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Keynote Address

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Thanks to ASME and the other engineering organizations for sponsoring this event. A lot of work must have gone into assembling a roster of speakers that reflects a variety of points of view about our nation's research and development status.

My own take on the current state of U.S. science and technology is that it is quite strong, and is receiving unprecedented federal support. It is, however, in a state of transition that requires attention and good management, including selecting and funding priority areas and building strength in specific fields that we know will be important in the future. This transition is forced by rapid changes in technology, by globalization of technology based economies, and by changing international patterns of technical capabilities.

Let me say at the outset that I think the sheer investment of dollars is not a particularly good indicator of how well federally funded science and technology is serving society. Science is a big subject, and some parts are more important than others to our nation's well-being. We ought to take these differences into account as we assess the health of the entire enterprise. There is a long history of efforts to do this. One of the earliest was a famous 1961 Science magazine article by Alvin Weinberg, at that time the director of Oak Ridge National Laboratory. He wrote during an era when support for science was rising rapidly in the post-Sputnik era. Weinberg asked whether we should "divert a larger part of our effort toward scientific issues which bear more directly on human well-being…" I will come back to this point in a moment because how we break down the science enterprise into parts affects judgments about how well it is doing. This morning I am going to look at the R&D budget in historical perspective, and from the top down, starting with the big picture and moving toward finer resolution.

The sheer investment of U.S. dollars in science is a very impressive number. It is three times that of Japan and half again as much as all the European nations combined. The current FY06 federal R&D budget request is an all time high of $132.3 billion, $733 million above last year's historic high, and a remarkable 45% above the FY2001 figure. [See Figure 1] Comparing this investment directly with that of other nations is one way of understanding its significance. Another way is to scale it to a national capacity such as population, Gross Domestic Product (GDP), or total government expenditures. The Organization for Economic Cooperation and Development (OECD) collects data on R&D as a percentage of Gross Domestic Product. Nation by nation, the relative contributions of government and private investment in R&D are different, so you have to combine public and private investments to get an overall measure of R&D performance per GDP that can be compared with other nations. For the U.S. that measure is 2.7%

compared with a somewhat greater 3.3% for Japan. The European Union would like this figure to be 3% for its members, but only tiny economies ever reach that magnitude. The U.S. and Japan are the only large economies that approximate the 3% figure, and we outspend Japan in absolute terms by a huge margin.

