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2011 GLOBAL R&D FUNDING FORECAST

- Globalization Narrows R&D Gap Between Countries
- Still In the Lead: U.S. Funds One-Third of Global R&D
- Fast Growth: China Overtakes Japan at #2
- Key Industry R&D Sectors Growing

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2011 Global R&D Funding Forecast: CEO Message

The year 2010 was a challenging one for economies around the globe, and the R&D landscape continued to change. Fortunately, overall R&D funding stabilized, which marked an improvement over the volatility that characterized 2008 and 2009.

As you will see in the following pages, this year's Forecast includes not only a country-by-country view of investment in R&D and our specific discussion of U.S. R&D funding and performance, but also a breakout of spending by six key, broadly defined industry segments – Life Sciences, Information Technology, Electronics, Aerospace/Defense/Security, Energy, and Advanced Materials. These critical industry segments will drive much of the future of global innovation, and though the recent economic volatility affected each one in different ways, they, along with overall global R&D, have stabilized and are now poised for continued growth in 2011.

Battelle's organizational structure is designed to address many of these key segments as well as to leverage our capacity for innovation through the six national laboratories that we manage for the U.S. Department of Energy. As the world's largest independent R&D organization, we have been dedicated to advancing science and technology to benefit mankind for over 80 years, and we bring together a world-class collection of human and technological assets to develop products, systems and services for global clients.

Although the volatility accompanying the recession has passed, current economic conditions still remain fragile. The impact of the overall economic climate in 2010 leads us to forecast a modest 2.4% growth forecast for U.S. R&D in 2011. This low growth rate assumes a likely decline in federal R&D funding in 2011, as many federal agency budgets are likely to be cut over the next year. The impact of these reductions could be greater if not for a continued expenditure stream resulting from previously awarded federal government "stimulus" funding. Without such resources, investment in the United States would actually decline in real terms in 2011.

This year's Forecast also addresses the continuing rise of China as a global R&D powerhouse. Now second only to the United States in R&D funding, China is realizing the benefits of an unprecedented investment in education. As a result, highly skilled workers will substantially boost China's annual GDP growth rate for a generation, to a level of more than $120 trillion by 2040.

In addition, the Forecast examines the global researcher community and provides a new perspective on the globalization of R&D. Both U.S. and non-U.S. researchers face many of the same concerns regarding their research challenges. Limited budgets and development times are affecting the entire global researcher community, and U.S. researchers in particular feel more challenged in these respects. When asked about the connections between global issues and their future R&D efforts, researchers identified areas including healthcare for the aging, demand for renewable energy, and global population growth as key concerns that the global research community must address.

In last year's Forecast, I addressed the need for sustainable, positive change in STEM (science, technology, engineering, and math) at all levels of education. China's investment in these areas is yielding great results, and the rest of the world would be wise to follow a similar course. Underinvestment in STEM, when coupled with a huge number of retiring "Baby Boomer" scientists and engineers, is creating a national "innovation crisis" for the United States and other nations in the years to come.

As we are always interested in providing the kind of data and other information that can help you, the readers of *R&D Magazine*, we welcome your comments and suggestions.

In the meantime, we appreciate your continued interest in the Forecast, which is increasingly being referenced as a "must read" source for information on global innovation.

Jeffrey Wadsworth
President and CEO
Battelle

Stability Returns to R&D Funding

Growth in R&D spending has resumed following recession-induced cuts in advanced economies, while growth in emerging nations continues unabated.

The global R&D outlook for 2011 is increasingly stable and positive, according to analysis performed by Battelle Memorial Institute and *R&D Magazine*. Having endured one of the worst recessionary periods in recent memory, R&D managers are adapting to expectations of moderate sustainable growth while competing on a global scale for market share and resources. Reflecting recent trends, prospects for R&D funding vary by region, with the United States (U.S.) expecting R&D growth to track GDP growth, Europe contemplating fiscal austerity that may restrict investment for several years, and most Asian countries maintaining strong financial commitments to R&D.

Total global spending on R&D is anticipated to increase 3.6%, to almost $1.2 trillion. With Asia's stake continuing to increase, the geographic distribution of this investment will continue a shift begun more than five years ago. The U.S., however, still dominates absolute spending at a level well above its share of global GDP.

During the recession, the Asian R&D communities generally, and China specifically, increased their R&D investment and stature. As a Reuters headline noted, "While the world slashed R&D in a crisis, China innovated". China entered the recession with a decade of strong economic growth. During that time, it increased R&D spending roughly 10% each year—a pace the country maintained during the 2008-2009 recession. This sustained commitment set China apart from many other nations.

In the U.S., a recession-related drop in industrial R&D spending in 2009 is expected to be recovered by increases in 2010 and 2011 at levels exceeding the rate of inflation. For federally-sponsored R&D, 2010's election results and increased attention on government spending could signal future pressure on funding. The high level of defense R&D spending (more than two-thirds of the federal total) may be among the first areas reviewed. Cuts in DOD mission-specific R&D, however, should not seriously affect the broad science and technology foundation supported by NSF, NIH, NIST, and the DOE's Office of Science. Some observers note that R&D funded by these agencies more directly affects U.S. competitiveness and economic growth than does defense-related R&D.

