

# Workshop

on

**High Performance Computing & Scientific Applications**

*- Future Trends*

*(Indo-US Science and Technology Forum)*

**December 20, 2002**

## Coordinators

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*INDIA*

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*USA*



## **C-DAC Knowledge Park**

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## Summary

During the workshop, the experts discussed many aspects of high performance computing and the associated issues. It was agreed that Indo-US Science and Technology Forum can provide appropriate opportunities for research scientists to work together and initiate collaborations on topics of mutual relevance. The expertise exists in both the countries. Three major disciplines were identified as the thrust areas of research for such collaborations viz. Weather / Climate Modeling, Bioinformatics and beyond (System Biology) and research associated with Peta flops computing. CDAC will act as the primary institution from the India side. It will also work closely with its US counterparts as well as the organizations within India. After initiating preliminary discussion and formulating the concept proposal, CDAC will approach the forum for its consideration and funding. The interactions may also consider some mega projects as well.

It was also recommended that after the interactions have come to certain levels and more intense discussions were required, the exchange visits between both the countries for project students and faculty will be encouraged. It will provide timely support and intellectual input to the continuing research work and accelerate the process. It was discussed, at length, and agreed that the project managers will be empowered with more flexibility and resources to initiate and continue the projects.

High Performance Computing was considered as one of the strategic resources and its fruitful utilization for scientific research, particularly, the identified areas were unanimously endorsed by all the experts and participants.

## Foreword

The last few years have witnessed a sea-change in the scenario of High Performance Computing technology, specifically related to software developments the world over. The scientific research community is immensely benefited by such activities, as it is strongly linked to socio- economic growth of the region. The rules of the game are changing rapidly; typically, shrinking geographical boundaries, reduce product life, cost structure and business models, commoditization, etc. Such changes, however, do not endorse the famous quotation that *complexities and speed do not mix*. While dealing with high performance computing, the scientists are able to utilize the technologies and conduct significant research at almost the same pace. The prerequisite being the interactions between the scientists, developers and users. The international conferences, workshops and publications of journals provide the apt opportunities.

The sixth international conference / exhibition on High Performance Computing in Asia Pacific Region was held during December 16-19,2002 at Bangalore. Many researchers from Academia, R&D Organisations and industries participated and discuss computing strategies as well as multidisciplinary applications. CDAC also demonstrate its latest product PARAM Padma, a one teraflop computing system during December 2002 at Bangalore. It was the occasion when US scientists could be invited to India for participating in the workshop on *High Performance Computing and Scientific Applications- Future Trends*. The technological advancements by US scientists and discussing with their India counterparts would have the desired impact on the scientific research. The Indo-US Science and Technology Forum was contacted and it readily agreed to support the event leading to a wonderful experience for everyone attended.

About eleven scientists participated from US while 50 attended from India. A few more US scientists attended the workshop who were visiting India at that time or attended HPC Asia 2002. The workshop was held at CDAC Knowledge Park, Centre for Development of Advanced Computing, Bangalore. The objective was to review the current status in HPC and the applications. The emphasis was more on discussing the technology and explore the possibility of working together. Many suggestions were received and a few of them were recommended for implementation as the initial step. Immediately after organizing HPC Asia 2002, the workshop provided an excellent opportunity for considering the collaborative efforts in a more meaningful way. Demonstration of PARAM Padma capabilities and weighing the resources for innovative research during the workshop at Knowledge park gave added impetus to starting new research areas.

During the workshop, there were many presentations including the forthcoming trends and the challenges. The advantages and pitfalls of various methods were discussed. The workshop was effectively conducted by Prof.L.M.Patnaik and many interesting observations were made. He set the trend for very focused presentations and desired to arrive at the specific conclusions for selected scientific disciplines about the future collaborative activities between India and US scientists. The participants included leading experts, postdoctoral fellows, and graduate students from various places from India and they interacted very closely with US experts. We thank the speakers and participants for making the workshop fruitful and exciting.

The workshop was made possible by the generous support from the Indo-US Science and Technology Forum. Dr.Y.P.Kumar and Dr.A.Mitra encouraged us at all the stages. We thank them for their timely action and support. Mr.R.K.Arora, Centre for Development of Advanced Computing and Dr.R.N.Madan, Office of Naval Research,USA provided the encouragements for organizing the workshop and suggested many ways to improve its outcome. Dr.J.Venkatratnam interacted with all the US experts and made their participation more meaningful. My colleagues at CDAC Bangalore arranged for the venue and demonstration of PARAM Padma to the workshop participants. Our thanks all of them.

Sharad Purohit , India  
S.Sitharama Iyengar , USA

**Workshop**  
**on**  
**High Performance Computing and Scientific Applications - *Future Trends***

**Presentations/ Discussions**

*The workshop was coordinated by Prof. Sitharam S. Iyengar from US side and Dr. S.C Purohit from India. The workshop was inaugurated by Dr. Y. P. Kumar, Adviser, Department of Science and Technology, Government of India. Dr. Purohit welcomes Dr. Y.P. Kumar for the workshop and requests him to share his views.*

**Dr. Y. P. Kumar**

*(Department of Science and Technology, Government of India)*

First of all, on behalf of Indo-US forum and Department of Science & Technology, I welcome the participants from US and India. Thanks to the organizers and the people behind this workshop who have taken the trouble in organizing this event. High Performance Computing is the area of specific importance, which has received nation level attention in India for strong economic growth. There is a need to access computing resources to tackle the interest of large number of engineering researchers and institutions countrywide. When we talk about issue like weather, climate change, natural disaster, we cut across boundaries of the nation, even continents. Predictions for climate and weather in India could not be made accurate without taking into account data from the, possibly, entire globe. Increasingly necessary, the processing of the data is in demand to the computing industry for a faster machine with a capability of larger and larger data analysis. It is the revolution in the field of IT, which has made it possible to handle higher and higher volume of information. The necessity to exchange information is the ultimate quest for science.

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***Editors Note:** These proceedings are prepared from the Video recording during the workshop. The contents have been slightly edited for the continuity of the text.*

Researchers in India and US have been constantly in touch. It is quite clear that the larger foreign participants have come from US. Today, the Indo-US workshop on High Performance Computing has been organized under the Indo US S & T forum. It is expected that the status of cooperation between our two countries will be discussed.

Indo-US forum was established in March 2002 in India and USA during the visit of the President of United States – Mr. Bill Clinton to India. This forum is an autonomous scientific society registered in India and its core funding is shared by Government of India and United States. The forum has 14 members governing body, 7 from each side. The forum has its registered office at Full Bright House, New Delhi and the other members of the forum, from the India side are the Secretary – DST, Secretary – DBT, DIT, DISR, Dr P. N. Tandon, and Prof. G. Mehta, Director, IISc, Bangalore. Indo-US forum currently supports joint workshops and symposia in India and US, in the emerging areas of science and technology. The Forum conducts symposia in India and US, distinguished lecture series, specialized establishment of center of excellence and networking such centers, promotes joint R & D projects of mutual interests and identifies and initiates mega projects linked with social benefits. The forum is also creating database on various aspects of science and technology. R & D thrust areas of cooperation identified by this forum are energy system, nuclear energy sources that improve bio-energy, Nano-technology including nano computing, nano fabrication, nano materials, quantum computing, bio-computing, molecule computing, climate modeling and global change with emphasis on importance of forecasting and ocean / weather system and the disasters management. The other areas are including developmental neuro biology and computational neuro sciences, diagnostics medical tools including telemedicine, health and Pharmaceutical, Human and plant genomics including bio-informatics, universal digital library, distance learning, communication connectivity for remote areas, the information technology and the security. These are some of the areas, which have been identified and approved by the governing body, but it does welcome any other areas as well, which can be further proposed and approved. We have already supported workshops in the areas of emerging science and technology issues like nano technology workshop at Barberra last year. Nano-computing workshop held at Punjab and brain search workshop, which was held at New Delhi, climate change modeling at New Delhi. The round table was organized with eminent scientists. In the near future, the forum is considering to have joint workshops.

Forum has received joint projects in the areas of Weather and Climate modeling, distributed power system, nano-technologies. I sincerely hope that by the end of this workshop, scientists will certainly come out with some joint projects and this can be considered as a support under the forum. Wherever any clarification is needed as to how to submit, how much time it will take for processing and what will be the processing method, I will be too glad to offer the information. It is our sincere desire, because this workshop had a very unique feature that the major part of interaction is over because for the last four days period during HPC Asia 2002, where the capabilities of each other and what we can do is already discussed. Today the time is very short. If we can spend most of the time in finding where is the compatibility, what we can do and where we can have the complimentary situation and, finally, whether the projects can be worked out, it will be nice. As I just told that the forum can support projects and also the mega projects, where groups of scientists can come together and propose to attempt the problems of mutual interest. For such proposals the funding can come from the forum and also we can supplement funding from other sources

I thank the organizer, particularly, C-DAC, the Executive Director – Shri R. K. Arora and the ACS Chairman, Prof. L.M. Patnaik for inviting me to be the chair of this session today. I welcome all the Indian and US Scientists once again who have spared their valuable time for participation in this workshop. I am sure today's discussions will result multiple benefits by way of our contributing joint program either directly or under the Indo –US Forum. I have a great pleasure to inaugurate the Indo-US workshop on “**High Performance Computing and Scientific Applications – Future trends**” and wish the event to be a great success.

*Dr. Purohit thanked Dr. Y. P. Kumar for sharing his valuable views and said that the primary and major objective of this workshop has been to strengthen the interaction between the scientists and experts from India and USA.*

*Dr. Purohit welcomed Dr. Rabinder N. Madan, Office of Naval Research, USA, and requested him to share his views on how this collaboration can be strengthen between the two countries.*

**Dr. Rabinder N Madan**

*(Office of Naval Research, USA)*

What is it that you are looking forward to? You are establishing a cooperative program and, I presume, both sides should walk away with something. Whether the collaboration is funded, refunded or just carried out.

