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NIAS

Workshop Report

Perspectives and Future Prospects in Higher Mathematics

National Institute of Advanced Studies
Bangalore, India

Workshop on

Perspectives and Future Prospects in Higher Mathematics

at JRD Tata Auditorium, NIAS, Bangalore

on

25–26 October 2006

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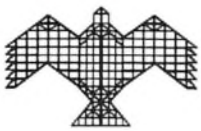

National Institute of Advanced Studies, Bangalore

Co-Sponsored by

Department of Atomic Energy, Mumbai
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Prespectives and Future Prospects in Higher Mathematics

Introduction

A two-day workshop on "Perspectives and Future Prospects in Higher Mathematics" was held at the National Institute of Advanced Studies on 25th and 26th October, 2006. The Conveners of the workshop were three eminent Indian mathematicians Prof. C. S. Seshadri, Prof. M. S. Narasimhan and Prof. M. S. Raghunathan who drew up the programme of the workshop defining its scope. About 60 mathematicians were invited from Research Institutes, Universities, IITs and User Departments of higher mathematics like Department of Atomic Energy, Department of Space, Defence Research and Development Organizations and also from the IT Sector. Panel discussions were held on the following topics:

1. Research and Development in Pure Mathematics
2. Applied Mathematics (Research, Training, Application)
3. Higher Education in Mathematics
4. Computer Science and Mathematics
5. Requirements of User Agencies

After one and a half days of intense deliberations, the drafting committee along with the rapporteurs of the various sessions held detailed discussions and came out with specific recommendations to be made to the Government regarding the steps to be taken to foster the interests of the future of higher mathematics in the country.

This report contains the Welcome Address by Dr. K. Kasturirangan, Opening Remarks by Prof. M.S. Raghunathan and Prof. P. Rama Rao; Inaugural Addresses by Prof. C.N.R. Rao, Objectives of the workshop; Recommendations emerging from the workshop; the programme and the list of invitees. We do hope that the report will be of use to those interested in the future of higher mathematics in India and to the Government and other agencies for allocating liberal finances to this most important scientific activity which undoubtedly has a great potential and great future in India.

B V Sreekantan

Welcome Address: Dr K. Kasturirangan

Professor C.N.R. Rao, Professor Sreekantan, Professor Narasimha, Professor Rama Rao, Professor Seshadri, Professor Raghunathan, distinguished mathematicians and other esteemed invitees, it is at the outset my pleasure and privilege to welcome all of you to this two-day workshop on the Perspectives and Future Prospects in Higher Mathematics at the National Institute for Advanced Studies. I would like to particularly welcome Professor C.N.R. Rao for agreeing to inaugurate this important workshop. It is one of the stated objectives of the National Institute of Advanced Studies to act as a think tank on topics of national importance in fields of science, technology, social sciences, humanities, and so on. And towards this, over the years, NIAS has been organizing workshops, meetings, symposia, conferences, and so on in a variety of fields, inviting scholars from all over the country and from the various institutions. And in the process of deliberating on the various topics, the Institute has been able to produce reports, recommendations, working papers, proceedings and so on, that could be used by the government and other agencies in formulating policies and directions for the appropriate areas.

I may mention that about a year back, Professor Rama Rao and Professor Narasimha and a few other eminent scientists got together to look at the issues of mathematics. I kept Professor C.N.R. Rao informed about this aspect of an important meeting. And he gave his blessings on this, and interestingly, the paper that they generated did find quite a lot of attention with the government. In fact, according to the Finance Minister, he said that both he and the Prime Minister attach a lot of importance to this area of mathematics. Therefore we took up this paper for the final discussions before the budget session. Then there were some competing demands, and in the process the decision on this was delayed. But I find that the enthusiasm has not waned as I talked to Professor C.N.R. Rao more recently. He felt that a meeting at the national level and discussing the issues of mathematics and its promotion in the country would certainly be both timely and appropriate. And in this connection we had Professor Seshadri who visited the Institute a few months back, with Professor Sreekantan. Professor Seshadri said that we need to do something with respect to supporting mathematics. Professor Sreekantan and myself suggested, to hold a think-tank session at NIAS. NIAS could organize this, and we could get some of the best people who are practicing mathematicians who use mathematics for a variety of national endeavours. This could

include the Information Technology and any related areas as well. This suggestion was taken up very enthusiastically by Professor Seshadri. He contacted Prof. M.S. Narasimhan and Prof. M.S. Raghunathan and they together with Professor Sreekantan, conceptualised this workshop as a consequence of this background.

