

## **Yale Talk**

### **Introductory Remarks**

I'm absolutely delighted to return to the peace and tranquility of dear old mother Yale...

Quite frankly, it has been one hell of a spring...

I started off the year as Acting President, presiding at that great Michigan tradition...our annual New Years Day thrashing in Pasadena...

Then in February I hosted a number of dignitaries at UM including Gerald Ford, Ed Meece, and Benno Schmidt... and wouldn't you know it...our students protested and threw eggs at the group (I wonder at whom...)

Three weeks ago negotiating with Jesse Jackson and a coalition of minority student and faculty groups...

For the past several days in intense negotiations with our graduate teaching assistants union trying to avoid a strike originally scheduled for today...

Next week back into the fray with the nurses union and house officers union in our medical center...

Hence, it is with a sense of deep humility and strong desire to learn that I come back to Yale to learn the art of effective negotiation at the foot of the master...

Actually, the resurgence of student activism on American campuses in recent months reminds me of the good old days of the 1960s...

And, of course, the 1960s reminds me of my own days as an undergraduate at Yale...

### **Yale Engineering in the 1960s...**

Actually, the early 1960s were an exciting time for Yale engineering...for it was then that an earlier Yale administration struck a blow for the liberal arts by taking the last step to demolish the old Sheffield Scientific School and with it Yale Engineering by converting it into a Department of Engineering and Applied Science.

Indeed, my class of 1964 was the last to receive the B.Eng degree...

Needless to say, engineering students at that time were a bit concerned...in fact, many of us almost transferred to other institutions.

Hence, it is with some interest that I note Yale's efforts in recent years to reestablish its science and engineering

programs as key priorities...

**Therefore, it seemed appropriate to make some**

observations from afar about the nature of science and engineering education at Yale...

As an alumnus, to be sure...

As a former dean of engineering...

But, perhaps even more, as a member of the National Science Board...

Let me do this in a rather round-about way by commenting not about Yale itself...but rather about that vast wasteland between New England and California known as the "Midwest"...

**The view from Michigan..."the Rust Belt"...**

While people generally look at the midwest as a relic of America's industrial past, let me suggest that in many ways, it can also be viewed as America's future...in both a good news and a bad news sense...

The bad news is obvious...

Industries of great economic importance to our nation such as steel and automobiles have fallen victim to intense competition from abroad...

Plants have closed...our cities are filled with cronically unemployed...

The introductory scene from Beverly Hills Cop...

In Michigan we no longer worry about nuclear war and and the bomb because we believe that

"The odds are greater that America will be bought up by the Japanese than blown up by the Russians..."

Yet, something else is happening in the heartland of America...

**The Challenge of Change**

The challenge of dramatic economic change...

Traditional industry economy is shifting to a new, knowledge-based economy just as our industrial enterprise evolved from an agrarian society at the turn of the century.

This change has gripped the Rust Belt...

Of course, the Midwest is where our nation makes things...

Cars, refrigerators...machines that make cars ...

Surrounded by excitement of industry in transition

"factory of the future"

robotics, machine intelligence, animate systems

But these are just tip of the iceberg!!!

A fascinating and unique convergence of technology...  
The chip, computers, AI, new materials, mech systems  
Driven by money (investment) and need (competitiveness)  
Machines that can perceive their environment, think,  
and act...First applications will be in manufacturing.  
However, the next generation of thinking machines  
will be designed and built by intelligent machines.  
CMI address is 2001...

A transition is occurring in which..  
Intellectual capital is replacing  
financial and physical capital as key to economic  
development

Some examples:

Industrial production is steadily switching away from  
material and labor intensive products and processes  
to knowledge intensive processes:  
Raw materials in a chip are only 1% - 3% of cost...  
in contrast to 40% for a car and 60% for pots.

Increasing manufacturing production has come to mean  
decreasing blue collar employment!  
In the 1920s, 1 of 3 was a blue-collar worker  
today 1 in 6 and dropping fast  
probably to about 1 in 10 within a couple of decades...

What is happening?

1. Acceleration of the substitution of knowledge and capital for manual labor -- replacement of manual workers by machines, the products of knowledge.
2. Shift to industries which are knowledge-intensive.  
Example: 70% of chip costs is knowledge -- only 10% labor  
Cars: even fully robotized, still 25% labor

In all developed countries, "knowledge" workers have already  
become the center of gravity of the labor force.

### **The Age of Knowledge in a Global Economy**

The major force is technology itself!

At one level, technologies of transportation and communication  
make possible an integrated economy.