Let me talk a little bit on this High Performance Computing. I got into computing seriously in my life since early 60's from Delhi University, came to Springton, completed PhD in Physics and worked on high energy problems, and specially tried working on three body problem. When you work on these problems and after you have conceived it, you land up either into a differential equation or a very typical intego-differential equation. But as you know, in quantum mechanics, only two equations can be solved by hand. One is the harmonic oscillator and the other is on potential. Everything else, after it is on approximation, has to be done on a computer. I have never handled a computer. After I wrote down all the equations which involved about 60 integrals and 2<sup>nd</sup> order differential equations, I showed it to my professor and I said that I can only solve it when the 1<sup>st</sup> zero is the only approximation, which is right now, calculated by hand. He said you have to do it with the computer. My computer was IBM 7090. That time, to solve any problem you had to punch the card. To solve the first equation of the problem it took me 11 hours to just punch the cards. Then, I went to the computer in the evening at about 6:00 P.M. They said that you are in a queue and your card will be put in at 12 P.M. You will get in at 8:A.M. in the morning but they didn't realize what the complexity of the problem was. Then they put my card in and they came out at 8 P.M. on the next day and that was the 1<sup>st</sup> equation. The result of the first equation was brought on the huge set of sheet and then I had to re-programme it for the second set that became input for the second equation. As I submitted, it took another, perhaps, 12 hours to compute. I repeated the exercise for few times and we realized that the convergence would take place after five iterations. My advisors said that it is out of question. Either you have to go and attack a new problem or you have to go to the computer that can do a better job. He got a visiting professorship at the University of California, Santa Barberra that was just establishing its physics department. When I was working on this problem, as he got to Santa Barberra, he found out that there was a person who was actually developing a supercomputing in those days. Its memory was about 2 MB and it

had no cache. My professor said, it is atleast twice as much fast as you have at springton but there was still small and it was no advantage in this supercomputer to solve your problem.

He was working on an experiment where all the electronics oscilloscope are hooked on to the computer and you can see the results and you can programme it sitting on the keyboard looking at the electronics oscilloscope. I was asked to come to Santa Barberra and try solving the problem. Finally, I did solve the problem and the fine part of that history was that, after the problem was solved on the computer, it was a sort of prediction on personal computer.

Recently, they have honored me, a few months ago, for the work that I have done and one of the citations, at the end of it, was that I was responsible for bringing in billions of dollars to University of California, Santa Barberra, for the work I did. Once I did that work in Santa Barbera that was used by Professor to apply for NSF grants to further extend on that computer. In those days, you see, the question of work on a super computer was very different. A Pentium II at that time would have been a real super computer to solve that specific problem. But now, of course, you know, super computer is a different thing. Dr. Hari Dass is there in the audience, while this conference was being organized, I came and talked to Dr. Hari Dass. At the time I got there, the University of California was just establishing its Department of Physics. They were trying to invite distinguished professors from Springston and from here and there and visiting professors and giving appointment to some of them. At that time, they had hired Prof. Bob Sheuger, Jim hardel. Haridass was one of the first Ph.D students who came to Santa Barberra. I can tell you something about Haridass. I contacted Jim Hardel who came over to me and said that I just gave them a set of problem in electromagnetic and a very original problem. I can tell you something about Haridass. If Haridass is of grade 90, the next students were of grade 60. There was such a difference between Haridass and rest of the students. Within a very short time Haridass finished his Ph. D, probably within 3 years and he wrote his thesis. Now this department of physics in Santa Braberra have achieved International prominence they have a Institute for Theoretical Physics which is funded by NSF, which is considered equivalent to the Institute for Advanced Studies. Dr. Haridass at the moment, is working on connecting 128 PCs together at Madras.

Now, coming to some administrative issues while we were discussing during the dinner last night. We thought of a workshop like this earlier also and what is it that you are looking forward to co-operative program. We should keep in mind that both sides should walk away with something. So you want to look at the research areas. There are some strength in India and some strength in United States and I know both of them will get something from each other. Finally, I want all of you to give a little bit of thought after you have given a sense of virtue and so here are some of my thoughts. If possible, I would like you to comment on what ever you are working, do have a collaborations continuing. Most of us cannot work , in isolation, in any advance field. You are in contact with people working in your field. You may also like to contact the funding agencies for such collaborations. I feel Indo-US Forum can be contacted for this purpose. I look forward to work for new technological initiatives through this forum.

**Prof L. M. Patnaik**

*(Indian Institute of Science, India)*

I would like to thank Mr. Arora and Dr. Purohit for hosting this workshop here at C-DAC, Bangalore. I would say, it is the refreshing departure from the hotel venue where we met for the last 4 days, during HPC Asia 2002. For most of the Indian HPC researchers, C-DAC is the Macca for them. As the typical Muslim has to visit Macca some or the other day, HPC researchers have to visit this great institute and great organization, which is nurturing these activities over the past several years and doing the outstanding work in this country.

What I was planning to do is first quickly find out who are the speakers. The objective of this workshop as, I understand, is primarily, at the end of the day, come out with tangible guidelines and the conclusion, so that these are the areas of co-operation. We have to identify specific area, rather than being general. This workshop is not the research conference where we are getting the details of the equations. Even if Dr. Haridass misses the equations, I am not worried whether we are not getting any graphs, curves, results, simulations, studies, tools etc. What we need to identify is, what are the goals where there is mutual expertise and how do we join hands and force Dr. Y.P. Kumar from this end to get some money and to do something tangible. Dr. Madan and some other people should help us. So keeping this in mind, I request the speakers to take maximum 10 minutes. But I would be happy with if they conclude within 8 minutes.

We will have the presentations by the following speakers

1. Dr. Sri Kumar
2. Prof. S.S. Iyengar
3. Dr. Suraj Kothari
4. Dr. Vason P. Srinivasan
5. Prof. S.K. Dash
6. Mr. John Michalakes
7. Prof. C.V. Ramamoorthy
8. Mr. Burton Smith
9. Prof. Shankar Sastry
10. Ms. Claire Tomlin
11. Prof. Hari Dass
12. Dr. Debabrata Goswami
13. Mr. R.K. Arora

I would also request all the speakers to give soft copies of their presentations details to Dr. S.C. Purohit, so that he can put together all these things along with the conclusions.

*Prof. Patnaik concluded his talk and invited Dr. Sri Kumar to make his observations. He repeated that it need not be technical presentations because we had enough of it during the International Conference, HPC Asia 2002.*

**Dr. Sri Kumar**

*(DARPA / IPTO, USA)*

I would like to start with a few new ideas of scientific applications using high performance computing. I had taken a broad perspective and selected about 10 points for this particular important research area. I knocked out a few last night and come up with the four following areas, which are my favorites. At various point of maturity, these have been tackled at different levels by different agencies. Some of them are beginning to get popularize.

1. Infrastructure modeling and simulation
2. Communication system biology
3. E-governance to E-policy
4. Persistent work

Today, if you look at the biology and computation, the main thing is bioinformatics, genome analysis, identifying the static interaction and extracting the interaction from the virtual data. Next thing we want to do is to predict the biology, characterize the dynamics of the cell as a system. There are some suggestions about what to do with the HPC. Look first for the tools and infrastructure enabling scientific discovery and technology development. In one or two workshops/ conferences, I talked, bio-spiel simulation program for intra-cell irradiation that was at DARPA and suddenly there was a room for everybody to jump in and do something over there and expand the cell in this field. The next one is again about the infrastructure. How do we build network knowledge servers for bio R & D, biology research, bio –technology. For example, I am researcher, sitting here and I have to make a query. Give the latest on bacterial spa-relation. Everyday there is a new research. New relations that are coming up and you will think that they are not being studied for bacterial spa-relation. Something has been studied in some other cell, for example, scan cell could potentially have an impact on spa-relation research. If you can make knowledge servers, not just worldwide web (www), but really serve knowledge to the researchers. It has that kind of tremendous impact.

Second one, Infrastructure Modeling and Simulation. Let us take Internet as an infrastructure, complex networks. All kinds of complex networks are designed poorly. So tomorrow, can we build this systems with much more web-tested components, little bit more principally designed. For example, in one of my programme in network modeling and simulation, we have built a one billion real time simulation test bench on a high beam HP compact High Performance Computing machine. This is going to be demonstrated within next one or two months.

Third, Reasoning and Knowledge formation. Everybody is contributing lot of information into the web. How do we extract the information and how do we form knowledge that is useful for us and how do we reason through these knowledge systems. I don't know whether if you have

studied Amar Sen's thesis that the great Bengal famine could have been altered if there was possibility of information, there was a possibility of creating knowledge, possibility of good analysis in reasonable amount of time. These all aspects are really knowledge formation. Everything is computer intensive, tailored for HPC kind of profession. So to do programming with an idea, which will involve HPC plus cognitive systems plus economic game theory, modeling is very important. I am trying to get something.

The last one is about persistent work. I don't know how many of you have played the online games. Only one there. Ok. It is a really growing industry. There is game called "ever crest" played by something like 60,000 people all over the world, no bars. They spend something like 6 to 8 hrs and many of them, grown up like me, spend more hours than they spend on their jobs. This is all good for game, good for entertainment and is also good for High Performance Computing. But can we absorb the phenomenon that is going on here. There is lot of peer socialization and peer learning that goes on. I would suggest to exploit peer socialization learning, which are natural thing. These are borderless, really borderless education. High school kids learning circuits, software persistent work in a place where the final program is going on in rural areas where foreigners can presumably emerge themselves with all the farmers. I am pretty sure that a farmer from Nagpur or Goa could potentially help somebody from Japan, if they have same kind of Language. Language means same kind of internal sense, internal relationship. There may be huge language barriers but, then, we are working on natural language processing.

**Prof. Sitharam Iyengar**

*(Louisiana State University, USA)*

Wish to talk about a topic called molecular communication system. It happened very recently when Prof. Joshi was visiting me and he was talking all about natural language processing. He said that if we could have way to link some of the DNA sequences to the natural language processing and so we worked on that aspect. We have some ideas on that.

There are lots of important applications over here. I am not going to go in its depth. I want to focus on very important ideas emerging in recent years called molecular language. Any way, the problem of environmental keyboard, mouse and all of these sorts are embedded on it. I am

talking in same context of typical natural languages processing. There are lots of applications for both civilians as well as defence applications.

What exactly are the functions of these molecular languages we are talking about? We know basically protein languages what I call function which is triggering reaction, regulation and transport of molecules. So as in the human languages, there are common symbols and these are not indigenous that are unified. I know a few languages, which have indigenous symbols and does not matter what these indigenous symbols are. Prof. Joshi has used them, who is a very distinguished expert in natural language processing and he said that why not we look at the grammar, adjoining grammar, which he discovered in 1960's. This is basically a data of structures for re-writing rules in the natural language processing and how it can be linked to the DNA sequences.

As Dr. Sri Kumar said, there are many computational difficulties exist in molecular biology. The first job is to sort out and look at the similarities between re-adjoining grammar and biological sequences. As we know, what the proteins cells are for the human body and what exactly it regulates. These are basic properties for triggering the functionalities of the human Cell.

So the molecular language as what we look into it. Let us say, for example, the communication between the molecules. These are natural language processing, movements and songs and the factor of technology between these theoretical molecular languages and also in the scale of song and other things what we consider in human language. The molecular language also uses alphabets and which essentially talks about plenty of natural amino acids and each one of these establishes its specific function. The protein alphabet essentially corresponds to the formation of genome languages.