Mathematics, I don't have to emphasize, has been one of the prime areas of interest in this country from ancient times. Apart from the very ancient contributions traceable to the Vedas and subsequently some of the mathematicians who came from Kerala - more recently we had also mathematicians like Ramanujan in the twentieth century. The tradition has been maintained even recently and pure and applied mathematics certainly has been an active area in this country. What is significant and a turning point in the case of mathematics is that it is finding increasing applications in a number of areas, not only in physics and astronomy, the traditional areas where mathematics has been extensively used but also in the engineering sciences, life sciences, social sciences, economics etc. With the advent of computers we have a new dimension added to mathematics research, ideas and concepts. Thus we think that it is very appropriate that we review where we stand in India with regard to mathematics and how we fare with respect to what is happening elsewhere in the world.

The workshop, of course, would have served its purpose if we throw some light on some of the urgent issues. For example, I would like to mention here a few of them, on which we expect the workshop to come out with certain recommendations. These would include areas in higher mathematics in which the country has worldwide reputation and intrinsic strength in terms of research, areas that have been neglected, new areas of mathematics that need to be introduced in research institutes and universities, where facilities and opportunities are available for research, additional things we need do in terms of infrastructure and expansion; dimensions we want to bring in; the status regarding research in higher mathematics in the universities and IITs, special areas of mathematics that need to be brought in and the teaching curriculum. We have a very strong programme in strategic areas like the Department of Atomic Energy, the DRDO, Space, IT and Meteorology. There any specialised requirements in mathematics that we need to address in the educational system to support these areas of activity. What is the status of employment potential in mathematics; are there Ph.D's in maths who are unemployed? These are questions, some of which, I am sure, could be debated. Another issue is the current geographical distribution of the institutions and universities in higher mathematics and major imbalances that need to be looked into. What is the realistic number to which our strength should be increased during the Eleventh Plan? Can we put some kind of a target for the Eleventh Plan? What is the current level of funding for mathematics and what is the factor to which it should be increased as part of the Eleventh Plan? In the area of applications of mathematics and

use of computers for special purposes, what specific actions do we need to take in terms of education, creation of Centres, infrastructure, etc? What should be the involvement of the private sector, industrial houses, IT establishments, and so on? And lastly, are we having an adequate number of international conferences, inter-institutional activities, research, and so on? Do we need to do anything with respect to these areas in terms of financial support?

In conclusion, I would like to once again thank Professor C.N.R. Rao for his enthusiastic support of this entire idea and also being with us today morning, to inaugurate this important workshop. He has also promised that he will take up the recommendations emerging from this workshop with the government and the Prime Minister in his capacity as the Chairman of SAC to PM. I am sure that this will be a tremendous support for all of you in terms of furthering the actions that we identify in this workshop. I would like to specially say my thanks to Prof. Sreekantan who was the key person in this Institute to conceptualise and organize this workshop, and to Prof. Seshadri and Prof. Raghunathan. I am also happy that we have with us Prof. Narasimha, Prof. Rama Rao, and many others who made it a point to be here today because they have been always involved some form or other in not only using mathematics in their own field but also in the context of education.

I should also mention the support that the Infosys has given us. I talked to Narayana Murthy, in fact, he wanted to be here with us today morning, but for the fact that he had to be away in New York. He has apologized, but what is more important is that he would like to have a look at these recommendations and is very keen whether something could be done from their side at the Infosys. We have a representative of the Infosys here today with us participating in these deliberations. We also have representation from other IT companies too.

Dr Kakodkar supported us in terms of financial allocation and also ideas. We are happy that we have the participation of the Department of Atomic Energy, Indian Space Research Organization as well as the DRDO.

What is unique is as Professor Sreekantan mentioned, that we have attempted to bring together not only the mathematicians both pure and applied but also the users of mathematics in a variety of endeavours. I am sure this will make the workshop unique and give the necessary importance in terms of recommendations.

Opening Remarks: Professor M.S. Raghunathan

Professor C.N.R. Rao, Dr Kasturirangan, Dr Rama Rao, distinguished participants and friends, I am indeed happy to be here on this occasion. As you have learnt from Dr Kasturirangan, the initiative for this meeting did not really come from mathematicians. It came from Dr Kasturirangan and Professor Sreekantan with of course, Professor C.N.R. Rao in the background always promoting these activities. Having given us the opportunities it is now up to us mathematicians to do something about giving some concrete recommendations for the improvement of mathematics in the country. Perhaps I should say a few words about what the current state of mathematics is. I am probably kind of carrying coals to Newcastle in some sense, but nevertheless let me say a few words about the current state of mathematics.

