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Remarks by

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When Neil Rudenstine first invited me to join you today, he suggested that it might be valuable to discuss the roots of the changes that our economy has been experiencing in recent years As leaders in higher education, you have all been dealing with the practical effects of these shifts

But, in more theoretical terms, what do these historic changes teach us about the way we learn and innovate? What is their impact on the workforce and on your graduates? How has technology transformed our ability to understand the natural and social world?

Our faculty for rational thought has carried the human race one arduous step at a time into a deeper understanding of how the world works Decade by decade, scholars have recorded their insights, building knowledge from one generation to the next We have learned to use that knowledge to alter our physical environment for the betterment of mankind

That process has become increasingly conceptual in nature and ever less reliant on physical materials Indeed, the endeavor to economize on physical resources has led to widespread downsizing of the elements of the nation's output We have dramatically reduced the size of our radios, for example, by substituting transistors for vacuum tubes Thin fiber-optic cable has replaced huge tonnages of copper wire New architectural, engineering, and materials technologies have enabled the construction of buildings enclosing the same space, but with far less physical material than was required, say, 50 or 100 years ago Most recently, mobile phones have been markedly downsized as they have been improved

Over the last century, for example, the rate of increase of the gross domestic product in the United States, adjusted for price change--our measure of gains in the real value of output--has averaged around three percent per year Only a small fraction of that represents growth in the tonnage of physical materials--oil, coal, ores, wood, raw chemicals, for example The remainder

represents new insights into how to rearrange those physical materials to better serve human needs

This process has enabled valued goods to be transported more easily and to be produced with ever fewer workers, allowing the more efficient division of labor to propel overall output and standards of living progressively higher

The share of the nation's output that is conceptual appears to have accelerated following World War II with the insights that led to the development of the transistor and microprocessor They have spawned remarkable alterations in how we, and other developed societies, live

Computers, telecommunications, and satellite technologies have enabled data and ideas, the ever more important elements of output, to be speedily transferred geographically to where they can be put to best use Thus, these advanced means of communication have added much the same type of value that the railroads added in transporting the more physical goods of an earlier century

Here in the United States, we have developed an exceptionally sophisticated stock of capital assets--plant and equipment--fostered most recently by what has to be the most conceptual and impalpable of all new major products--software

The breakthroughs in information technology have facilitated an elevated rate of "creative destruction," as noted Harvard economist Joseph Schumpeter put it earlier this century Our capital stock is undergoing an increasing pace of renewal through investment of cash flow from older-technology capital facilities into new, more efficient vintages Some Silicon Valley firms claim that they completely reconstitute themselves every year or two This renewal process is driven by an increasing ability to more finely calibrate the value preferences of consumers In

turn, those preferences are converted, through market transactions, into prices of products and assets They, in turn, signal entrepreneurs which capital facilities to build to meet those shifting consumer needs

But as human intelligence appears without limit to engage our physical environment, human psychology remains, in some more primordial sense, invariant to time The rapidity of change in our capital assets, the infrastructure with which all workers must interface day-by-day, has clearly raised the level of anxiety and insecurity in the workforce As recently as 1981, in the depths of a recession, International Survey Research found twelve percent of workers fearful of losing their jobs In today's tightest labor market in two generations, the same organization has recently found thirty-seven percent concerned about job loss

The fear of job obsolescence when confronted with a rapidly changing work environment is arguably one reason for a massive increase in the demand for educational services--the rise in on-the-job training, the proliferation of community colleges enhancing work skills, so-called corporate universities that combine jobs-oriented curricula with some broader excursions into the liberal arts, and, of course, the traditional university curricula

The heyday when a high school or college education would serve a graduate for a lifetime is gone Today's recipients of diplomas expect to have many jobs and to use a wide range of skills over their working lives Their parents and grandparents looked to a more stable future--even if in reality it often turned out otherwise

