p20

GRC RBCC Concept Multidisciplinary Analysis

Dr. Ambady Suresh

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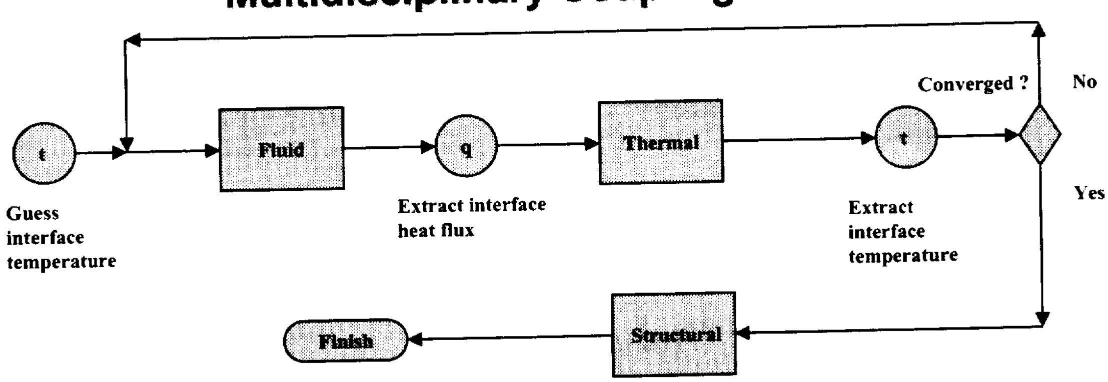
Multidisciplinary Coupling Procedure



1. Solve fluid (OVERFLOW) problem with a guess interface temperature.
2. Calculate heat flux at interface.
3. Solve thermal (ANSYS) problem with this heat flux loading.
4. Calculate temperature at interface and solve fluid problem again.
5. Once converged, solve structural (ANSYS) problem with pressures and temperatures as loading.

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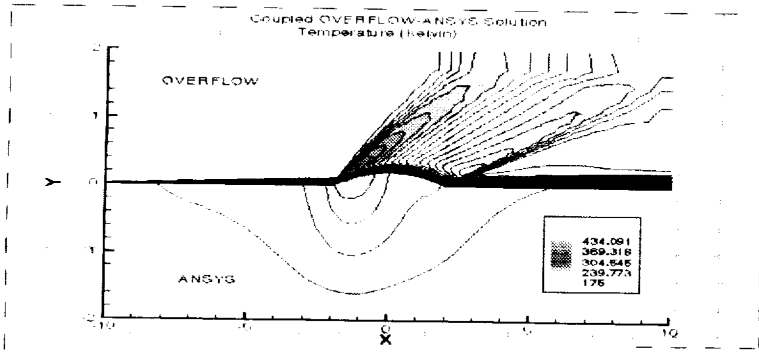
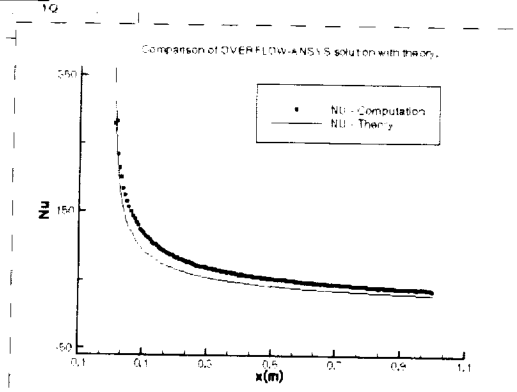
Technique Validations



Supersonic Flow Over a Bump

Conjugate Heat Transfer on a Plate



Nu - Nusselt Number

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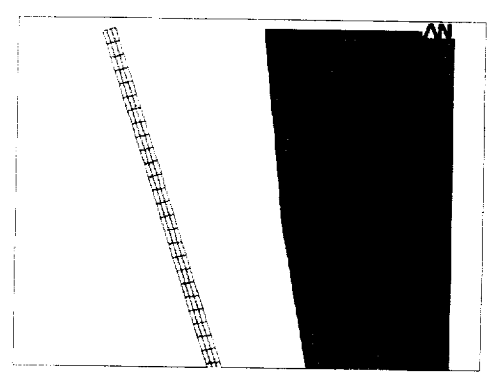
Axisymmetric Multidisciplinary Inlet Results

Fluid Grid & Solution
- Overflow simulation
- Structured grid

Thermal-Structural Grid
- Ansys simulation
- Structured grid



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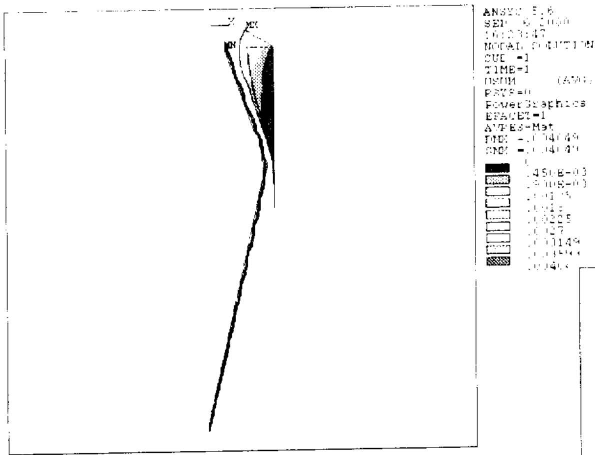
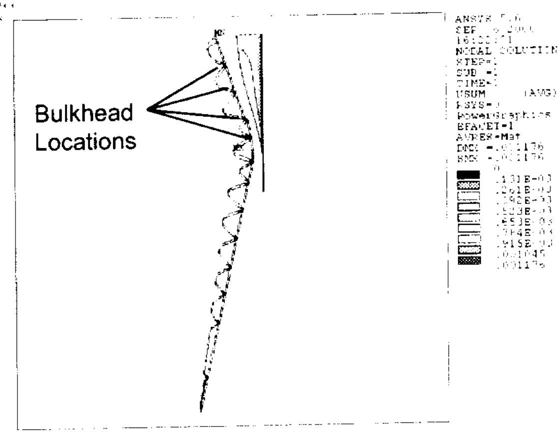
Axisymmetric Structural Results



Thermal-Structural Solution

Structural Solution



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Future Directions

- Couple the fluid and thermal-structural solutions.
- Improve GTX solution by modeling the external flow, better approximations for material properties and more realistic boundary conditions.
- Incorporate the coupling methods into the NPSS-CORBA framework for coupling between codes.

