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NUCLEAR SCIENCE COMMITTEE

WORKING PARTY ON ADVANCED COMPUTING

14th and 15th October 1993
Madrid, Spain

Summary of a Specialists' Meeting on Adapting Computer Codes in Nuclear Applications to Parallel Architectures

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Working Party on Advanced Computing

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I. Introduction

The meeting was opened by L. Garcia de Viedma, who was charged by the Nuclear Science Committee (NSC) and the Working Party on Advanced Computing (WPAC) to coordinate the activities in supercomputing in nuclear applications and to report to both of them.

The meeting was held at the headquarters of the Spanish Nuclear Society.

Participants (list enclosed as Appendix 1) were welcomed by R. Caro, commissioner of the Spanish Nuclear Safety Board (CSN). He recalled some of the early developments in computational science and its evolution. He stressed the impact the interaction of theoretical, experimental and computational activities have had on the understanding of nuclear systems. In particular he pointed out the importance of advanced computing in reactor safety and reactor operation.

L. Garcia de Viedma then recalled the scope and objectives of the task force on supercomputing in nuclear applications.

The medium term objectives include:

- devise an internationally agreed and appropriate set of criteria and measures which help identifying the most effective computer for solving particular problems in nuclear applications
- preparation of a state-of-the-art report on technologies for producing software with massive parallel constructs with emphasis on algorithms for equations required for nuclear applications
- benchmarking and validation of parallelized programs and determination of speedups achieved
- organisation of seminars, workshops and conferences addressing specific topics in massive parallel programming.

The short term objectives include:

- adapting computer codes to clusters of workstations and to computers with a relatively small number of processors working in parallel

- the issue of adaptation to massive parallel architectures should also be addressed

- the specialists' meeting should lead to setting up a task force with the aim of addressing practical problems, organising international exercises, through which improved performance can be measured and portability verified.

II. General Overview

A. Kavenoky of CEA, France was invited to chair the meeting. The specific objectives of the meeting were presented:

- identify activities that can benefit best from international collaboration

- set up a task force on supercomputing in nuclear applications

- define a work programme covering parallelization of codes, exchange of experience (and codes), make a cost/benefit analysis, prepare a report

- recommend specific actions for the NSC.

He pointed out that speed and memory are the parameters normally used to define a supercomputer; however, this definition varies over time. A more time invariant definition is related to the price and he proposed the following convenient definition: a supercomputer costs more than 10 million US dollars. The speed vendors cite is often misleading; in practice it represents the speed their computer never exceeds.

He then presented an overview on "nuclear applications and parallel architectures" [1]. The highlights of this presentation were: impressive results were achieved recently in several domains of computation (structural dynamics, fluid dynamics, ...); two architectures for parallel computing are available: 1) clusters of workstations (WS), providing an effective use of available heterogeneous computing resources (parallel virtual machine) 2) new generation of parallel computers with a large number of homogeneous processors; this architecture can lead to solving "grand challenge" problems.

Nuclear research centres developed a large part of the numerical analysis tools and are still at the leading edge in the development of new algorithms for solving those classes of equations needed for nuclear analysis. Through this research, leading to a refinement in simulation of systems, nuclear safety of new reactor types can be improved. A fast computer and a convenient display system can be seen in practice as equivalent to a time microscope or telescope (K. Wilson). The challenge is to reach the teraflops (10**12 floating point operations per second) computational speed by the end of this decade. The scientific community needs to get ready for when these computers reach the market.

The presentation developed then the following themes:

- Fifteen years of microprocessors and a tentative perspective: device density has increased by a factor 100 000 and the speed by 2000; today's extrapolations predict that by the end of this decade a density of 10**9 (giga) transistors per chip and speedups to 4 gigaflops will be achieved.

- Principles of parallel computing: the speedup is strongly dependent on the sequential fraction of the program; for certain classes of problems the use of parallel computing has little sense.

- Examples of speedups achieved on different parallel machines for different problems were presented as well as results from some nuclear benchmarks. Some of the performances were impressive.