However one views the uncertainty that so many in our workforce are experiencing in their endeavor to advance, an economist can scarcely fail to notice a marketplace working efficiently to guide our educational system, defined in its widest sense, toward the broader needs

of our economy

But this is not new The history of education in the United States traces a path heavily influenced by the need for a workforce with the skills required to interact productively with the evolving economic infrastructure Historically, technological advance has brought with it improvements not only in the capital inputs used in production, but also new demands on workers who must interact with that increasingly more complex stock of capital Early this century, these advances required workers with a higher level of cognitive skills, for instance the ability to read manuals, to interpret blueprints, or to understand formulae

Our educational system responded In the 1920s and 1930s, high school enrollment in this country expanded rapidly, pulling youth from rural areas, where opportunities were limited, into more productive occupations in business and broadening the skills of students to meet the needs of an advancing manufacturing sector It became the job of these institutions to prepare students for work life, not just for a transition to college In the context of the demands of the economy at that time, a high school diploma represented the training needed to be successful in most aspects of American enterprise The economic returns for having a high school diploma rose and, as a result, high school enrollment rates climbed

At the same time, our system of higher education was also responding to the advances in economic processes Although many states had established land grant schools earlier, their support accelerated in the late nineteenth century as those whose economies specialized in agriculture and mining sought to take advantage of new scientific methods of production Early in the twentieth century, the content of education at an American college--as you all are aware--had evolved from a classically based curriculum to one combining the sciences, empirical

studies, and modern liberal arts Universities responded to the need for the application of science--particularly chemistry and physics--to the manufacture of steel, rubber, chemicals, petroleum, and other goods requiring the newer production technologies Communities looked to their institutions of higher learning for leadership in scientific knowledge and for training of professionals such as teachers and engineers The scale and scope of higher education in America was being shaped by the recognition that research--the creation of knowledge--complemented teaching and training--the diffusion of knowledge In broad terms, the basic structure of higher education remains much the same today That structure has proven sufficiently flexible to respond to the needs of a changing economy

Market economies have succeeded over the centuries by granting rewards to those who could anticipate changes in the value preferences of society America's system of higher education has evolved into a highly diverse and complex range of institutions--large research universities that combine undergraduate and graduate offerings, small liberal arts colleges, and vocation-oriented community colleges--all seeking their competitive advantage What makes that system work effectively is that it has been influenced importantly by the values of a strong market economy--competition, risk-taking, and innovation

America's reputation as the world's leader in higher education is grounded in the ability of these versatile institutions, taken together, to serve the practical needs of the economy and, more significantly, to unleash the creative thinking that moves our society forward

In a global environment in which prospects for economic growth now depend importantly on a country's capacity to develop and apply new technologies, the research facilities of our universities are envied throughout the world The payoffs--in terms of the flow of expertise, new

products, and startup companies, for example--have been impressive Here, perhaps the most frequently cited measures of our success have been the emergence of significant centers of commercial innovation and entrepreneurship--Silicon Valley, the Research Triangle, and the clustering of biotech enterprises in the Northeast corridor--where creative ideas flow freely between local academic scholars and those in industry

Beyond these highly visible achievements, what has made our research universities so extraordinarily productive is their promotion of peer-reviewed scholarship and the value they place on creativity and risk-taking Although some innovations move quickly from the development stage to applications, more often, we cannot accurately predict which particular scientific advance, or synergy of advances, will ultimately prove valuable One has only to recall our experience with the laser, which had to wait for improvements in fiber optics to yield important applications Indeed, according to Nobel Laureate Charles Townes, in the late 1960s the attorneys for Bell Labs initially refused to patent the laser because they believed it had no applications in the field of telecommunications Our universities have shown the patience and the flexibility to accept that uncertainty, confident that the rigorous effort to explore ideas would eventually lead to discovery

If we are to remain preeminent in transforming knowledge into economic value, America's system of higher education must remain the world's leader in generating scientific and technological breakthroughs and in meeting the challenge to educate workers With two-thirds of our high school graduates now enrolling in college and a growing proportion of adult workers seeking opportunities for retooling, our institutions of higher learning now bear the

overwhelming responsibility for ensuring that our society is prepared for the demands of rapid economic change