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Current Status and Future Plans

STATUS

- GRC RBCC Project
  - Aerodynamic simulation of forebody-inlet-diverter yielded significant impact on design of diverter.
  - Aero-thermal-structural simulation of inlet provided considerable insight on multidisciplinary simulations - difficulties and techniques.
- Code Enhancement
  - Added AUSM+ flux scheme to the OVERFLOW code and validated, providing an accurate and efficient scheme for calculating flows at all speed regimes (AIAA 2000-4404).

PLANS

- NPSS
  - Incorporate lessons learned and release Dev. Kit coupling tool.
- GRC RBCC Project
  - 120-degree sector simulation.
  - Nose-to-tail conjugate multiphysics simulation.
- Development of an Efficient Grid Generation Methodology -- DRAGON Grid
- Code Enhancement
  - Full finite-rate chemistry.

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NASA Glenn Research Center
October 4-5, 2000

Testbed Developments and Code Parallelization

Isaac Lopez

Contents

- Milestones
- Accomplishments
- Running R4 fan application on the PII cluster
  - Comparison to other platform
- National Combustor Code speedup

Testbed Developments and Code Parallelization

	2000	2001	2002	2003	2004	2005
Code Parallelization		Achieve a 2.5-hour turnaround of a full compressor simulation using APNASA Achieve a three-hour turnaround of a full combustor simulation (1.3 million elements) Demonstrate a 100:1 reduction in turnaround time (relative to 1999) of the new parallel MSTURBO code (unsteady)	Demonstrate highly-parallel, distributed algorithms for aerospace propulsion applications		Demonstrate compressor code application using new highly-parallel, distributed algorithms	Demonstrate combustor code application using new highly-parallel, distributed algorithms
Testbed	Demonstrated a cost/performance ratio of 9.4 in favor of the commodity-based cluster (PII, 64 CPUs)		Demonstrate distributed engine simulation on NASA distributed testbeds (PIII, 128 CPUs; SGI Origin 2K)	Demonstrate 99% availability on distributed computing systems (P?, 128 CPUs: SGI Origin 2K)	Demonstrate propulsion application running in 4th generation of commodity-based cluster (P 64 bit?, 512 CPUs?)	

Accomplishments

- Demonstrated 9.4X cost/performance ratio on Pentium II cluster as compared to SGI Origin 2000.
- Demonstrated an application running over a WAN (GRC and LaRC) using LSF Multicluster software. LSF Multicluster is a tool similar to the functionality of Globus but only between sites using LSF.
- Demonstrated an AvSP application running on NASA IPG.
- Upgraded the Pentium II cluster to Pentium III. Added an additional 64 processors to the cluster.

WAN - Wide Area Network
LSF - Load Sharing Facility
AvSP - Aviation Safety Program
IPG - Information Power Grid

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Accomplishments

- Achieve a 6-hour turnaround time with NCC on a large-scale, fully reacting combustor simulation.
- A prototype of the parallel version of the MS TURBO code was released to NASA GRC for evaluation.
- Lattice Boltzmann model codes have been parallelized and tested on NASA Linux cluster. Close to 100% scalability has been achieved.

NCC - National Combustion Code

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Accomplishments

- Achieved an overnight turnaround (10.7 hours) of a full compressor simulation when using APNASA. This represents a 560:1 reduction in a full compressor simulation turnaround relative to a 1992 baseline.
- A paper concerning the parallel performance of the 3-D CE/SE codes was prepared and presented at the 1st Intl. Conference on CFD during July 10-14, 2000 in Kyoto, Japan. The 3-D code was run on from 1 to 256 processors.

CE/SE - Computational Element/Solution Element

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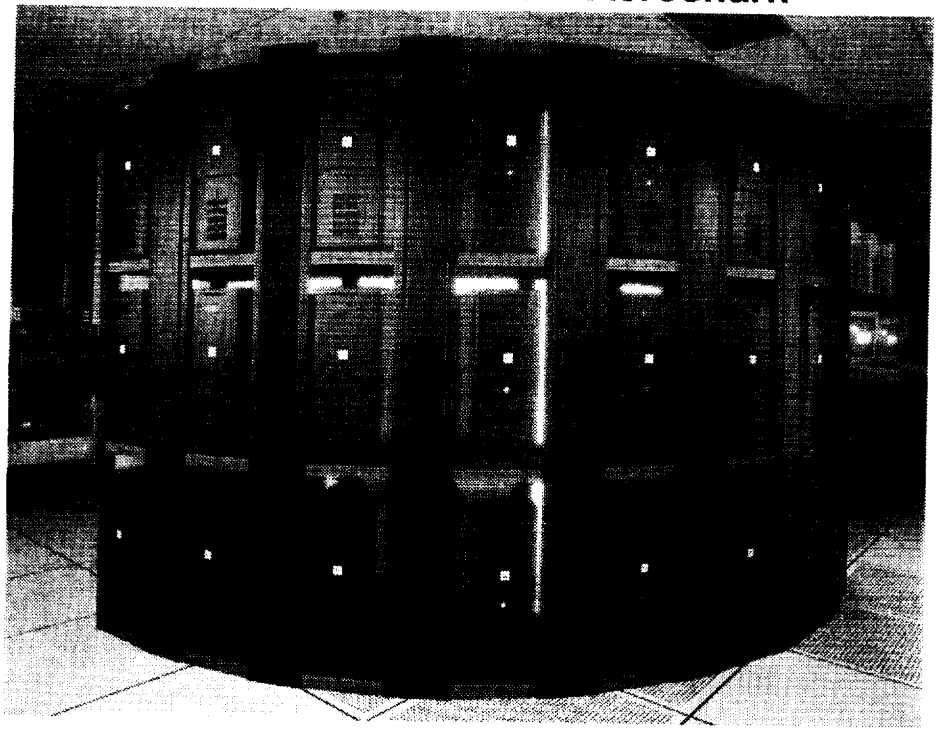
Pentium II Cluster "Aeroshark"