Among the global research communities, the state of R&D in the European Union (EU) is the most concerning. Challenged by weak economies in Greece, Spain, and Ireland, Europe is struggling to recover from the recession and to cut deficits, which in turn affects government support of R&D. As the *Washington Post* observed, "The pressure on European science … is yet another legacy of the financial crisis." The EU's ambitious goal to increase its R&D funding to at least the

Share of Total Global R&D Spending

	2009	2010	2011
Americas	39.1%	38.8%	38.4%
U.S.	*34.7%*	*34.4%*	*34.0%*
Asia	33.6%	34.8%	35.3%
Japan	*12.6%*	*12.3%*	*12.1%*
China	*11.2%*	*12.3%*	*12.9%*
India	*2.5%*	*2.9%*	*3.0%*
Europe	24.1%	23.3%	23.2%
Rest of World	3.1%	3.0%	3.0%

Source: Battelle, *R&D Magazine*

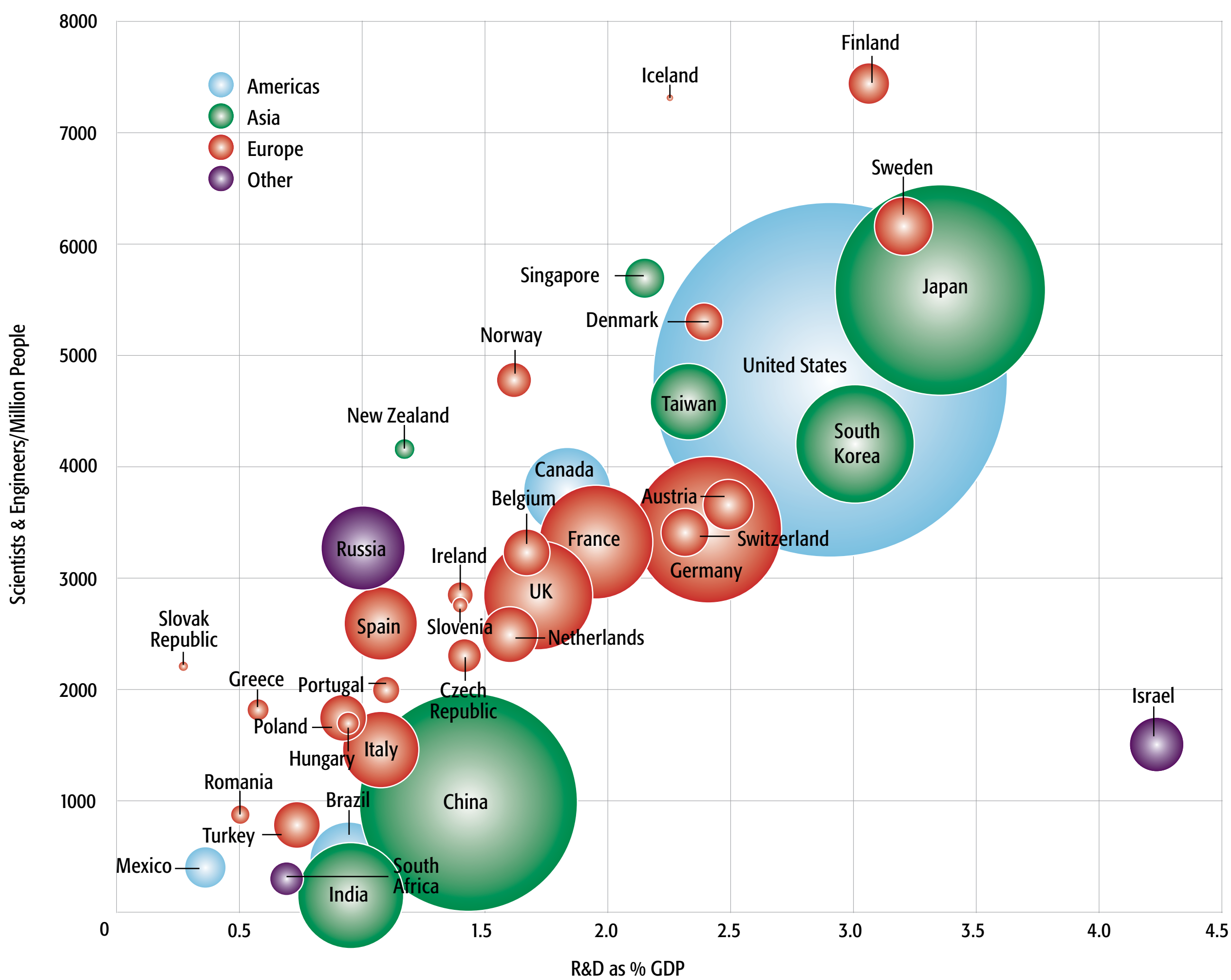
Global R&D Spending Forecast

	2009 GERD PPP Billions, U.S.$	2009 R&D as % of GDP	2010 GERD PPP Billions, U.S.$	2010 R&D as % of GDP	2011 GERD PPP Billions, U.S.$	2011 R&D as % of GDP
Americas	433.2	2.2%	446.7	2.2%	458.0	2.2%
U.S.	*383.6*	*2.7%*	*395.8*	*2.7%*	*405.3*	*2.7%*
Asia	372.5	1.9%	400.4	1.9%	421.1	1.8%
Japan	*139.6*	*3.4%*	*142.0*	*3.3%*	*144.1*	*3.3%*
China	*123.7*	*1.4%*	*141.4*	*1.4%*	*153.7*	*1.4%*
India	*28.1*	*0.8%*	*33.3*	*0.9%*	*36.1*	*0.9%*
Europe	267.0	1.7%	268.6	1.6%	276.6	1.7%
Rest of World	34.2	1.2%	34.8	1.2%	36.3	1.2%
Total	1,107.0	1.9%	1,150.6	1.9%	1,192.0	1.9%
PPP, Purchasing Power Parity						

Source: Battelle, *R&D Magazine*

World of R&D 2010

Size of circle reflects the relative amount of annual R&D spending by the country noted.



