programme of workshops and conferences, as well as through its large network of affiliated centres in developing countries, ICTP contributed greatly to the education process at the international level.

B. Recommendations of the Conference

15. On the basis of the discussion, the Conference made a number of recommendations aimed at enhancing the role of scientists and researchers from developing countries in international scientific cooperation. Those recommendations may be summarized as follows:

(a) Scientists, researchers and educators from developing countries should have more opportunities for in-depth training in the design, construction and applications of space-based optical instruments used in remote sensing, telecommunications, astronomy and astrophysics;

(b) International efforts should promote the adequate transfer of appropriate technologies from developed countries to developing countries, and universities and research centres in developing countries should actively participate in that process;

(c) A follow-up conference should be held in three years and regional workshops on the subjects covered by the Conference should be organized as well;

(d) Distribution of scientific and technical information should be promoted in order to keep researchers in developing countries informed of the latest developments in the field;

(e) A "focal point" for information on opportunities and possibilities for participation in international cooperative projects should be established;

(f) Five per cent of the scientific payloads of spacecraft should be devoted to instruments and/or experiments developed by research institutions in developing countries;

(g) United Nations efforts aimed at establishing regional centres for space science and technology education, as well as the COPINE project, should be encouraged and supported.

II. SUMMARY OF PRESENTATIONS

A. Use of space-based lasers in remote sensing, communications and instrumentation

16. It was stated that the feasibility of using ground-based and airborne laser systems in remote sensing, communications and instrumentation had been demonstrated in numerous projects worldwide. With recent advances in the development of new materials and improvements in the lifetime, frequency stability and reliability of lasers to be used in space, the development of spaceborne laser systems was approaching its operational stage. Some experiments had already been performed on the Space Shuttle, and several instruments were planned for use on missions in the near future.

17. Major efforts in the development of space-based laser systems were devoted to remote sensing instrumentation. In fact, the application of light detection and ranging (lidar) instruments was considered an extremely promising new way of obtaining essential atmospheric and geophysical parameters on a global scale. There were currently four types of lidar systems under development: (a) the back scatter lidar, with a wide range of possible applications in meteorology and climatology; (b) the differential absorption lidar (DIAL), which could provide precise measurements of atmospheric humidity, temperature and pressure; (c) the Doppler lidar, with the capability of improved weather forecasting and applications in global atmospheric studies; and (d) the ranging and altimeter lidar, which could provide very accurate measurements of Earth's surface features.

18. Spaceborne laser systems could also play an important role in the area of inter-satellite and inter-orbit communications. The request for optical systems originated in the need for smaller payloads and/or equipment, broader bandwidths and more reliable data links.

19. In future space missions, lasers, especially very small, lightweight semiconductor emitters, would often be incorporated into standard attitude control instruments and into scientific payloads. The equipment under development included, for example, laser gyroscopes, as well as narrow-band spectrometers which required a compact and stable internal calibration source.

B. Spectrum-UV mission: an internationl ultraviolet laboratory

20. It was stated that the Spectrum-UV mission was an international ultraviolet observatory for solar spectroscopy and wide field imaging of the Sun. Launch aboard a Spectrum-series space platform into a seven-day, highly eccentric orbit (HEO) by a Proton booster from the Baikonour launch pad was currently scheduled for the year 2001. The spacecraft's initial orbit, with a perigee of 500 km and an apogee of 300,000 km, met the criteria of stability of the operational orbit during the expected three-year lifetime of the mission, as well as the criteria of quasi-continuous visibility from ground stations in the Russian Federation and Ukraine and of rapid evolution of the perigee altitude to reach 40,000 km one year from launch.

21. The mission would be operated in real-time mode in order to fully utilize the advantage of long, uninterrupted observation sessions allowed by injection in HEO, including flexible scheduling, on-line monitoring of data quality, and fine-tuning of observation modes and exposure time. In order to make effective use of spacecraft during periods of non-visibility from ground stations or occasional unavailability of the network of the Deep Space Communications Centre, a fully automated operation mode would also be implemented.

22. The primary scientific payload of the satellite consisted of an f/10 Ritchey-Chrétien configuration telescope with a 170 cm aperture. Mirror coating (Al + MgF_2) was optimized for enhanced and normal incidence reflection in the 900-1,500 angstrom band. In-flight correction of the thin (10 cm) primary mirror was ensured by a system of actuators. Secondary mirror rotation ensured 0.1 arcsec pointing and tracking accuracy within the 2.5 arcsec accuracy of the platform's attitude and orbit control system.