Tremendous new industries have been created by new  
technical knowledge: electronics is the obvious example  
of the last three decades; biotechnology may be the  
example for the coming three decades.

These industries depend on knowledge as the most critical

resource.

Intellectual capital -- brainpower -- is increasingly regarded as the key element

needed to compete effectively in a highly technological and rapidly changing global economy.

But knowledge is highly mobile...it is not tied to geographic regions as coal or iron or oil.

By contrast, the knowledge revolution is happening worldwide and at a very rapid rate.

Even less developed nations are also learning the lesson and drawing knowledge from the developed world or generating it themselves.

Brazil, India, Korea are quickly advancing along the competitive path that Japan took 30 years before.

The morale of the story:

In the age of knowledge in a global economy, the economic strength of a nation, its security, the well-being of its citizens...

Will depend on its science and engineering base...

That is, the collection of people, institutions, equipment, and facilities that make basic research and innovation possible

### **Clouds on the Horizon**

But here America faces serious challenges...

WARNING SIGN 1: America is slipping

No question that US has lost lead in many areas

Steel, autos

Energy (particularly nuclear)

Electronics

Also serious signs that lead is slipping rapidly in

Computers

Aerospace

WARNING SIGN 2: S&E Manpower Shortage

US faces a S&E manpower crisis of unprecedented proportions

Some examples:

Per capita production of US engineers lowest among industrialized nations:

President of Sony:

"In US you produce 4 lawyers for every engineer.

In Japan, we graduate 4 engineers for every lawyer!"

But things are going to get MUCH rougher:

## NSF Study

Traditional source of S&E college students is declining  
25%-30% falloff in HS graduates by 1992

Assuming that same fraction (4.8%) choose to enter S&E,  
and assuming constant demand (very conservative),  
there will be a cumulative shortfall of 700,000  
by 2010!

## WARNING SIGN 3: THE IMPACT OF TECHNOLOGY

We really haven't appreciated impact of technology.

Example:

Technology doubles every 5 years in some fields!

Engineers are obsolete by the time they graduate!

Engineers must factor change into their career objectives.

Change is a permanent feature of our environment

Continuing education will be an absolute necessity.

## WARNING SIGN 4: Technological Illiteracy

Claim: We are rapidly becoming a nation of illiterates ...

in science and technology, no longer able to comprehend  
or cope with the technology that is governing our lives.

Public's knowledge and understanding of science has not  
kept pace with technology -- they have become  
disenfranchised from the very society in which they live...

## **A National Response is Required**

And people must be the major focus...

Because people -- not equipment or buildings -- are the source  
of creativity.

They generate the knowledge that makes the technological  
innovation possible. They are the workforce that makes  
society run.

They are our researchers and teachers, our leaders, managers,  
and decisions makers in modern technological society.

We face a two-fold challenge

1. Achieve basic scientific literacy among all our citizens
2. Provide enough scientists and engineers for industry and  
academe

## **An Obvious Conclusion**

Hence, I would contend that Yale has a responsibility to this nation  
to make the sustained commitment

to build outstanding programs in science and engineering...

But it also has a responsibility to itself...

Indeed, I believe that no modern university can be distinguished

without a major commitment to both basic and applied science...

**Question: But what should the "flavor" of E&S be at Yale?**

Can spot a number of models...

MIT/Michigan/Berkeley/Cornell

"mega-engineering"...

E.g. At Michigan, EECS has 1,800 students...

We graduate 1,700 engineers each year!

Yale cannot do this...at least without seriously  
distorting the institution

The Harvard Style...

Engineering at Harvard = MIT

(Where can Yale find an analogue in New Haven...)

Let me suggest an alternative...in fact, another one of my alma  
maters...

The Caltech model:

Strong focus at the interface between  
engineering and basic science

The Caltech style...

Do only what you can do very well...

Focus your resources on a few areas in which  
you can really be leaders...

Build "spires of excellence", to use an old Fred Terman  
phrase...

Try to work on the early, exponential portion of  
the "Knowledge Curve", where a few individuals  
of unusual talent and broad intellectual span can  
have extraordinary impact.

Yale cannot be an MIT or Michigan...but, if it focuses its  
efforts, and chooses these areas with "good taste" to  
be at the cutting edge, it can play a leadership role for  
far larger engineering schools.

Yale aspires to leadership in education and scholarship.

It is therefore natural to expect the same aspirations to  
apply in engineering and applied science!

**Ah, enough of telling Yale what to...**

as academics from other institutions are prone to do...

**Let me instead thank you once again for this honor..**

and let me wish you the best as Yale science and engineering  
moves toward the 21st Century!