Source: Battelle, *R&D Magazine*, OECD, IMF, CIA

level of the U.S. (2.7% of GDP) has gone unmet, and that may continue to be the case for some time.

Conversely, the positive direction of R&D in Asia is driven by multiple synergistic factors, beginning with policy. Leading Asian nations recognize that their economic expansion can be sustained by continued commitment to R&D investment across a wide range of science and technologies. The scale and significance of research and development in Asia continues to grow, with implications for the rest of the world. Experienced researchers are becoming harder to find in the U.S. and Europe, as Asian emigrant scientists return to attractive opportunities at home. At the same time, industrial, academic and even Western government R&D organizations are increasingly establishing. They are supporting substantial R&D facilities throughout Asia to take advantage of lower labor costs and larger pools of skilled scientists and engineers; and in some cases to support marketing efforts to an increasingly affluent and large local consumer population. Most U.S. and European *Fortune* 1000 companies already have multiple R&D centers and manufacturing sites throughout Asia, and they direct increasing shares of R&D budgets accordingly.

Finally, funding and geographic dynamics in the R&D landscape are likely amplified by macroeconomic factors, such as the rate of innovation and balances of trade, with corresponding shifts in liquidity, affluence and advanced manufacturing. These factors could make it more difficult for the U.S. to maintain its historic lead in the development and economic leverage of innovation, even as it invests as much on R&D as its next four global competitors combined.

Forecast Gross Domestic Expenditures on R&D (GERD)

Billions of U.S. Dollars

Global Rank	Country	2009 GERD PPP Billions, US$	2009 R&D as % of GDP	2010 GERD PPP Billions, US$	2010 R&D as % of GDP	2010-11 GDP Growth	2011 GDP PPP Billions, US$	2011 GERD PPP Billions, US$	2011 R&D as % of GDP
1	United States	383.6	2.7%	395.8	2.8%	2.3%	14,963	405.3	2.7%
2	China	123.7	1.4%	141.4	1.4%	9.0%	10,747	153.7	1.4%
3	Japan	139.6	3.4%	142.0	3.3%	1.5%	4,339	144.1	3.3%
4	Germany	68.0	2.4%	68.2	2.4%	2.0%	2,957	69.5	2.3%
5	South Korea	41.4	3.0%	42.9	3.0%	4.5%	1,512	44.8	3.0%
6	France	41.1	2.0%	41.5	1.9%	1.6%	2,176	42.2	1.9%
7	United Kingdom	37.2	1.7%	37.6	1.7%	2.0%	2,218	38.4	1.7%
8	India	28.1	0.8%	33.3	0.9%	8.4%	4,193	36.1	0.9%
9	Canada	23.2	1.8%	23.7	1.8%	2.7%	1,357	24.3	1.8%
10	Russia	21.8	1.0%	22.1	1.0%	4.3%	2,288	23.1	1.0%
11	Brazil	18.0	0.9%	18.6	0.9%	4.1%	2,253	19.4	0.9%
12	Italy	18.7	1.1%	18.7	1.1%	1.0%	1,775	19.0	1.1%
13	Taiwan	17.6	2.4%	18.2	2.3%	4.4%	839	19.0	2.3%
14	Spain	17.3	1.3%	17.2	1.3%	0.7%	1,366	17.2	1.3%
15	Australia	15.0	1.8%	15.3	1.8%	3.5%	907	15.9	1.7%
16	Sweden	11.5	3.4%	11.6	3.3%	2.6%	366	11.9	3.3%
17	Netherlands	10.5	1.6%	10.6	1.6%	1.7%	681	10.8	1.6%
18	Israel	8.8	4.3%	9.1	4.2%	3.8%	223	9.4	4.2%
19	Austria	8.2	2.5%	8.2	2.5%	1.6%	339	8.3	2.5%
20	Switzerland	7.3	2.3%	7.4	2.3%	1.7%	327	7.5	2.3%
21	Belgium	6.8	1.7%	6.8	1.7%	1.7%	402	6.9	1.7%
22	Turkey	6.4	0.7%	6.7	0.7%	3.6%	983	6.9	0.7%
23	Poland	3.5	0.5%	3.6	0.9%	3.7%	738	6.9	0.9%
24	Mexico	5.8	0.4%	6.0	0.4%	3.9%	1,599	6.4	0.4%
25	Finland	6.1	3.2%	6.1	3.1%	2.0%	200	6.3	3.1%
26	Singapore	5.7	2.4%	6.0	2.2%	4.5%	287	6.3	2.2%
27	Denmark	4.9	2.4%	4.9	2.4%	2.3%	213	5.1	2.4%
28	Norway	4.1	1.6%	4.1	1.6%	1.8%	263	4.2	1.6%
29	Czech Republic	3.7	1.4%	3.7	1.4%	2.2%	273	3.8	1.4%
30	South Africa	3.6	0.7%	3.6	0.7%	3.5%	526	3.7	0.7%
31	Portugal	2.8	1.2%	2.8	1.2%	0.0%	239	2.8	1.2%
32	Argentina	2.6	0.4%	2.6	0.4%	4.0%	641	2.7	0.4%
33	Ireland	2.6	1.4%	2.6	1.4%	2.3%	191	2.6	1.4%
34	Greece	1.8	0.5%	1.8	0.6%	-2.6%	318	1.7	0.6%
35	Hungary	1.7	0.9%	1.7	0.9%	2.0%	201	1.7	0.9%
36	New Zealand	1.3	1.2%	1.4	1.2%	3.2%	123	1.4	1.2%
37	Romania	1.3	0.5%	1.3	0.5%	1.5%	269	1.3	0.5%
38	Slovenia	0.8	1.3%	0.8	1.4%	2.4%	60	0.8	1.4%
39	Slovak Republic	0.5	0.4%	0.5	0.4%	4.3%	129	0.5	0.4%
40	Iceland	0.3	2.3%	0.3	2.3%	3.0%	13	0.3	2.3%