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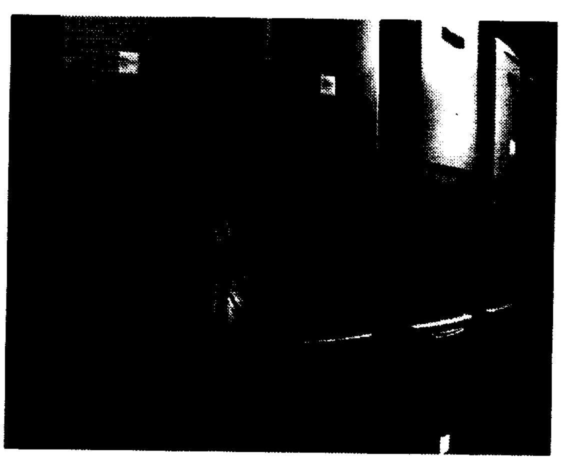
Pentium II Cluster



- Hardware
  - 74 Pentium II 400MHz CPUs
  - 4 Pentium Pro 200 MHz
  - 18 GB RAM; 65 GB swap
  - 45 GB permanent user storage; 192 GB temporary storage
  - Gigabit ethernet & Fast ethernet
  - Debian Linux 2.2 Beta

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Pentium II Cluster

Computing Nodes

Hardware
- 2 Pentium II (Deschutes) 400MHz CPUs
- 512 MB RAM
- 2048 MB swap
- 8GB local disk
- Fast Ethernet
- Debian Linux 2.2 Beta

Software
- Portland Group Compilers V3.0
  - C, C++, F77, F90, HPF
- MPICH
- PVM3
- LSF
- Globus

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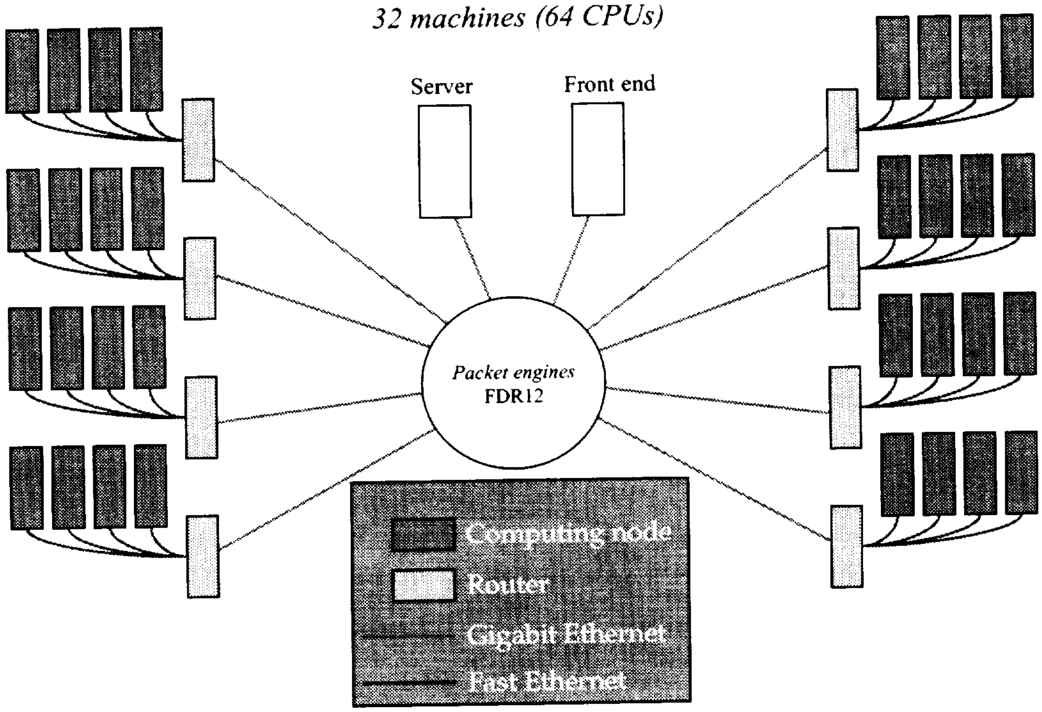
Pentium II Cluster Network Architecture

32 machines (64 CPUs)



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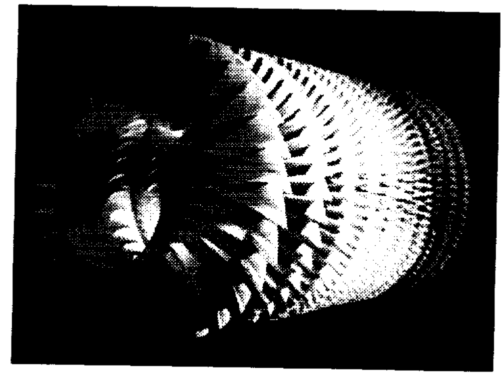
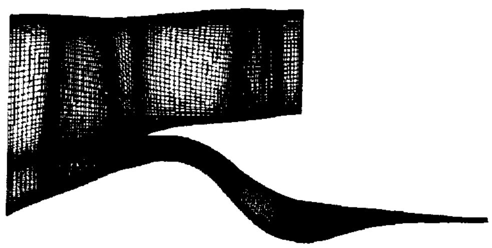
APNASA

APNASA is a computer code being developed by a government / industry team for the design and analysis of turbomachinery systems. The code is based on the average-passage model developed by John Adamczyk at the NASA Glenn Research Center.