As the components of these molecule languages, what we are looking into are what are the natural amino acids and each of it has its specific functions. What are the enzymes? Enzymes can act like words in the reaction process and then of course DNA sequence and also the RNA.

If you look into the each of the component for a set. Each of these are highly computational intensive problems forming upper direction like, for example, protein folding. If you look at

some of these proteins these things can be used as a sort of processors that essentially interacts with other cells in the human body. The whole idea is how we can express it in the language that we are talking about.

So what are the communicational problems? Let us think about it. One of it is basic formal framework and type of formal system, which we can look into it and the computational parts of it. You know, we have already solved one part. How, in the example in the natural languages, a few things normally take place after long time and then we arrive at a general purpose communication system to solve the problem. This is the basic principle.

What we are trying to do is to look at it and define the molecular language in the context of the natural language processing. What are the problems that still remain open, for example, the partition of a function of a bio-molecule in terms of context free grammar function? There has been some progress in this direction but still it is not very efficient in order to generalize in the context of molecular communication system. There is still a problem that needs to be resolved.

There is another interesting thing that Prof Joshi pointed out when he looked at these structures, what is called nested dependency He considers domain of localities. This can be sorted out easily by looking into the context of molecular language. Also, because essentially it is an interesting aspect of what takes place in the cell structure and how that can be propagated? These are some of the details of how we do it. The most important thing, what I really think, is a language that can be facilitated to solve many of the important high performance computing problems, and I think this is a good start. This sort of molecular communication system can really enhance many of the high performance computing applications.

**Dr. Suraj Kothari**

*(Iowa State University, USA)*

Thank you for inviting me for this workshop and also giving me the opportunity to attend HPC Asia 2002. I was in the first year of my college and made up my mind to go into the Indian Administrative Services. My elder brother was a secretary and I wanted to follow his footsteps. I had a teacher Mrs. Fernandes. She was my quadratic geometry Teacher. One day, she said there

is a lecture at the University and you may want to go there, I have an invitation. So she gave me the card. The title of the lecture was “ What is an Hyperbola” Sounded like something I could understand. So I went to the lecture. I listened to this person who was one of the greatest mathematician of India. He gave this talk and after the talk he asked if any one has a question. I got very interested. I didn’t know who this person was and I asked him lot of questions and he patiently, for 15 minutes, tried to explain to me the things, which I didn’t understand. At the end of it, he gave me a problem to solve and told me if you can solve this problem you can call me on such and such place in Pune. After couple of days, I was able to solve the problem, so I went to see him. He looked at the answer and he said, well that’s good. Now I am going to ask you another problem and I want you to tell, what a line is. You have studied quadratic geometry so tell me what a line is. I started telling him what a line is. Line is an equation  $y=x+b$ . So he asked me, do you know some other way of defining line. So, for half an hour, he told me what he thinks what a line is and at the end of it, I felt, its like listening to somebody giving a concert in music. At the end of it, he told me that he is not going to ask me a question but to prove the theorem on what a line is and if you prove that theorem you will get the Ph.D. It doesn’t matter if you prove it tomorrow, you will get Ph. D tomorrow. About three years later, theorem on the line was proved. It was a paper of Adams of mathematics and the entire issue was of Adams of mathematics of what a line is. The entire issue of mathematics was a proof of what a line is and after that he has a question what a Jacobean conjecture is? In 1946, somebody had published a proof of Jacobean conjecture and this person showed that proof is wrong and he related it to another question called what is a plane. So the first question was, what is a line and another was what is a plane. So Ph.D was completed in about five years. I worked on that problem, what is a plane and at the end of it, I decided to quit mathematics because god gave me enough intelligence to appreciate what beautiful mathematics is, but not enough to do beautiful mathematics. I develop tools for automation in software. It was my great fortune to listen to Prof. C.V. Ramamoorthy a day before yesterday during HPC Asia 2002. This is something, I will remember for a long time.

We develop software the way Egyptians build pyramids. We write millions of millions of lines of code with sheer human labor and based on, what I have observed in my opinion, the way the software are developed today, may be , about there are 10% – 20% of the people who have the vision to design a complex software. Then after that, may be, remaining 80% - 90% experts

develop that software. It is my observation that, about 90% human force in many ways were used as very inefficient human machine and I am interested in how to automate all of it. But, may be, we can automate 50% or 80% and we can develop much better quality software with more efforts and with less errors. So that's what I am interested in. Most of you know, what I do and if you are interested, we can talk about it. C-DAC in India has been working in this area and has been developing complex systems for the last 10 years. Those are some of the things that I would be interested in for working together. If the opportunity is available, I would welcome to interact and initiate in implementing some interesting ideas

**Prof. Vason P Srinivasan.**

*(University of California, Berkeley)*

I am happy that Prof. Sankar Sastry is with us for presentations and discussions.

The point here is to show you some new directions in High Performance Computing and what are the things that we would like to collaborate. First of all, let me talk about some of the future challenges as we see. The first thing is power. The second challenge is in software development. We don't want to write FORTRAN, C or any of these codes. We are going to talk in terms of intuitive user software that is Simulink. The reason behind this is that we have got to have HPC for the masses and the high school students should be able to program it.

The third challenge is application of hardware and software, which means you should have interesting libraries of components and those are tuned to the applications. The hardware is going to be matched with the applications which means you put together an application using the blocks and there is automatic mapping to the hardware.

Some of the interesting applications that we believe are going to be important over the next ten years is individualized drug discoveries. By that, what we mean is a person has certain problems. So today what we do is pick a drug, find out its effect and observe the adverse side effects. Then go back to the specialist and change the drug and accordingly find something that the person can tolerate. What we want to do is to go and to do it more like custom tailoring. We are going to

find out what are the person's side effects and what the person's problems are and then make the drug to fit the requirement.

The same thing applies to signal and video processing applications. We are going to look at HPC and focus on reliability, fault tolerance, light weight and low cost because some of these are definitely carried by people with them in their briefcase and other is going to be in satellites and aircrafts.

What are the emerging technologies that we have available at PWRC and also at other places, there are CMOS sensors, which are visible, and MEMS, Laser. It forms a platform to FPGA that's emerging and then invertly we have developed RAMP architecture. This facilitates match processing. If you have an application you can tune your application to this, you get reduced power. Consider library of functions level hardware components and we are building those libraries. This is where we want collaborations worldwide. Last month, I was in Newzealand and the next month, I will be in Italy and so I am planning to go and travel all around the world to have these libraries developed. Apparently, we have this simulation engine that can deliver about three tera operations. Functions are available over the net and there is the software getting developed. Without software these hardware are useless. So we have automated mapping from architecture description to simulate the sequels that allows you to map it on to the BEE hub. We also have a flow that allows you to map it on a chip. We have the methodology called "*chip in a day*". You take your design, simulate it and so when you are done with it, you can emulate it on the BEE and if you are satisfied with it, in a matter of a day, you get a chip. This gives you the RAMP architecture where you have clusters. You would tune your applications, match things into this and the communication is building rapidly on something like RAMP.

So this gives you the over all design. What happens is, you do high-level architectural analysis, make sure that it satisfies your power and performance constraints. You do power and performance iteration. This all happens in an automatic way. Then when you are satisfied with that, you have two different paths you go to the emulation path. Now you really go and get it.

Now, I need to tell you something about program. It needs to convert from MPEG to MPEG coding, which is the top-level view of the IDCT function. These are the library of components.

There is a specific level of writing the code. Libraries are available for doing this job. We have done all these testing for 1D FFT and we plan to do it in 2D FFT and other types of functions. Other types of kernels are already identified. This will have both FPGA and ASCII. This is the kind of programming module we want to do.

We have got a kind of problem, we want look at, with the research institute during this year. Essentially we want to look at the protein structures discovery. The kind of algorithm we want to develop for protein folding recognition and then do it by computation. We want to develop library modules for such computations. We also want to look at Individualized drug discovery. So we go into the iteration process and find the best solution. In this case also, we want to use the same kind of process of power and performance constraints. It is something like steering the application.

Another application is sensor-based application. It is a very involved application. In course of time, we need to have for high rising buildings tens and thousands of sensors. So if there are any problems, the people who are rescuing it, can handle it. And for this project, we want to interact with people in the area of threat tracking. I will be talking on this issue with people over the Internet. There are very specific areas in which we would like to collaborate.

**Prof. S.K. Dash**

*(Indian Institute of Technology, Delhi, India)*

It is on the Weather Forecasting and Climate Studies in India and the background is our institute. i.e. IIT Delhi, It is very important to discuss weather forecasting especially in view of the monsoon failure in the year 2002 and the predictions not very correct. It was in the year 1922 that Mr. Richardson visualized, probably with about 800 processors, each processor is of one degree by one-degree grid, which is not sufficient for good resolution. We have even now not achieved the required resolution. So in India, with the support of the department of Science and Technology, we have been parallelizing the code for weather forecasting. The purpose is to get better forecasting capabilities. PARAM is in the forefront. We have also started collaborations with National Centre for Medium Range Weather Forecasting, which is the official agency for predictions announcements and we have also interacted with C-DAC and Indian Institute of

Tropical Meteorology, Pune. We have learnt a lot from these exercises. We have started from eight high-end workstations and also 128 low-end processors. We have learnt a lot and we have achieved a lot. We are also happy that our process of prediction has accelerated. As you know, weather forecasting is very complex. There is always a requirement for using faster and faster computing systems and we have a project with C-DAC for this purpose to use higher methods and to improve on inter-processor communication. We are using the transport method and efficiency is improved by 40%. We have also tried better weather forecasting models like T126 and intend to go further. But as Prof. Patnaik told, I will be very specific to my goals and objectives.

Let me take some time to talk about why weather forecasting is important for India. The whole India is divided into five major zones for weather forecasting purposes. There are 35 meteorological sub divisions for India and the variation is very large across these subdivisions. What we are concerned is about the special variation, particularly related to the average rainfall during June, July, August and September and the variation is about 27%. In case of the North East India, the rainfall is 1419 mm and the variability is very less i.e 8.5. Even if you take all the five zones, the variability is too high. If you consider such variations, the meso scale modeling is essential. If the resolution required 35 Km or 10Km, you can very well imagine the complexities. It will require lots of computing power. The problem for India is effective prediction of monsoon, regional monsoon, particularly, during June, July, August, and September. This should be done for less than 50 Km resolutions.