- Use of workstation clusters: the efficiency in the use of computing resources can be improved considerably. There is a single system view for user access; however a somehow reduced reliability for the user accessing the system may pose some inconvenience and there is a rather large software based communication system overhead. Clusters can make access to "supercomputing" available to many, but are not suitable in general for massively parallel applications.

- What a teraflops computer can do:

  . it allows carrying out a spatially detailed diffusion calculation in three dimensions and two energy groups in one second
  . a spatially detailed 3D transport calculation in 20 energy groups will take less than a minute
  . but one with detailed energy description would take about 6 hours,
  . a detailed in-core fuel management calculation would take one full day; ideally one should be able to carry out such a calculation overnight.

III. General Presentations of Techniques and User Experience

Presentations by participants followed; the full papers or viewgraphs are listed as references. A brief summary is included here:

- J. Labarta presented "Architectures and Algorithms for Parallel Computers" [2] in which he introduced the different architectures (vector, array and multi-processors with distributed memory), outlined their characteristics, and showed what effect these have on applications, algorithms, programming languages and on the basic software. The programming models and architectures were presented together with examples of data distribution. At the end of the presentation a view on future needs for research and development was presented.

- "Solving Linear Systems on Parallel Computers" was presented by J.M. Cela. After defining the problem in general, he showed why linear systems are problematic: the order of matrices is very large, they are sparse, the condition number is high and special sparse storage formats are required. The advantages and disadvantages of classical direct and

iterative methods were presented next; the role of preconditioners was explained and the degree of parallelism achievable with the different methods outlined. Two optimal methods were introduced: multigrid and domain decomposition methods. In optimal methods the number of arithmetic operations required to obtain solutions increases only linearly with the size of the system. Among the options for solving the system the iterative method is the one showing a high degree of parallelism, but needs special preconditioners.

- J. Pena described the "Present and Planned Activities in Optimization of Computer Codes in Nuclear Applications at the CSN" [4]. The areas of major concern are related to nuclear safety and radiological protection. Computation activities cover neutronics, thermohydraulics, accident analysis, radiation shielding and emergency planning and handling. Their work in code optimization is carried out in three steps: first, all the programs are optimized to obtain better performance in general, then they are vectorized. In this phase a gain of a factor two in speed was achieved. In parallel computing work is devoted mainly to shared memory systems. A message passing software has also been installed and will be mainly used for MC applications (KENO-V).

- B. Kirk presented "Advanced Communication Scheme for the Neutron Diffusion Nodal Method on High Performance Computers" [5]. The results of work carried out previously show that shared memory architecture produces higher efficiency compared to the distributed memory model on parallel computers. With the increase of number of processors the communication among them deteriorates parallel efficiency. Communication overhead was strongly reduced in recent work by reorganising the assignement of processors. This scheme, based on global combined operations offers the least communication penalty.

- J.P. Gregoire presented "Parallelization of COCCINELLE Code on CRAY Computer" [6a,6b]. COCCINELLE developed by EDF, carries out LWR static and kinetic calculations. The parallelization was achieved on the vectorized version and was carried out manually. Once parallel regions are localized, the implementation of parallelism could be achieved without major problems. On a 4 processor CRAY a speedup of 2.8 was achieved. From this experience it becomes clear that parallel processing is attractive only for large computations.

- F.B. Brown presented "Experience with Vector and Parallel Monte Carlo Codes" [7]. To achieve results with acceptable low statistical uncertainty for large problems, millions of particle histories may be required, consuming large amounts of time on supercomputers. The MC method has been adapted both to vector and parallel computers. On vector processors gains of a factor 10 can be achieved but the computation algorithm must be based on events and not histories, requiring complete code restructuring. The MC method is inherently parallel, therefore existing codes require minor changes. Because of statistical independence of histories, the gain in computational power can be almost proportional to the number of processors. It is expected that in future speedups of 100-1000 can be achieved. The adaptation of code must however be carried out by computational scientists familiar

with the physics and mathematics of the processes. He addressed the issue of domain decomposition, reproducibility of results and software considerations such as recoding effort required and software portability. The different problems and achieved results were exemplified on two codes: VIM and RACER. Several, still existing challenges were presented covering time dependent and non-linear problems which use algorithms that are largely sequential in nature and therefore not readily adapted to parallel computers, variance reduction methods, algorithms with fault tolerance, dynamic load balancing of processors, etc. He concluded that to be able to provide more accurate and realistic results, nuclear application areas have a need for solving problems 10-1000 times larger than those solved today. The gain of computing power of a factor 100-1000 would allow detailed 3D modelling of depletion of entire reactors or run MC programs interactively.