Objective

- To develop a turbomachinery simulation capability that will provide a detailed analysis during the design process of gas turbine engines.



Significance

- The APNASA code can be used to evaluate new turbomachinery design concepts.
- When integrated into a design system, the code can quickly provide a high-fidelity analysis of a turbomachinery component prior to fabrication. This will result in a reduction in the number of test rigs and lower development costs.
- Either APNASA or the methodology on which it is based has been incorporated into the design systems of six gas turbine manufacturers.

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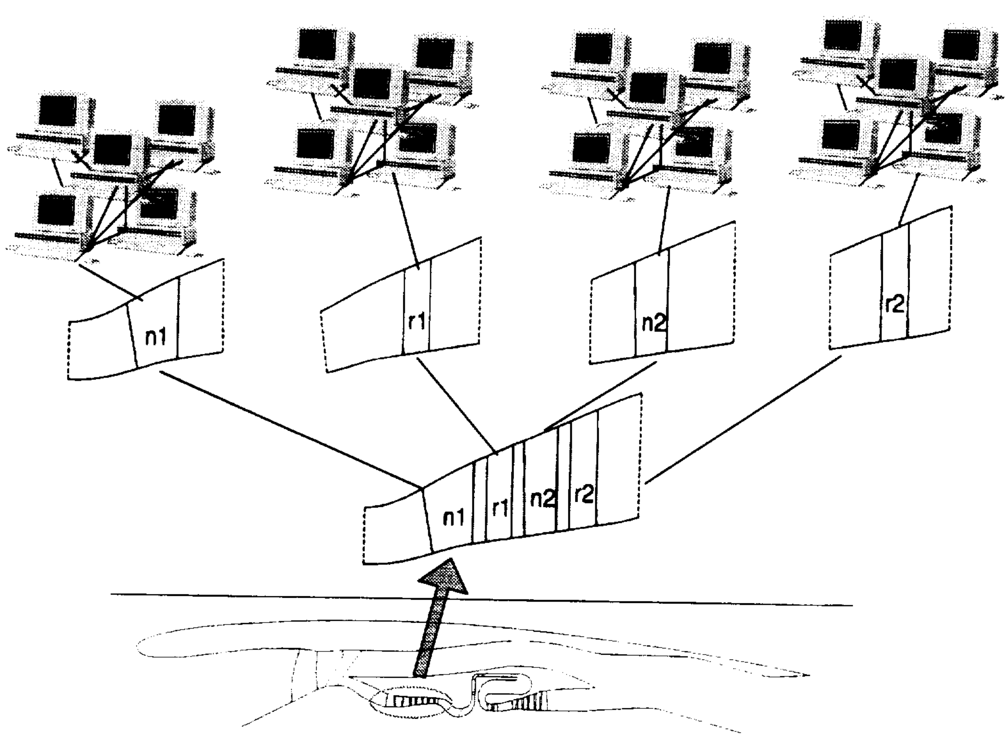
Two Levels of Parallel Capability in APNASA Average-Passage Code



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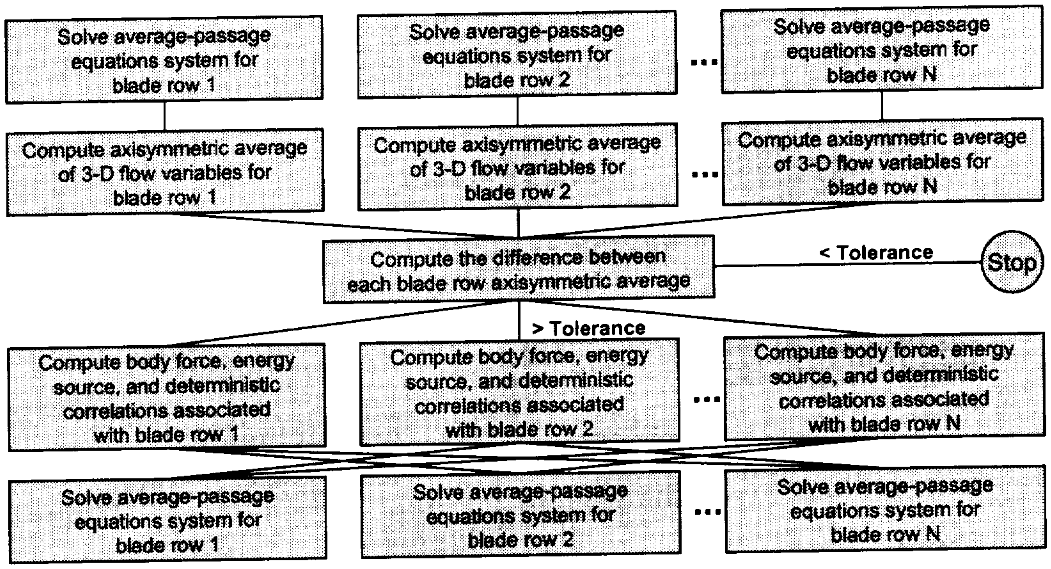
APNASA
Solution Algorithm for the Average-Passage Model



