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<p>Research is directed at the application of modern computer technologies, with emphasis on emerging parallel computing techniques to the solution of fluid dynamic problems. CFD algorithms will be developed, implemented, analyzed and benchmarked on several different architecture parallel computers.</p>			
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CFD RESEARCH FOR MINI-SUPERCOMPUTERS  
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## Final Report

In the second year of this contract, our research centered on studying various parallel algorithms. This included additional work on the model CFD problem studied in the first year, and work on domain decomposition and fast multipole methods. These latter algorithms show promise for many CFD applications. In particular, the domain decomposition work is already being applied to work in CFD with combustion, and the fast multipole method makes the vortex method for high Reynolds number flow computationally practical.

Greater computational power is needed for solving Computational Fluid Dynamics (CFD) problems of interest in engineering design. Parallel architecture computers offer the promise of providing orders of magnitude greater computational power. We have quantified that promise by considering an explicit CFD method and analyzing the potential parallelism for three different parallel computer architectures. The use of an explicit method gave us a "best case" analysis from the point of view of parallelism, and allowed us to uncover potential problems in exploiting significant parallelism. The analysis was validated against experiments on three representative parallel computers. The results allow us to predict the performance of different parallel architectures. In particular, our results show that distributed memory parallel processors offer greater potential speedup.

The import of our model for the development of parallel CFD and our experiences in converting our model code to run on three different parallel computers was presented as *Computational Fluid Dynamics on Parallel Processors*, AIAA paper 88-3793-CP, at the First National Fluid Dynamics Congress, Cincinnati, OH, July 25-28, 1988.

We considered the application of domain decomposition techniques to the solution of sparse linear systems arising from PDE discretizations on parallel computers. We also considered two representative types of MIMD parallel computer: a message passing and a shared memory architecture. For each we developed complexity estimates and compared these against actual computations. Various

tradeoffs in parallel computation costs were investigated. Our complexity estimates were tested for a variety of methods, decompositions, and problem sizes. This work was described in *Domain Decomposition on Parallel Computers*, presented at the SIAM Conference on Domain Decomposition Methods, January 15-16, 1988.

*A Parallel Version of the Fast Multipole Method*, (Technical Report YALE/DCS/RR-640, Yale University, Department of Computer Science, August, 1988.) presents a parallel version of the Fast Multipole Method (FMM). The FMM is a recently developed scheme for the evaluation of the potential and force fields in systems of particles whose interactions are Coulombic or gravitational in nature. The sequential method requires  $O(N)$  operations to obtain the fields due to  $N$  charges at  $N$  points, rather than the  $O(N^2)$  operations required by the direct calculation. We considered the modifications necessary for implementation of the method on parallel architectures and showed that the expected time requirements grow as  $\log N$  when using  $N$  processors. Numerical results are given for a shared memory machine (the Encore Multimax 320).



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