- J. Altes presented "Experiences with the Parallelization of a Finite Element Code on a Massive Parallel Machine" [8]. The finite element code SMART for calculating static and transient heat diffusion, radiation and convection (300 000 statements) using a hypermatrix scheme was parallelized both on a 32 node and 72 node Intel ipsc/860 and Intel Paragon. Speedups, using a varying number of nodes for problems of increasing complexity and for different linear system solving methods (conjugate gradient and Cholesky) were compared. It was clear that inter-node communication and I/O should be reduced to a minimum and instead computation and storage should be preferred. The concept of nodes with equal rights was introduced which reduces the cost for communication and I/O and the advantages of the block-Cholesky method for FEM calculations, i.e. stability, nearly linear local speedup and reduced communication requirement, were outlined.

- Z. Stankovski presented "First Massively Parallel Algorithm Implemented in Apollo-II Code" [9]. The collision probability (CP) module is very time consuming, but suitable for parallelization, thus opening the way to RZ and 3D extensions in geometry capabilities. The approach chosen parallelizes the different energy groups. For each group, in complex geometries, integrations over a large number (1 000 to 10 000) of neutron trajectories need to be carried out. The message passing MIMD program model has been chosen and implemented on a CM5 computer. The speedup achievable with this scheme depends strongly on the ratio number of groups over number of processors. This represents just a first experience and will be extended to RMBK and PWR assemblies.

In addition to the participants, several others have shown great interest in these activities. They expressed regrets for being unable to attend the meeting at this time, but expressed their intention to participate in the work of the task force. The contributed papers are summarized here:

- A. Haghighat contributed "Sn Transport Theory Codes for Parallel Architectures" [10]. He reviews the new algorithms that operate on the new computer architectures, based generally on domain decomposition for different variables. References for energy domain, angular domain and spatial domain decompositions are provided. Parallel computers with shared memory architectures and the distributed computing using

parallel virtual machine (PVM) pose different problems during implementation. The experience in parallelizing TWOTRAN-II shows that to achieve high efficiency, the data structure needs to be redesigned and numerical algorithms need to be further developed.

- M. Yavuz summarized his work on the "Development of Parallel Algorithms for Neutron Transport and Diffusuion Problems" [11] for advanced architecture computers. These comprise 1D and 2D Sn methods, 1D and 2D diffusion methods and combinations of the two. Parallelization will be extended to the new "Spectral Nodal Method".

- H.S. Aybar contributed his plan for "Adaptation of the DSNP to Parallel Architecture Computer" [12]. DSNP (Dynamic Simulator for Nuclear Power-Plant) consists of independent modules describing each the behaviour of specific plant components. Because of little intermodule communication, DSNP is an excellent candidate for parallelization.

- S. Haberhauer contributed a paper on "Computational Fluid Dynamics on MasPar's MP-1" [13]. He reported about a scheme for the solution of the time-dependent 2D Euler equations using Roe's approximate Riemann solver on unstructured grids. Complex geometry can be handled but requires complex hierarchical data structures. It was implemented on a MasPar-1216 with 16k processor elements using MasPar's Fortran-90 language subset. Proposals for improving the mappings are presented.

