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This project initiated on 8/1/97 with the goal of experimentally realizing small quantum computers using nuclear magnetic resonance (NMR) techniques. Our collaboration involved four groups with Stanford and IMB developing algorithms and numerical models, UC Berkeley synthesizing molecules and implementing algorithms at their high magnetic field NMR facility, and MIT investigating scaling to 100s of quantum bits and desktop size apparatuses. Our three principal aims were to: (1) Make quantum information processing feasible to transcend the classical limits in computation and communications (2) Take advantage of the inherent computational capability of physical systems using natural materials to eliminate the need for billion-dollar fabs, and (3) Integrate the physics, chemistry, electrical and mechanical engineering, computer science and mathematics needed to develop and deploy useful quantum information technology.

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# A Desktop Bulk Spin Computer

## Final Report

J. S. Harris

November 1, 2002

U. S. Army Research Office

DAAG55-97-1-0341

Stanford University

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# I. FINAL PROGRESS REPORT

## A Statement of the problem studied

This project initiated in 8/1/97 with the goal of experimentally realizing small quantum computers using nuclear magnetic resonance (NMR) techniques. Our collaboration involved four groups with Stanford and IBM developing algorithms and numerical models, U.C. Berkeley synthesizing molecules and implementing algorithms at their high magnetic field NMR facility, and MIT investigating scaling to 100's of quantum bits and desktop size apparatuses. Our three principle aims were to: (1) Make quantum information processing feasible to transcend the classical limits in computation and communications, (2) Take advantage of the inherent computational capability of physical systems, using natural materials to eliminate the need for billion-dollar fabs, and (3) Integrate the physics, chemistry, electrical and mechanical engineering, computer science and mathematics needed to develop and deploy useful quantum information technology.

## B Summary of the most important results

We have succeeded in demonstrating the feasibility of quantum computers by experimentally demonstrating numerous quantum algorithms including quantum searching and order-finding. The experiments culminated in the world's first ever implementation of Shor's factoring algorithm using seven quantum bits to factor the number 15. This work is the most complex quantum computation performed to date, and won the DARPATech 2002 "Significant Technical Achievement Award".

We furthermore advanced theoretical studies in the field of quantum information by investigating how quantum states could assist classical machines. Among other discoveries, we developed a clock synchronization algorithm which could assist GPS systems to achieve better guidance and spatial locating ability. We also found that the creation of a *Quantum Software* protocol could potentially play a role in constructing large-scale fault-tolerant quantum computers.

## C Listing of all publications and technical reports supported under this grant or contract

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**D List of all participating scientific personnel showing any advanced degrees earned by then while employed on the project**

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