Firstly, in practically every forum people lament the state of mathematics in the country. My own attitude sometimes is somewhat like that of the proverbial mother-in-law in the funny story. There is this beggar who goes to a house seeking alms and the woman comes out and chases him off. A little later an older woman comes, she calls him back, and he goes back very expectantly only to be told, "My daughter-in-law had no business to send you out. It is I who should throw you out." Probably I have that kind of attitude sometimes towards mathematics being discussed in other forums, but nevertheless, it's a fact that the situation is not a very happy one, but there are positives at the same time, I must say, which are probably not mentioned too often. Let me just give you a few examples to suggest that India has a good place in the world of mathematics, internationally, in some sense. We have this International Congress of Mathematicians, which happens once every four years and this is centred around a number of invited talks; there are some fifteen to twenty plenary talks and about a hundred and fifty invited talks in specific subjects in various areas of mathematics. From 1966 on, or 1970 on, at every Congress there has been at least one Indian giving a talk, except in 1986. So, out of about two hundred invitees, two hundred people invited to talk, there has always been at least one Indian in these Congresses. Actually the number two hundred is recent. In the old days it used to be close to 125 to 150 in those days, if you go back to the 1960s. Anyway, so that is an indication, that in some sense, in the peak, India is performing not too badly. There is enough work to make the international community sit up and take notice. That said, on the other hand, the general level of mathematics has been pretty bad, as you all know. For example, the Fields medal, which is given out at

these ICMs has so far eluded us and more importantly, if you look at the work of the Fields medallists, how many people in this country are familiar with the work of one of the several Fields medallists? In the last 50 years, there has been something like forty Fields medallists. How many of our mathematicians are familiar with the work of at least one Fields medallist, or in the general area, have done something interesting? If you look at that it's not a very good picture. In fact, there are not enough people to understand this kind of areas, except in some small pockets in a handful of Institutions. That is the problem. There are only a handful of institutions in the country where mathematics of a reasonably good quality is being done, in terms of research. That's the research picture in general.

On the other hand, the teaching picture is not particularly good either. In fact, it looks like the teaching in our universities and more importantly in the undergraduate institutions and colleges has deteriorated badly over the last fifty years. And the main reason for these things, it seems to me, is that not enough talented people are getting into mathematics, do not pursue mathematics at the undergraduate level, to say nothing of the higher levels. The Ph.D's produced are by and large of not very good quality except, again, in a handful of institutions in the country. One of the main reasons is that, as I said, talented youngsters are not studying mathematics, even though they may have the ability to pursue the subject if they would. It simply doesn't happen.

This is basically a socio-economic problem. Employment opportunities are not particularly good and not very attractive. In the recent past, other fields attract people because of excellent salaries and perks. Mathematics is not attractive economically. But, in the old days at least there was some respect accorded to the profession, which compensated to some extent. If you study mathematics your future doesn't look all that attractive to many people, which is probably why people are not taking to mathematics, in larger numbers. There is apparently plenty of talent. We have been running the Olympiad programme and we do find good students coming there. But at some point they stop going into mathematics and that is probably the reason why we do not have good input into the field. This is something to be discussed, and this is not peculiar to mathematics. I think, across the board, for all pure subjects, basic science subjects, the number of people getting into them is dwindling. If this has to come to an end, if this has to be improved, we need to improve the living conditions and the working conditions of people in the academic profession, especially in the teaching position. Something should be done about this across the board. This is something, which is common to all areas. Mathematics has suffered particularly badly, because in some other disciplines, people feel that there are other opportunities to get into. In mathematics, that has not been there. Of course, things are slowly opening up. Maybe in the next few years we will have many more opportunities for people to enter the industry,

finance and so on. Some people are already doing it. There will probably be more people. In any case these are matters for us to discuss in this workshop and to come up with some conclusions.

We have to discuss the nitty-gritties of what should be done to improve mathematics in the country. We will come up with something interesting and, worthwhile for the government to look into.

Professor P. Rama Rao

Professor Rao, Professor Kasturirangan, Professor Raghunathan, Professor Sreekantan and distinguished mathematicians, and ladies and gentleman, I am terribly conscious of the fact that I don't deserve to be here. The only explanation for my being here is that I could not say no to Professor Sreekantan and Dr Kasturirangan.

Let me make a very few observations. Firstly, from the perspective of funding, the viewpoint of funding, the nature of mathematics is very different. Any science funding, of course, naturally goes into building human resources. But in most of the fields, a substantial part of the grant is used up in setting up facilities. In the case of mathematics, it goes in a far more concentrated fashion to building human resources not only in the universities but also in schools and so on and so forth. Broadly speaking, a substantial part of science funding is consumed by the national laboratories. If you look at mathematics we don't have such national laboratories, may be Institute of Mathematical Sciences, may be TIFR to some extent, a few institutes here and there. I don't know where to place ISI.