IV. Review of Lessons Learned from Different Experiences

Participants presented first the advanced computing facilities at their organisations:

ORNL: together with LANL, ORNL was chosen by the US Administration as one of the two High Performance Computing Centres (HPCC). ORNL has:
- Kendall Square Research (KSR1) computer with 64 cells, 32 Mbytes/cell, 40 Mflops/cell operating at 20 Mhz
- Intel Paragon XP/5 with 66 processors 5 Gflops nominal speed and a memory of 8 Gbytes (reserved to "grand challenge" software tuning)
- Intel Paragon XP/35 with 512 processors 35 Gflops nominal speed (for "grand challenge" problems)
- access to a Thinking Machine Corporation CM2 computer at the University of Tennessee. Furthermore the following utilities were developed:
- PVM (Parallel Virtual Machine) by Al Geist, available for most types of WS and parallel computers, e.g. iPSC and nCube hypercubes, and Paragon
- PICL (Portable Instrumental Communication Library) by Al Geist and Pat Worley
- ParaGraph, a visualisation tool for monitoring events occuring during a parallel execution; it produces post execution histograms of what is happening and is useful for debugging or understanding the behaviour of a program on a parallel system.

CEPBA: their work is devoted in general to computer architecture, operating systems and in particular to compiler development; compilers are studied for shared memory vector processors (Convex - 8 processors), array processors (CM2), distributed memory processors (Transputers), parallel processors with distributed (Convex) or shared memory (Alliant

- 8 processors). Languages considered are Fortran-D and areas of application are computational fluid dynamics, the method used is domain decomposition.

ANL: the computer configuration has migrated from a strong central computing centre to a distributed computing for each division relying on WS. For instance, in the reactor analysis group, 60 users share 17 WS. Users can work on any machine. Large computations are run in the background, sometimes for a full week. MC parallel processing is carried out through the P4 software (similar to PVM). For "grand challenge" problems an IBM-SP1 is used with 128 nodes, each with an RSX 6000 with 128 Mbytes. This configuration will be extended later to 512 processors. An FDDI switch interconnects these nodes. At present it is not used for large nuclear calculations.

CEA: they are members of the SEH (experimental site for hyperparallelism) which has a Thinking Machine Corporation CM5 with 32 processors. At the Saclay site an IBM-SP1 with 16 processors is installed, open to SEH. This computer will be upgraded to an IBM-SP2 with a peak performance of 5 Gflops. The CEA computer configuration is being upgraded to include a C90-3 and a Virtual Shared Memory T3D with 128 processors. The main areas of application will be:
- 3D radiation transport
- nuclear safety
- studies in turbulence

KFA: the advanced computer configuration at KFA consists of a CRAY-YMP M94/4256, an IBM ES/9000 Model 620 and an Intel Paragon XP/S 10 with 140 compute nodes. User can access them from their WS via Ethernet with a FDDI backbone.

CSN: the computer configuration consists of a CONVEX 3440 with four vector processors, 1 Gbyte of core memory. Users are accessing this computer from WS via Ethernet.

From the discussion it results that for a distributed computing environment (DCE), which we see implemented more and more, the same infrastructure needs to be provided as for centralized systems. The centre of the working computer environment is not any longer a large mainframe, but is replaced by FDDI switches, which integrate all the work of the distributed computers or clusters in one environment. The system is in general transparent to the users: they do not know where their jobs are executed. Difficulties that have been identified are the management of large files that are exchanged between the processors as well as the reliability of these types of systems. UNIX does not provide facilities taking care of them, therefore they have to be added.

The following general conclusions were drawn during the discussion:

- The state of computers is changing so fast; therefore there is a need to focus on methods and algorithms rather than special machines; at most the distinction SIMD/MIMD should be made.

- The only plausible way to continue increasing available computing power for research and engineering is parallel computing.

- It takes a long time for a programmer to get used and learn parallel programming, because it is very difficult. To produce effective parallelization, the physics and mathematics underlying the simulated phenomena need to be well understood. In order to have efficient parallel algorithms, programs need probably to be rewritten from scratch.

- However, parallel computers are not likely to be widely used, unless they are easy to program, programs are easily debugged, maintained and portable to different machines.

- Not all applications are suitable to be run on parallel machines: application programs must contain sufficient parallelism to take advantage of these architectures and this parallelism must be effectively scheduled on multiple processors. Considerable effort has been devoted to optimal parallel loop scheduling. Loops without dependencies are frequent in scientific algorithms.