Source: International Monetary Fund, *R&D Magazine*, Battelle

U.S. R&D: Slow Growth Ahead

Last year at this time, industrial prospects were starting to improve, and 2010 was emerging as a respectable year for R&D investment. This was evident initially in significant Q3 and Q4 2009 R&D investments across a host of industrial segments as a result of backlog projects being released and catch-up investments being made to get R&D efforts back on track after the recession. Yet, as we prepare this year's forecast, the U.S. economy is still far from robust. For 2011, every indication points to a correspondingly sluggish outlook for R&D investment growth. The Battelle/*R&D Magazine* team forecasts that U.S. R&D will grow by only 2.4% (equal to the global median rate) over the final 2010 estimate, reaching $405.3 billion in 2011. With 2011 inflation forecasted to remain a low 1.5%, this growth in R&D still leads to 0.86% ($3.4 billion) growth in real terms.

This forecast of R&D investment is based upon the best available current intelligence regarding the state of the U.S. R&D enterprise, as well as the condition of the U.S. and global economies. While concerns over a possible double-dip recession have dissipated, the overall economy remains fairly fragile, with unemployment high, consumer and industrial confidence weak, and major concerns over federal spending and deficits.

The Source-Performer Matrix
Estimated Distribution of R&D Funds in 2011
Millions of Current U.S. Dollars *(Percent Change from 2010)*

Source	Performer					
	Federal Gov't	Industry	Academia	FFRDC	Non-Profit	Total
Federal Government	$27,499 -0.71%	$25,983 -0.05%	$36,098 0.58%	$15,595 -0.24%	$6,245 -0.19%	$111,421 -0.04%
Industry		$260,878 3.33%	$2,765 5.89%		$1,781 2.56%	$265,444 3.35%
Academia			$12,140 4.35%			$12,140 4.35%
Other Government			$3,413 5.34%			$3,413 5.34%
Non-Profit			$3,088 1.58%		$9,778 2.13%	$12,865 2.00%
Total	$27,499 -0.71%	$286,862 3.01%	$57,524 1.93%	$15,595 -0.24%	$17,803 1.35%	$405,283 2.40%

Source: Battelle, *R&D Magazine*

The Source-Performer Matrix: Characterizing the U.S. R&D Enterprise

To allow for easier interpretation of funding flows and performance within the U.S. R&D enterprise, the forecast is summarized in a source-performer matrix reflecting the relationships among those that sponsor and execute R&D. Based on the structure established by the NSF, R&D funding comes from five potential sources: the Federal Government, Industry, Academia, Other Government (state and local), and Non-Profit (primarily foundations). Five types of R&D performers are identified by NSF: the Federal Government, Industry, Academia, Federally Funded Research and Development Centers (FFRDCs: large research institutions funded by various federal agencies and in many cases managed by industry, university, or non-profit operators), and Non-Profit organizations (primarily research institutes).

Significant Factors and Assumptions in the 2011 Forecast

The magnitude, stability and flows within the source-performer matrix are affected by multiple factors each year. For 2011, six factors shape much of the forecast.

The recession is "technically" over

A year ago, we discussed how the economy was showing signs of recovery in the second half of 2009. With the September 2010 announcement by the National Bureau of Economic Research that the recession was technically over in June 2009, those signs were validated.

Nevertheless, there are many other current signals, unemployment among them, indicating that the economy has a long way to go to establish a broad recovery and reach pre-recession performance. According to our sample of the SEC filings of leading technology-based companies, U.S. R&D funding and performance increased substantially in the second half of 2009, with the notable exception of the automotive sector. Yet even with this surge, industrial R&D in 2009 ended down more than 3.5% from 2008 levels.