A large part of human resources in the area of mathematics resides in the universities, in the academic system. So, whatever funding we do, whatever investment we make goes again far more directly into academic R&D. I am very fond of data and I have a plot, which shows the relationship between investment in academic R&D and per capita income of countries. For instance, until recently, this country invested just about 3 or 3.5% or so in academic R&D, 3.5% of total R&D funding. The United States is about 20%. You can see the relationship. All these correlations are pseudo correlations, I confess. But there is a point there. If we invest more and more in mathematics, I believe it will contribute more directly to the prosperity of this country, any country.

In this backdrop, let us look at the level of funding. We have the National Board of Higher

Mathematics, just about 50 or 60 crores during the entire plan period. And during the time that I was associated with the Department of Science and Technology, one of the good things we were able to accomplish was we created a new Programme Advisory Committee for Mathematics, in 1993 and I requested Professor Kalyan Sinha to be the first Chairman. He is a pioneer in one sense and in fact, one of the initial large grants went to northeast in one of the Centres in Assam. But I checked on the figures in the present Plan, that Programme Advisory Committee has spent less than fifty crores. That programme, over a five-year period has spent less than fifty crores. I am not saying money alone is important but money is an input. It is only a question of our coming up with meaningful proposals that Professor Raghunathan mentioned. We can think of many things which will support individual - large number of fellowships, post-doctoral fellowships, visiting scholars, international scholars, all that Dr Kasturirangan detailed, and all of that money can go to building people. We have a great prospect. This prospect has to be realised. This meeting is a great initiative and we are lucky to have Professor Rao and Dr Kasturirangan here and with their support I am sure things will go forward.

Inaugural Address: Professor C.N.R. Rao

Dr Kasturirangan, Prof. Rama Rao, Dr Raghunathan, Dr Sreekantan and friends, I guess Rama Rao had more reason to be here than myself. I guess my research is far removed from mathematics, though at one time I used to guide, many students in theoretical chemistry and so on. Nowadays I don't. I have become more and more an experimentalist, getting far away from theory. In fact, India is extremely short of talented experimentalists. If you are in trouble in mathematics, you must come to experimental science. They are going to bury experimental science in the next five years.

I was intrigued with the title of this workshop - Perspectives and Future Prospects in Higher Mathematics. What is higher mathematics? Just mathematics. We don't have higher physics or higher chemistry. Just do mathematics. Don't worry about higher. Always do good mathematics, not higher mathematics.

What has happened to mathematics is really something sad, because in my undergraduate days in Bangalore - people like B.S. Madhava Rao, N. Srinivasa Iyengar and Venkatachala Iyengar - they all taught me mathematics in my undergraduate classes. They were outstanding teachers. Amazingly, the mathematics background of an undergraduate with a B.Sc. Honours or B.Sc. in my days was fairly good. In fact, I could use mathematics enough to do all kinds of things even during my Ph.D. in the United States. I still use it. But what has happened is that *that* basic knowledge of mathematics in an average undergraduate student's eyes - has come down. I have been guiding students for the last forty-five years - and getting Ph.D. students in India. The Ph.D. students I get now, even in physics have poorer mathematics background than say, ten or fifteen years ago. I don't know why.

Don't be enamoured with all Information Technology, computers and so on. Please pardon me. It has done a big damage to us. Too much of the use of Internet has destroyed scholarship. There is a big problem appearing in the United States. I was giving a course in University of California. You ask for a term paper in the class. They all print down everything from the Internet and bring you the material. They don't write a word. I said, "Look here. This is a term paper. You are going to write it. I am not going to accept what you download from Internet". Scholarship has been destroyed. Nobody reads. If I ask a student, "Have you read that paper in the Journal of the American Chemical Society or Physical Review?" he says, "No, I have downloaded it." Downloading is equivalent to having read it.

The same thing has happened to mathematics. I have studied diffraction, spectroscopy, theoretical chemistry during my Ph.D. days. If I ever had to do a Fourier transform, I take a diffraction pattern or some image, and do a Fourier transform of that. I knew what that transform, what that equation was. Today my computers, my instruments in my lab, my students know more crystallography than I ever did. They don't know what a Fourier transform is. The machine does it. So there is a peculiar effect we are facing. We need to teach mathematics, more than before. Because computers are interfering with the non-use of mathematics. Before, that was not true. That is only an incidental observation. Not a serious one but something we should not forget.

The knowledge of physics and chemistry for students in mathematics has been really coming down. And what about biologists? How come biology does not require mathematics in India? Of course, medical people don't need any mathematics. After high school they never read mathematics. If you are a medical doctor in India, after high school you never look at mathematics. At least they should know how to count the income they have. But they don't know even arithmetic properly.