I can visualize that for Indian context we cannot have a global model. We should have different models with different resolutions like 50 kms, 35 Kms, and 12.5 Kms. Look at the different operations one has to calculate and it should not be difficult to guess, which I have done and I don't wish to discuss it in detail due to lack of time. For example, for  $2 \times 10^{15}$  calculations. It will require 20 days of integration. We also will be dependent on the global input. We will have to consider not only the plains, but also the Himalayan geography. It will also be necessary to consider, for the onset of monsoon. The ocean atmosphere interaction will be clearly a basic requirement. So the question is always to give correct predictions for 12.5Kms resolution.

The next problem will be related to the extreme weather conditions like what happened during 1999 and the movement of cyclonic storm in the Bay of Bengal. Cyclonic storms will also need 5 –10 Kms resolutions and the appropriate model. Now, I am showing you the nested model with different zones. This model is tailor made for Eastern zone and will support 5 Kms resolution. This also will give nesting for extreme climate. It will capture the movement of weather from zone to zone and the weather effects.

Now I wish to summarize, why we need efficient weather forecasting for India.

- a) Special geographysical location in the tropics with vast wide land to north and ocean to the south-giving rise to large differential heating.
- b) Large mountain ranges with numerous peaks and complex terrain.
- c) Weather and Climate dominated by south west monsoon circulation which give rise to rainfall of large spatial and temporal variations.
- d) Long coast line affected by severe cyclones.
- e) Full of glaciers, ecosystems and biodiversity which are vulnerable to global warning.
- f) Impact of climate studies in the regional scales.
- g) Very high resolution (5 –10 Kms) regional nested to global model essential.

C-DAC has already contributed a lot towards the development of such models. But we aim at working together towards more efficient weather forecasting capabilities. Perhaps, these efforts have to be intensified with more experts joining us like Prof. Suraj Kothari and Mr. John Michalakes, and then only we can achieve the objectives, specifically for India.

**Dr. John Michalakes**

*(National Centre for Atmospheric Research, Colorado, USA)*

Thanks for the invitation and the travel support I have received. I had a good opportunity to interact with many people. I visited IIT, Delhi and IISc Bangalore. During this process, we explored lot of possibility of collaborations in the broad area of atmospheric science. I have couple of papers with me, which I would share with all the people interested and I look forward to fruitful interaction.

I am a software engineer and I work at National Centre for Atmospheric Research, Colorado, USA. I interact with my colleagues at this place in the area of climate modeling. I work in the area of weather research. In recent years, I have been working with a model developed by Dr. Moris Weisman and the objective is to understand the high-resolution weather system associated with severe storm system using the climate model. The point is that we want to get on to one-kilometer resolution. The computation requires 37,000 trillion operations. The emphasis is therefore on high performance computing with high-resolution broadcasting. The benchmark WRF for different machines are available. The point is to understand the model, the physics and the performance of the computing system. In this respect, I had a discussion with C-DAC and the idea is to develop performance model, which characterize the efficiency and inefficiency of the computational process. The next is to explore the possibilities, if any technical or scientific collaboration is possible. As I envisaged, it will require lot of validation and developmental exercises. We already had a required data for different machines and their performances with reference to such models. There is already a proposal for five years with five and half million dollars to set up a facility. The first phase is already on the way and to test the date of 1996. We have one and half year to go for this computational facility to be available. Next two years will be spent on a few other models for the validation. This time will be sufficient for validation and publishing the results and interacting with the research scientists. I already had preliminary discussions with IIT Delhi. They are interested in the monsoon predictions and simulations. IISc Bangalore is interested in tropical convection and cyclone genesis is of interest. Coupling for hurricane prediction, I would like to couple this with the ocean model and resolution of meso scale convective model. There have been opportunities for me to interact with IISc, Bangalore and Dr. S.V. Singh, NCMRWF of New Delhi and there seems to be lot of interest in

collaborations. The participation from all the concerned agencies is possible. The development of new models and using the available high performance computing resources is of interest particularly, to Centre for Development of Advanced Computing. We have already been interacting with Chinese Department of Meteorology and developing a model of mutual interest. I suppose on the similar line with India also the collaborations can be initiated.

It will be very interesting to go through such exercises in the course of time we can develop many software libraries under the classification of the software frame work which can be done under a typical agreement, IDE. We can also develop case tools for atmospheric studies, software infrastructure for model coupling and coupled ocean atmospheric model. Also to analyze the performance model and its capabilities. C-DAC has particularly in focus to work on specific atmospheric models and benchmark the computing system. Also, they have interest in development of data mining systems and deployment in the model. Working at NCAR and interacting with researchers, I find a gap between computer scientists and atmospheric scientists. I hope with high performance computing as one of the resource both the disciplines can understand each other better. This may also help us to create a new team to work in this important multi-disciplinary application.

**Dr. C. V. Ramamoorthy**

*(University of California, Berkeley, USA)*

I am very happy to be here and to participate in the Indo-US Workshop. I am seeing my old friends like Dr. Patnaik, Dr. Iyengar and Dr. Purohit. I also thank for the wonderful hospitality extended to me and make my stay and participation meaningful. I have been a teacher and a researcher throughout my life. I am still learning and I feel very happy about it. Before starting the technical discussion, I wish to apologize that all my slides are handwritten. I don't carry a laptop and there is reason for it. As you know, I need to travel extensively and I always pass through San Francisco Airport. The people there are very strict. They check each and everything and some times, I feel very uncomfortable opening everything and showing it to them, of course, for their satisfaction. Well, they may be doing their job but it is hassle for me. Now a day, I prefer to travel with minimum baggage but with maximum knowledge. I feel very proud of my belongings including knowledge.

All right, now I am going to be very fast and explain some of my handwritten slides. More details are available in the slides I presented during the conference. Let me start with the vision. What is my vision? It is “Creating an internet of mind through high performance computing”. It is very close to the Ross-Ashby Law, which says knowledge, technology, and human needs grow at exponential rates.

What I would like to emphasize is that along with the technology also grows the obsolescence. There is a need to talk and discuss more about such issues, which my team has been doing for quite some time. As a teacher, we feel, we are responsible how to impart education to the next generation or the people with whom we have been working in the industries. The knowledge is increasing very very fast. I also want to talk about the knowledge corridors and the things associated with it. What are the areas HPC can do? It is very important that we discuss more about the software and its development, which has to follow certain ground rules. On this topic, last night I discussed in detail with one of my students Dr. Krishan Rao who is the Managing Director of one company in Bangalore.

Let me talk little bit on the Internet of tomorrow. The needs keep growing up with time at exponential rate. This is called in sociology, the Ross Ashby Law. We consider each mind as a website. Of course, it looks our minds won't agree. But let me call it that way and then let us say the ideas and knowledge spread at the speed of light. There is a very nice Mexican greeting, which says my home is your home. But in the terminology of today's discussion, let me call it that my mind is your mind. That I would call as the basis of the Internet of minds and then there is Brazilian song. I go to Brazil very often. It says if I dream I dream alone but if we dream together, it comes true – it happens. I called it team interaction. Infact, this business of Internet works only on this basis. Let us take the look at the rate at which the knowledge is growing. The growth rate of knowledge, I don't know, how they measure, it is of the order of 20 – 30% according to the Harward Business School, US Department of Education, Clinton and Gore. These great people say that this is doubling every three years. And then the technology growth rate, as per the Moore's law is 66%. Now you observe a mismatch that the knowledge is growing at a rate, which is different from the technology because knowledge gives technology or technology is driven by knowledge. That is interesting. I would like to show you something

better than that. Technology and knowledge obsolescence rate amongst the human being is 20% depletion rate per year. This figure comes from Mr. Bill Joy who is the chief scientist of Sun Microsystems. He goes on to substantiate this number by saying that it is common amongst the people who are at mid 40 years of age. Please note that I am beyond this range. He also assumes from his model of statistics about the knowledge acquisition. Then the question comes is what affects obsolescence. It is the staleness of old knowledge; growth of the new knowledge, but the unfortunate part is degradation of human mind and its effectiveness. If that is the case we can calculate the knowledge overtake rate per year. In other words, how do I overtake and go from human state to the next state. Such things are revived from moving different states like those of monkeys and chickens. Now please observe that the knowledge overtake rate is 50% and the technology overtake rate is 86% and then we can also see the knowledge depletion rate that is obsolescence. It means there is big gap between knowledge and technology and it is to be fulfilled. We come to the remedial part and to indicate some of the points my good friends must have discussed in terms of self-renewal via HPC support, e-learning and distance education.

Let me summarize the issues involved in these aspects. It is like knowledge content (liquidity), knowledge storage (security), knowledge access and knowledge delivery. The knowledge delivery (Internet) should then be tailored to linking the system for humanization and then such system should be personalized for knowledge, which is trained for each individual. Let me summarize next two minutes how does the Moore's Law works and why. That is the validity of the law. It is very simple. What we generally talk of discovery is nothing but the consolidation of knowledge. Knowledge is like dots on a radar screen. The technology is then linking these dots and finding patterns. Then the technology growth is then directly proportional to number of identifiable links and patterns. It is this pattern, which defines the usable knowledge. Once it recognizes the pattern and links, the Moore's law becomes effective. It is not a generalized law but a specific law for specific situations. Some of my slides will be made available to you. You may go through it and I am ready to be shot at. Please feel free to contact me any time.

**Prof. Hari Dass**

*(Institute of Mathematical Sciences, India)*

The area of Lattice gauge theories required very large computational resource. I have put it on the tenth plan and it is under consideration for international collaboration. This falls under the category of fundamental research. Special thanks to Dr. Rabinder Madan for inviting me to this workshop. Infact, we are involved into the cluster building. I would like to give you a small flavor of what is lattice gauge theory is all about. From the earlier days to even today, fundamental physics is one of the biggest user of high performance computing. We need lot of resources of HPC to realize our goals. So, what is lattice gauge theory? The Lattice Gauge theory consists of approximating the universe by discrete lattice of space-time points and assigning suitable variable to the sides and edges. This is a problem of quantum mechanics. This talks of a behavior of a large number of particles and some of the particles colliding as per the Einstein Theory of relativity. The challenge is to apply this theory of relativity for large number of particles and that is what I am calling it as a field theory. We are doing lot of work at the Institute of Mathematical Sciences. A candidate theory for this is the so-called Quantum Chromo Dynamics. Technically speaking, this is a Non-abelian gauge theory of quarks and gluons. The explanation of this theory can go on and on, but I would like to emphasize on complexities of computations in High Performance Computing.