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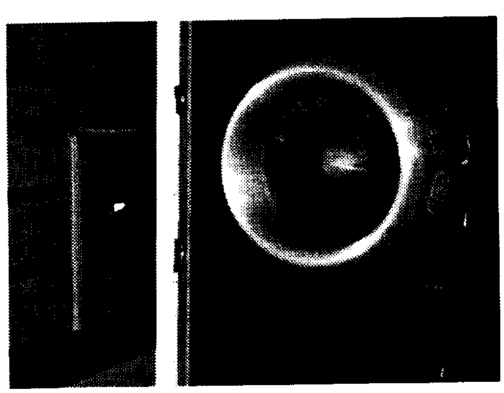
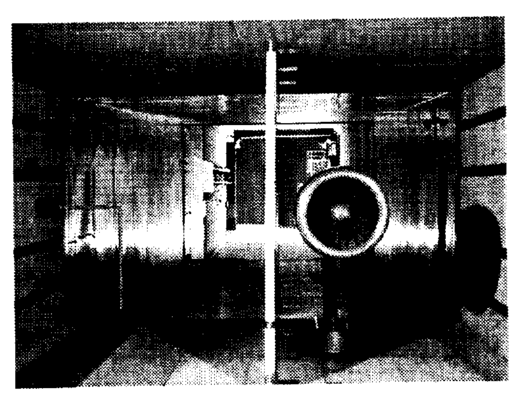
Fan Noise Prediction

- Goal: Use CFD-Based Flow Field Predictions as Input to Fan Noise Prediction Codes
- Testbed: NASA-GE Scale Model Fan





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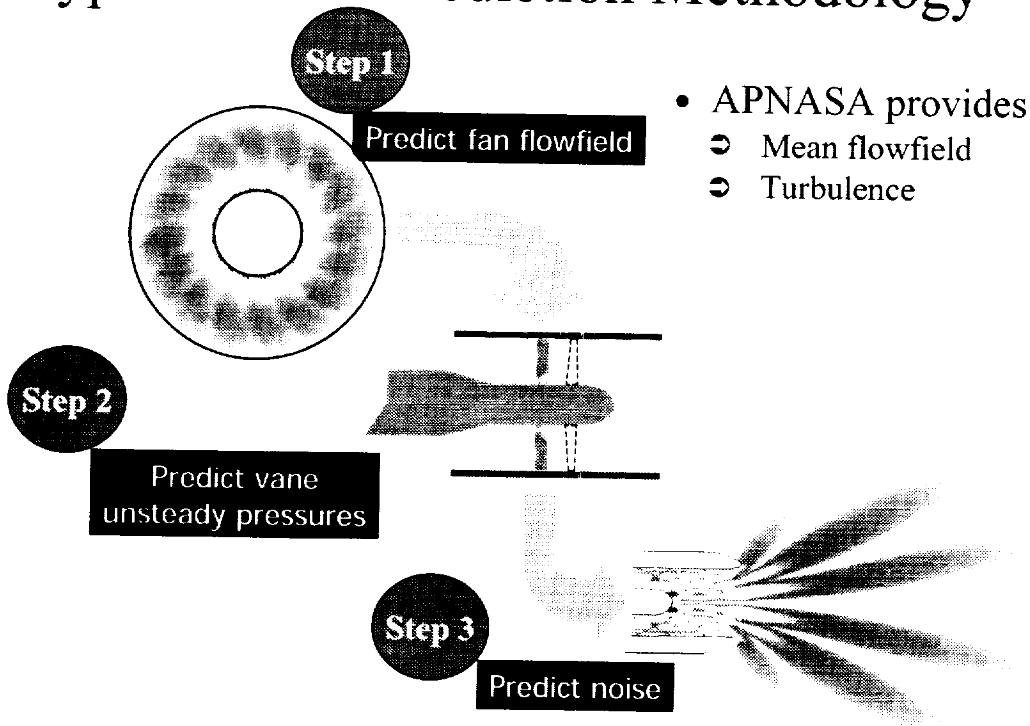
Typical Noise Prediction Methodology



- APNASA provides
  - Mean flowfield
  - Turbulence

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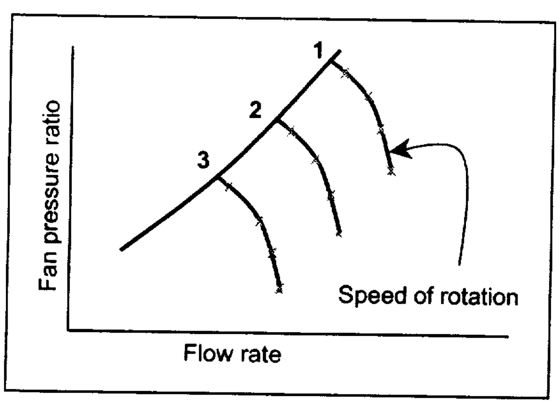
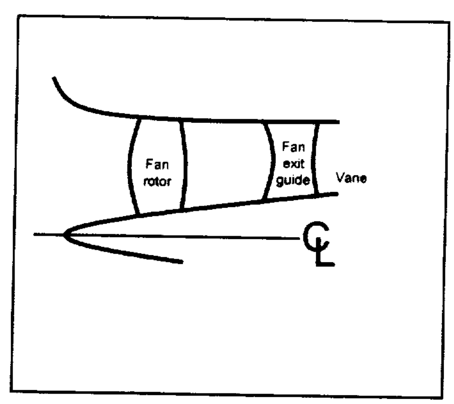
Simulation of High-Speed Fan in Support of Aeroacoustic Analysis





Time average flow field of 3 configurations, each configuration simulated at 4 throttle condition along speed line corresponding to 1)takeoff, 2) cutback, and 3) approach.

