I. INTRODUCTION

Thirty-nine years and two weeks ago here at Livermore, I began what has turned out to be a great adventure -- an adventure as full of discovery and dilemma, risk and excitement, reward and satisfaction as any kid could ever dream of. But most of all it has meant having the company of fellow adventurers of a class few people are fortunate enough even to know.

There have also been very few occasions which provided an opportunity to look back. So today it is a special pleasure and an honor -- for me to share a little time with many of my co-adventurers, and to pay tribute to a special one -- Sid Fernbach.

Go to a library, and you'll find listed some 1,400 books, magazines and newsletters on business management. That's a mind-boggling amount of (mostly useless) information. These days there is a great deal of advice about being "close to the customer." Like most things of a common sense nature that's a heck of a lot easier said than done. But if Sid Fernbach was your customer, being "close to your customer" was never the issue. The problem was to get him out of your hair!
More seriously, much has been written about U.S. leadership in high-speed computing: its roots in research, individual contributors, the role of government, U.S. economic pre-eminence in the post WW II years, and so on. In the past decade with the advent of significant competition from abroad this analysis has become more fervid.

Overlooked in all that is the fact that, as real and important as all those factors were, it was the vigorous partnership of industry, government and academia which impelled us toward leadership in high-speed computing. And it was due to a very few individuals that that partnership flourished. Sid was one of those individuals.

He could see the potential, was willing to take the risks, and understood the kind of partnering that advanced computing entails.

Over the past twenty years I have spent a lot of time in Washington dealing with technology policy. As an exercise in frustration, it is hard to beat. But Sid was vivid proof that individuals can prevail even when policy languishes.

II. THE SUPERCOMPUTER STORY

The widespread concern today and for technology generation and transfer as a principal underpinning of U.S. competitiveness is neither misplaced nor overstated.

With very few exceptions the federal government policy has historically concerned itself with fostering, nurturing and paying for basic research -- "pushing" technology into the economy. However, it is equally important for government policy to concern itself with technology "pull."
The development of the supercomputer is one sparkling example where government and industry worked to achieve technology "pull." This was not consciously done as a governmental technology transfer or economic competitiveness initiative. But it had that result and we should learn from it.

The story of advanced high speed computing has important technological and economic implications for the U.S. Supercomputers have been the driving force of technology development in the computer industry. They are also the driving force in the advancement of scientific disciplines in general.

The most significant characteristic of the supercomputer business is high risk -- very high risk. Supercomputers are the highest risk part of the high-risk computer industry because they involve both extraordinary technical risks and market risks.

The lessons we have learned over the years of super computer development are ones we must heed if the U.S. is to remain a world leader in technology. Since by definition we are dealing with the highest performance systems for any given state of technology, the technical risk may seem obvious. But the risk goes far beyond that. In building the most powerful system possible, there is an extremely subtle balance that must be struck between architecture and circuit technology. In oversimplified terms, this is because the design of a supercomputer takes roughly four years. So, you are aiming at a point four years out. Trying to anticipate the state of technology that far out, can lead and has led to an absolute dead end. On the other hand, working only with proven technology will almost surely preclude the successful implementation of the most advanced design concepts.
But that is only the beginning. To be effective, advanced architectural concepts require new software, and, beyond that, new approaches to, and algorithms for the solution of complex problems.

The advancement of knowledge in basic technology, design concepts, and software in an uneven thing at best. And over it all hangs the specter of market risk.

The most advanced computers are, again by definition, initially addressing a limited number of users, a limited market. And those initial customers are key to the ultimate success of market development.

Moreover, market access for such systems is a political as well as an economic matter. And, because of procurement cycles, delays are highly leveraged in terms of available market windows.

The past is filled with examples of this technical and market-risk -- and failure.

The supercomputer story really started with the efforts of IBM and Univac in the middle 1950s, which produced "high performance" computers known as the LARC and STRETCH. There were shared-risk developments, by which I mean the government contracted in advance for the machines. The vendors' risks involved agreeing to a fixed price and guarantee of completion of the contract. Both these early projects suffered from the soon-to-be-familiar experience in supercomputer development of underestimating complexity and technological challenges. In both cases, something was finally delivered. But the attempts can only be labeled as financial disasters.
The beginning of supercomputers as a distinct class however came in 1964 with the delivery of the initial Control Data 6600 computers. It was in connection with this event that the term "supercomputer" actually came into use. The great success of the 6600 has obscured a crucial matter. It was designed twice. The first attempt failed in trying to anticipate circuit technology development. But with the existence of a government contract calling for the delivery of a machine with specific performance, the development effort had economic as well as technological motivation to start over. Sid Fernbach’s unwavering support was crucial. The second effort succeeded.