Lattice formulation for it consists of assigning to each link of the lattice, a SU (3) group element which is a 3x3 complex matrix of unit determinant, and to each site 12 grassmann variables for each species of quark. If there are N grassmann variables, they can be represented by  $2^N \times 2^N$  matrices. The weight factor for each configuration is given by the action, functional of the quantum field theory. The mathematical procedure for evaluating this grassmann variable is very strange, because if you multiple them they become zero. But they are not zeroes. The only known way to tackle this problem without using perturbation theory is through numerical simulation based on Monte Carlo Techniques.

These numerical simulations are extremely demanding for computer resources. If quarks are ignored, the simulation of the pure gauge theory involves around  $2 \cdot 10^4$  floating points operations per site. Since you are approximating for approximate results, one has to work with lattice with

$64^4$  to  $100^4$  sites and imagine if we introduce quarks, the situation becomes hopeless. Then, it is necessary to either evaluate or estimate a determinant of a Maximum matrix with  $M=12$ ,  $N_f N$  where  $N_f$  is the number of quark species and  $N$  the number of sites. Nature has chosen  $N_f$  equal to 6.

The autocorrelation of the configurations generated by Monte Carlo techniques is of the order of 100. One needs to generate 2000-5000 times this number for obtaining reasonable unbiased results. That is the complexities that I am talking about. The most challenging problems are expected to take tens or even hundreds of teraflop-years to match the precision required to confront experimental data. But fortunately, many interesting results have already been obtained with much smaller lattice and much less efforts. The good news is that the problem naturally lends itself to parallelisation. That is one reason we, at "MATSCIENCE", are trying to build PC clusters for such work. Since the High Performance Computing solution is very expensive, we are going into such PC clusters. Unfortunately, I will not be able to give you the details at this stage. Since the problem is so complex, our community has been using the SIMD Extensions on some recent processors (AMD, Intel). The speedups by a factor of 2 have already been achieved. As one goes to larger lattices, load imbalance due to random nature of the Monte-Carlo algorithms becomes a serious problem. Also, the fermion determinant problem is still a major obstacle. We realize that this required a very strong and powerful algorithm from the computer scientists and numerical analyst.

There is a tremendous scope of collaboration between India and US in many different aspects. Lot of efforts are continuing in United States of America. In India, however, the efforts are only confined to theoretical exercises. In India, we do lot of work and the testimony is that, we conducted a workshop two years ago on the lattice theory at Bangalore and many experts shared their experiences. At that time, our efforts were also appreciated. At the moment, we would welcome Indo-US Collaboration in terms of supporting a few workshops and some visits that can accelerate the process of research in our country.

**Dr. Burton Smith**

*(CRAY, INC.)*

The programming languages for High Performance Computing have been one of the issues, which many of our colleagues have talked about. Infact, it is not high performance computers, but we need better programming languages. Even there has not been better productivity of the programmers who can write good software. I can tell you that most of the programming languages are not of higher level as expected, which we have not yet got proven. One of the areas, which are complementary, is parallel processing. The real question to be asked to the parallel processing business is this. Suppose, I give you an option for parallel processing, which language you will opt for? How you will like to do the programming for high performance computers and what will be your option? And very few people can answer that question. I suppose, there will be different answers. Most of them will be confusing and there is likelihood not to get any straight answer. So, how the parallel computer should be programmed. There were bunch of people a few years ago who believed almost confidently that functional language is the way to programme parallel computers. The people like Prof. Arvind, who at the moment, is not here and also Mr. John Bacus, who believed that parallel programming can be liberated from the design. Many such kinds of people tried to attack the problem by the use of functional languages and many a times they have put the efforts to bring the programming language to a higher level. The efforts are well appreciated. I think, lot of work is still continuing in this direction. The basic issue is how to take control of variables during computations. Some new languages have also been developed at that time and were comparable with FORTRAN on CRAY X MP. The performance was very impressive. But there are some sectors, which require specific attentions. If you don't put the calculations in a particular manner, it seems to have very nasty implications. Actually, it requires such corrections at the outer layer of programming which allows you to modify the statements with lot of flexibility. Prof. Arvind had tried a lot and he was successful upto some extent. Also, there is an ideal language called MODEX, which fortunately serializes the computations. I wish to share this idea with you. The basic idea is to implement, automatic multi object transaction so that we can lock multiple objects, store the variants and change the variance. This is very much like the transaction. Infact, the trouble with locking multiple objects is concurrence in the data. The functional language seems to be equipped with solving

such problems of multi object transactions and concurrency control is already built into the system. It gives us a vehicle to ride into a smooth computational process. Suppose we are doing the mesh computations and we need to delete the mesh points dynamically as we progress the computations. Deleting such mesh points requires dynamic transaction considering neighboring mesh points, we need to lock them and that implies almost parallelism in the process. I will call it the classical mechanics in computing. Something similar to taking the position in one direction as in quantum mechanics. Equipping the programmer at this level is a good idea and at our level, we should be able to do it. This is not in physics. This is what we did ourselves by introducing classical mechanics in computing. This is a very serious proposition and risky as well. There are very few people who take such projects. Prof. Arivnd is one of them. Whether we are successful in developing such functional languages or not, it is very essential that it should be attempted. It could form one of the topics for joint collaborations between India and US. This will make a very good project and I am for it.

**Prof. Shankar Sastry**

*(University of California, Berkeley, USA)*

I am here to share some of the thoughts in the area of high performance computing. At the outset, let me tell that I would very much endorse the ideas of Mr. Burton Smith. I will make this presentation through some of my slides, which I discussed some time back with Dr. Sri Kumar. He is doing lot of activities about HPC at DARPA. Infact, his programme calls for HPP i.e High Performance Productivity. It always calls for new programming languages and in turn for new architectures. I hope, Sri may already be thinking of telling you in more details or he must have told you during the conference, HPC Asia 2002. Infact, the manager at DARPA of HPC has been talking to Sri and me about it. We have been conducting some courses in bioinformatics and we feel there is a need to go much more beyond bioinformatics. What are the problems of computational systems biology? Let me tell you in the context of my department at Berkeley. This is what I call a big wheel of biocomputing where bioinformatics interacts with computing devices and embedded systems and we would like to know what is its net impact? They are linked with development of computational software and such issues. New computational strategies have got lot of interest. The prime time has not yet come. We need to do a lot of work in molecular electronics, quantum computing and so on. There is lot of interest in knowing

computing strategies , the basic algorithms and even DNA computing. It also calls for knowing what it means by computational substrates. It also has generated interest in terms of information substrates and heterogeneous computing/ communications. Also it talks about the cognitive. I know what Prof. Ramamoorthy talked about and I feel the human capabilities are not used more than 20%. It is roughly constant and not growing further. It is a question of how we project our cognitive capabilities outside. Actually, there are many activities going on in this direction and requiring computing powers in terms of multiple flops. I would like to again reemphasize on system biology and the aspects related to which is the infusion of bio, info and micro.

I think the biggest of interest is bio magnetic architecture. It actually flies like birds. You know, now a days, they fly at the Mach 7 and 7000 feet. We need to understand a lot about aerofoils. There are many things going on in this direction and one need to get a feel before we proceed. The requirement is to go further down to the basic, to the level of proteins and lupines. There are sort of micro soles that are currently the levels where we are operating in CMOS. It is more or less a challenge in bioinfo. While we go into the design and development, we need to understand a lot. However, at the moment the speed is much less than what we should call it HPC. Nevertheless, we can still do a lot of complicated things. The things, which we do at Berkeley, are in the area of bio substrate. I think, the need for High Performance Computing comes from many calculations to be done at much faster rate. I think, there are many issues related to High Performance Computing and many complex technological issues. The answers may be given in many ways in view of instances like “nine eleven”, but however many details cannot be shared. I do not know how would you call it in India, like nine eleven or eleven nine or whatever. I think one of the mandates under Indo-Us collaboration is high performance computing and innovative ideas implementation. The question comes like how do we protect the infrastructure and the things like community services and the benefit driven from the technology. Everything comes into technology up-gradation, use of biology, informatics etc. I would like to tell you what is the real need of computation and from the system biology. The primary interest of mine, and as Sri must have talked, is in the area of bacteria. There are many reasons why this is of interest and I have very little time to go into the details. It is the movement of the bacteria, which enters into another system and spoils, it and then we start migrating towards DNA and simulating genes and which is very different from the logic circuits. Then we talk of different genes, proteins and that is what we talk of genes, protein circuits and then there is similarity and dissimilarity in analog

devices. Thus, we start talking in terms of speed, noise in the system and data transfer and so on. Then we talk about cellular circuits, gates and flops. It is a very interesting exercise. Then the question comes how do we simulate. Sri has got a program called BIOCOMP at DARPA, where we put all kinds of software and this is an ideal case for putting 4K genes of proteins and this is the order I am talking about. There are many ways to do simulation. Monte Carlo is one such method. I am not a big fan of Monte Carlo, but there should be definitely many other ways.

Here is story very relevant what is going on in Berkeley. We had many microelectronics valves during 70's and thousands and thousands of such valves representing genes. No body trusted anybody else's model. Many companies had their own simulation packages, the companies like Motorola, IBM, CDCs. I am not complaining about IBM but that is the way the things were. So Berkeley had its own model called CANCER. During those days, they were lot of protest against the war and nobody wanted radiations and wanted to avoid it. I hope Prof. Ramamoorthy will recall those days. The key feature of this package was the open source. Many reasons can be attributed to the success of this package and major reason being that it delivered the results. The open source provided addition of many features to it and contributed in the software development.

In the end, I would like to summarize that there are many computational challenges and many aspects which I have talked about but would like to emphasize on the open source simulations models, which I think even Sri is perusing it, that is intra-cellular validation. Certainly, one of the grand challenge problem is protein folding. One takes care of proteins and ions and many such things and the challenge is what are the right aspects to be included into the simulator. There are tons of things, which are to be put in a particular sequence. We do need to have high performance computing system. I think in terms of peta flops and that is the demand of the day. I hope the researchers will continue to work.