- A poor vectorization can reduce performance of a code by a factor of 10 at most; a poor parallelization can reduce it by a factor of 100 to 1000. Therefore increased attention must be devoted to parallelization techniques. Computers with teraflops performance are expected for the year 2000; researchers and engineers need to get ready for when these machines reach the market.

Nuclear application problems are not listed among the "grand challenge" problems discussed today. This omission has as a consequence that nuclear application problems receive little attention from providers of research funds. The group agreed to identify "grand challenge" problems in nuclear applications, to properly describe them and to take actions so that they are included in the "grand challenge" lists. In nuclear applications, different equations need to be solved using different methods, which depend on the specific problem. These equations are listed in Table I.

In the field of radiation transport, detailed, complex geometry, 3D problems including time dependence can be classified as "grand challenge" problems. For improving operating margins of power plants a detailed simulation of whole systems is required. Plant optimization studies require calculations to be repeated a large number of times. Emergency planning and management at accident sites, where dispersion of radioactivity has to be predicted faster than real time is another application needing fast computing resources. High energy physics calorimeter optimization, nuclear model calculations for high and intermediate energies also require very large computations.

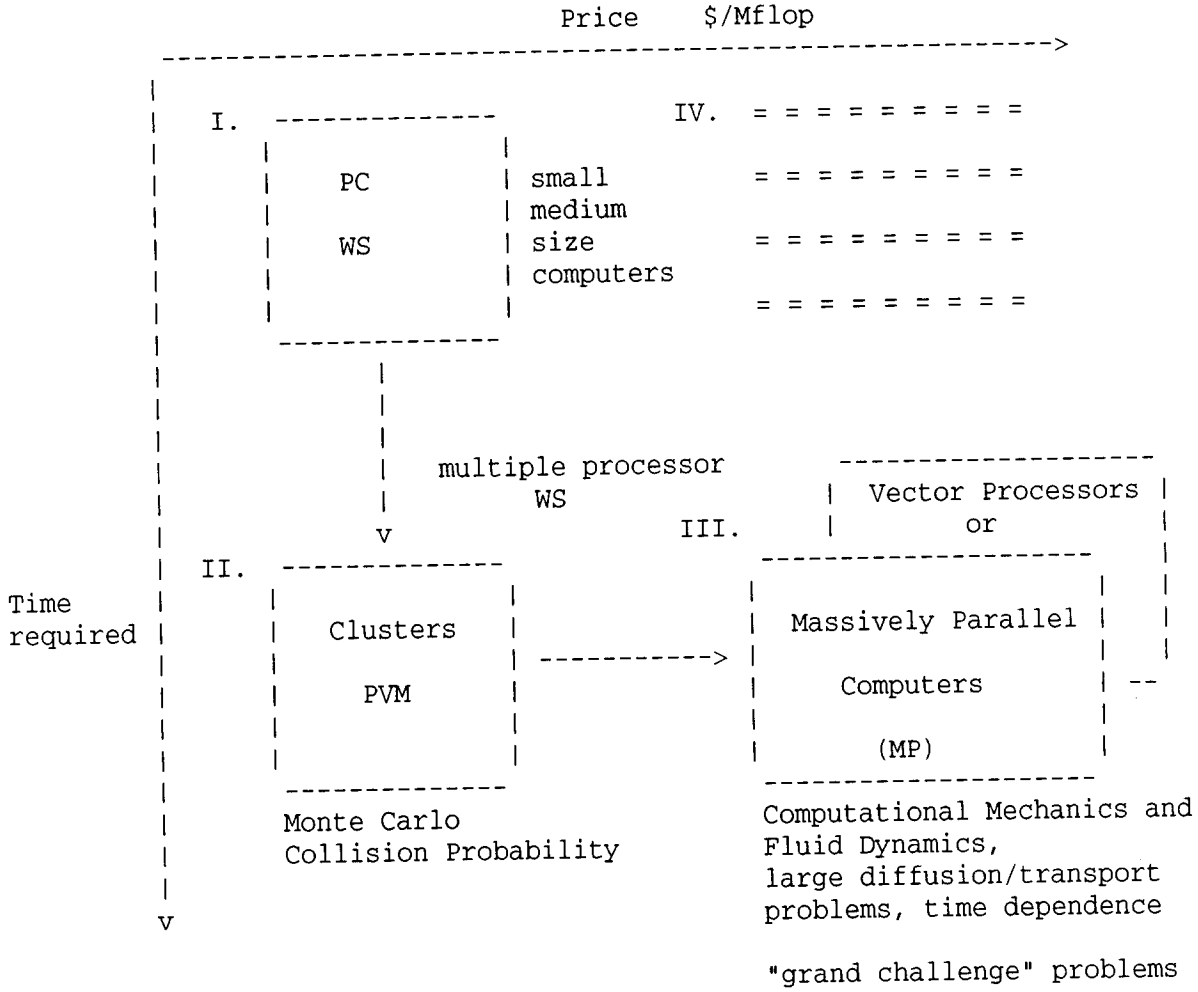
In conclusion, nuclear applications have a strong need for large and intensive calculations. To be able to carry them out, suitable algorithms need to be developed to take advantage of the new architectures of the most powerful computers of today.

