I R P S BULLETIN

Newsletter of the International Radiation Physics Society

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From the Editor :

Two issues of substance are addressed in this issue.

In the first our President, John Hubbell, outlines the history of our professional society. It had its origin in mutual-benefit projects conducted between the Bose and the US Government twenty five years ago. Since then it has grown to be a healthy child with an interest in all aspects of Radiation Physics. That child was formally named in 1975 in Ferrara.

Whether or not the child matures into and lively, healthy adult depends on the enthusiasm shown by members ***between*** conferences, as well as ***at*** conferences. It is human nature to give in to the pressures of the present, and let slide other, more remote, involvements and responsibilities. The society was founded to foster dialogue between scientists from all sections of our discipline. Dialogue does occur during the conference: we ought to continue those contacts in the time between conferences.

To that end Walter Gilboy is seeking to establish a register of all IRPS members responsible for junior staff and students, so that we can make more efficient contact with young scientists, in whose hands, ultimately, the fate of our society lies.

The second matter concerns conferences which are of significance to our society. The first is the ***Third Radiation Physics Conference*** which is to be held in Egypt from ***13 to 17 November 1996***, and for which Professor Mahommad Gomaa is the contact person. The second is the primary conference of our society, the ***Seventh International Symposium on Radiation Physics (ISRP-7)*** which is to be held in Jaipur, India from ***24 to 28 February 1997***, and for which Professor Bikash Sinha is the contact person.

Advertisements for both of these conferences are included in this issue.

I urge members to make strong efforts to attend at least one of these conferences, and to encourage as many of their colleagues as possible to attend as well.

Dudley Creagh

PRESIDENT'S COLUMN

John Hubbell

ORIGINS AND CHRONOLOGY OF THE INTERNATIONAL RADIATION PHYSICS SOCIETY

Some of you who were at ISRP-6 in Rabat, Morocco in July l994 may remember meeting Prof. **Alexander Tsybin,** Chief Scientific Secretary of the Moscow-based International Higher Education Academy of Sciences (IHEAS). In view of the many goals held in common by the IHEAS and the IRPS, **Prof. Tsybin** invited me to apply for membership in the IHEAS, and I was duly elected as an Academician in his organisation. For the May 1996 IHEAS Annual General Meeting in Moscow, I was requested to write a report for presentation, and the following Origins and Chronology of the IRPS was the result. **Jean** (my wife) and I hope to flesh out this account into a booklet with photos and additional details, but in the meantime this version serves as a start on this archival project. A little of this material has appeared in previous President's Columns, but omitting that material would leave noticeable gaps. Some of my memory and notes may be in error , so I will appreciate corrections from regular members as well as from the Council, also any interesting episodes, photos, etc. you think might be interesting inclusions in the above proposed booklet.

"IN THE BEGINNING . . . "

1972 My first connection with the founding and nurture of the International Radiation Physics Society was a visit at the Bose Institute in Calcutta September 1972, as the US Technical Monitor for joint India-US mutual-benefit scientific projects supported by US-owned rupees, administered under US Public Law 480 ("PL-480"), later called the Special Foreign Currencies Research Program ("SFCRP"), and authorities in the Government of India.

The two PL-480 projects in radiation physics already existing in India in 1972 were (a) at Bose Institute, Calcutta, "Gamma-Ray Interactions with Matter" with **A.M. Ghose** as the Indian Principal Investigator, and (b) at the Indian Institute of Technology (IT), Bombay, "Investigations of Coherent and Incoherent Gamma-Ray Scattering 0.6-2.0 MeV" with **P.P. Kane** as the Indian Principal Investigator. Besides other radiation physics visits at the Osmania University in Hyderabad (**D.S.R. Murty**), at the National Physical Laboratory (**A. P . Jain**) and the Institute for Nuclear Medicine, Department of Defence **(M.M. Gupta)** in Delhi, and at the Punjabi University, Patiala **(B S. Sood),** I was instrumental, at Andhra University, Visakhapatnam, in establishing a third PL-480/SFCRP project (c) "Experimental Studies on Interaction of Gamma Rays with Matter" with **K. Parthasaradhi** as the Indian Principal Investigator.

1973 Prof. A.M. Ghose visited me in the US in 1973, at which time he proposed, in addition to a radiation physics resource book (we should still do this), an International Symposium on Radiation Physics to be hosted in India.

1974 ISRP-1: Calcutta In collaboration with Prof. **S.C. Roy** and others, **Ghose** organized an International Symposium on Radiation Physics (now denoted ISRP-1) at the Bose Institute in Calcutta November 30-December 4, 1974. I was invited as the Keynote Speaker. The National Bureau of Standards (now NIST) supported this conference by publishing the Proceedings as NBS Special Publication 461 (January 1977). Other financial and other support for ISRP-1 was received from the Government of India Departments of Atomic Energy and Science and Technology, and from the International Atomic Energy Agency, Vienna.

I here quote from the preface of the ISRP-1 Proceedings in NBS SP 461 (l977), edited by **A.S. Ghose**, **D.V. Gopinath**, **J.H. Hubbell** and **S.C. Roy**:

"Radiation Physics is an interdisciplinary science and in the past different aspects of the subject such as nuclear and atomic cross section measurements and analysis, shielding of accelerators, dosimetry , nuclear electronics, radiation biophysics, etc., have been discussed in specialized symposia and seminars. It has been increasingly felt that a symposium presenting the subject matter in an integrated manner would be useful to specialists working in isolated areas of radiation physics as well as to those interested in the global view of the entire subject. The International Symposium on Radiation Physics held in Bose Institute, Calcutta from November 30 to December 4, 1974, with these ends in view provided a forum for exchange of experience and ideas among different workers in Radiation Physics from different countries."

In my opening remarks in my ISRP-1 Keynote Address I endeavoured to set the tone for the conference:

"Dr. **Ghose, Dr. Ramanna,** Chairman **Snyder,** fellow Symposium Participants — it is my pleasure to revisit on this occasion the city of Nobel Laureate (literature, 1913) **Rabindranath Tagore** who in his Gitanjals wrote:

'Where the mind is without fear and the head is held high;
Where knowledge is free;
Where the world has not been broken up into fragments by narrow domestic walls;
Where words come out of the depth of truth;
Where tireless striving stretches its arms toward perfection;
Where the clear stream of reason has not lost its way into the dreary sand of dead habit;
Where the mind is led forward by thee into ever-widening thought and action
Into that heaven of freedom, my Father, let my country [or, my world] awake.'

so appropriate to the spirit of this Symposium."