**Ms. Claire Tomlin**

*(Stanford University, USA)*

Thank you very much for providing me the opportunity to participate in this very important workshop on High Performance Computing and discuss the associated future trends. I do really thank Indo-US Science and Technology forum for such discussions as well. I want to discuss a few of the applications in which I have been working and which certainly require high performance computing. We have been working on this application at Stanford and trying to see if we can collaborate with Berkeley. The application deals with software development for aeronautics and automation industry. We have a sort of history to work in this area. We initiate in 1952 to work with an industry at VanCouver. Now, we have, matured enough and come to a very high level of automation (as you see in the slide) particularly, related to, on board systems. But still they are certain problem we are facing. This aspect is important for civilian aircrafts. Some of the activity goes in parallel and each one is to be tackled effectively. The question comes is, how do we structure the automation. There are different kinds of aircrafts and the automation is to deal with sometimes, military aircrafts as well. Here is some data for which we are working very closely with NASA, Ames. Around the California area, along with FAA i.e the Federation of Aviation Association to work closely with NASA administration and coordinate the activity of the flight path of these aircrafts. These aircrafts needs to communicate with each other as well and, hence, the safety becomes very relevant. What I would like to emphasize that these aircraft movements needs to be independent of ground control and automate the structure of such sequences. Then not only it has to communicate but also to improve on the system and make it more efficient. It is our observation that this automation requires a lot of improvement, as it can be seen from the incidence of “nine eleven”. Some work was initiated between 1985 to 1992 and a little progress was made. We have been working on the type of control structures and models, which combines to the traditional theory of automation and it starts with a single aircraft. The model is defined in the computer science for automation. It has to be improved for dynamic automation and to define the structure accordingly. It should improve the flight management model of the aircraft. This essentially defines the flight control model for hybrid system and, then, designing the software to improve the implementation strategy.

(This slide shows) The design model for automation for landing of the aircraft. How do we make sure that the aircraft will land safely and will follow the predefined trajectory? The pilot has to be aware of the automation process and should have the confidence in the capability of the software. The pilot also is to be equipped with the capabilities that, in case the automation is not in order or deviating from the specifications, he should be able to take over the aircraft and complete the landing process manually. So, if I have to characterize the automotive control system, then my interest is to design the software for the control system, which is effective and has a provision for improvement. We consider the whole software development in the two broad categories of continuous and static system and of course, not considering the final stage, which may have different kinds of constraints and the process, is not very repetitive. We may have to take specific precaution for unsafe model and its influence on the dynamic system. It is very important to consider this aspect with reference to the intersection of the two different systems, particularly with the back propagation of the unsafe system. (What am I showing you in this slide are ) the schematic of two aircrafts moving in particular direction and the unsafe part of the automation is propagated. The control automation model needs to take care and mask the unsafe region. It is basically the issue of lower dimensions being computed properly but the higher dimensions pose considerable challenge. It should be possible to capture all aspects of the invader movements and the persuader should be in the knowledge of such changes and intensions. So, this is the work what we have done. It is a three dimensional model in which all aspects of automation are considered and, at the moment, the computation takes about fifteen minutes. How do we do the high dimensional systems, I feel, it is a challenge. Thank you.

***Mr. Debabrata Goswami***

*(TIFR, Mumbai)*

I really figured out that nobody here was talking about quantum computing. I thought, I should mention that in India also this is an effort, which I believe the first one, which we have set up at Tata Institute of Fundamental Research with the help and funding from Department of Information Technology. I will tell you couple of small things that we are doing and are different from other part of the world. That is the reason why we are having different kinds of collaborations with USA that is MIT. It is primarily because the approach that we have taken in this project is complimentary to their current efforts.

The basic quantum computing implementation requirements are preparation of initial qubit states, manipulation of qubits (resulting in evaluating  $2^{\text{nd}}$  levels independently) and measurements of final qubit states before decoherence.

The QC implementation has current bottlenecks like Ion Traps, cavity QED, quantum dots, NMR techniques, and, the major problem is, scalability. There is lot of work to be done, because the computational information is to be transmitted. We have developed some optical schemes that lead to optical quantum computing (OQC). In terms of quantum, it can be done in three ways

- a) Classical, bit based computing of today's digital machines
- b) Classical, light wave computing, which uses limited aspects of quantum computing
- c) Quantum Computing, which uses entanglement of quantum states as well as their wave nature.

And for the major issues that come out of decoherence, I have tackled atleast one problem, which deals with intermolecular diffusion and mobility. What we do here is the coherent superposition of many monochromatic light waves within a range of frequencies that is inversely proportion to the duration of the pulse. Then I use Fast Fourier Transforms (FFT) for the analysis and interpretation. I am actually able to do it and it has come into the July issue of the journal published from Amsterdam. I need to do the similar operations about the entanglement in the quantum system. Other issue is basically the development of algorithm to understand such phenomenon in greater details. This requires a good collaboration in quantum computing. There is a lot of scope of development, particularly related to coherent control and control of bimolecular in both centers of mass and internal degree of freedom motion. I would have liked to discuss more on these issues and the possibilities of collaboration.

**Mr. R. K. Arora**

*(Centre for Development of Advanced Computing, India )*

Thank you very much Prof. Patnaik. Being the last speaker and as per your suggestion, I would like to summarize some of the points related to High Performance Computing specifically to the

future trends. Also, I will highlight some of the activities in HPC and the involvement of C-DAC. I hope, it will also set a trend for discussions amongst the participants of this workshop.

Let me divide my presentation into two broad categories. One is the presentation during the last four days in HPC Asia 2002 and discussions within the delegates and the other one related to what we should do and reinforce our knowledge in this domain. It is demanding lot of resources and collaborative activities. On the first day of HPC Asia 2002, I recall, we discussed about the capabilities of HPC, not only in India but also all over the world. The HPC not being only the resource but the enabler to tackle many scientific and engineering applications more effectively. I think, this resource is very strategic for any country atleast amongst the technologically advanced regions across the globe. Also, these activities provide skilled and trained manpower to work amongst various teams .

We just had different speakers talking about range of applications in science and engineering. There was an agreement amongst the speakers that HPC is a very important tool, which helps them to understand their problems more clearly. Whether it relates to numerical simulation for aircrafts, biosciences, weather predictions, climate modeling and so on. All these get related to many capabilities in the area of Graphics, Software Engineering, Software tools, environments, etc. The discussions were very detailed and we have discussed at length not only in this workshop, and also during the conference HPC Asia 2002. C-DAC has been participating in many of the HPC activities. I made some slides, which are enclosed, and I wont go into many details describing the capabilities.

However, I would like to take one step further and would like to discuss what should be done now and how should we proceed from here. The areas are very challenging, particularly, like biosciences, weather modeling, algorithm development, software engineering, and also different aspects of parallel processing. I, therefore, would like to suggest two three points which may be discussed and debated amongst us during the remaining part of this workshop. I have shared these points with some of you during HPC Asia 2002 and, I thought, I would repeat again with a larger audience in this workshop.

There has been a situation that the students are coming out of IITs and Premier Institutes in the country. Same is the case with United States. They have done excellent work and they are equipped with the state-of-the-art technology as well as the strategy for its implementation to improve product performance. The suggestion I have is that, is it possible to make use of these trained students to work with some of our premier institutions in India and US and reinforce their knowledge. They might also work as a post graduate students or research scientists for certain typical projects. Having completed their assignments, they return back to their respective countries and work for specific task. C-DAC is only one such organization but there are many premier institutes who would like to get their students trained and get them join back and work again to reinforce the movement of HPC. I presume, when they return, they should be associated at least for the equal number of duration with the parent organization and contribute in the areas, which are of importance to us. May be, it is biosciences, climate modeling, basic research, software design, etc.

Going one step further, may be the professors and research scientists from academia or R & D institution come to India for a longer duration. It can be sabbatical. They come on a very specific problem. We can define the process of problem areas and the duration. They can guide some of the students or fellow colleagues in the organization working on a very specific domain.

Another suggestion would be that the students get registered for Ph.D with the faculty in India and in US, where research topic can be defined and all necessary procedures are completed, which can lead to the degree. During this process, it is also possible to allocate certain human resources from the Indian side and on the US side. In the course of time, it is possible to create a pool of resources from both sides to work and progress significantly for that project.

These are some of the points, I thought, I would share with you and which I discussed last night. With the permission of the chair, I would like to discuss with all of you and have your views on these few points. You may give some guidance as to how to go about. I will be very happy to receive your comments.

Another point is, could we all sit together and identifies some of the areas we can work together. I don't mind if you identify most of the areas we have discussed for collaboration under Indo-US

forum. As we progress, during few months, we can add a few more disciplines depending on the requirements, orientation and needs. It should be nice idea to discuss these issues and identify the focus areas for interaction under Indo-US Science and Technology Forum. I will stop here and, probably, I feel this is the right time to debate on these issues or any other issues related to the presentation and the expertise available with all of us regarding HPC and the future technologies.

## DISCUSSIONS

*Prof. L. M. Patnaik, Indian Institute of Science, Bangalore, moderated the discussions. In continuation of the presentations made by the experts from Indian and US side, Prof. Patnaik emphasized on discussing various issues particularly related to the research activities, possible collaborations between India and USA and expected support from Indo-US Science and Technology forum. To start with, he requested Dr. Y.P. Kumar, Adviser, Department of Science and Technology, to express his views on the administrative set up and the resources required for such collaborations.*

**Dr. Y.P. Kumar** If you wish to write project in a specific research area, we would welcome submission of such projects. We have got the procedure in place for approval of such projects. It will be nice that the project is submitted from both the sides i.e. Indian and US. Since we expect the projects to be submitted into electronic form, it should be easy. The office of the forum is located in New Delhi and is supported by both the Indian and US government. The forum facilitates the submissions and approvals. It has got a cell in US also. Mr. Michael Cheetham is in-charge of this cell in US. The projects can be submitted there as well. One of the prerequisite is that the project should be agreed by both the sides and should be submitted by the coordinators from both the sides. I am using this word project, but I would emphasize more the activity, which continues and gets strengthened in next two - three years. It could be small projects or mega projects. So far, we have not supported any projects. We have got four – five projects, which are at the moment in the pipeline, and they will put up shortly to our governing body for the support. Earlier, the view of the governing body was to intensify the interaction between the experts from both the sides and organize some workshops. This will give a very important input to the form of finalizing the activities and the kind of money required. I feel that for bigger projects we may still have to go to the government. It may also be required to go to other multinational agencies for the support. For submission of the proposal we have devised a format, which is available with us, and I request the participants of this workshop to collect it. This format essentially requires the details about both the PI's, the activities they want to do together, summary of the project, detailed activities and the funds required. In case, you want to propose a workshop, the venue and dates are also required. In order to save time for approval

there is a provision to submit the preliminary proposal, in which you can also indicate whether it falls into the priority category. This will enable us to process the proposal when you are working out the details. After the preliminary proposal accepted in principle, we will invite for the detailed proposal, which will be submitted to the peers. Once we receive the recommendations from both the sides, we look for the allocation of funds. At the moment, we have enough money, which can support workshops under this forum. But, I suppose don't ask for mega money. The forum can support the activities which are bilateral and which help to contribute significantly in the area of scientific research. However, we need to keep in mind not to adversely affect the ethical values and the environment between the two governments. We generally follow the procedure of reviews from both the sides. If there is endorsement to the proposal from both the sides, then there is no problem. If there is no from both the sides then, the project attracts emphatic rejection. However, if there is yes and no from either side, then the project goes for revision or discussion. Apart from this forum activity, there is another support from DST-NSF. Lot of science and technology related activities continue under this umbrella and I am sure, many of the scientists sitting here are making use of it. Under this programme, the projects are invited, follow the similar procedure and once accepted, the travel is supported on both the sides. From Indian side, we do support some contingencies and consumables. I am sure, similar support must be coming from US side also. I thought, I will put forth these aspects before you so that you can consider availing this support. With this background, we can start discussing the issues related to projects and workshops. If you any specific thing in mind about holding a workshop, you are most welcome. Also, as Mr. Arora just now mentioned, we would like to involve many students to take advantage of such support. It is in the form of training, travel etc.