Limited, flat growth in 2010 R&D investment likely through 2011

Economic uncertainty appears to have led to a more cautious, post-recessionary R&D investment climate. R&D investment in Q1, 2010 was lackluster at best, and Q2 and Q3, 2010 industrial R&D investment levels, while increasing, are still below those at the end of last year. According to an *R&D Magazine* survey, 67% of the industrial respondents saw their R&D budgets decline or stay the same from 2009 to 2010, a level that held fairly consistent regardless of the size of firm. The picture for 2011 is somewhat better, with slightly over 50% of the respondents indicating expected R&D budget increases for 2011.

This percentage drops to near 40% for those firms spending $100 million or more on R&D in 2010.

As expected, the federal government R&D budget was basically flat from 2009 to 2010, though some departmental changes did occur in the final enacted budget. Even as more American Recovery and Reinvestment Act (ARRA) funds are spent, these funds will not offset budgetary declines. Hence, fewer federal resources will be invested in on-going R&D activities in 2011.

ARRA continues to affect R&D expenditures

ARRA provided an additional $18.4 billion for R&D efforts and related facility construction, above and beyond departmental FY 2009 baseline budgets. But as we noted in last year's forecast, much of 2009 involved making grant awards from these funds, and awards were still being made in 2010.

We estimate, using data from Recovery.gov, that approximately $9.6 billion (or 52%) of the ARRA R&D commitment will have actually been spent by the award recipients by the end of calendar year 2010. We also estimate that an additional $6.1 billion of the ARRA funding will be spent in 2011, and it has been included in our forecast of federal R&D funding for 2011. Much of these 2011 funds (and those to be spent in early 2012) are flowing to academic research institutions.

Looming federal R&D funding cuts?

At the time of this writing, the overall FY 2011 budget is still a work in progress, with no appropriation budgets reaching approval in either the House or the Senate. With the growing federal deficit, it is well understood that overall federal government budget cuts are likely in the near future. Whether these budget cuts affect R&D budgets, either in FY 2011 or in FY 2012 and beyond remains to be seen. As discussed in more detail in our Federal Funding section, we believe significant cuts to the administration's R&D budget request are unlikely for FY 2011, and significant Congressionally-directed increases are also unlikely.

Meanwhile, the Obama administration has issued budget recommendations to the agencies to submit FY 2012 budgets with at least 5% in cuts while identifying an additional 5% for reductions or modification. Recent statements made by the President indicate that R&D budgets are less likely to be included in these reductions. Whether this sentiment carries over to the Republican-controlled House in 2011 is the big question and has important ramifications regarding the completion of the doubling of basic science funding mandated by the America COMPETES Act and its reauthorization.

Continued uncertainty regarding federal R&D tax credit

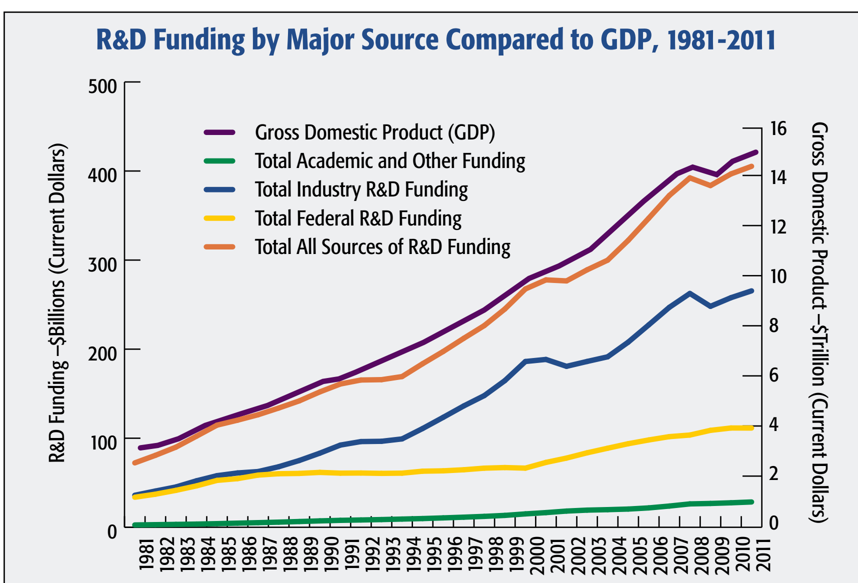
Once again, failure to permanently establish the federal Research and Experimentation Tax Credit (R&D Tax Credit) will cause uncertainty, delays and perhaps reductions in industrial R&D expenditures. The discussion in early 2010 was promising, with interest in simplifying and enhancing the credit from 14% to 20% and to finally making it permanent—allowing companies to take it into account over the long-term horizons often required by R&D efforts. However, Congress has yet to reauthorize the credit since it expired on Dec 31, 2009, although there are only limited concerns over it not being extended this year—it has been extended 13 times in its history—and companies are beginning to expect its renewal on an annual basis.

This incremental approach to the R&D tax credit may influence decision horizons in the private sector. Corporations are often criticized for emphasizing short-term profitability over longer term opportunities and costs. Decisions about R&D are typically long-term, with decision points and possible benefits occurring during the research process. Failing to make the credit permanent adds unneeded uncertainty to these decisions, causing them to be viewed with a short-term financial mindset.

Even with the influence of these preceding factors, it is important to consider the level of stability and inertia within the U.S. R&D enterprise and how it tends to dampen many potential year-to-year swings in R&D funding and performance.