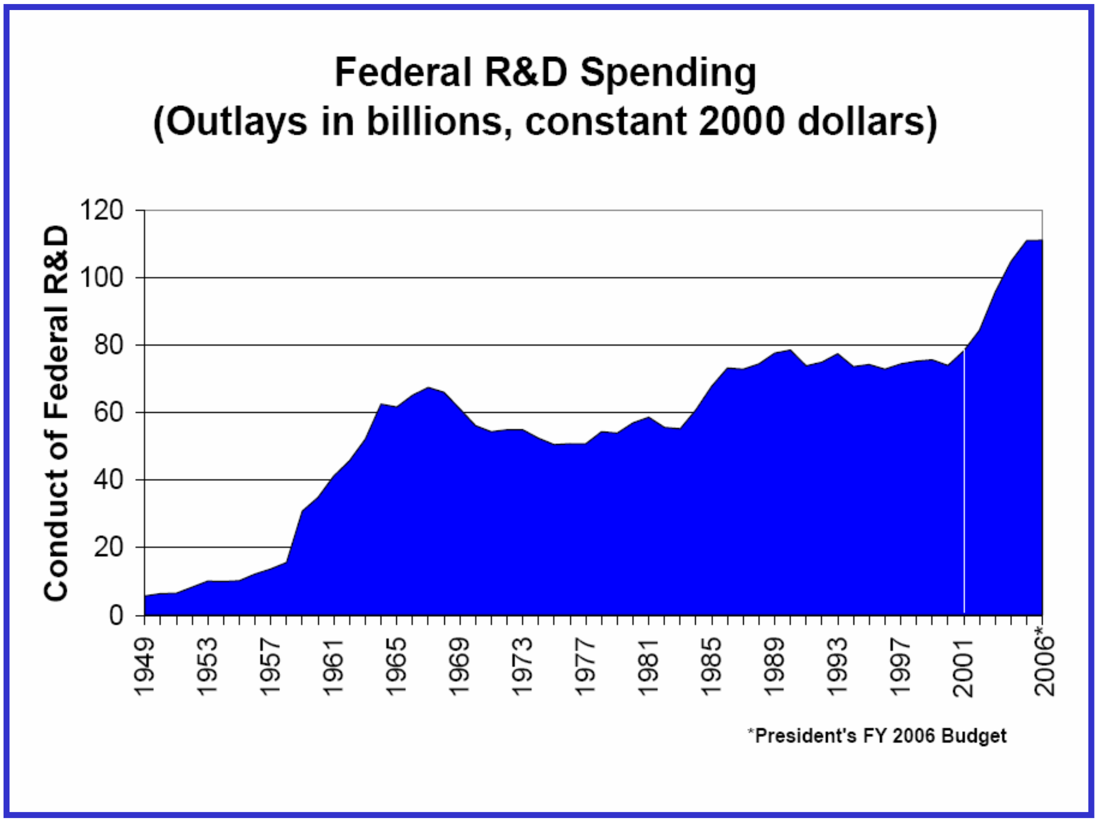

Figure 1. Post-war U.S. R&D budget outlays

I do not like to scale the *federal portion* of R&D budgets with GDP as a denominator because government spending itself does not scale with GDP. As a fraction of GDP, federal R&D spending will trend down even in a period of dynamic growth, which is very misleading. Because R&D is a discretionary expenditure, I think it makes more sense to measure the government's investment against the total discretionary budget, which historically has grown more slowly than GDP. Science policy scholar Dan Sarewitz, now at the University of Arizona, publicized an interesting property of this measure in an article with the provocative title "Does Science Policy Exist, and If So, Does it Matter?-- Some Observations on the U.S. R&D Budget." Sarewitz points out that over the years the fraction of the U.S. Domestic Discretionary Budget devoted to science *is practically constant*. It is actually very constant at close to 11% if you look only at the non-defense parts of numerator and denominator. I looked up the figures myself and found that the only significant deviation from this ratio was during the Apollo program, and if you accounted for Apollo, the 11% figure holds for four decades. That is an amazing fact, and signals a kind of stable equilibrium among the numerous political forces pulling the Discretionary Budget in all directions. Figure 2 shows how stable this ratio has been for the past three decades. There is no conscious intent to achieve this stability, which explains Sarewitz's tongue-in-cheek title, and it is remarkable that the non-defense portion of the FY06 R&D budget proposal is right on the 30 year average of about 10.8% as a percentage of the discretionary budget.