The participants then discussed which computer should be used for what class of problems. The results of the discussion are summarized in Fig.1.

Table I : Equations Used in Nuclear Applications

Application	Equation	Method/Model
Nuclear Engineering	Neutral particle transport diffusion time dependence	Collision Probability Monte Carlo Finite Difference Finite Elements Discrete Ordinates Nodal ...
Fluid Dynamics	Navier-Stokes	Lagrangian Eulerian ...
Heat Transport	Heat-diffusion	Finite Difference Finite Elements ...
Structural Dynamics Stress Analysis		Finite Elements ...
Nuclear Models	Schroedinger Dirac Pre-equilibrium	Optical Statistical Direct Intranuclear Nucleon Cascading ...

Fig 1. What Type of Problem on Which Type of Computer?



Region I Covers Personal Computers and Work-Stations. These types of computers double their performance every 1 1/2 years. Within a couple of years, WS with performances around 300 - 500 Mflops will be available. This region covers the needs for small and medium size problems in nuclear applications. Most proprietary software will be developed for this performance region.

Region II When moving from region I to region II we encounter multiple processor WS on the way to clusters of WS. Clusters can be run as a parallel virtual machine (PVM). This allows users to make the best use of existing computer resources. Monte Carlo and Collision Probability are examples of problems that can be run in such a computing environment. In general, this architecture is suitable for applications with coarse grain parallelism. In addition, it is economical and programs can be run on public domain systems.

Region III Contains the fastest computers on the market, comprising both SIMD and MIMD architectures. For the near future, vector machines with a small number of processors will be the "work horses" in research and application. The cost per unit of computation is rather high, but are of interest because only they will be capable of solving certain classes of problems. The multiple processor vector computers will be needed for fine grain parallelism and for problems requiring many time steps. They will be used for event based MC simulations. Performances up to 100 Gflops are expected within a year. The massive parallel computers include MIMD architectures (Intel Paragon, Thinking Machines (CM5) and Parsytec (GC); the teraflops performance seems to be still out of reach for these) and Shared Virtual Memory (SVM) (Kendall Square Research (KSR)). This architecture will be adopted by many other manufacturers and seems to be the most promising one. Message passing systems are also the object of research. It seems however that portability might be problematic.

These computers are required for computational mechanics and fluid dynamics, very large radiation transport problems and in general "grand challenge" problems.

Region IV Represents the use of expensive computers for small problems and is therefore of no interest.

Some discussion was devoted to identifying possible sources of funds and of information for research in supercomputing.

In Europe, funds for specific projects can be made available through the CEC High Performance Computing HPC/ESPRIT projects:

- EUROPORT1 for porting codes from sequential to parallel systems
- EUROPORT2 for porting codes from sequential to workstation clusters

Additional funds are made available by different supercomputing centres (a ranked list of the largest centres was distributed to participants) for selected projects or free computing time is provided.