I was looking at the performance of the United States in science and mathematics. There is a very good analysis written by an excellent group of people in the United States of how US performance in basic science and mathematics itself is going down compared to some other places. Of course, China and Asia are coming up in many ways. But Asian contribution is not due to India. It is due to mainly other countries like South Korea, China, Japan, Taiwan, and so on. What surprised me is by and large, it looks like the western world will have slow decrease in their contribution to science in the next fifteen to twenty years. I predict America will be second rate in science and mathematics compared to today. Of course they will import people from India. But their own native abilities come down. It also looks like, this analysis says, this is because of the increasing age of the American population. The Americans are getting old. So are the Europeans. The average age of the Europeans and Americans will be sixty or seventy in the next twenty years. But in India, between twenty-five and thirty-five is the average age. India is a very young country and will be the biggest supplier of talent to the world from what I expect. I feel the role of India is not just to do science, but to produce science for the world. Produce thousands of scientists and mathematicians. Doesn't matter, they can go to America, Timbuctoo, wherever, it doesn't matter, because we will produce so many. We should become the knowledge centre of the world as such. Not only sending teachers and nurses, which we are doing now. Not the labour in the Middle East, but scientists, engineers, mathematicians going from India. Doesn't matter. Let them go. After all we can't keep them or give them jobs here anyway. We need a small but finite percentage of brilliant people to stay in India. That's all. But that is also not happening. For that, as Raghunathan said, we have to improve

opportunities for employment. We are going to do that.

We are going to set up a National Science Foundation. Professor Roddam Narasimha is also part of this. We have done the planning. And I hope it will go to the Parliament in the next session. It is going to be called the National Science and Engineering Research Foundation. We don't have to repeat the NSR, the same name. We will call it NSERF. If that gets established in the next Parliament, the budget is going to be 5,000 crores for the next five years. Money is not going to be the limiting factor. What they should have is a Directorate of Mathematics in that. Make sure when it is established, such things happen. That Directorate of Mathematics is not like the National Board. They will be continuously monitoring what our lacuna is, what our weaknesses and sins are, what Centres should be created, which individuals need support etc. They well look for problem areas and do something. That is their role. In fact, right now we don't have such an agency. Hundred percent of the time we have to worry about science and research in India. We have no organisation for this.

Imagine, why is it that China has made a change? This analysis brings out that establishment of the National Science Foundation in China has made the biggest difference in China. It is not just the money. There are people worrying about each subject continuously on a day-to-day basis. Therefore, please contribute to that. Please contribute to what we should do in mathematics. Not once in a while when, NIAS organises meetings, but regularly. And if you do that, I hope money will be available.

We just don't work hard enough in India. And that is why India is second rate. Even mathematicians, I think, have to work hard. In fact I just completed reading the latest biography of Hans Bethe. You must all read it. It is one of the finest books I have ever read. He was that great man. He died in the year '99, I think. What an outstanding person he was! He was a man of sharp intellect. He always said, "I am not going to revolutionise physics or theory. I am not that type of a theorist like Heisenberg or Schrödinger or Pauli or someone. I am a different kind of theoretician. When given a problem I will solve that problem by actually calculating and giving a number and saying what that is. I will explain what it is. In fact, he has calculated his famous Lamb shift while travelling between Schenectady and Washington D.C. on a train. That is what got him the Nobel prize. Till the age of ninety-something he was working very hard throughout the day. He was a theoretician. He would work morning after breakfast, work continuously throughout the day in Caltech. When I was a young student in America, Erdos a Hungarian mathematician, used to come. I even talked to him once. People would follow him all over the place. He never had a student of his own. Apparently he wrote I don't know whatever papers. I don't know much about his mathematics. But he was very popular wherever he went. Whenever he came to Berkeley I used to see him, or at Purdue University or Illinois. He was a great mathematician

who attracted people, young people working with him. Why can't we have such people in India? I don't see why not. People go around and there are young people following them, they all want to do mathematics and want to solve a problem. Erdos apparently collaborated with everybody on earth but never had a student of his own. That's what I was told. I don't know if it's true. I am even told he wrote a 1000 papers but people don't think much of 1000 papers. I am one of those who does that. They look down upon it. I am just mentioning this because I think India has stopped working, at least in science. The low performance of India contributes directly to the low performance of individuals and of institutions like the Indian Institute of Science, IITs, including TIFR. The amount of production is terrible. Indian Institute of Science with 400 faculty produces 140 Ph.D's. It is a ridiculous number. IIT Kanpur last year produced 51 Ph.D's with 320 faculty. We have to produce more Ph.D. students. Just produce Ph.D's. Do publish your papers. Don't worry about what happens to those papers. I am told this is a disease in our Institute also in Bangalore, - worrying about index, H index, M index, R index, all kinds of impact. Don't worry, just publish. Forget about it. Your index gets recorded somewhere. And mathematics, of course, has to contribute. But then it is much easier, as he said, since you don't have to have big laboratories.