I think many of **Tagore's** ideals, above, can be found in the unstated as well as the stated objectives of both the IHEAS and the IRPS.

1982 ISRP-2: Penang By 1982, Prof. **Ghose** was at the University of Science of Malaysia, in Penang, where he was the prime mover in organising the Second International Symposium on Radiation Physics (ISRP-2) in Penang, May 25-29, 1982. At ISRP-2, 93 participants (including **Joseph Rotblat,** 1995 Nobel Peace Laureate) from 21 countries presented 99 papers grouped into eight sessions:

- Basic Radiation Physics Data: Experimental and Theoretical,
- Radiation Source Types: Characteristics, Spectra,
- Radiation Detectors: Instrumentation, Interpretation,
- Radiation Transport,
- Applications of Radiation Physics,
- Radiation and Environment,
- Teaching Radiation Physics, and
- Miscellaneous Topics Ranging from Laser Fusion to Microwave Medical Applications.

All subsequent ISRP's have approximately followed this same spectrum of topics.

The Proceedings from ISRP-2 were published by the University of Science of Malaysia in the form of a 941-page booklet with the Editorial Board consisting of: **D.A. Bradley, C.S. Chong, A.M. Ghose, J.H. Hubbell, P.K. Iyengar, D. Jackson,**
T. Nakamura, R.H. Pratt and J. Rotblat.

Following ISRP-1 (Calcutta, 1974), interest had been expressed in forming an International Radiation Physics Society (IRPS) which could serve as the primary sponsor for further Symposia in this interdisciplinary subject area on a more formal and regular basis. At a meeting on May 28, 1982 in Penang, the ISRP-2 Technical Program Committee, expanded to include 14 attending participants from ten countries, elected a pro tem committee consisting of:

A.M. Ghose (Malaysia), Chairman
J.H. Hubbell (US), Secretary
M.A Gomma (Egypt)
D. Isabelle (France)
P.K. Iyengar (India)
D.F. Jackson (UK)
A. Ljubicic (Yugoslavia [now Croatia])
N. Muslim (Malaysia)
T. Nakamura (Japan)
I.B. Whittingham (Australia)

to explore and to take the necessary actions to form such a Society (IRPS).

The primary objective of the Society would be the global exchange and integration of scientific information pertaining to the interdisciplinary subject of radiation physics, with emphasis on:

•Research, theoretical and experimental, in the field of radiation physics,
•Investigations of the physical aspects of the interactions of radiation with living systems,
•Education in radiation physics, and
•Utilization of radiation for peaceful purposes.

1984 Under **R.H. Pratt** (US) as Chairman, and with the addition of **E. Casnatti** (Italy) as CoChairman and also **F. Rustichelli** (Italy), the above IRPS Pro Tem Committee comprised an ISRP-3 International Programme Committee and met October 18-19, l984 in Ferrara, Italy [E. Casnati, principal host].

1985 ISRP-3: Ferrara Founding of the International Radiation Physics Society (IRPS) The 3rd International Symposium on Radiation Physics (ISRP-3) was organized at the University of Ferrara in Ferrara, Italy by **E. Casnati** and his colleagues **G. Baraldi,**
A. Tartari and others, and took place September 30-October 4, 1985. ISRP-3 drew 139 participants from 31 countries on five continents.

During this meeting, the above IRPS Pro Tem/Programme Committee met, at a nice Italian restaurant in Ferrara, and declared the IRPS to exist, with Officers informally agreed upon, with their acceptances, to serve until an election would be held prior to the next Symposium three years hence. These first Officers of the IRPS, who served 1985-l988 were:

P.K. Iyengar (India), President
R.H. Pratt (US), Secretary
D.B. Isabelle (France), Treasurer

Regional Vice Presidents:
G.F. Knoll (US), The Americas
M.A. Gomaa (Egypt), Africa and the Middle East
A. Ljubicic (Yugoslavia [now Croatia]), East Europe and the USSR
D.F. Jackson (UK), Western Europe
A.M. Ghose (India), Asia and the Pacific

Executive Councillors:
D. Berenyi (Hungary)
E. Casnati (Italy)
J.H. Hubbell (US)
T. Nakamura (Japan)
I.B. Whittingham (Australia)

The Proceedings for ISRP-3 were published in Nuclear Instruments and Methods A 255 (1,2) (1987), with
E. Casnati, C. Baraldi and **A. Tartari** serving as the Guest Editor. Each participant received a cloth-bound copy of the Proceedings.

1986 Newsletter Started: Vol. 1, No. 1 of the IRPS newsletter, then called the IRPS-News, was first published dated "Summer 1986" with **R.H. Pratt** (US) as Editor-in-Chief and **D.A. Bradley** (UK, then Malaysia) as Associate Editor, and has since been published on a quarterly basis with Editors **S.C. Roy** and **A.M. Ghose** (India), and is currently Edited, produced and distributed by **D.C. Creagh** (Australia) under the present name IRPS Bulletin.

1986-1988 Council Meetings: The IRPS Council met in Sao Paulo [**I.C. Nascimento**, principal host] early in 1986, then in Zagreb [**A. Ljubicic**] September 26-27, l986, then in Orleans [**D.B. Isabelle**], France May 22-23, 1987, and at NIST [**J.H. Hubbell**], Gaithersburg, US April 1922, 1988.

1988 ISRP-4: Sao Paulo The 4th International Symposium on Radiation Physics (ISRP-4) was organized under the leadership of **I. Nascimento** at the University of Sao Paulo in Brazil, and took place October 3-8, 1988. ISRP-4 drew 173 participants from 25 countries including 90 from Brazil and 83 from elsewhere.