A good source of information in this field, apart from specialised journals, is the HPCwire service accessible on-line.

V. Shaping a Programme of Work

The following are the major fields of interest for activities in supercomputing in nuclear applications: about half of the interest goes to radiation transport problems, 3D deterministic and Monte Carlo receiving about the same attention. Computational mechanics and fluid dynamics covers more than a third of the interests. Participants have agreed to devote their efforts to these fields. Consequently the group proposed to set up a task force, formed of four different interest groups. These groups are defined in Appendix 2. Each group will concentrate on aspects specific to one of the following domains: Monte Carlo, Deterministic Transport, Computational Mechanics and Fluid Dynamics and Safety and Accident Analysis. The group leaders have been identified and are in charge of coordinating the work in their specific field. Participants, having expressed their willingness to contribute, are also listed together with those (in parentheses) having expressed interest in the topic in a previous inquiry. The work will be organised in three steps:

1. cooperation and sharing of experience at the level of the algorithm mainly via electronic mail

2. cooperation in preparing chapters of a report specific to the topic chosen, in which experiences made in programming and implementation of the algorithms are described, the performance and results are presented, comments on the ease of programming are provided and tools used and their function are described

3. preparation of proposals for further work.

As far as the Monte Carlo (MC) Group is concerned, a small MC computer code will be acquired which is easy to understand and contains all the essential algorithms. Each participant will try to parallelize it and will report to the group leader about the techniques used and the efficiency achieved. Experiences from parallelizing MC codes (such as KENO and MCNP) should be reported. The final report, in addition to this, should describe expected performance, actual granularity, random number generation, etc.

The group on deterministic transport will exchange experience and information in particular on codes such as TORT/DORT, TWOTRAN and TWODANT; Experience with small codes running on iPSC/860, KSR1, WS and Paragon are available and will be reported.

As far as the activity on computational mechanics and fluid dynamics is concerned, particular attention will be devoted to the finite elements hyper-matrix scheme. Also in this case, the main activity will be exchange and collection of information.

The activities for the safety and accident analysis group will concentrate on collecting information on vectorizing and parallelizing large codes.

In addition, each group should identify one "grand challenge" problem specific to the subject and provide justifications for inclusison in a "grand challenge" list.

This activity should lead to improved knowledge on how to parallelize a code, so that it can be extended to large production codes later. Some specific advice should be provided as to which architectures will have a major impact on computing efficiency in nuclear application areas.

The task force will also propose workshops addressing specific problems and will play a role in shaping the technical programme of the Third International Conference on Supercomputing in Nuclear Applications (SNA'97) to be held in the USA.

The report to be prepared should answer some of the questions asked specifically by A. Kavenoky and F.B. Brown at the meeting, both enclosed as Appendix 3.

VI. Date and Place of Next Meeting

The next meeting has tentatively been scheduled for 30-31 August 1994 and will be held in Paris, France. It has been proposed also that the meeting after next be held in Oak Ridge, Tennessee, USA.

Appendix 1

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* sent regrets for being unable to attend

Appendix 2

Interest Groups in Supercomputing in Nuclear Applications

1. Monte Carlo:	F.B. Brown (ANL) (group leader) J. Pena (CSN) (M. Akimoto (JAERI)) (Th. Vergnaud (CEA)) (L. Guidi (ENEL)) (M. Roshd) (K. Tsuchihashi (JAERI)) (J. Wood (Imperial College))
2. Deterministic Transport	B. Kirk (ORNL) (group leader) (Y. Azmy (ORNL)) Z. Stankovski (CEA) (A. Haghighat (PSU)) (M. Yavuz (TAEA)) (C. Catelli (ENEA))
3. Computational Mechanics and Fluid Dynamics	J. Altes (KFA) (group leader) J.P. Gregoire (EDF) J.P. Magnaud (CEA) (D. Grand (CEA)) (A. McDonald (AECL)) (G.R. Groetzbach (KfK))
4. Safety - Accident Analysis	L. Garcia de Viedma (CSN)(group leader) J. Altes (KFA) J.M. Cela (CEPBA) J. Pena (CSN) (M. Roshd)

() not present at the meeting

Appendix 3

Questions to be Considered in the Final Report

I. How can dirty decks be parallelized? (by A. Kavenoky)

- The parallel computers use various programming models: message passing, data parallel coding, ...
- The architecture of these machines are numerous: SIMD, MIMD, shared memory, distributed memory, ...
- A few software tools are intended to automatically parallelize existing programs or at least help the parallelization. Can they be efficient?
- Do the algorithms used in the existing codes provide sufficient parallelism to achieve a good efficiency?