**Prof. L. M. Patniak** - Thank you Dr. Kumar. Now the floor is open for discussion. I am told there are about 50 more participants attending this discussion remotely in a near by place. I invite them also to take part in discussions. They can come here and join us.

**Dr. Dheeraj Bharadwaj** – It is OK with me for this kind of support and I definitely would like to welcome it. There is a kind of meeting, which is talking about finalizing the standards for grid, the global grids. I was already in touch with Professor of the North West University and I wanted to attend it. Unfortunately, such meetings do not fall under the category of either conference or workshop. I would like to suggest that there should be option available under this

forum to support attending such meetings which are very important in finalizing the specification for standards.

**Dr. Y.P. Kumar** - I can only say that we have noted the suggestion. At the moment, we are concentrating on supporting the projects and workshops. The individual needs are not considered.

**Ms. Savitri Bevinakoppa** - I am from Australia and there are lot of activities in the area of science and technology which are worth collaborating with Indian counterparts. We have agencies to support scientific research in Australia and I would like to know whether there is any possibility of Australia – India collaboration for science and technology.

**Dr. Y. P. Kumar** - This is not the forum for discussion on this topic. We, however, have some arrangement between Australia and India for S & T activities but it is not active at the moment. There are indications from the Australian side to prepare some basic documents to activate this collaboration. Once it is through, we will start again. If you have a project at hand, you can write to me and we will consider it at appropriate time.

**Dr. Anirban Basu** - The collaborations you are talking of, I would like to know if, they restricted to only government agencies or it is open to private organizations and industries as well. Because there may be need for technical people and the people from private organizations can contribute.

**Dr. Y. P. Kumar**: - Actually, there is no bar of this kind. We are looking forward to some projects, may be of mega level. We are expecting participation for different agencies and private firms can definitely get in.

**Prof. L. M. Patnaik**- I am looking forward to very specific comments on the points raised by Mr. Arora. The needs for training, involvement of students and initiating innovative projects. I want you, specifically the US friends, to address this issue and give your views.

**Prof. S. S. Iyengar** - Coming from the University , I would feel the points are good but it takes lot of time and efforts of faculty to work for this programme . So let us see, what can be done

under this forum. There are many bright students who have left the country and went to US and they have worked hard in tune with the programme of that country. It is possible to make use of these students to participate in such activities, as they know the culture and style of working in both the countries.

**Dr. P. K. Sinha** - Recently, lot of activities are continuing in the area of e-Learning. How under this forum this activity can become more effective. This is the question specifically addressed to the Professors and Research Scientists from the US side.

**Dr. V.P. Srin** – It is a good question and we have got a lot of activities going on at my place. If some people are interested, I can open an account for them and they can get benefited. We can make this arrangement proactively. This is definitely one of the possibilities. Another one is that I would like to find out the availability of space in India may be on the C-DAC machines, specifically on IBM P690. Let me know the mechanism of such connectivity and I will work in that direction. . That is what I am referring to is “cyber collaboration”. I can open an account within a day and you can get going. The procedure is very simple. Indicate the project briefly and tell us how long you want to get connected and what will you do.

**Mr. R. K. Arora** - You mean to open an account on this side and then the another one with you.

**Dr. V. P. Srin** - The idea is that along with you, many people can use this facility and get immensely benefited. One thing I want to make it very clear is that the literature available over there is in public domain and no classified information can be shared. I hope you can live with this provision.

**Dr. Dheeraj Bharadwaj**- MIT is offering “Bio-Grid” on the similar lines.

**Prof. L. M. Patnaik** – On this e-Learning issue, the University of California, Berkeley is well represented and I would like to hear from Prof. Sankar Sastry his views.

**Prof. Sankar Sastry** - In my own evaluation for this system, there seems to be many generic problems in these collaborations. The collaboration has to be at the grass root level. Let me tell

it specific to Indo-US collaboration. My apologies for to be very frank. I think we discuss always at the Government level or at very senior levels. Many practical problems are overlooked. I can tell you, the collaboration involving students attracts many grievances. In my own University at Berkeley, I have got about 100 odd students who were involved into the collaborations of this type. The experience is not very good. But that is a very pessimistic view. I suppose there are many American Universities, say like, Stanford, MIT, Louisiana State University, etc, they may be having good experience. On the contrary, there may also be a sense of ownership and they may not like to share with others, for example, the course in bioinformatics . People have put lot of efforts to make a course content or a software upto some level and now you want to collaborate and share. I think it will be difficult upto some extent. Well , I will suggest other way. Let us built the joint ventures on the collaborative projects. Let us develop a group of experts working in this area and jointly develop on a complementary fashion the capabilities in the specific areas. In United States, there are many agencies, which can fund such projects. Infact, they can do so with the help of foreign participation as well. I would suggest involving students at the training level and give them confidence to work for specialist domain. The traveling requires lot of money and it cannot be given to the students just because he is working in the project. I would hesitate to do so as what Mr. Arora has suggested. Once the training of the students is done, I would recommend exchange of professors to the countries and sharing their experiences which would be beneficial. Then, you can start lot of other activities say like “cyber security”. The “cyber security” is a very tricky issue. During the Clinton administration, while organizing a efficient summit , there was need for exchanging the signatures and it was hell of a job to get even one signature across. On the other hand, initiating the European Union Science and Technology exchange programme, exchanging the experts and having discussions, tailored to the need of specific project, was found beneficial. So, I think we should concentrate more on activities in the working models at the grass root level.

**Mr. R. K. Arora** – Let me ask a question about students working in IIT and requiring the projects under a typical exchange programme. The students travel for their Masters and Doctor degree. I feel the programme is on and it is very popular. You are not talking about that programme. Isn't it. We are referring to a programme where we pick up five students of our choice for the project, they are selected and they intend to work for it and they are recommended to work in

USA, say for example, at the University of California for next five years. They come back and join us and work on the similar project or extension of the same project. I think that is highly beneficial programme and we should think in that direction

**Prof. Sankar Sastry** - I think students coming for a particular degree in a University is Ok. But under the projects, if the students come I think it is the subversion of the admission process. The notion of visiting students is always very critical. That is what I am saying of students-faculty relationship. What I would like to emphasize is that the students have to work in their respective country on a subject of their interest. When they are fully integrated into the research programme and started contributing significantly, they become a part of the team like what we did in the University of California. Then we can think of the exchange of their visits either six months or one year and then if they want they get registered for Ph.D. Consequently, this system becomes very robust and there is no fear of losing any student due to many reasons, which are not in tune with the research opportunities. When they come back with this small visit and experience they do wonders. What I am advocating is not the exchange of students but that of research scientists.

**Prof. S. S. Iyengar** - It is a very complex system and every university has to go through this exercise and make it better and better. Sometimes, it looks it will not work and sometime it looks the best. I think the issue is very subjective and depending on the resources, the details should be worked out.

**Prof. S. K. Dash** – It is very interesting that instead of sending a student for some project work, let the students get registered for Ph.D in their respective country and also work on the project of mutual interest. Once they come up to some level, and then affect the exchange of visits. I feel it will be highly beneficial mode of working collaboration

**Mr. R. K. Arora** - So instead of exchanging students we are exchanging research scientists. It can be either way whether a student is working on Ph.D programme or for a research topic.

**Dr. V.P. Srini** – Well, we should be very specific on such commitments . Sometimes the students comes for two weeks or for two months. They also come from not only research

organization but also from industries. This is a very flexible programme. We need not be so rigid about their Ph.D degree or registration but let us consider whether the research project will benefit by such exchange programme. And infact, we have number of such programme, I think about ten. That is what I am talking about the grass root level. .

**Dr. Dheeraj Bharadwaj** - I would suggest before the students exchange visit takes place, the faculty should be given the opportunity for the visits. This will help to reinforce the research programme and endorse the basic issues.

**Dr. Y.P. Kumar** - I feel this exchange programme should not be considered under isolation. Lots of activities are taking place. Exchange of information between students, faculty, research scientists, industries, laboratories. Almost everybody is benefited. We are also working with the industries. We are also using their setup and the interpretations are complimentary

**Prof. S. K. Dash** - I think you are referring to a programme which is not very specific to any IIT, Laboratory or Industry. This is , I feel, is application for all disciplines. This should be an exchange programme amongst the Universities which is clearly identified and well defined.

**Dr. V. P. Srini** – You should emphasize more on the collaboration rather than individual University or research group. We should try to minimize the bureaucratic process .

**Prof. S. K. Dash** –I fully agree with what Dr. Sankar Sastry is telling that collaboration is very important and it should be taken very seriously. If the resources are identified and the project is well identified , what is the problem in supporting such collaboration.

**Mr. Mishra** – I would like to know if there is any programme for students within India itself to learn more. Like TIFR has got a visiting student programme . If a short visit of this kind is given to students atleast within his own country, it will give exposure to some of the new ideas. I want to know, whether is there any similar programme in US where the students are exposed to and shown number of facilities, say like what C-DAC is doing by showing its facilities to the students.

**Dr. Suraj Kothari** - I recall , in earlier days, there used to be National Science Talent Search Competition. I think, it will be a good idea to conduct a one or two months workshop which will be participated by Indian and US students . The workshop can be on a specific topics and students can be selected based on certain criteria. This will give opportunity for faculty and students to work together and many good things can emerge . I would suggest that all concern people should consider this aspect as well.

**Mr. R. K. Arora** – Another idea I mentioned was for the faculty to visit organizations like ours and spend some time together on topics of mutual interest. The duration can be from two months to six months. What is the reaction to this suggestions? I want to let it happen on a regular basis. What can be the suggestion for the mechanism?

**Prof. Sankar Sastry** - I would say though the idea is good and we have experimented it between Berkeley and Stanford, there is a sense of traffic jam. Many activities in the pipeline and lot of efforts are required to consolidate. About visiting students, I still feel there is a problem. On the other hand, it will be still preferable to call them under typical funded research projects. We should have an objective to visit a place and not just to get exposed to the technologies. It can happen through DARPA or say even under this forum. I would confess that it would be very hard atleast for Berkeley to participate.