Changing baseline data from NSF

This 2011 U.S. forecast is built upon a data foundation detailed in the National



Source: NSF National Patterns of R&D Expenditures Data, Battelle/*R&D Magazine* Analysis, Estimates, and Forecasts

Science Foundation's (NSF) National Patterns of R&D Resources, a longitudinal database of the sources of R&D funding and the structure of R&D performance. This database of expenditure estimations is adjusted as new data are obtained. Early results from the 2008 NSF Business R&D and Innovation Survey (BRDIS) have been released. The results have led NSF to update the current National Patterns data time series. The estimate of industrial R&D performance for 2008 has been reduced from $289.1 billion (as originally published and used as part of last year's forecast baseline data), to $283.1 billion. This change, along with a few other minor data updates, reduces our estimate and forecasts of overall U.S. R&D by about $6 billion over the last few years. Hence, with this revision, this year's R&D level will exceed $400 billion for the first time, as our revised estimate shows 2010 only reaching $395.8 billion.

The forecast also draws upon a number of additional resources, including: our detailed surveys of R&D performers, R&D budget information compiled by the White House Office of Science and Technology Policy (OSTP) and the American Association for the Advancement of Science (AAAS), secondary data from a variety of sources, and corporate financial reporting to the Securities and Exchange Commission (SEC). Ultimately, estimation and interpretation of recent data are required, due to various collection time lags and non-disclosed data, to develop the final 2011 forecast.

Source Details

We begin the description and analysis of the forecast with a discussion of the major sources of funding for U.S. R&D. This discussion focuses on the overall magnitude, nature and distribution of these funds to the various performers.

Federal Funding of R&D

Broad recognition of the importance of R&D by the federal government (including Presidential administrations, Congress and individual agencies) cannot be questioned, even though ideological differences do influence funding priorities. Federal R&D funding is often seen as a specific policy tool, whether it is the "doubling" of NIH research funding, increasing basic research funding through the America COMPETES Act, or boosting R&D activities to stimulate the economy under ARRA. However, fiscal realities can at times cause slower federal spending growth than expected, and occasionally even reductions in discretionary areas. Even so, federal R&D has been cut in real terms only three times in the past thirty years: 1991, 1994 and 1996.

Though the final FY 2011 budget is still incomplete, the Obama administration's budget increase for R&D was proposed only to be 0.2% over final FY 2010 enacted levels. Even with a likely increase in the defense R&D budget over the administration's request, other committee actions indicate, as of this writing, a willingness to reduce the budget somewhat. Whether or not the November elections and any perceived mandate to reduce federal spending are taken into consideration by the outgoing 111th Congress in finalizing a FY 2011 budget is the big question.

Based upon these dynamics, our 2011 forecast projects the fourth decline in overall federal funding over the last 30 years. We project a slight (0.04%) reduction over our final 2010 estimate—reaching $111.4 billion in total federal support funding R&D performance in 2011. This forecast takes into consideration the continued expenditure of ARRA funds in FY 2011 and the fact that in a given budget year a substantial portion of the budgeted or appropriated funds actually get spent in future years. Federal agency sources will undoubtedly report that the total ARRA funding has already been invested in previous years. However, organizations that receive ARRA funds will likely report them as expenditures in the year they are actually spent. Without ARRA expenditures in 2011, our estimate of federal R&D funding would have reached only $105.3 billion.

The overall portfolio of federally funded R&D shows little change from recent years, as academia receives 32%, industry receives 25%, and federal intramural research receives 23%. The remaining shares go to the FFRDCs and non-profit research organizations, at 14% and 6%, respectively.

Industrial Funding of R&D

Industrial support for R&D is forecast to reach $265.4 billion in 2011, up 3.4% from our final 2010 estimate of $256.8 billion. The peculiarities of early 2010 industrial R&D investment and the economic forecasts for 2011 have diminished some of the optimism we originally had for 2010. This is in part due to the automotive industry, which is obviously a large part of the overall U.S. R&D enterprise, not appearing to have participated in the second half 2009 surge in R&D investment like other sectors. Industry, therefore, is bringing a lower level of R&D investment into 2010 and a flattened R&D trajectory into and through 2011.

Some observers may feel that the 3.4% growth forecast is still too optimistic. However, since the average annual growth rate of industrial R&D funding over the 1981-2008 period is approximately 6.8%, an annual growth rate less than half that amount is not unreasonable. With federal funding likely to grow at a much slower rate from 2010-2011, the industrial share of overall R&D funding continues to increase from 64.9% in 2010 to 65.4% in 2011.

Compared with other sources of R&D funding, industry investment has demonstrated an even more stable distribution over the last 30 years. Consistently, 98% (plus or minus 0.5%) of industry R&D funding stays within the industry context, either funding internal R&D or purchasing R&D services from other companies. The remaining 2% is invested in academic or non-profit research.

Other Funding for R&D

Combined, the federal government and industry provide 93% of all U.S. funding for R&D. Support from the other three funding sources—non-profits, academia, and other government (primarily state governmental research investment programs)—has been subject to even more economic pressure than the federal government and industry. Across the country, state budgets are currently in dire straits, with conditions projected to improve in late 2011. Similarly, academic and non-profit organizations felt a combination of financial burdens, as most lost investment incomes during the recession. The overall economic climate has reduced donor and alumni contributions. Slowly improving economic conditions will undoubtedly increase the ability of all three of these sources to support R&D activities, though they will fail to regain 2008 levels in 2011.