II. Questions by F.B. Brown on Parallel Codes

- First question ...
  Why? What?
  . what are the important problems we cannot solve today?
- Second question ...
  For those problems, what are the difficulties?
  . nr. of iterations or time steps?
  . nr. of operations or CPU time per step?
  . memory size limits?
- Third question ...
  How?

* Parallel Codes - Details

  Level
  - high-level, coarse grain <---> MIMD
  - low-level, fine grain <---> SIMD

  Object
  - SIMD - what are the vectors
  - MIMD - what is the domain decomposition

  Algorithm
  - iteration method
  - block method
  - convergence tests ...

  Data Layout
  - local, within nodes
  - global, communications

  Language (+software tools)
  - FORTRAN-77, FORTRAN-D, HPF, C, C++

  Communication Package
  - PVM, vendor package, ...

  Coding

  Quality assurance

Papers Distributed at the Meeting

[1] A. Kavenoky: Nuclear Applications and Parallel Architectures (viewgraphs)

[2] M. Valero, J. Labarta: Architectures and Algorithms for Parallel Computers (viewgraphs)

[3] J.M. Cela: Solving Linear Systems on Parallel Computers (viewgraphs)

[4] J. Pena: Present and Planned Activities in Optimization of Computer Codes in Nuclear Applications at the Consejo de Seguridad Nuclear

[5] B. Kirk, Y. Azmy: Advanced Communication Scheme for the Neutron Diffusion Nodal Method on High Performance Computing

[6a] J.P. Gregoire, F. Blanchon: Parallelization of COCCINELLE Code on CRAY Computer

[6b] J.P. Gregoire, F. Blanchon, D. Verwaerde: Vectorization and Parallelization in the 3D Neutron Diffusion Code COCCINELLE (SNA'90)

[7] F.B. Brown: Experience with Vector and Parallel Monte Carlo Codes

[8] J. Altes, A. Watermann: Experiences with the Parallelization of a Finite Element Code on a Massive Parallel Computer (viewgraphs)

[9] Z. Stankovski: First Massively Parallel Algorithm Implemented in APOLLO-II Code

Papers Submitted but not Presented

[10] A. Haghighat: Sn Transport Theory Codes for Parallel Architectures

[11] M. Yavuz: Development of Parallel Algorithms for Neutron Transport and Diffusion Problems

[12] H.S. Aybar: Adaptation of the DSNP to Parallel Architecture Computer

[13] S. Haberhauer: Computational Fluid Dynamics on MasPar's MP-1

List of Actions:

1.	Secretariat	Prepare summary record
2.	F.B. Brown	Coordinate activity on Monte Carlo
3.	B. Kirk	Coordinate activity on deterministic transport
4.	J. Altes	Coordinate activity on computational mechanics and fluid dynamics
5.	L. Garcia de Viedma	Coordinate activity on safety and accident analysis
6.	Secretariat	Summarize meeting at NSC bureau meeting, 21.XII.93
7.	Participants	Provide information to group leaders
8.	F.B. Brown	Obtain the sample MC code and distribute it to members of the group. Instruct members about work to be carried out on the code.
9.	Participants	Identify "grand challenge" problems in nuclear applications and provide them to the group leaders
10.	L. Garcia de Viedma	Report activity to the WP on Advanced Computing (NSC-WPAC) at the next meeting (18-20 April 1994)
11.	Group leaders	Prepare draft chapter of state-of-the-art report and distribute for comments to members
12.	Secretariat	Organise next meeting; (tentative date: Paris, 29-30 August 1994)