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Average-Passage Simulation of the R4 Single-Stage Fan

- Geometry
  - 3 different rotors
    - 61.7% (cutback speed)
    - 87.5% (approach speed)
    - 100% (takeoff speed)
  - 3 different stators
    - Baseline
    - Reduced noise
    - Reduce vane count
  - Each with an axisymmetric mesh measuring 407x51 and a 3-D mesh measuring 407x51x51

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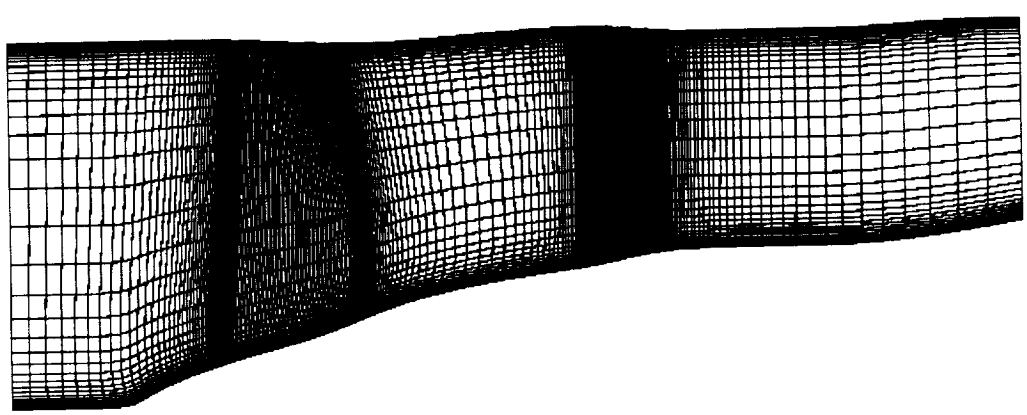
R4 Single-Stage Fan

Rotor (100% Speed) + Vane (Baseline)



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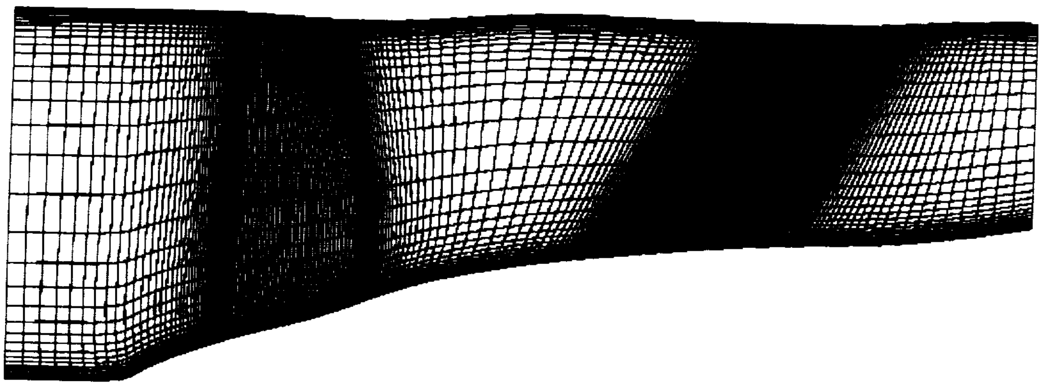
R4 Single-Stage Fan

Rotor (100% Speed) + Vane (Reduce Noise)



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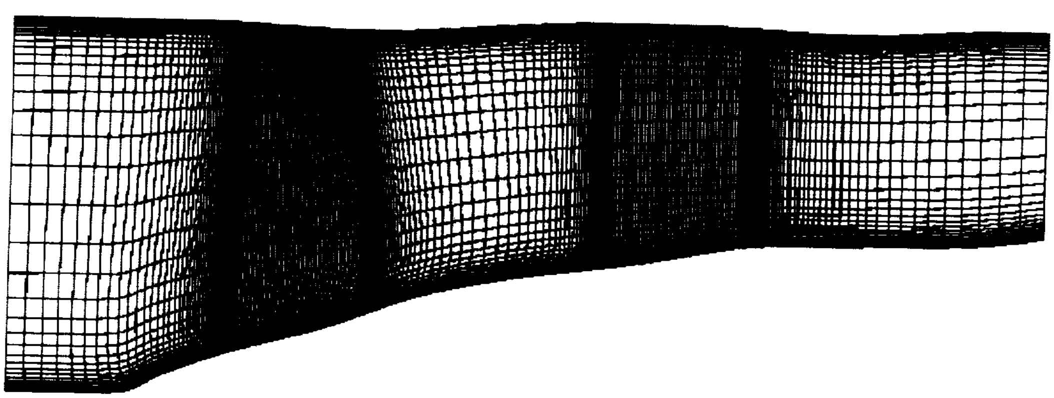
R4 Single-Stage Fan

Rotor (100% Speed) + Vane (Reduce Count)



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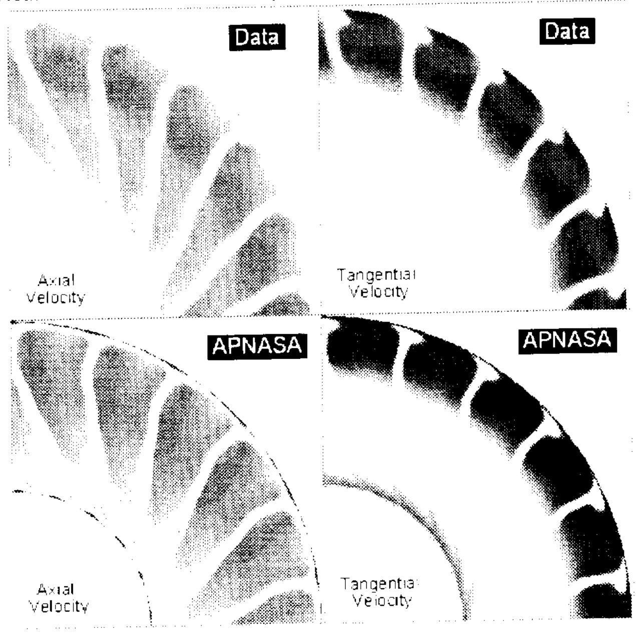
APNASA Flowfield Predictions