We forecast R&D funding from internal academic sources (typically generated through endowments, royalties and general institutional support) to increase by 4.4%, to $12.1 billion in 2011. As part of this increase we assume that improving stock market conditions will allow some institutions to replace declining funds from other sources with some internal funding. Other government sources of R&D funding are forecast to reach $3.4 billion in 2011, an increase of 5.3% over 2010. Although overall state budgets are likely to see some improvements in 2011, this growth also takes into account increased funding from state technology investment programs that are being funded through various bond issues, such as Ohio's Third Frontier Program.

Finally, non-profit funding sources are still forecast to be limited in their ability to invest in R&D efforts in 2011, with their growth rate just slightly higher than the consensus projection of a 1.5% inflation rate for 2011. At this rate of growth, non-profit R&D funding will reach just under $12.9 billion in 2011.

Performer Details

Examination of the performance dimension of the source-performer matrix leads to a more detailed understanding of the research role that the federal government, industry, academia and non-profit organizations play in the U.S. R&D enterprise.

Federal Performance of R&D

The final enacted FY 2010 federal budget turned the previously forecast small gain in federal performance in 2010 to a very slight decrease. Given our somewhat pessimistic forecast for the FY 2011 budget's R&D funds, we see this decline continuing into 2011. Under our forecast, federally performed R&D (intramural research) will decline by slightly more than $200 million, to $27.5 billion in 2011. Part of this decrease comes from the fact that unlike other performers receiving federal ARRA funding, most federal intramural activities will have spent their funding in 2009 and 2010. It is important to note that while this intramural research is important, from a funding perspective these intramural resources account for just under 25% of all federal R&D investment on an annual basis.

Industrial Performance of R&D

Industry R&D performance in the U.S. will reach $286.9 billion in 2011, an increase of $8.4 billion (3.0%) from 2010. With this overall increase, the 2011 level of industrial R&D performance will slightly exceed the previous 2008 peak ($283.2 billion), at least in current dollars. At this level, industrial R&D activities will account for 70.8% of all R&D performed in the U.S.—a share that is once again rising (up from 70.4% in 2010), but is still below the industrial share peak of 72.3% set in 2008.

Within these 2011 funds, we forecast industry funded and performed R&D to increase by 3.3% over 2010, reaching $260.9 billion. This assumes the continuation of the slow growth evident in 2010, but necessarily without a similar significant Q1 scale-back in 2011. As with federally funded R&D activities, we forecast a slight decline in 2011, down $120 million (-0.05%) from our final 2010 estimate. At nearly $26 billion, federal funding supports about 9% of the R&D performed by U.S. industry.

Academic Performance of R&D

Research by U.S. academic institutions is forecast to reach $57.5 billion in 2011, an increase of 1.9% over 2010. Though the overall increase is small, growth is found across all five funding sources.

Consistent with previous years, $36.1 billion in federal funding will support just over 60% of academic R&D. This is the only performer area where federal funding is not expected to decline in 2011. This is due to the continued expenditure of ARRA funds by academic institutions, accounting for slightly more than $5 billion of the academic total.

Of the remaining funds for academic R&D, the majority (21% of total performance) come from internal or institutional sources. Other Government and non-profit resources each fund over $3 billion in academic research, with other government funds forecast to increase by more than 5% from 2010 to 2011, as state budgets start to improve. Finally, industry-sponsored research, growing at slightly more than 5%, will account for nearly $2.8 billion in 2011, or roughly 5% of total performance.

FFRDC Performance of R&D

The 39 current FFRDCs, though managed in many cases by private sector contractors, receive their R&D funding largely from the federal government. The FFRDCs are forecast to receive $15.6 billion in federal R&D support in 2011, a decrease of 0.2% over our final 2010 estimate. This decline is almost entirely due to the reduction in ARRA support from 2010 to 2011.

Non-Profit Performance of R&D

Research activities performed by non-profit institutions (outside of academia) are expected to increase 1.3% in 2011, reaching $17.8 billion. The largest sources of support for non-profit R&D are internal funds or other non-profit resources. These funds account for $9.8 billion, or approximately 55% of the total non-profit research activity. The largest increase in support, 2.6%, will come from industry-sponsored research, leading to a total industry investment of nearly $1.8 billion in 2011.

U.S. Federal R&D Funding: Long-Term Stability, But Short-Term Uncertainty

Again this year, Congress did not pass a budget before the start of the new fiscal year on October 1. As of this writing, the FY 2011 federal budget is operating under a continuing resolution (CR) through December 3, 2010, and at least one more extension is likely. Views on how the changing political composition of Congress will affect final FY 2011 federal funding for R&D are uncertain, especially given larger issues tied to a number of federal agency budgets.

The starting point for the budget process was the Obama administration's initial request, which would have increased overall R&D by only 0.2% over enacted FY 2010 levels. Three agencies—Defense (DOD), Agriculture (USDA), and Veterans Affairs (VA)—were slated for R&D funding decreases.

Several scenarios are possible as the budget process unfolds. In the first scenario, Congress and the Administration enact an omnibus FY 2011 budget before the end of the calendar year, with continued (and increasing) funding for some specific R&D initiatives, such as America COMPETES. While some observers see the potential for bipartisan support for this outcome, others anticipate an effort to begin cost-cutting now instead of waiting until the FY 2012 budget process.