23. Complementary instrumentation consisted of:

(a) A dual Échelle spectrograph with three independent channels covering, respectively, 1,150-1,800, 1,780-3,500 and 1,150-3,500 angstrom intervals;

(b) A spectrograph in the Rowland mounting with three independent channels covering, respectively, 900-1,050 and 1,050-1,200; 1,150-1,900 and 1,300-1,900; and 1,150-4,000 angstrom intervals;

(c) A 4 x 4 sq arcmin field of view direct camera for wide and narrow band imaging in the 912-3,600 angstrom range with a resolution of 0.3 arcsec; a narrow field of view (10 x 10 sq arcsec) camera for imaging at a restored resolution of 0.03 arcsec was also being considered.

24. An advanced feasibility study of the mission was being carried out by an international research team supported by space agencies of the four participating countries: Germany, Italy, the Russian Federation and Ukraine.

C. Trends in satellite communications

25. It was stated that, at the World Administrative Radio Conference held at Torremolinos, Spain, in 1992, there had been signs of a revival of the enthusiasm displayed at the advent of satellite communications in 1965, when the first commercial satellite - the Early Bird - had been launched. Apart from traditional telecommunications services, satellite technology had found increasing applications in rural telecommunications, direct and digital broadcasting (sound and television) and mobile telecommunications (land, maritime and aeronautical), as well as in global computer networking.

26. The general trend was towards the development of a universal personal telecommunications system that would allow communications with network interface selected by a customer. Satellites would continue to play a major role in the new wireless personal communications system, the global information infrastructure and the future public land mobile telecommunications system. The latter system would provide telecommunications facilities particularly adapted to the needs of developing countries on account of its (a) capability for rapid provision of services in new areas; (b) growth capacity and flexibility; (c) potential for cost reductions resulting from technology advancement and mass production; and (d) capability for covering large geographical areas.

27. Breakthroughs in microcircuit technologies had made it possible to "pack" an entire satellite communications ground terminal into a hand-held telephone unit, as well as to use satellites in non-geostationary orbits, such as low Earth orbits (LEO) and medium Earth orbits (MEO), for mobile telecommunications. LEO microsatellites could benefit from technical characteristics that made that technology well suited both for mobile voice, data and messaging services and for fixed communications services, especially monitoring and control applications. The main advantages allowed by a constellation of LEO and MEO satellites were: the low cost of individual satellites; the limited complexity of satellites; limited system design and production time; the use of small launching vehicles and the placing into orbit of a group of satellites (6-8) with a single launch; the increased reliability; the use of low-cost hand-held terminals; and global coverage.

28. The inter-satellite link (ISL) was a further development of the on-board processing concept utilized in some communications satellite constellations. ISL could be used for direct "repeaterless" communication between intercluster satellites; co-located satellites; interregional satellites (GEO to GEO); and LEO and GEO satellites. In comparison with ISL based on microwave technology, optical ISL payloads had some advantages, especially in weight and size of equipment.

29. Some optical communications subsystems of ISL payloads under development were based on the following technologies:

(a) Carbon dioxide laser system with heterodyne detection receiver;

(b) Neodymium-doped laser system with direct detection receiver;

(c) InGaAsP laser system with a neodymium power amplifier and direct detection receiver;

(d) GaAlAs laser system with direct detection receiver;

(e) GaAlAs laser system with direct wavelength division multiplexing and direct detection receiver;

(f) GaAlAs laser system with heterodyne detection receiver.

Test results for both analog and digital traffic had indicated a preference for the ISL system based on the GaAlAs semiconductor diode laser because of its small size, high electrical-to-optical conversion efficiency, direct modulation capability, broad wavelength selectability, and potential for high reliability. Furthermore, the high level of research and development in the field of GaAlAs technology promised rapid advances in the development of GaAlAs diode laser communications systems.

D. Submilli-arcsecond astrometry Struve mission

30. It was stated that the Struve space astrometric project was under development at the Pulkovo Observatory at St. Petersburg, Russian Federation. The aim of the project was to obtain more accurate measurements of parameters of stars covered by the Hipparcos satellite and to extend the reference system to 100 reference stars per square degree (4.1 million stars in the output catalogue). The accuracy of observations was expected to be improved in comparison with the Hipparcos mission.

31. The geometrical principle of measurements was similar to that of the Hipparcos mission, but two basic angles of 62 degrees and 74 degrees had been chosen instead of a single one in order to minimize systematic errors of observations. Accordingly, two telescopes, each with a focal length of 2.5 m, would be installed on board the Struve spacecraft. Two basic angles would be formed by a beam combiner placed inside the spacecraft. A special optical system would be used for passive control of image scales and stability of the telescope components.

32. The registration system of the instrument consisted of two micrometers and an on-board processing unit. Two-phased charge-coupled devices were to be used as micrometers for both telescopes. Flux from each registered star would be measured in seven visual wavebands that would also allow researchers to obtain information on the physical properties of the observed stars.