A mailed ballot prior to ISRP-4 resulted in the election of the following IRPS Council for the period 1988-1991:

P.K. Iyengar (India), President
R.H. Pratt (US), Secretary
D.B. Isabelle (France), Treasurer

Regional Vice Presidents:
- **G.F. Knoll** (US), N. America
- **I.C. Nascimento** (Brazil), S. America
- **M. Berrata** (Morocco), Africa and Middle East
- **A. Ljubicic** (Yugoslavia [then]), Eastern Europe and Middle East
- **M.J. Cooper** (UK), Western Europe
- **A.M. Ghose** (India), Rest of Asia and Oceania

Executive Councillors:
- **D. Berenyi** (Hungary)
- **D.V. Gopinath** (India)
- **J.H. Hubbell** (US)
- **T. Nakamura** (Japan)
- **F. Rustichelli** (Italy)
- **I.B. Whittingham** (Australia)

The Proceedings for ISRP-4 were published in Nuclear Instruments and Methods A 280 (2,3) (1389), with **D.B. Isabelle** and **I.C. Nascimento** serving as the Guest Editors. Again, each registered (fee paid) participant received a cloth-bound copy of the Proceedings.

1989-1990 Council Meetings: The IRPS Council met at the University of Warwick [**M.J. Cooper**], Coventry, UK May 4-5, 1989, at BARC [**P.K. Iyengar**], Bombay, India January 16-17, 1990, and in Rabat [**M. Berrada**],Morocco November 21-25, 1990.

l99l ISRP-5; Dubrovnik The 5th International Symposium on Radiation Physics (ISRP-5) was organized under the leadership of **A. Ljubicic** (Rudjer Boscovic Institute, Zagreb) and took place in the historic and picturesque Adriatic seacoast town of Dubrovnik, Yugoslavia [Croatia] June 1014, 1991. Despite the political (and shortly military) turmoil in Yugoslavia, 119 participants from 32 countries braved the uncertain situation to materialize in Dubrovnik, where they presented 21 oral invited papers and 102 contributed poster papers.

The mailed ballots were counted at ISRP-5, and the election results were announced, for the IRPS officers for the next triennial period (between Symposia) 199l-1994:

D.J. Beninson (Argentina), President
R.H. Pratt (US), Secretary
A. Ljubicic (Croatia), Treasurer

Regional Vice Presidents:
- **J.H. Hubbell** (US), N. America
- **I.C. Nascimento** (Brazil), S. America
- **M. Berrada** (Morocco), Africa and Middle East
- **D**. **Berenyi** (Hungary), Eastern Europe and USSR
- **M.J. Cooper** (UK), Western Europe
- **B. Sinha** (India), Rest of Asia and Oceania

Executive Councillors:
- **D.A. Bradley** (UK)
- **D. C. Creagh** (Australia)
- **A.M. Ghose** (India)
- **D.B. Isabelle** (France)

Continuing terms as Councillor:
- **T. Nakamura** (Japan)
- **F. Rustichelli** (Italy)

The Proceedings for ISRP-5 were published in Nuclear Instruments and Methods A 314 (2), 225398 (l992), with **M.J. Cooper** and **A. Ljubicic** serving as Guest Editors. Each registered participant received a paper-bound copy of the Proceedings.

l992-l994 Council Meetings: The IRPS Council met in Debrecen [**D. Bereny**], Hungary May l517, l992, in Cairo [**M.A. Gomaa**], Egypt November 20, 1992, in Chengdu [**Zhengming Luo**], People's Republic of China August 30-September 5, 1993, and in Ancona [F. **Rustichelli**], Italy March 4-6, l994.

l994 ISRP-6: Rabat The 6th International Symposium on Radiation Physics (ISRP-6) was organized under the leadership of **M. Berrada** and took place in Rabat, Morocco July 18-22, l994. ISRP-6 drew 121 participants (plus 21 local organizers) from 30 countries. 22 oral plenary papers and 105 poster papers were presented, plus one special evening public lecture.

The mailed ballot IRPS election results were announced, giving for the next triennial period l994-l997:

J.H. Hubbell (US), President
R.H. Pratt (US), Secretary
A. Ljubicic (Croatia), Treasurer

Regional Vice Presidents:
D. Nagel (US), N. America
A. Paschoa (Brazil), S. America
M. **Berrada** (Morocco), Africa and Middle East
D. Berenyi (Hungary), East Europe and FSU
M.J. Cooper (UK), Western Europe
B. Sinha (India), S.E..Asia and Pacific
Zhengming Luo (PRC China), North East Asia

Executive Councillors:
L. Gerward (Denmark)
M. Monnin (France)
T. Nakamura (Japan)
S.C. Roy (India)
F. Rustichelli (Italy)
Continuing terms as Councillor:
D.A. Bradley (Malaysia)
D.C. Creagh (Australia)
A.M. Ghose (India)

The Proceedings for ISRP-6 were published in Applied Radiation and Isotopes 46 (6/7), 375-734 (1995), with **M.J. Cooper** and **M. Berrada** as Guest Editors. Each registered (fee paid) ISRP-6 participant received a paper-bound copy of the Proceedings.

The participation of **Prof. A.S. Tsybin**, Chief Scientific Secretary of the IHEAS, in ISRP-6 (Rabat) was welcomed and appreciated.

1995-l996 Council Meetings: The IRPS Council met in Jaipur [**B.K. Sharma,** Jaipur; **B. Sinha** and **P. Sen,** Calcutta], India February 25-26, 1995, at the University of Warwick [**M.J. Cooper**], Coventry, UK November 9-l0, l995, and in Prague [**L. Musílek**], Czech Republic May 9-l0, l996. The Fall 1996 Council Meeting will be at the National Institute of Standards and Technology in Gaithersburg, USA [**J.H. Hubbell** hosting], October 3-4, l996.

1997 ISRP-7: Jaipur The 7th International Symposium on Radiation Physics (ISRP-7) is being organized under the leadership of **B. Sinha,** Chair of the National Organising Committee and **R.N. Singh** (Jaipur) as Co-Chair, with assistance from **P. Sen**, Calcutta, and will take place in Jaipur, India February 24-28, 1997. **D.A. Bradley** (Malaysia) and **F. Rustichelli** (Italy) are Programme Committee Chair and Co-Chair, respectively, for ISRP-7.

The ISRP-7 Scientific Programme, following the format established at previous ISRP's, will include oral invited papers grouped under the topics:

• Fundamental Processes in Radiation Physics,
• Radiation Sources and Detectors,
• Applications of Radiations in Fundamental Research,
• Radiation in Technology, and Radiation in Archeometry, Earth and Space Science and Cosmology

The remainder of the Scientific Programme will be contributed papers, presented as posters, on these and other radiation physics topics.