I hope this meeting when it looks at the future, will come out with just a paragraph of five or four simple recommendations, which can be executed. Don't say, "Improve the quality of mathematics". That is not a recommendation. Or, "Produce more students." That is not a recommendation. Please tell us what type of institutions you want, what you would like to create. I am sure people like Narasimha, Rama Rao, Kasturirangan, all of us, we will work together to see that it happens. There is no question. And I hope the new National Science Foundation Board will do it. I really hope for the sake of this country, that science does very well in the future, particularly mathematics, where there is a good possibility. As Raghunathan said, why is it that the Fields medal eludes us? Now there is another equivalent to the Nobel prize, as you know, the Abel prize. It is equivalent to a million dollar prize in mathematics. Why not some Abel prizes for India?

I hope the future is bright and you will come with such recommendations as would allow us to become top notch in mathematics, if not in all of science.

Objectives

Mathematics has been one of the prime areas of interest in India from ancient times. Apart from the ancient contributions traceable to the Vedas, the contributions of the Kerala mathematicians and most importantly of Ramanujan in the early part of the 20th century is familiar to most Indians. This tradition has been maintained in recent times too. India has produced several very distinguished mathematicians especially since independence whose contributions have been recognized the world over. However, the proportion of such mathematicians is much too small and a concerted effort needs to be made at the national level to create a large pool of mathematicians working at the cutting edge of research in mathematics, statistics, computing science and branches of applications of mathematics. The Indian mathematicians are particularly well known for their contributions in the fields of Lie groups, probability, and number theory. These areas of mathematics are finding particular relevance in several areas of natural sciences in recent years. In fact mathematics is now pervading fields like engineering sciences, life sciences, and social sciences in addition to areas like astronomy and physics. The advent of computers has enlarged the applications of mathematics to a much greater extent than envisaged earlier. Mathematics has become relevant and necessary for strategic areas like atomic energy, space, defence and also in communication, weather forecasting and in the IT industry.

However, the number of young talented students going for a career in research and teaching has come down drastically because of more attractive and lucrative salaries offered in other jobs in India and abroad. The most immediate need is to rectify this problem by evolving new career opportunities with more conducive ambience and more attractive emoluments for those trained in advanced mathematics.

In the light of these developments and to look at the future in India, **a two-day Workshop on "Perspectives and Future Prospects in Higher Mathematics"** was held at the **National Institute of Advanced Studies, Bangalore on 25–26 October 2006.** The workshop has come out with specific recommendations on an action plan for ensuring a rapid enhancement of the quantity and the quality of mathematical research and education in the country. **Sixty mathematicians and a few scientists** from various institutions, universities, IIT's, and user agencies (DAE, ISRO, DRDL, IT) participated in the workshop. Panel discussions were held under the following broad heads.

(i) Research and Development in pure Mathematics

(ii) Applied Mathematics (Research, Training and Applications)
(iii) Higher Education in Mathematics
(iv) Computer Science and Mathematics
(v) Mathematical Requirements of user agencies.

Unlike in most areas of experimental scientific research, the character of mathematical education and research is such that no very major facilities and sophisticated infrastructure are needed. Also continuing expenditure is comparatively low.

The programme of the Workshop is given in **Annexure 1** and the List of Participants and their affiliation in **Annexure 2.**

Recommendations

The workshop came up with the following specific recommendations:

NEW INSTITUTIONS TO BE CREATED

(1) INRIA (National Institute for Computing and Information Sciences) created in France to serve as a catalyst for promoting applications of mathematics, and facilitating interaction with users, has groups of mathematicians as well as engineers who serve as consultants to industry and to government agencies. **An analogous institution is needed in India.**

(2) **An institute for training mathematicians** in the areas of particular requirement by the strategic departments like DAE, ISRO, DRDL, and also for Departments of Meteorology, Communications, IT etc. should be set up. This institute will serve as interface between hardcore educational system for mathematics and the user agencies.

(3) A centre to be set up on **Computational Mathematics** – dealing with cryptography, coding theory, computational number theory, fluid dynamics, mathematical finance, mathematical biology and economics.

(4) **An institute like (ICTP)** International Centre for Theoretical Physics at Trieste which also encourages interaction between mathematicians, physicists and scientists and engineers from various disciplines should be set up.

(5) One or two Inter **University Centres in Mathematics** on the lines of IUCAA (Inter University Centre for Astronomy and Astrophysics) in Poona and Nuclear Science Centre, New Delhi should be set up for training of teachers and researchers for a period of 2 years.

CONFERENCE CENTRES

(6) **Two conference centers** with all the infrastructure facilities on the lines of Oberwolfach in Germany, where National and International conferences could be held round the year, should be set up. There should be a separate funding arrangement for graduate students to attend national and international conferences.