Comparisons of Measured and Predicted Fan Flow Fields
Distirbutions of Mean Velocity Components Downstream of the Fan



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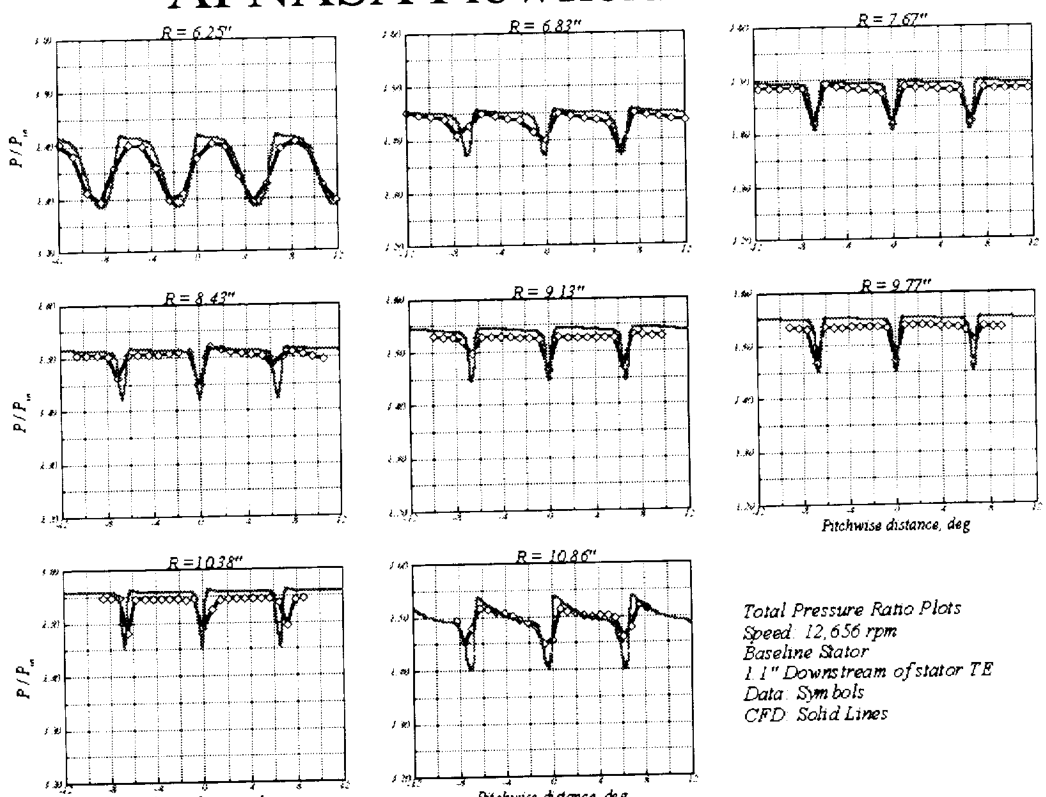
APNASA Flowfield Predictions



Total Pressure Ratio Plots
Speed: 12,656 rpm
Baseline Stator
1.1" Downstream of stator TE
Data: Symbols
CFD: Solid Lines

Average-Passage Simulation of the R4 Single-Stage Fan (continued)

- CPU Requirements
  (per blade row running both blade rows simultaneously)
  - 130 seconds per iteration
  - 360 CPU hours for a 100 “flip” run (100x50 iterations x 2 blade rows)
  - 180 wall clock hours for a 100 “flip” run (100x50 iterations)
- Memory Requirements
  - ~250 MB per blade row
  - 500 MB total running both blade rows simultaneously (2x250)

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Performance

- For the single-stage fan case (with a mesh size of 407 x 51 x 51 for each blade row), a single"flip" takes approximately 6500 seconds of wall-clock time on the aeroshark cluster.
- This compares to 2750 seconds of wall-clock time to run the same case on an SGI Origin 2000 system composed of 250 MHz R10000 MIPS processors.
- This equates to roughly a factor of 2.36.

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Cost / Performance Ratio

- Cost
  - SGI Origin 2000, 250 MHz R10000, 24 CPUs
    - $468K
  - Aeroshark, 24 CPUs
    - $21K
- Cost Ratio
  - 22.3
- Cost / Performance Ratio
  - 9.4X

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Conclusion

- Clearly the use of the commodity-based cluster has a tremendous potential to provide a computing platform on which detailed aeropropulsion simulations can be executed in a time compatible with the engine design cycle.
- The cost/performance ratio shown by the cluster was impressive considering the cost differential between commodity-based clusters and traditional UNIX workstation clusters.
- As a result of this work the aeroshark cluster will be upgraded to address all the performance issues.

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Future Work

- Upgrade Cluster
  - Larger number of CPUs
  - Improve interprocessor communication