The Proceedings from ISRP-7 will be published in Radiation Physics and Chemistry, with **D.A. Bradley** serving as Guest Editor.

Inquiries about ISRP-7 (Jaipur, India, February 24-28, 1997) should be directed to:

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2000 ISRP-8: Prague At the May 9-l0, 1996 Council Meeting in Prague, the Council voted to hold ISRP-8 in the year 2000 in Prague, to be organized under the direction of Prof. **Ladislav Musílek,** Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague.

Summary:

The above account of the origins and chronology of the International Radiation Physics Society (IRPS) is only a brief outline, with its main value a series of dates to which many more names and their important contributions should and will be added. However, it does provide an idea of the aims and objectives of the IRPS, many of which the IRPS and IHEAS hold in common, for making this incredibly precious planet Earth a friendlier and happier home for the global human family.

There are many possibilities for IRPS-IHEAS cooperation and joint ventures in the future, including joint IRPS-IHEAS support of radiation physics education in the African Continent, with some ideas already proposed by Prof. **Rex Keddy**, Johannesburg, I look forward to some future IRPS venues in Russia for both IRPS Council Meetings and International Symposia (ISRP's), some perhaps scheduled adjoining IHEAS Meetings, to strengthen our IHEAS-IRPS communication and cooperation.

As mentioned at the beginning of this Column, your corrections, additions, photos and suggestions for developing the above material into an interesting and archival document will be welcomed, sent to:

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A Future for the IRPS?

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Under this slightly disturbing caption in his President's Column in the March/April issue of IRPS bulletin John Hubbell stressed the vital importance of building up our membership towards a critical mass beyond which our society would greatly increase its influence and effectiveness. To this end I am seeking to establish e-mail contact with all IRPS members who are responsible for junior personnel or students in order to extend an experiment I recently tried at the University of Surrey. I publicised IRPS to 79 postgraduates comprised of 21 Radiation Physics group research students, 24 Radiation & Environmental MSc students and 34 Medical Physics MSc students and with very little effort a dozen of these have completed application forms for membership. I urge all the more senior members of ISRP to try the same experiment to see if we can rapidly double our total membership in this way. The membership fees have always been kept low, particularly for students, so that there is little financial impediment to joining. Of course this means that the income generated will be small initially from new student members but they are literally the future of our society and many will go on to full membership in their radiation physics related careers. In future e-mail addresses will be collected automatically on joining IRPS or at membership renewal to aid rapid and low-cost communication with members and I would be grateful if those of you in academic posts or management would send me your e-mail addresses to foster recruitment.

We are in the process of launching IRPS on the world-wide web and an announcement is now to be found on **http://www.ph.surrey.ac.uk/IRPS** and items you would like to publicise there should be sent to me for consideration. I look forward to hearing from you via my e-mail address **w.gilboy@surrey.ac.uk**.

PAPERS

ONE HUNDRED YEARS OF X-RAYS AND RADIOACTIVITY – RADIATION PROTECTION : THEN AND NOW

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It is not particularly remarkable that this topic was one that I chose for an IAEA Symposium which I presented in 1974 (1). My thesis in 1974 was that the basic recommendations and regulations on dose limitation were unchanged from the early 1920s to the date of that lecture. What is remarkable is that during the middle to late 1970s the basis for such recommendations changed to a scientific approach based on risk, and as a result, the recommendations have been under change and modification ever since, although perhaps, as we will see, we may be at a point of some stability once again. I will return to the historical developments, particularly relevant during this Congress when we are celebrating the discovery of the X ray by William Conrad Roentgen just 100 years ago this past November, and the discovery of radioactivity by Becquerel 100 years ago last month. You should also understand that much of this presentation will focus primarily on activities of both the National Council of Radiation Protection and Measurements (NCRP), with particular emphasis on the International Commission on Radiological Protection (ICRP).

Of course, man has evolved in a sea of ionizing radiation. Enhanced exposure to natural radiation took place the first time man moved to a cave where the radon progenies were there for him to inhale. The first occupational exposure that we can trace back in recorded history was to the miners of Joachimsthal and Schneeburg in the 15th and 16th century Czechoslovakia and Saxony who developed lung cancer from breathing radon progeny while mining for lead (2).

In the middle to late 1850s, gas-discharge physics was a hot topic and the source of wide-ranging experiments in virtually every physics laboratory. These tubes could be found in every high school science laboratory and in any university physics laboratory. On November 8, 1985, Wilhelm Conrad Roentgen was working in his Würzburg laboratory with a Crookes discharge tube. As he was adjusting the high voltage on his gas-discharge tube that he had covered with dark cardboard, he saw his screen of florescent materials lying on the table nearby fluoresce. He realized that he was observing the results of a highly penetrating ray, which he called the X ray. He spent the next two months carefully investigating in detail the properties of this new X ray. During this period, he discovered virtually all of the classical

physics properties of the X ray. During these two months he told no one about this discovery except for an anecdotal story which relates that his wife was complaining about his missing meals and being extremely introspective and uncommunicative. Roentgen reportedly took her to his lab where he took an X-ray photograph of her hand -- to her complete astonishment and to his great relief -- he was not, after all, losing his mind! He submitted a paper describing his observations in less than 60 days, during December of 1895 (3). The results of his work were reported in the popular press in Vienna on January 5, and in London and New York by the middle of January 1896. Everyone who owned a gas-discharge tube learned that if they applied high enough voltage they could generate X rays. Thomas Alva Edison was one of the first to see the potential commercial applications of these X rays. For example, in early February, he began a highly publicized attempt to X ray the human brain. Edison had hoped to market an X-ray light bulb, but eventually came to understand the inherent dangers associated with such practices when his assistant, Clarence Dally, died in 1904 as a result of his excessive exposures (4). Dally's death, which was widely reported, had a sobering effect on all of those who were using X rays. In fact, Edison completely stopped working with X rays at this point, although he had already developed a hand-held fluoroscope (5).

When Antoine Henri Becquerel learned of Roentgen's discovery of the X ray using fluorescent materials, he was determined to study these processes in more detail. The material Becquerel chose to work with, fortunately, was a soluble sulfate of uranium and potassium, which he exposed to sunlight and then placed on photographic plates wrapped in black paper. When developed, the plates revealed an image of the uranium crystals (6). His conclusion was that "The phosphorescent substance in question emits radiation which penetrates paper opaque to the light ". He believed that the sun's energy was being absorbed by the uranium which then emitted Roentgen's X rays. However, because the weather was poor on the 26th and 27th of February, Becquerel returned to a desk drawer the uranium-covered plates that he had intended to expose to the sun. On the first of March, when he developed these plates, he expected only very faint images. To his surprise, however, they were clear and strong.