FELLOWSHIPS, AWARDS, GRANTS

(7) **National Fellowships** – to begin with 100 which can go to 500 gradually, with an allocation of Rs. 5 lakh/yr for each fellowship should be instituted to encourage pursuit of research in mathematics which can be availed of by faculty members in the universities, IIT's and other centres. While part of this fellowship can be utilized as honorarium in addition to the salary, bulk of it will be for attending national and international workshops, conferences, purchase of PC's and books, contingency expenses, hiring of project assistants and associates and also towards inviting visitors from within the country and abroad. Apart from the honorarium, the remaining amount should be given under a single head (like the existing DST Raja Ramanna Fellowship) so that the fellow has complete freedom towards the utilization of the fellowship amount without any bureaucratic hurdles. While the fellowship duration can be five years, there should be a review after 3 years. The fellowship would be renewable subject to satisfactory performance.

(8) **Existing research centres and university departments** which have proved successful in Research and Training should be provided further financial support for improvement of infrastructure facilities and construction of additional guest houses where researchers, teachers and students from other smaller centers and universities, can be accommodated for periods of weeks, months or even for a sabbatical year. Those institutions that have a component of undergraduate training in mathematics in addition to research, need to be strongly supported since they constitute the core centers where young talent can be identified and nurtured. There is need for more institutions of this type in the country.

(9) **About 60 colleges that have created good teaching programmes of high**

repute may be recognized by a grant of 25-40 Lakhs per annum for the mathematics departments. This could be used for developing libraries, computing labs, scholarships etc.

(10) **About 100 leadership awards** may be given annually to college teachers for dedicated and innovative mathematics teaching.

(11) About 1000 college **mathematics teachers** may be provided grants of Rs. 50,000 to 100,000 per year for 3 years at a time. These may be used by them for purchase of books and computing equipment, travel to conferences etc. The grants may be renewed subject to continued good performance.

EMPLOYNMENT OPPORTUNITIES FOR MATHEMATICIANS

(12) There should be increased employment opportunities for Ph.D's in mathematics in addition to those in colleges, universities and research institutions. Agencies like DAE, ISRO, DRDO, IT institutes should make special efforts to open up career opportunities for qualified mathematicians.

(13) General but Important Recommendations:

- Curriculum improvement in mathematics should be entrusted to a central body.
- Pre-PhD mathematics courses must be made compulsory in all universities.
- Good text books should be made available in regional languages at the school level.
- Effective innovative use must be made of satellite TV education especially digital libraries through the creation of specific centres where necessary facilities are made available.
- Special workshops should be organized for students who will be attending national, international conferences.

(14) Allocation to NBHM (National Board for Higher Mathematics) and DST's PAC on Mathematics should be enhanced at least 8 fold, as the present expenditure during the whole 5-year plan period is only about Rs. 40 Crore. In the likely event that the new Autonomous Foundation with an annual allocation of Rs. 1000 Crores, as suggested by SAC-PM, comes into being, a **Directorate dedicated to Mathematics** should be set up as an arm of the Foundation. This apex body could then take up implementation of some of the recommendations made here.

(15) The estimated budget projections for the various programmes are as follows:

Sl. No.	Programme	One Time	Annual
1	Institute similar to INRIA (National Institute for Computing and Information Sciences)	2 Cr/yr (2 yr) = 4 Cr	40 Lakhs/yr
2	Institute for Training Mathematics for User Agencies	5 Cr (2 yr) = 10 Cr	1 Cr/yr
3	Institute for Computational Mathematics	2 Cr /yr = 4 Cr	40 Lakhs/yr
4	Institute like ICTP	3 Cr (2 yr) = 6 Cr	50 Lakhs /yr
5	Institute similar to ICUAA (TWO)	1 Cr (1 yr) = 2 Cr	40 Lakhs /yr
6	Conference Center (TWO)	10 Cr	-
7	National Fellowships (100 fellowship - 5 Lakhs/yr)	5 Cr	5 Cr/yr
8	Existing Research Centre in the Universities/upgradation	25 Cr	2 Cr/ yr
9	Grants for good Teaching Departments	24 Cr	24 Cr/yr
10	Leadership Award	2 Cr	2 Cr/yr
11	Grants to Math Teachers	10 Cr	1 Cr/yr
	Total	**~100 Cr**	**~40 Cr /Yr**