33. The Struve spacecraft had a symmetrical shape to reduce the impact of solar light (i.e. to minimize torque on the spacecraft). Additional surfaces were to be installed at edges of the solar panels in order to make the centre of solar pressure coincide with the centre of mass of the spacecraft. The satellite payload did not contain any moving devices or parts because they created inner torque that might disturb the spacecraft's smooth rotation.

34. The three-year Struve mission was to be launched soon after the year 2000, approximately a decade after the Hipparcos mission. The Struve output catalogue would allow astronomers to establish a fundamental coordinate system with a higher level of accuracy and to extend it to fainter stars in comparison with the Hipparcos catalogue. It would also bring a new level of accuracy to studies on structure and dynamics of the Galaxy and on evolution and chemical properties of stars.

E. New technologies for Earth observations and astronomy

35. A number of presentations made at the Conference were devoted to new technologies and materials applicable to the design and construction of optical instruments used in astronomy (both ground-based and space-based) and in remote sensing. Developments in design and manufacturing of small satellites and microsatellites and platforms for Earth observation and astronomical missions were discussed in detail as well.

36. It was stated that modern science required an extremely high imaging performance and quality of astronomical instruments. For ground-based systems, a resolution better than 0.5 arcsec and higher could be considered a standard requirement, but in some observation projects a resolution of 0.3 arcsec could be requested. For space-based instruments, the theoretical limit of the optics used was the only performance ceiling (except, naturally, such a limiting factor as budget constraints). New technologies, advanced manufacturing processes and new materials might make it possible to achieve increased performance at reduced cost. Active optics, computer-assisted polishing and ion-shaping of mirrors, and silicon-carbide mirror technology were typical examples of applications of new technologies for astronomical optics manufacturing.

37. Accuracy and reliability of Earth observation data also depended on the performance of optical imaging instruments. New materials such as fused silica glass, ultra-low expansion titanium silicate, and glass-ceramic, to

name a few, as well as application of advanced glass coating techniques, could improve dramatically the capability and reliability of remote sensing instruments.

38. The concept of small satellites and microsatellites and platforms had recently received considerable attention because of growing costs associated with "regular" scientific and Earth observation missions. Low design and manufacturing costs, short construction periods, the low cost of launches and the availability of launchers, and opportunities to use updated technologies made such satellites very attractive to the scientific and educational communities, especially in developing countries. A number of ongoing small satellite and microsatellite projects, including Central European satellite for advanced research (CESAR), joint ultraviolet night sky observer (JUNO) and Italian universities satellite (UNISAT), were discussed at the Conference.

F. Applications of optical instruments in remote sensing and meteorology

39. A number of speakers at the Conference presented their experiences in applications of data derived from optical instruments installed on-board Earth observation satellites. Those applications covered hazard assessment in tropical regions, environmental monitoring, water resource inventory and monitoring, atmospheric studies and meteorology. National programmes and projects in applications of remote sensing data were also featured.

Notes

[1]See *Report of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space, Vienna, 9-21 August 1982* (A/CONF.101/10 and Corr.1 and 2), para. 430.

[2]*Official Records of the General Assembly, Forty-ninth Session, Supplement No. 20* (A/49/20), para. 37.

Annex

PROGRAMME OF THE CONFERENCE

Date/Time	*Subject*	*Speaker*
20 November 1995	**Registration and opening**	
Morning session; S. Chernikov, Chairman		
0930-1030	New technologies for ground and space based astronomical optics	F. Merkle (Germany)
1100-1245	Personal satellite communications	J. Shapira (Israel)
Afternoon session: Optics in telecommunications; J. Shapira, Chairman		
1430-1500	Telespazio activities on small satellite scientific programmes	G. Rondinelli (Italy)
1500-1530	Shielding of the electromagnetic pollution in space by conductive polymer composites	A. M. Zihlif (Jordan)
1530-1600	UNISAT: A microsatellite for educational purposes	F. Graziani (Italy)
1600-1630	Some trends in satellite communication	G. O. Ajayi (Nigeria)
1630-1700	Practical use of Inmarsat terminals	E. Marchetti (Italy)
21 November 1995		
Morning session: Remote sensing; A. Narayana Swamy, Chairman		
0900-0930	Application of satellite remote sensing to geomorphological hazards assessment in tropical regions	V. C. Jha (India)
0930-1000	Determination of the effective particle radius of clouds from space: new approach	A. Kokhanovsky (Belarus)
1000-1030	Impact of direct reception of satellite data on African Meteorological Service: operational use of NOAA AVHRR and METEOSAT products in Ethiopia	T. Tadesse (Ethiopia)