With the 6600, the supercomputer era was launched. The realization of computational rates in the "megaflop" range led immediately to demands by high energy physicists for even greater horsepower. With the potential of the 6600 barely digested, the government labs set forth needs which led to more advanced designs involving greater parallelism. Vendors responded with designs involving vector processing, multi-processing, and parallel processing.

Parallel processing, incidentally, which is only reaching any semblance of maturity in recent years, has had perhaps the longest history of any computational concept in high-speed computing. It also best illustrates the enormous task of matching software and algorithmic knowledge with hardware architecture.
I am reminded that when I came to work at Livermore in February, 1953, we had two “computers.” One was serial and was called the “Card Programmed Calculator” or CPC. The other was a parallel processing system. We had “banks of processors” which consisted of people at desk calculators. They worked in parallel at carefully partitioned algorithms. And yes, there were heated arguments even then. The relative merits of the Friden vs. the Marchant calculators were much discussed.

In any event, the response to the needs of the lab included developments such as Texas Instruments "Advanced Scientific Computer" [TI-ASC], the Burroughs "ILLIAC IV" and the Control Data "STAR-100." The hope of developers and customers alike was that these machines would be available as early as 1970. This was not to be the case.

Meanwhile at Control Data, another new machine -- the 6800 -- was being designed. The machine was to be a compatible extension of the 6600 and four times faster. It also failed. Once again it was necessary to start over and by using a different design -- incompatible with the 6600 -- the desired performance was achieved. But, because of the incompatibility, the software costs were enormous.

This redesigned 6800 was called the 7600 and enjoyed an extraordinarily long run as the world's most powerful computer.

The reason for that longevity was that the TI-ASC effort failed and was abandoned. The ILLIAC-IV failed and was abandoned. The STAR-100 failed and was redesigned, redesigned, and redesigned again until finally in 1979, the CYBER 205 appeared. Needless to say, hundreds of millions of dollars were involved in these attempts.
What's the significance of the supercomputer story?

One, there have been more failures than successes.

Two, the early U.S. advantage in supercomputers was established not only by the technical expertise of some truly remarkable people but equally by management perseverance and very enlightened cooperation between the labs and industry.

But the technological cooperation between government and industry was only one dimension of the cooperation that propelled the U.S. to leadership in supercomputers. Equally important was the cooperation between the large semiconductor manufacturers and the supercomputer designers, and between universities and industry in critical areas of both basic research and the application of supercomputers to the frontiers of science.

In addition, scientists and mathematicians at the laboratories were instrumental in assuring the successful application and refinement of these computers, which when they were first delivered at best only qualified to be called prototypes.

Thus, there developed an informal infrastructure of technology "push" from basic research and technology "pull" toward leading-edge products. Market risk was mitigated through industry-government cooperation. This cooperation was not only financial in nature, but equally important, it addressed the successful application of the product to a vital government task or mission. Sid Fernbach understood and nurtured this unique cooperation.
Supercomputers are the ultimate embodiment of the most advanced computational technology. Indeed, supercomputers are equally, if not more important, in the electronic and architectural technological advances they spawn as they are in their role as engines of computation. Those advances ultimately find their way into the mainstream of computers from mainframes to workstations and personal computers.

Equally important, supercomputers have been the driving force behind new advances across a broad spectrum of science and engineering. Clearly, the U.S. has reaped huge benefits from the enlightened cooperation of government, the computer industry and universities.

III. TECHNOLOGICAL PUSH AND PULL -- BEYOND SUPERCOMPUTERS

The story of how the U.S. achieved technological leadership in supercomputers points the way to achieving more general technological leadership and enhancing the competitiveness of U.S. industry. It also vividly illustrates the importance of technology cooperation and transfer.

As I said earlier, the federal government has mostly concerned itself with pushing technology into the economy.

Over the past decade, it has become more proactive in helping to push technology into the private sector. The seminal legislation in this regard was the Stevenson-Wydler Act of 1980.

Implicit in all this activity is the feeling that technology can, with dedicated effort, be pushed more rapidly into the economy. Unfortunately, this is analogous to the old saw about "pushing a wet noodle."
Government policy must encourage technology pull as well as technology push.

Developing high-risk products, services and processes, will involve the transfer of very advanced technology from research into commercial application. In order for that to occur, there must be some incentives. By its very definition, high risk is something that you wouldn't do otherwise -- it's beyond the limits imposed by normal commercial risk-return ratios. But once that is made possible, the technology moves from these high-risk projects out into the mainstream products and services. The entire economy benefits.

Government-industry cooperation in such high-risk applications of technology is a cost effective way of keeping a steady infusion of leading-edge technology into the economy. And a government policy that fosters this technology pull is just as important as one that fosters technology push.

But finally it comes down to individuals like Sid Fernbach who make it all happen. Our industry has been blessed with individuals of many and varied talents. But there have been few customers like Sid who could, and would, with great clarity, point out not only the error of your ways, but also the importance of your task.