What our colleges and universities produce is highly valued in today's economy The rise in that value over the past several decades has been reflected in a widening spread between compensation paid to college-educated workers relative to those with less schooling Accordingly, college enrollment rates among new U S high school graduates have been rising And despite competitive pressures to improve university education abroad, almost one-third of all students who leave their home countries to study elsewhere choose to study in the United States In recent years, the most popular fields of study for both groups have been business and management, but, as you are all aware, interest in life sciences, math, and computer sciences has been growing rapidly

Another measure of the value placed on university education is the rising propensity of older workers to return to school Today, more than one-fourth of all undergraduates are over thirty years old, one-fifth of these older students are enrolled in full-time programs These individuals are already responding to the need to seek retooling during their careers As a result, education is increasingly becoming a lifelong activity Businesses are now looking for employees who are prepared to continue learning and who recognize that maintaining their human capital will require persistent hard work and flexibility

The press for lifelong learning and the availability of technology have spawned a variety of education initiatives outside the traditional classroom Courses now can be taken "at a distance" over the Internet These are just the newest in a series of attempts to move learning closer to workers on the job and to make it more relevant to changing business needs Although

many of these new programs focus on specific, applied skill training, some degree-granting programs already exist, and companies that have successfully developed interactive educational software for the classroom are looking to move it online Competition is the necessary driving force toward delivering a superior product or service We should not shy away from it Colleges and universities are being challenged to evaluate how new information technologies can best be employed in their curricula and their delivery systems

Beyond these more practical issues, the most significant challenge facing our universities is to ensure that teaching and research continue to unleash the creative intellectual energy that drives our system forward As the conceptual share of the value added in our economic processes continues to grow, the ability to think abstractly will be increasingly important across a broad range of professions Critical awareness and the abilities to hypothesize, to interpret, and to communicate are essential elements of successful innovation in a conceptual-based economy

The roots and nature of how the human mind innovates have always been subject to controversy Yet, even without hard indisputable evidence, there is a remarkable and broad presumption that the ability to think abstractly is fostered through exposure to philosophy, literature, music, art, and languages Liberal education is presumed to spawn a greater understanding of all aspects of living--an essential ingredient to broaden one's world view by "vaulting over disciplinary walls," as my good friend Judith Rodin put it, and exploring other fields of study Most great conceptual advances are interdisciplinary and involve synergies of different specialities

Yet there is more to the liberal arts than increasing technical intellectual efficiency They encourage the appreciation of life experiences that reach beyond material well-being and, indeed,

are comparable and mutually reinforcing The intense pleasure many experience from listening to Mozart's great D Minor Piano Concerto has much in common with the deep satisfaction of solving a complex mathematical problem The challenge for our institutions of higher education is to successfully blend the exposure to all aspects of human intellectual activity, especially our artistic propensities and our technical skills

What makes the challenge particularly daunting is that scientific knowledge expands and broadens the measurable rewards of its curriculum at a pace that liberal arts, by their nature, arguably have difficulty matching The depth of knowledge in nuclear physics is today far greater than it was a century ago, creating an enormous expansion in economically useful teaching hours But do the same economic opportunities exist for courses in English literature?

A related difference between science and the arts arises in the non-academic world Engineering and metallurgical advances have reduced the number of hours required to produce a ton of steel, but the same number of musicians will be needed to perform a Beethoven quartet this evening as were needed a century ago Many of you will recognize this application of Baumol's Law To make the point even more graphically, Senator Daniel Patrick Moynihan has noted that the Minute Waltz could be played in 50 seconds, but he wondered if it would sound as good

Overwhelmed with the increasing scientific knowledge base, our universities are going to have to struggle to prevent the liberal arts curricula from being swamped by technology and science It is crucial that that not happen

The advent of the twenty-first century will certainly bring new challenges for our society and for our education system We cannot know the precise directions in which advances in

technology and the transmission of knowledge will take us However, we can be certain that our institutions of higher education will remain at the center of the endeavor to comprehend those profound changes and to seize the opportunities to direct them toward ever-rising standards of living and quality of life