He now realized that the uranium itself was emitting radiation without an external source of energy and he had discovered radioactivity (7). All by the first of March 1886.

Marie and Pierre Curie, quickly realizing the importance of Becquerel's findings, separated the uranium from pitch blend and eventually found the elements radium (8) and polonium (9), which they laboriously separated from the ore over a period of four years. By 1902, they had a tenth of a gram of radium. During this period, Henri Becquerel had obtained a sample of radioactive material from the Curies, which he placed in a waistcoat pocket. He observed that having worn this waistcoat for less than six hours, he had received a deep burn on his chest (10). He recognized that if this could be destructive to healthy tissue, it should also be destructive to cancerous tissue. As a result of his and the Curies' work, radium followed the same path as X rays in the development of both the medical and nonmedical use of radiation.

By and large, it was the medical community that recognised the enormous potential of the X ray and radium. It was interesting that medicine at that time was dealing with a difficult problem of the use of electrotherapy. Although this practice was being discouraged by the medical community as a whole, the practitioners were still there, and their equipment was ideally suited to the generation of X rays.

During the next few years, medical use of the X ray expanded rapidly, and indeed, this became known as the era of "bullets, bones, and kidney stones." The physicians realized from the beginning that while the medical benefits were unlimited, there were potential hazards from radiation exposure. There were reports in the scientific literature and in the popular press of ulcers that did not heal and scores of skin burns, both among the patients and the physicians (11). The first ulcerating skin lesion was reported by an electrotherapist named Grubbe on January 26, 1886, within a month of the discovery of the X ray (12). By 1915, only 15 years after the introduction of the X ray, both the Gertnan Radiological Society and the British Radiological Society had prepared recommendations for physicians on avoiding unnecessary exposure (13). Although these rules were not very definitive, they demonstrated that the societies understood that there was a problem.

As indicated above, the medical community had adopted this technology, and once a medical association takes ownership of a modality of this kind, they tend to protect it as their own. In the United States, and pretty much in England and in France, a physicist could not publish an article unless he had a physician sponsoring the paper. As a result, most of the literature was related to clinical effects and to clinical use. The situation was different in Germany, where physics and medicine grew up together, and the medical community embraced the physics community as its equal. This was primarily because medicine was more heavily regulated in Germany than it had been in these other countries.

Protection advice was not heavily organized until, in 1921, the newly organized X-Ray and Radiation Protection Committee in England presented a set of detailed recommendations as rules that every physician was expected to use (14). The pressure for these recommendations resulted from the development of the hot cathode tube by Coolidge, an engineer at General Electric (15) This tube was able to produce much higher currents and much higher energies. Many of the radiologists now recognised the significant hazard that the use of this equipment posed for them and their patients. Second, World War I had just ended, and hundreds of X-ray machines, mostly with the new Coolidge tube, had been used in the battlefield and were implicated in the many reports in the public press about anemia in the returning soldiers.

It is interesting to note that these military X-ray machines had an enormous impact on the course of radiation measurements as well. The Army Quartermaster Corps wanted to be certain they got what they paid for, i.e., these battlefield machines had to meet military standards. As a result, the National Bureau of Standards was called upon to provide standards, and the physicists involved became more interested in measurement and quantification than had the physicians who had depended upon the redness of skin and whether or not they obtained a good image (16).

Radium commerce also had an impact on measurement. The only way one could specify the quantity of radium was through detailed measurement, which at $100,000 per gram. was very important. Commerce ensured that, at last, there was attention being paid to the measurement of radiation and radioactivity.

In 1922, Mutscheller, in the United States, and Sievert, in Sweden were concerned about the adequacy of radiation protection. Mutscheller visited a number of well-run clinics in New York City and found that they could operate quite well without anyone being exposed to more than .01 of an erythema dose in 30 days (17). The erythema dose, which is the dose to cause reddening of the skin, had become a common measure of exposure at this time, primarily since there was no generally accepted physical measurement. Nearly every X-ray operator knew how long it would take to develop an erythema at given locations around their X-ray facilities. At the time Mutscheller made this recommendation, Sievert, in Sweden, arrived at a recommendation of .1 erythema dose in a year (18). It is remarkable that these two independent investigators ended up with virtually the same number. Inherent in their recommendation is the concept of a threshold dose. For example, Mutscheller stated, "for in order to be able to calculate the thickness of a protective shield, there must be known the dose which an operator can, for prolonged period of time, tolerate without ultimately suffering injury". Mutscheller's assumption of a "tolerance" level is consistent with the classical threshold response curve so common in toxicological studies. In fact, it is the kind of relationship we see now in most toxicological studies.

In 1925, the International Congress of Radiology at its meeting in London, formed an X-ray unit committee which was to become the International Commission on Radiation Units (ICRU) (19). Even at the time of formation, the international society recognized the need for an internally accepted definition of an exposure quantity. In 1928, the International Congress held in Stockholm adopted a recommendation from this new committee that defined the Roentgen as "the exposure when the X- or gamma-ray field produces 1 e.s.u. of positive charge and 1 e.s.u. of negative charge in 0.00129 grams of air" (20). This definition remained essentially unchanged for 50 years.

At the Stockholm meeting, the International Congress formed the origins of the International Commission on Radiological Protection, the Advisory Group on X-ray and Radium Protection. The U.S. representative to that meeting was Dr. Lauriston S. Taylor, of the National Bureau of Standards. Dr. Taylor was instructed to return to the United States and form a similar organization for the United States so that they could bring a unified position to the future meetings of International Congresses. Taylor returned to the United States and formed the origins of the National Council on Radiation Protection (the U.S. Advisory Committee on X-ray and Radium Safety). Lauriston Taylor was to chair this advisory committee and its successor organizations, the National Committee on Radiation Protection and Measurements and the National Council on Radiation Protection and Measurements, for 49 years until his retirement in 1977.