Annexure - 1

Programme

WEDNESDAY, 25 OCTOBER 2006

09.30 a.m. - 10.00 a.m. **Welcome Address** **Remarks by** **Inauguration by**	 **K Kasturirangan,** Director, National Institute of Advanced Studies, Bangalore **M S Raghunathan,** TIFR, Mumbai and **P Rama Rao,** BRNS, Mumbai and Former Secretary, DST **C N R Rao,** JNCASR, Bangalore
10.00 a.m. - 10.15 a.m.	**HIGH TEA**
10.15 a.m. - 11.45 a.m. *Convener/Rapporteur:* **Prof. Nitin Nitsure** *TIFR, Mumbai*	**Panel 1: Research and Development in Pure Mathematics** **R Balasubramanian,** IMSc., Chennai **S G Dani, TIFR,** Mumbai **G Misra, ISI,** Bangalore **I B S Passi,** Harish-Chandra Research Institute, Allahabad **V Srinivas,** TIFR, Mumbai
11.45 a.m. - 01.15 p.m. *Convener/Rapporteur:* **Prof. G. Rangarajan** *IISc, Bangalore*	**Panel 2: Applied Mathematics (Research, Training, Application)** **Roddam Narasimha,** JNCASR, Bangalore **Prabhakar G Vaidya,** NIAS, Bangalore **Phoolan Prasad,** IISc, Bangalore **S Ranganathan,** IISc, Bangalore **Anurag Kumar,** IISc, Bangalore
01.15 p.m. - 02.15 p.m.	**LUNCH**
02.15 p.m. - 03.45 p.m. *Convener/Rapporteur:* **Prof. Rajat Tandon** *Univ. of Hyderabad, Hyderabad*	**Panel 3: Higher Education in Mathematics** **H P Dikshit,** IIITM, Jabalpur **S Kumaresan,** Univ. of Mumbai, Mumbai **Shobha Madan,** IIT Kanpur, Kanpur **Alladi Sitaram,** ISI, Bangalore
03.45 p.m. - 04.00 p.m.	**TEA**
04.00 p.m. - 05.30 p.m. *Convener/Rapporteur:* **Prof. Madhavan Mukund** *CMI, Chennai*	**Panel 4: Computers and Mathematics** **Madhavan Mukund,** CMI, Chennai **V Arvind,** IMSc., Chennai **V Vinay,** PicoPeta Simputers Pvt. Ltd., Bangalore **Satya V Lokam,** Microsoft, Bangalore
05.30 p.m.	**TEA**

THURSDAY, 26 OCTOBER 2006

09.30 a.m. - 11.00 a.m. *Convener/Rapporteur:* **Prof. Rajeeva Karandikar** *Cranes Software International Ltd., Bangalore*	**Panel 5: Requirements of User Agencies** **Rajeeva Karandikar,** Cranes Software Intl. Ltd., Bangalore **V Adimurthy,** VSSC, Trivandrum **Guruprasad Athani,** INFOSYS, Bangalore **B K Dutta,** BARC, Mumbai **S D Paranjape,** BARC, Mumbai **Debasis Chakraborty,** DRDO, Hyderabad
11.00 a.m. - 11.15 a.m.	**TEA**
11.15 a.m. - 12.00 noon	**GENERAL DISCUSSION**
12.00 noon onwards	**Drafting Committee Meeting** SUMMARY SESSION Presentation by Rapporteurs of the Panels DRAFTING COMMITTEE **M S Narasimhan,** TIFR, Bangalore **Rajendra Bhatia,** ISI, Delhi **M S Raghunathan,** TIFR, Mumbai **P Rama Rao,** Former Secretary, DST **C S Seshadri,** CMI, Chennai **V Adimurthy,** VSSC, Trivandrum
01.00 p.m.	**LUNCH**
02.00 p.m. onwards	**Drafting Committee Meeting Continues**
03.00 p.m.	**TEA**

Annexure - 2

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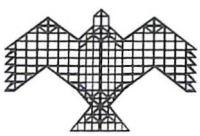
The National Institute of Advanced Studies was conceived and started by the late Shri J. R. D. Tata. Shri Tata was desirous of starting an Institute which would not only conduct high quality research in interdisciplinary areas but also serve as a medium which would bring together administrators in government and private sector with members of the academic community. He believed that such an interaction could be of great help to executives in their decision making capabilities.

NIAS is situated in the picturesque Indian Institute of Science Campus in Bangalore. Its faculty is drawn from different fields representing various disciplines in the natural and social sciences. The institute carries out interdisciplinary research and is unique in its integrated approach to the study of the interfaces between science and technology and societal issues.

Dr. M. S. Swaminathan is the Chairman of the Council of Management of the Institute. Dr. Raja Ramanna was the Director since its inception till his retirement on July 31, 1997. Prof. R. Narasimha was the Director from 1997 to March 2004. Dr. K. Kasturirangan, (Member of Parliament, Rajya Sabha), Former Chairman, ISRO, is currently the Director of the Institute.



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