**Shri. R. K. Arora** – What you are saying is, if there is a research project then only the exchange programme should be effected. May be, it is either for faculty or students.

**Prof. S. S .Iyengar** - I think this is the way it should work . Previously, Indian Institute of Science, Bangalore use to encourage such visits. This was focused for the graduate students who could visit US for a short duration and get exposure to the newer technologies. That seems to be the plan of least resistance and should be acceptable to all of us. If the principal investigator has interacted with more than one University in US and if he asks students to visit all such universities, some of them may be very famous, the student will be definitely benefited. It has worked very well in the Institute and it should work well for R & D organizations also. I think this model should work.

**Mr. R. K. Arora** - The project need not be associated with the University but it can be with R & D organizations or the laboratories.

**Dr. Sri Kumar** - This is ok with me. The business of exchanging students for the project or working for a degree. That may, I think will be a sort of equilibrium at a lower level. We should go for medium or mega size projects with many organizations and many research scientists involved. Let there be some industries involved. You may fail but you should think big and try big. That is the DARPA style of functioning. Build something big and aim for large objectives to be achieved. Let all of us think in that direction. The objective should have value. The duration may vary but it should not be of major concern.

**Mr. R. K. Arora** –I like the idea. Let us pick up a subject area in itself. We have talked of bioinformatics and we need to take the subject beyond to the drug design, genome sequence and beyond. Let us convert this topic for the mega project and work towards it from both the sides.

**Prof. S. K. Dash** - Under the DST-NSF, if we have an agreement between Institutions, then the work can progress very well. For example, in the area of ocean modeling and weather forecasting. But the problem arises within the country itself. A person in my institute has no money to come to C-DAC. How do I address this issue?

**Dr. Y.P. Kumar** – Actually, you are mixing the issue. In my introductory remark, I have already mentioned that you can build in such provisions in your project itself. We are addressing all the issues related to such collaboration at a grass root level, if there is no bureaucracy involved. All the money required has been made available and kept under the safe custody. The money is available with the scientists; however, they have to work under a framework, which is reasonable and acceptable.

**Dr. Sankar Sastry** - I feel, we should think of the mega project and the idea is acceptable with the focus areas like bioinformatics, climate modeling, etc, in mind. I also have a suggestion to talk of functional genomics. It is very useful for human body. It is popular in US and we should consider it. When you are doing so much effort for the good projects, then you should empower the project manager to do justice and you should believe in him. In US, I believe the coordinators

and the managers have full freedom to select the project and go ahead. Sri will agree with me. Please empower the project manager to do the best and I will tell you, it will do wonders.

**Prof. S. K. Dash** - I fully agree with Dr. Sankar Sastry that there is a need to take reviews of some many people and getting satisfied at the administrative level. If the programme manager says Ok, it should be acceptable. It will also save lot of time and energy. Once we have agreed that we will work for weather models, bioinformatics etc., the decision should be left to the programme manager. Dr. Kumar and DST can follow the normal process for the projects on the general topics.

**Prof. S.S. Iyengar** - I think Shankar has made a very strong point. This process should give lot of confidence to the programme manager, and we should work for it. We should try to deviate from the traditional review process and do something which will revolutionize project management and achieve targets well in time. It is possible that for some of the top priority projects you may not attract may US experts, but what you will get will be very focused and will be extremely useful to you.

**Dr. Sri Kumar** - I would like to give one more DARPA model. Invite the people for typical research topics and select the best, based on credentials, his research output and his team. Accept the proposal. Review it every year. If the progress is not done, you can terminate it there itself or encourage him to continue if good work is done. This model has worked in DARPA and it should work here also.

**Prof. S.S. Iyengar** – One thing we should emphasize that instead of bureaucrat handling the total operations, it should be with the scientist who has worked enough. What I mean to say is why have a chairman of a department, who has not published papers in last twenty years. Why not have a person who is a good researcher. Have a person with a positive outlook. I hope there are lot of people in India who can take such responsibilities.

**Dr. Y.P. Kumar** - We generally ask the proposer of the project the list of people who work in his area. And based on his suggestion, we try to shortlist the reviewers. If there is any another mechanism of review, please tell me. I fully agree with Dr. Sastry that project manager should

be given lot of flexibility. We need to work with the cross section of scientists. We are sure that the scientific research is multi-disciplinary and many ideas can emerged from the researchers. If we decide to identify these two areas, namely, bioinformatics , weather/ climate modeling, then we have to discuss very specifically and with a group who is working in this filed only. I agree with Dr. Sastry and would like to work out this model also.

**Prof. L.M.Patnaik** –I have got something related to the program manager and undertaking some research projects. It should be nice idea to identify the people in India as well. I would suggest to the US scientists that when they interact with the Indian researchers and find some good people , they should give the input to Dr.Y.P Kumar, DST regarding their expertise and the type of projects they are handling. This will reinforce the data bank of Dr. Kumar and he can work at a faster pace.

The second point I want to talk is that we have been so far discussion the collaborations with IIT's and Premier Institutions. I want to inform that there is another level of elite group of research scientists at the regional college level how have their own mechanism for interaction. Infact, the students coming out of Universities, State Government Colleges, and Regional Engineering Colleges are to be interacted and used for projects and research activities. It is one of the prime issues in Indian Education system, which should be tackled effectively.

**Dr. V.P. Srini** – I have come to India with a dream. I have written it to many professors in India. I want to build a peta flop emulator system with 1/10<sup>th</sup> the cost of what IBM is proposed with Blue Gene. I was hoping that everybody would jump at the bandwagon. I am not able to do it today and I am going to Shanghai. In 1980, it was CRAY-1 , when working with Mr. Samuel Cray, I have given him ten chips and I told him that I would give him one board with all chips put together and with the same performance. Mr. Cray thought for a while and said I don't want to go that way and instead he decided to go along with vector computing. Then DARPA funded me this project alongwith Prof. Yale Patt, to take on symbolic computing. Today, Japan is developing 5<sup>th</sup> generation computers. We single handedly did the work and beat Japan in the area of VLSI chip.

**Prof. L. M. Patnaik**- With no further points, we need to conclude. I would like to thank C-DAC for nicely organizing this workshop .

**Dr. Y.P. Kumar** – The time has come to conclude but we also need to answer the question, which Mr. Arora has posed during his presentation. May be, we should finalize one or two projects and work on the model. There may not be possibility to write the projects immediately, but we can identify the disciplines and we can ask from Indian side and US side to think of such projects. They may be , a sort of, mega projects. We can ask both the sides to write the pre-proposal and indicate the area of work and the kind of funding required for such projects. We can also think of appointing the program managers and think of how to go about it. If we can do it, it can be brought to the notice of the forum and the governing body. The detailing can be worked out accordingly. If we can freeze and suggest those two disciplines. I would say that the outcome of this workshop is very encouraging

**Mr. R. K. Arora** – I would like to suggest those two areas and C-DAC would like to take a lead from the Indian side. I will also encourage the individual experts from the US side to get in touch with us and write preliminary proposal. One will be on the climate modeling and another one is, say, post bioinformatics i.e. individualized drug designs, cell research and that kind of programme. To be more specific the system biology. There can be a few more areas like emulators, innovative parallel processing etc. But if we stick to these two disciplines i.e. climate modeling and bioinformatics, we at C-DAC, are willing to take from Indian side and are also willing to work with another institutions who are interested in this disciplines. We will work with them in a given time frame and come to DST with a firm proposal.

**Mr. John Michalakes** - I would like to say that during my presentation, I have indicated many areas where the collaborative work can be done. Some specific areas like weather and climate modeling, NCAR is deeply involved into the research and WWF projects. I am certainly willing from my side to take up this research area and collaborate. This also, I feel will give me a chance to work with IIT and C-DAC.

**Mr. Pramod** - I am from the department of space and I want to know whether these discussion are confined to DST or other departments as well.

**Dr. Y.P. Kumar** – It is a national programme irrespective the various departments or the agencies

**Prof. L. M. Patnaik** – You may be from different department but DST can be the facilitator for this activity.

**Mr. R. .K. Arora** – How about discussing on the peta flop computing which deals with not only the infrastructure but also the basic research. C-DAC would like to collaborate in this field as well.

**Dr. V. P. Srini** - These are the mega projects and we undertake with many projects under this category. It is a leapfrog approach and we may succeed in getting the things done. The projects will require money definitely and we need to put efforts for that as well.

**Mr. R..K. Arora** - Do you think yourself, IBM, Dr Sastry and C-DAC can form another project in this direction.

**Dr. Sankar Sastry** - Who is from your side? If it is C-DAC, Srini, myself, IBM – accepted. Let us get the project rolling.

**Prof. L. M. Patnaik** - So it is the closing time. I would like to thank Mr. Arora, Dr. Purohit and their colleagues in hosting this workshop and making it very focused. It is an excellent workshop and C-DAC Bangalore has provided all that was required. I also would like to thank all the distinguished speakers and participants for the wonderful time. My special thanks to Dr. Y.P. Kumar who has travelled all the way from Delhi to interact with all of us and give us the information for the collaboration and to initiate the projects.

It is interesting that we have come down to very specific projects. It is important that we should work at grass root level in discussing technologies rather than formulating proposals and getting approvals. I have interacted with Prof. Iyengar for long time and had many papers published. For the benefit of those who want to know that there is a excellent scheme of DST for young scientist whose research is supported for about two years. I am on that committee and so I can

tell you about the scheme. The students can use this opportunity. They can contact the professor in US and proceed with their research work. DST gives the entire money.

Another opportunity is through the Indo-US forum to do the projects. Instead of discussing at micro level, let us talk about mega projects and think big. Also we should work in that direction. One more interesting suggestion was to identify programme manager and give him lot of flexibility to complete the projects.

Lastly, we probably talked of three major disciplines namely a) system biology b) weather/ climate modeling and c) the research related to peta flop machine. These are all inter-disciplinary applications and many research scientists could work together. We should see that the dream should become reality.

**Dr. Purohit** -- Thank you very much Dr. Patnaik for conducting this workshop so nicely and in time. The discussions were excellent and the distinguished speakers could tell their views in the time allotted by Prof. Patnaik. They have respected him and responded to our invitation to attend this workshop.

In conclusion, I would like to thank all the distinguished participants for sharing their views. Before we close, I want to repeat the Brazilian song, which Dr. C. V. Ramamoorthy mentioned, “ *If I dream, I am alone, but if we dream together it comes true, it happens*”. So it is a team effort and all of us have to work together. Let us get started. Thanks!