Shortly after the ICRU provided the definition of the Roentgen, both the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP) made recommendations dealing with exposure levels. The ICRP recommended no more than .2R/day (21). This is a reasonable measure of the exposure that would result in about .01 of the erythema dose in thirty days. What they had done was to adopt, in a way that could be measured, what Mutscheller and Sievert had recommended earlier. This recommendation, although quantifiable, was still based on skin reddening. Three years earlier, in 1931, the NCRP recommended .1 R/day (22). The ICRP recommendations applied to measurements made at the surface of the body, while the NCRP recommendations applied to measurements made free in air. Measurements of exposure made at the surface of the body with low energy X rays would indeed be just about twice what they would be free in air. In fact, the NCRP and the lCRP recommendations provided virtually the same level of protection.

Dr. Faina noted, in the 1960 hearings before the U.S Congress' Joint Committee on Atomic Energy, that he endorsed a limit of .1 R/day based on his observation that two technicians who received that level of exposure showed no observable effects and this limit could thereby be judged to be safe (23).

In the middle 1920s, there were a number of young women working as radium dial painters in New Jersey and elsewhere who tipped their brushes between their lips -- the famous radium dial cases. A New York dentist, Theodore Blum, noted in a three-line footnote to a paper on osteomyelitis of the jaw that he had seen what he termed "radium jaw" in a girl working in a New Jersey dial-painting plant (24).

Much of the early attention to the dial painters came from the National Consumers League, which began under Florence Kelly, and became a virtual crusade (25). By the end of 1926, most of the dial painting intakes had stopped; however, the medical and quasi-medical use of radium and its emanation products were booming. In 1932, a prominent steel executive named Eben Byers, who was a well known amateur golf champion, died of excessive use of a patent medicine, Radithor. Since each one-half bottle contained one microcurie of 226-Radium and one microcurie of 228-Radium, it is not surprising that Mr. Byers' habit of ingesting four bottles per day over an extended period of time resulted in radium poisoning (26). The Los Angeles County Health Department simply could not understand how such a thing could be happening in California, so they went to the California Institute of Technology, where they were put in touch with Robley Evans. This began a long and careful analysis of the effects of radium in bone. By 1941, Evans had studied twenty-seven cases of Radium ingestion, and noted that there were seven cases with residual body burdens below 0.5 micrograms of Radium and no injuries, and 20 with 1.2 to 23 micrograms with various degrees of injury. He presented this data to the Advisory Committee on X-Ray and Radium Protection. Their consensus opinion was that they would accept Dr Evans' suggestion of .1 microgram (.1 microcuries) of radium as a level "we would feel perfectly confident if our wife or daughter were the subject" (27). This value was published in NBS Handbook 27, March 2, 194l.

Eisenbud has made the point that I will reiterate here that it was remarkably fortuitous that, before Pearl Harbour and just after the discovery of plutonium, the community had at its disposal two recommendations, an external exposure limit of .1 R/day and body burden limit on internally deposited radium of .1 ug Ra. Without these numbers, it is hard to imagine what the consequences to workers might have been during the Manhattan Project.

During the Second World War there was extensive research in radiation biology going on in places like Oak Ridge, the University of Rochester, the University of California at Berkeley, and the University of Washington, to try to obtain information on the effects of ionizing radiation. Data was obtained on dose and dose rate effects, depth dose, R.B.E.s, radionuclide metabolism, and dosimetry. Perhaps the most influential radiation protection recommendation to come out of this work was that developed by a committee at the Tripartite Conference Meetings held among scientists from Canada, the United States, and Great Britain, countries with access to extensive wartime data (28). They brought their recommendations to the ICRP and the NCRP in the late 1940s. By the middle 1950s, both the NCRP and ICRP had produced new sets of dose limits derived from all the data obtained during World War II (29,30).

They recommended 600 mrem per week for the skin, and 300 mrem per week for other organs. I was fascinated to realize that .1R/day is .6R/week, with is 600 mrem per week, which means that the 600 mrem per week for the skin is based on the .01 of the erythema dose of 1928. The 300 mrem per week limit is more interesting. If the body is irradiated with 150 kV X-rays, the limiting dose to the organs at 5 cm would be .05 R/day. If, however, the body is irradiated with high-energy gamma rays, and the same level of protection is desired as that with 150 kV X-rays, then the limit for the skin must be 600 mrem/wk (.1 R/day) and one half of that value or 300 mrem/wk (0.5 R/day) for the organs taken to be at 5 cm.

Starting in about 1954, we entered a new era characterized by weapons testing and the public response to it. Perhaps one of the most important contributors to the public's fear of radiation can be traced to the worldwide reaction to the fallout from the Bravo Weapons Test on Bikini in March 1954. The subsequent plight of the crew of the Lucky Dragon fishing vessel made headlines, and was coupled in the U.S with the *Life* magazine cover published on April 29, 1954 depicting, for the first time, a thermonuclear explosion. Now people all over the world became concerned about radioactive fallout. Specifically, there were two individuals in the U.S. who led the scientific community in expressing concern: Mueller, a geneticist, who had been speaking about the linearity of genetic effects even during the late 1930s, and Linus Pauling, who worried about internal exposures. As a result of the public concern about fallout, a National Academy of Sciences Committee on the Biological Effects of Atomic Radiation (BEAR) in the United States and the Medical Research Council (MRC) in the United Kingdom were asked to review the radiobiological data (31,32). Both committees came up with about the same estimate of detriment, having focused their attention on genetics. They said that it was unlikely that all of man's suffering and pain from genetic abnormalities came from natural radiation background, but that some of it did. Such a consideration bracketed the genetic risk since they knew the natural radiation background levels and the natural incidence of genetic effects. Based on this analysis, both committees came up with an estimate that suggested individuals (workers) should not receive more than 50 rem to age 30 and another 50 rem to age 40. (The MRC actually recommended 50 R to age 3() and 200 R lifetime). For the population the BEAR Committee suggested a limit of 10 rem to age 30 for all exposure except natural background. I might add that I was able to discuss this with Eugene Cronkite many years ago. Dr. Cronkite was Chairman of the Haematological Effects Subcommittee of the BEAR Committee at the time of the preparation of the 1956 report. I asked him if the recommendations on exposure limitation came from considerations of the radiologists who had been shown to have an excess incidence of leukemia. He answered that the dosimetry was so uncertain that they could not estimate the dose nor the risk per unit dose associated with leukemia among the radiologists. He noted that what they did decide was that they would accept the genetic panel recommendations and the Academy recommendations were therefore based almost entirely on the genetic estimates based on a linear extrapolation.