Date/Time	***Subject***	***Speaker***
1100-1130	The application of satellite pictures for synoptical analyses in Western and Central Africa	M. M. Diallo (Guinea)
1130-1200	Satellite remote sensing in earth sciences: a technology in search of problems to solve? The case of Zimbabwe	P. S. Ngwazikazana (Zimbabwe)
Afternoon session: Astronomy; M. Hack, Chairman		
1400-1500	Astrophysical applications of micro-satellites: an evaluation module for (Italy) solar measurement	M. Messerotti
1500-1530	X-ray optics for space applications R. Hudec	(Czech Republic)
1530-1600	Applications of light scattering theory to identify dust grains in astrophysics (Sri Lanka)	N. C. Wickkramasinghe
1600-1630	IDES, an EUV spectrometer for the measurement of the diffuse cosmic background	R. Stalio (Italy)
22 November 1995		
Morning session: Remote sensing; S. C. Chakravarty, Chairman		
0900-0930	Status of optical and microwave satellite remote sensing for runoff forecast in high mountainous catchments	A. Narayana Swamy (India)
0930-1000	Applications of radiometric corrections for optical remote sensing data	L. A. Frulla (Argentina)
1000-1030	Image quality under the influence of gradient temperature in space	Guorei Zhang (China)
1100-1130	Optical instruments in satellite remote sensing	E. E. Ekuwem (Nigeria)
1130-1200	Water resources inventory and monitoring by remote sensing techniques in Romania	G. Stancalie (Romania)
1200-1230	Laser technologies utilization aboard space platforms for remote sensing, communication and instrumentation	F. Svelto (Italy)

Date/Time	*Subject*	*Speaker*
Afternoon session: Astronomy; R. Stalio, Chairman		
1400-1430	Multifrequency observations of active galactic nuclei	A. Treves (Italy)
1430-1500	Gamma ray sky as seen by EGRET on board the Compton Gamma Ray Observatory Satellite	P. Sreekumar (United States of America)
1500-1530	Astrophysics with new infrared and ultraviolet cameras on the Hubble space telescope	G. V. Coyne (Holy See)
1530-1600	The future of ultraviolet astronomy from satellites	M. Hack (Italy)
1600-1700	The Spectrum-UV mission: an international ultraviolet observatory	E. G. Tanzi (Italy)
23 November 1995		
Morning session: Remote sensing; A. Kokhanovsky, Chairman		
0900-0930	Activities in research and applications of remote sensing in Viet Nam	G. Hoang Viet (Viet Nam)
0930-1000	Optical remote sensing of the atmosphere over Indian region	S. C. Chakravarty (India)
1000-1030	Optical remote sensing of the upper atmosphere during daytime using ground-based spectro-photometry	R. Narayanan (India)
1100-1130	A solar calibration device for remote sensing systems	Dayuan Yan (China)
1130-1200	Spacial and temporal distribution of convective clouds over Ethiopia from satellite data	T. Dinku (Ethiopia)
1200-1230	Demonstration of the programme "OPTIKA"	
Afternoon session; P. Sreekumar, Chairman		
1400-1430	Processing and analysing of satellite data in visible, infrared and microwave region of electromagnetic spectrum for risk assessment in nuclear power plant area environment	M. Zoran (Romania)

Date/Time	*Subject*	*Speaker*
1430-1500	Satellite constellations for telecommunication services	G. B. Palmerini (Italy)
1500-1520	Small satellite system approach for multimission payloads	L. Bonino (Italy)
1520-1540	SPACECOM Project - A new model of partnership inside the ITU development sector to promote a wide-spread application of satellite communications technology in developing countries	C. Girard (Switzerland)
1540-1800	**Conference discussion: Prof. G. O. Ajayi, moderator**	
	Development of optical sensors technology for astronomy, remote sensing and space communications: international cooperation, participation of developing countries	

24 November 1995

Morning session: Astronomy; E. G. Tanzi, Chairman

0900-0930	Evolution of low and intermediate mass stars: the observational evidence from the infrared astronomical satellite (IRA) and International Ultraviolet Explorer (IUE)	M. Parthasarathy (India)
0930-1000	Submilli-arcsecond astrometry with the Struve satellite	V. Yershov (Russian Federation)
1000-1030	The new generation of gamma ray telescopes	A. Cicuttin (Italy)
1100-1130	Activity of astronomy in Egypt and Kottamia observatory in the past and at present	F. Abdel Badie Mahmoud (Egypt)
1130-1200	One of the possible reasons for improving visibility of Earth's objects from space	V. V. Barun (Belarus)
1200-1230	Optical ground based network for gamma ray satellites	R. Hudec (Czech Republic)
1230-1245	Closing ceremony	

1400	Visit to Centre for Advanced Research in Space Optics