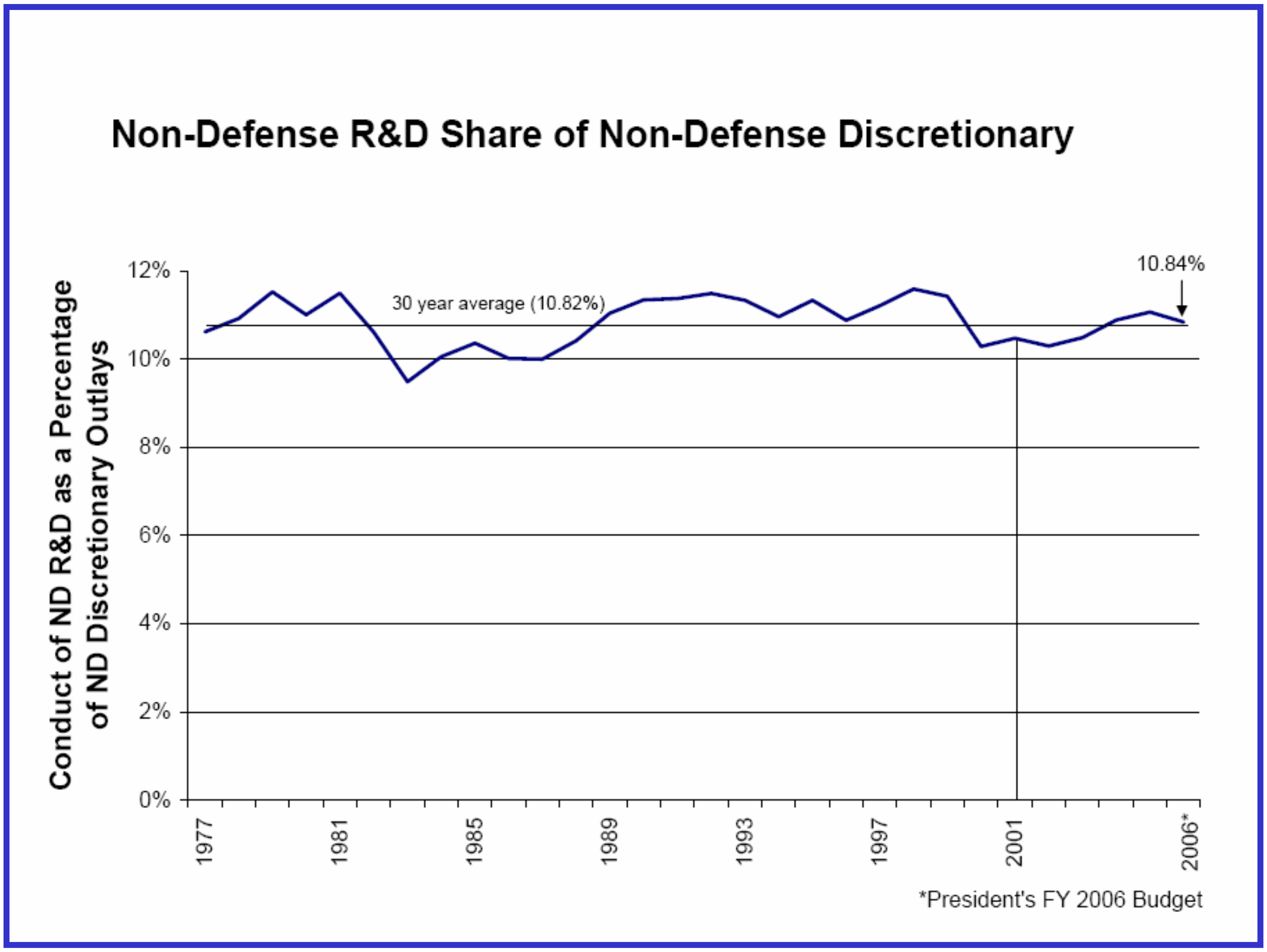

Figure 2. Percent of non-defense U.S. Domestic Discretionary Budget devoted to non-defense R&D.

In moving from the total R&D budget to the non-defense budget, we have already begun making choices about what things are important to measure. Before continuing, I would like to ask some provocative questions about such choices. What criteria should we use to establish priorities or impacts, and how valid are they? Breakdowns into diverse categories are essential, but I worry about the proliferation of arbitrary "benchmarks" and "indicators" without an overall framework that explains the logic and significance of the categories. My office and OMB struggle to identify budget categories for national priorities such as nanotechnology and information technology, and we track these along with traditional categories of "basic" and "applied" research and "development." Patterns of R&D are changing, however, and it is not clear to me what these traditional categories mean.