The NCRP and ICRP had to decide the way in which they would recommend that the worker be protected under these new recommendations (33,34). As we know, the answer was an annual limit of (age – 18) ∞ 5 rem, which delivered 60 rem to age 30, etc. The whole-body limit was 3 rem/quarter and (age - 18) ∞ 5 and 15 rem/year for individual organs. By the way, 300 mrem/wk for 50 weeks results in 15 rem/year. Again, the organ limit of 15 rem finds its way back to .01 of the erythema dose in 30 days.

As noted above, my thesis on this subject in 1974 was that there was not a very strong scientific basis for our dose limits. However, this situation changed dramatically by 1977. This was a result of information that came, not in 1977, but from the period 1960-77, and was based primarily on data that was becoming available from the Japanese survivors of the atomic bombing of Hiroshima and Nagasaki who had been under study from the time of the bombs. This study is performed by the Radiation Effects Research Foundation (RERF) under sponsorship by the U.S. Department of Energy (DOE) through the National Academy of Sciences and by the Government of Japan.

I would like to stop here for a moment because everyone should understand the enormous contribution those survivors and the government of Japan have made by their continuing participation in this study. I should add that funding for continuing this important work is now in question by the U.S. DOE, and it is incumbent on us all to see if we can help to maintain it and to support the absolute necessity for the RERF Directors and Scientific Councillors to set the research agenda.

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the National Academy of Science's Biological Effects of Ionizing Radiation (BEIR) Committee review the data that comes from RERF. The UNSCEAR was a product of the same issue that brought about the l956 NAS BEIR Committee: worldwide fallout from atmospheric nuclear weapons tests. It was created by the United Nations General Assembly in December l955. The UNSCEAR noted that in l962 the incidence of solid cancer in the Japanese survivors was slightly greater than might have been expected in that population if it had been unirradiated, but that excess leukemia was clearly evident (35), and in 1964, they estimated that other cancers were about equal to leukemia (36). In the early 1970s, they estimated that other cancers were about two times leukemia (37). In 1977, the UNSCEAR provided a fatal leukemia risk estimate of 2 x 10^{-5} per rem and a total fatal cancer risk estimate of 1 x 10^{-4} per rem, i. e., the solid tumor risk is about ifive times the leukemia risk (38).

Based on its own review, the ICRP adopted in 1977 total nominal risk of fatal cancer of about 1 x 10^{-4} per rem (39). They then compared this radiation risk with the average risk of accidental death in safe industries. In safe industries at that time, one person in ten thousand died each year (l x 10^{-4}/year) from accidents, and the ICRP suggested that the radiation workers ought to have at least that level of protection. The ICRP then set a limit of 5 rem/year on the expectation that most people who were protected by a limit of 5 rem/year would be unlikely to exceed 1 rem/year, and, therefore, the average risk fatal cancer will be the same as that for workers in safe industries. In addition, the ICRP suggested that the annual limit on intake (ALI) of radionuclides be based on the specific fatal cancer risk of each tissue results from that intake over the next 50 years. Inherent in the total risk approach is the need to combine internal and external radiation.

The recommendations of the ICRP Publication 60 are based on further changes (40). In l986, a later set of data from Japan became available which suggested two things. First, there is evidence of increased risks based on new dosimetry and some additional solid cancers. This new data also gave further evidence that cancer from exposure to radiation follows a multiplicative projection model, i.e., attributable cancers will occur at the age they would if there were no exposure, so it isn't until people approach their mid-seventies that these cancers are likely to occur. The ICRP and NCRP have adopted this new risk projection model. Having such a model is needed to estimate what is going to happen to the Japanese survivors over the next 40 years or so. The ICRP and the NCRP had both used an additive model prior to 1990. It is very clear from the Japanese survivor data that exposure to radiation at high dose rates results in excess cancer. You will note "high dose rate" since the doses that show these excess cancers are about I Sv, but 1-2 Sv is on the order of the lifetime exposure we might expect for the most highly exposed radiation workers. Therefore, we are talking about an extrapolation from high dose rates to low dose rates, ane we must ask the question of whether there is time for recovery and repair which might alter our estimate of risk at lower dose rates. ICRP's Task Group on Risk, chaired by Dr. Arthur Upton, suggested you might be able to reduce estimates from very high doses (dose rates) by about a factor of two to get the best estimate in the risk at low doses (low dose rates) (41). The NCRP Committee on Risk, chaired by Dr. Michael Fry, suggested the risk at high doses (dose rates) could be reduced by a factor of two to three (42). What all this means is that although we now are on a very firm basis in stating that there is excess cancer in the Japanese, we still have concern about whether we are overestimating the risk by a factor of two or three, or underestimating it by about the same factor. But at least this gives us confidence that we have a fairly firm understanding of the risks that people face. In fact, the latest data from the former Soviet Union suggest that this reduction factor might be about three (43). As we apply these risk estimates to deriving dose limits, the ICRP and the NCRP recognized that the risk estimates had increased by about a factor of four since l977 when ICRP Publication 26 was published. Since the annual limit was 5 rem in 1977 they might logically have been expected to divide by four and obtain a new limit of 1 rem/yr. The ICRP did note, however, that the new projection model also changed the most likely age of death from an attributable cancer. That changed from an expectation of death in the middle sixties to expectation of death in the late seventies. As a result, the ICRP felt it was important to base the limit on the risk to the most highly exposed individuals (for whom the limit is needed). In this regard, they also noted that the risk of accidental death in industry has been decreasing by ~2% per year. "Safe" industries are now at ~5 x 10^{-5} rather than 1 x 10^{-4} yr^{-1}. Rather than using the safe worker criteria, the Commission felt that it was more appropriate to base their limits on a comparison with an individual worker at the upper end of safe industry risks. This turned out to be about 10^{-3}/year. On this basis, the ICRP recommended a limit of 100 mSv over 5 years and the NCRP recommended a limit based on age in tens of mSv, i.e., if you are 45, you shall not have a cumulative dose >450 mSv (45 rem).