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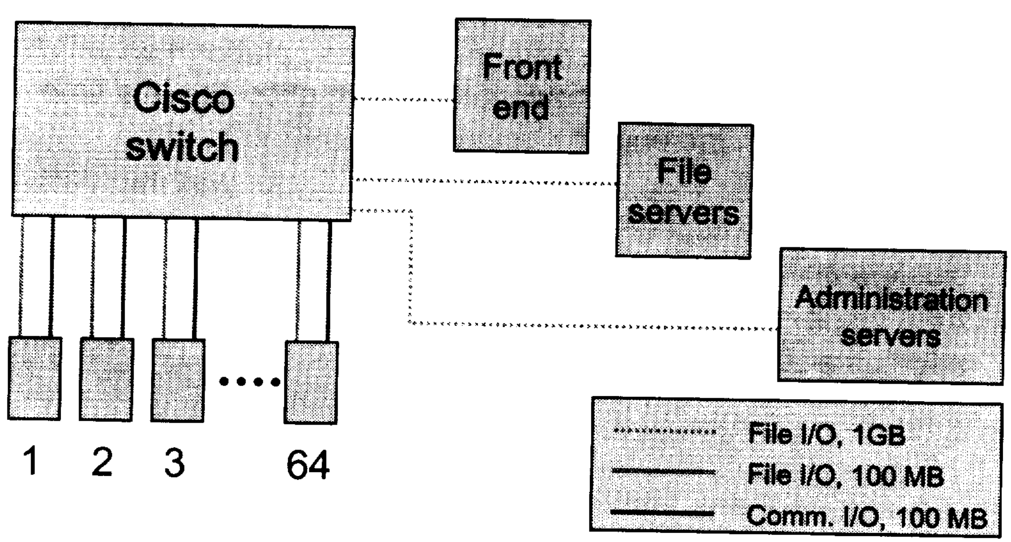
New Pentium III Cluster Network Architecture

64 machines (128 CPUs)



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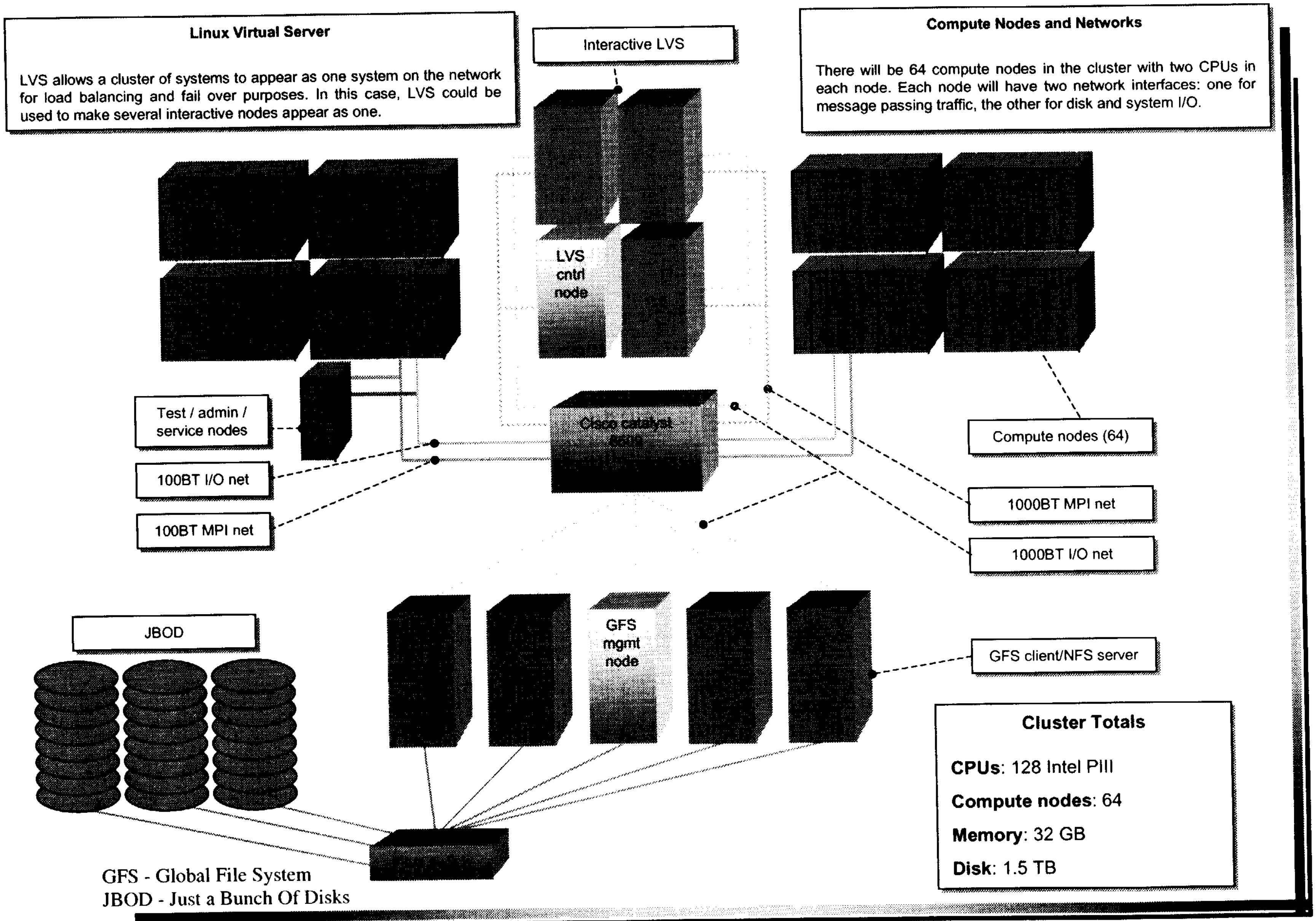
Linux Virtual Server
LVS allows a cluster of systems to appear as one system on the network for load balancing and fail over purposes. In this case, LVS could be used to make several interactive nodes appear as one.
Interactive LVS
Compute Nodes and Networks
There will be 64 compute nodes in the cluster with two CPUs in each node. Each node will have two network interfaces: one for message passing traffic, the other for disk and system I/O.
LVS cntrl node
Cisco catalyst
Test / admin / service nodes
100BT I/O net
100BT MPI net
Compute nodes (64)
1000BT MPI net
1000BT I/O net
JBOD
GFS mgmt node
GFS client/NFS server
Cluster Totals
CPUs: 128 Intel PIII
Compute nodes: 64
Memory: 32 GB
Disk: 1.5 TB
GFS - Global File System
JBOD - Just a Bunch Of Disks