It has become conventional wisdom to simply ignore the $65 billion defense development budget – most of the "D" in "R&D" – as irrelevant to the technical strength of the nation. I have usually done that in my own speeches on science funding, but I admit I am uneasy about it. That funding sustains a huge technical workforce. Development work is not routine testing and manufacturing. It requires the identification and resolution of countless technical obstacles, many of them entailing investigations that we might describe as applied research in another context. And it produces ideas and proprietary information that are intellectual property that must have some impact on national innovation. I wish we had a better fix on the contributions of that huge "D" to our innovation ecology, but it has not been closely studied from this perspective.

Non-development research was examined in 1995 by a committee of the National Academies of Science chaired by Frank Press. Their report recommended a category called Federal Science and Technology (FS&T) as more representative of the kind of technical work that discovers new knowledge and contributes to new technologies. Since 2002, OMB has begun reporting a rather different FS&T category that includes non-research activities such as some types of education programs. Since it is not possible to track these categories back in time, I have been using the non-defense R&D budget as a surrogate for the more nuanced FS&T category.

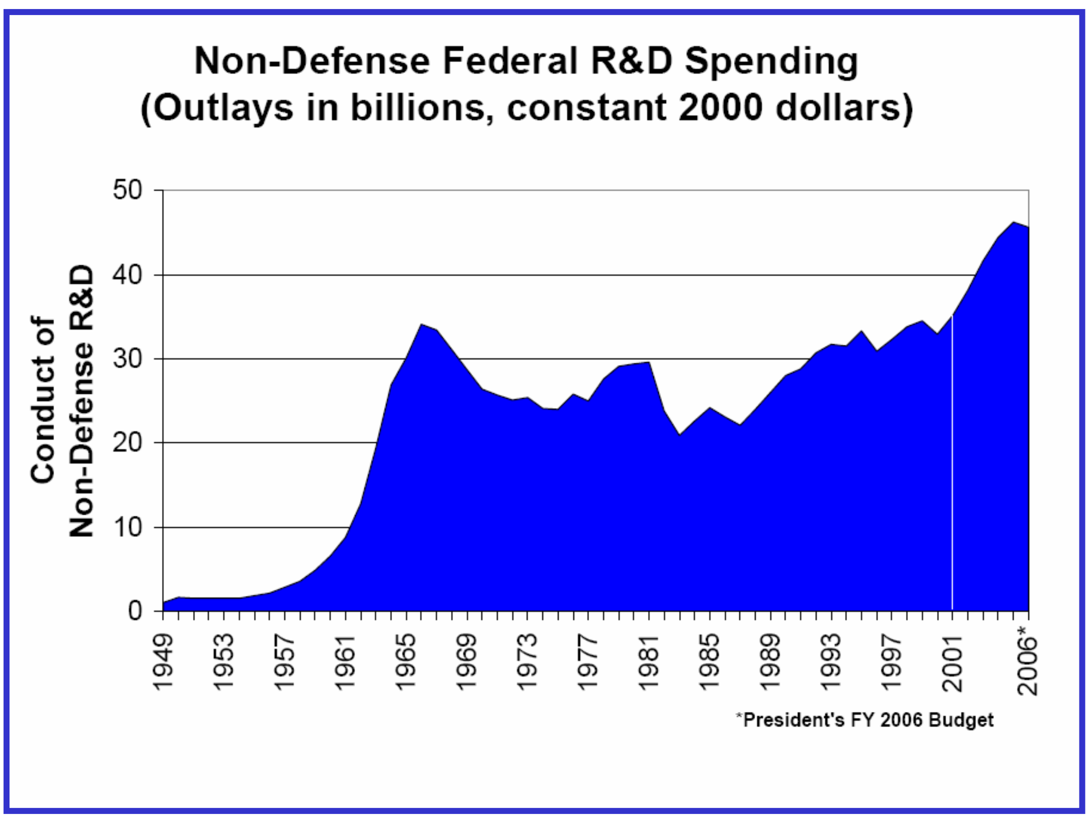

Figure 3. Postwar non-defense U.S. R&D outlays

Figure 3 shows the postwar history of non-defense R&D, which is mostly "R". It looks much the same as the chart for the total R&D, except for that big chunk missing during the 80's when we were driving the Soviet Union into ruin trying to keep up with our cold war defense technology development. The current FY06 budget request for this category is up – not down – by about three quarters of one percent. That is to be sure not a huge increase, but it signals favorable treatment for science at a time when all the rest of the non-defense discretionary budget is down by about a quarter of a percent. I want particularly to call attention to the huge increase in this category during the first term of the current Administration.