These approaches are tolerable for the rare individual operating at the dose limit, but are totally unacceptable to use for any kind of average exposure for individuals who are working in the industry. It is for this reason that both the NCRP and the ICRP stress that the dose limits themselves are entirely unsatisfactory as a basis for designing a protection system and that optimization should be the focus of our efforts.

The data on exposure to workers and the general public demonstrate the remarkable effectiveness in the application of the optimization philosophy. We can rest assured that the breathtaking advances in medicine and industry can flourish for the benefit of all mankind.

It is only the fear of radiation engendered by incidence the fallout from atmospheric weapons testing (the Lucky Dragon incident), reactor accidents (Three Mile Island, Unit 2), and reactor disasters (Chernobyl) which threaten to derail this remarkable resource. It is essential that those of us in the radiation protection sciences begin to understand public perception and public value so that we can be active and effective participants in public decision-making efforts.

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C A L E N D A R

1996

June

3–7 *Fourth International Conference on Radioactive Nuclear Beams*, Ohmiya, Japan; Mrs S Odai, RNB-4 Secretariat, Institute of Physical and Chemical Research (RIKEN), Linac Lab, 2-1 Hirosawa, Wako, Saitama 351-01, Japan
Fax : 81 484 62 4689; Phone : 81 484 62 111
ext. 4211; e-mail : RNB4@rikvax.riken.go.jp;
WWW http://www.rarf.riken.go.jp

9-15 *5th International Conference on Applications of Nuclear Techniques – "Neutrons in Research and Industry"*, Crete, Greece; G Vourvopoulos, Dept of Physics, Western Kentucky University, Bowling Green, KY 42101, USA
Phone : 1 502 745-5277; Fax 1 502 745-5062
e-mail : vour@wkuvx1.wku.edu

TBA *15th Annual Panasonic International Dosimetry Symposium*, Lake Geneva, Wisconsin, USA; David Katzman, Panasonic, USA.
Phone : 1 201 348 5339

July

9–12 *International Workshop on Radiation Exposures by Nuclear Facilities : Evidence of Health Impacts,* Portsmouth, England; German Society for Radiation Protection. Dr M Schmidt, University of Portsmouth, School of Chemistry, Physics and Radiography, Park Building, King Henry 1 Street, Portsmouth P01 2DZ, England
Phone : 44-1705-842150; Fax : 44-1705-842157

21–25 *X International Conference on Small-Angle Scattering*, Campinas, Brazil; Prof. Aldo Craievich, LNLS, Cx Postal 6192, 13081-970 Campinas, SP, Brazil

September

9–11 *Second International Workshop on the Industrial, Medical and Military Applications of Radionuclides*, Salzburg, Austria. Workshop Secretariat, Institute of Physics and Biophysics, Hellbrunnerstr. 24, A-5020 Salzburg, Austria.
Fax : 43 662 8044 5704;
Phone : 43 662 8044 5700;
e-mail : physik@edvz.sbg.ac.at

18–20 *International Symposium on In Vivo Body Composition Studies*, Malmö, Sweden; Symposium Secretariat, Department of Radiation Physics, Malmö University Hospital, S-205 02 Malmö, Sweden.
Fax : 46 40 963185; Phone : 46 40 331235

October

6–9 *3rd Topical Meeting on Industrial Radiation and Radioisotope Measurements and Applications (IRRMA'96)*, Raleigh, USA; W.F. Troxler, IRRMA'96 Conference General Chairman, Troxler Electronic Laboratories, PO Box 12057, Research Triangle Park, NC 27709, USA. Phone : 1 919 549 8661

14–16 *International Symposium on Nuclear Energy and the Environment*, Beijing, China; Leng Ruiping, Wang Hengde, Chinese Society of Radiation Protection, PO Box 2102-14, Beijing 100822, China. Fax : 86 10 8539375; Phone : 86 10 8510370

21–25 *4th International Conference on High Levels of Natural Radiation*, Beijing, China; Prof. Tao Zufan, Secretary General of 4th ICHLNR, Laboratory of Industrial Hygiene, Ministry of Health, 2 Xinkang Street, Deshengmenwai, Beijing 100088, China.
Fax : 86 10 2012501
Phone : 86 10 2021166 ext. 378

November

3–7 *International Conference on Radiation and Health in Israel*, Ben Gurion University of the Negev, GBeer Sheva, Israel; International Conference on Radiation and Health, Ortra Ltd., 2 Kaufman Street, Textile Center, POB 50432, Tel Aviv 61500, Israel.
Fax : 972 3 5174433; Phone : 972 3 5177888
e-mail : ortra@trendline.co.il

3–8 *2nd International Symposium on Ionizing Radiation and Polymers*, Guadeloupe, France. Natacha Betz, IRaP96, CEA/Saclay, DSM/DRECAM/SRSIM, 91191 Gif sur Yvette Cedex, France.
Phone : 33-1 69 08 48 34 Fax : 33-1 69 08 96 00
e-mail : irap@drecam.cea.fr

1997

February

24–28 *7th International Syumposium on Radiation Physics (SIRP-7), Triennial Meeting of the International Radiation Physics Society (IRPS)*, Jaipur, India; B. Sinha, Director, Variable Energy Cyclotron Centre, 1 A/F, Bidhan Nagar, Calcutta 700 064, India
Fax : 91 33 346781; Phone : 91 33 370032

March

15–20 *Sixth Conference of Nuclear Sciences and Applications*, Cairo, Egypt; Prof Dr A I Helal, Atomic Energy Authority (ESNSAS) 101 Kasr El-Eini Street, Cairo, Egypt, Fax : +20 2 3543451

May

19–23 *ICRM'97*, Gaithersburg, Maryland, USA; Dr J.M.R. Hutchinson, Radioactivity Group, NIST, Gaithersburg, MD20899, USA
Telefax : +1-301-926-7416; e-mail : jmrh@micf.nist.gov

June

2–5 *2nd International Workshop on Electron and Photon Transport Theory Applied to Radiation Dose Calculation*, Seattle, Washington, USA. David Jette, Lanzl Institute, 3600 15th Ave.W., Suite 205, Seattle, WA, USA 98119
Phone : 1-206-286-0241; Fax : 1-206-286-0231
e-mail : dave@meihua.lanzl.com

July

21–25 *X International Conference on Small-Angle Scattering*, Campinas, Brazil; Prof. Aldo Craievich, LNLS, Cx Postal 6192, 13081-970 Campinas, SP, Brazil