As we break down the non-defense R&D or FS&T budgets into smaller chunks, the next big categories we encounter are Basic and Applied Research. The 1995 Press Committee report emphasized how difficult it is to separate these. The traditional distinction between Basic and Applied work was probably never as clean as we have pretended, and is rapidly becoming obsolete. Vannevar Bush's "Endless Frontier" report in 1945 established a paradigm for technical work that starts with basic research, merges into applied research, then development, and ends in a product. Today the frontiers of science lie very much closer to end-products than this one-dimensional model implies. That is one reason I am reluctant to leave military development expenditures completely out of the S&T health index. Donald Stokes, a former Princeton dean, now deceased, advocated charting technical work in two dimensions rather than one, with basic and applied objectives along different axes. You can find the details in his book called "Pasteur's Quadrant" published by Brookings in 1997. His idea was to rank research vertically according to whether or not it seeks fundamental understanding, and horizontally according to whether or not applications are a consideration. The quadrant where the answer is no to both questions is empty, the others are exemplified by the work of Bohr (pure basic research), Edison (pure applied research) and Pasteur (use-inspired basic research). Other authors, especially Harvard's Gerald Holton and Lewis Branscomb, have advocated similar systems with the names Newton, Bacon, and Jefferson in the quadrants.

No one has yet tried to arrange the FS&T or non-defense R&D work into the quadrant scheme, and therefore we do not have indicators to help decide priorities and make international comparisons. In this vacuum, we have no recourse but to fall back on the budget numbers for Basic and Applied research.

During the first five years of the current Administration, the Basic Research category grew by 26% to a high of $29.9 billion, and the FY06 proposal essentially maintains that gain at $26.6 billion. The large increases in non-defense research owe much to the NIH budget doubling campaign that ended in the FY03 budget, and from increases related to homeland security S&T. These were by no means the only increases, however. The budget of nearly every major science agency grew during this period so that now we are facing an admittedly difficult budget period from a historically high level of science funding.

That does not mean we should be satisfied with how we are spending these funds, nor that all programs are appropriately funded. But we have a huge amount of money on the table for R&D, and we owe it to the American people to spend it as wisely as we can.

Spending wisely to me entails planning ahead to establish priorities and shifting funds in an orderly way toward the high priority programs. If you wait for the natural growth of the discretionary budget to deliver new money for high priority programs, you may never reach your goals. Well designed budgets will therefore inevitably have reductions as well as increases within large clusters of programs like the R&D budgets.

I do not have time this morning to go through the rationales for the various parts of the President's FY06 budget proposal, but I recommend that you actually read the budget narrative itself. Many mysteries are explained in this document. Let me close with a single example of a widely misunderstood action: the reduction of the Math and Science Partnership in the National Science Foundation. Contrary to popular belief, this program is not being reduced overall. The budget recommends *increasing* it by $71 million or 28% – but not in NSF. The increases are in the same type of program within the Department of Education. If you look only at the NSF budget, you will erroneously assume this important program is slated for a reduction. The roles of the two agencies are different, and they cooperate in developing and then promulgating educational best practices to the largest possible number of school districts.

In making decisions about how to spend public funds on research and development, we rely on the technical community for ideas and analysis. Over the years, the organizations you represent have played an important role in advising, criticizing, and shaping the nation's R&D profile. This Symposium is an example of that process, and I am grateful for the opportunity to participate in it.