In the second scenario, a budget very similar to FY 2010 is passed for expediency. This would basically extend the CR-based funding (again via an omnibus appropriation) through the remainder of the 2011 fiscal year. This would allow the new Congress to focus on the FY 2012 budget, the starting point of which is the Administration's interest in 5% cuts in non-security budgets. While this FY 2011 budget scenario seems like an ad hoc approach to managing expenditures in excess of $3 trillion, this is exactly what occurred in FY 2009.

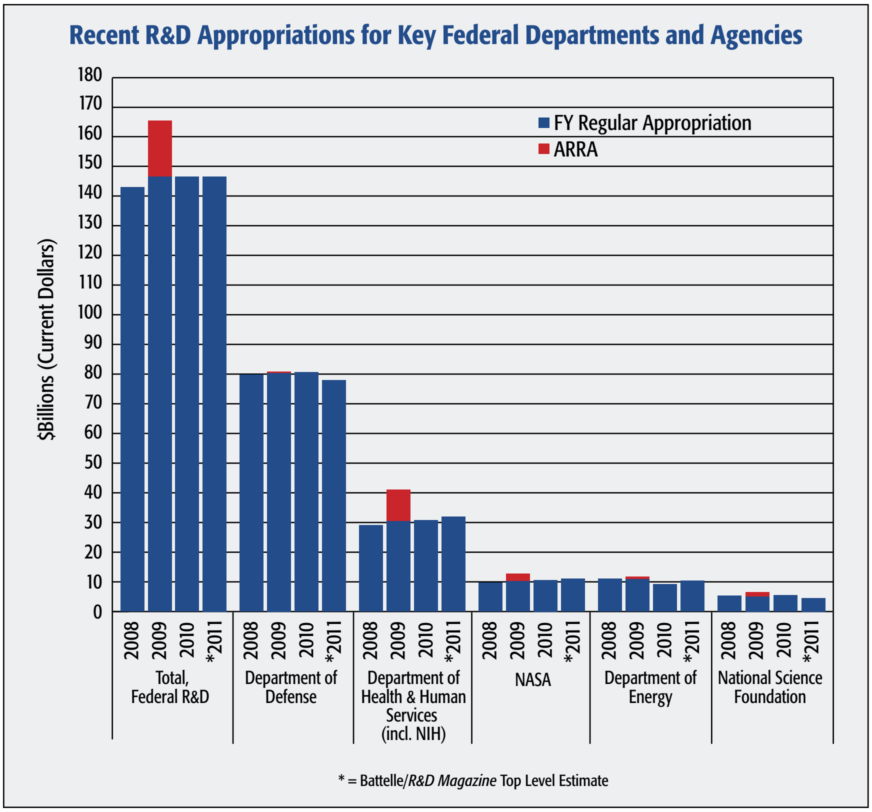
The third scenario is that the outgoing 111th Congress defers the FY 2011 budget debate to the 112th, where interest in spending cuts and deficit reduction could have more influence. Statements by incoming Republican House leaders indicate a desire to "cut non-security-related government spending for the next year back to FY 2008 levels, before all of the bailouts, government takeovers, and 'stimulus' spending sprees began." As in the first scenario, this third scenario depends on whether Republican leadership decides to focus fiscal attention on the FY 2011 or FY 2012 budget process (the latter of which would typically begin in early February of 2011).

Regardless of which scenario plays out for the overall FY 2011 budget, from an R&D perspective, federal funding has been, and will more than likely continue to be fairly stable and would likely be spared significant cuts. This is especially true with each party controlling a chamber, and with an administration and senior members from both parties recognizing the importance of R&D for economic growth and national security.

Given both the year-over-year stability and the current uncertainty regarding FY 2011 budgetary actions, we have developed a likely conservative estimate of the final FY 2011 federal R&D funding levels, drawing on the work of the White House Office of Science and Technology Policy (OSTP), the American Association for the Advancement of Science (AAAS) R&D Budget Program and other sources. We project that total federal R&D funding will reach $147 billion in FY 2011, nominally equal to enacted FY 2010 funding, and a decline in constant dollars of approximately 1.4% (using the Third Quarter 2010 Survey of Professional Forecasters 1.5% estimate of 2011 inflation). The outlook is better for non-defense R&D (i.e., excluding DOD, DHS and VA), with our forecast reaching $66.8 billion in FY 2011, an increase of 4.5% over FY 2010 levels (or about 3% in inflation-adjusted terms).

Dept. of Defense (DOD)

Estimating the final outcome of federal funding for defense R&D has been a challenge since the current annual wave of CR-impacted budget processes began. It is further compounded by the significant use of the DOD budget for enacting congressionally directed spending, or earmarks. The president's official budget request often provides at least rough guidance for most departments on their R&D budgets. For the DOD, it often becomes just a starting point for the budget. For example, according to the OSTP, while the president's request for DOD R&D funding for FY 2010 was $79.7 billion, it reached $81.1 billion when finally enacted—an increase of 1.8% over the president's budget (at a time when overall total R&D funding ended up 0.2% below the president's FY 2010 budget request). For FY 2011, we expect a similar effect on DOD R&D spending, though in the context of more austere times. The administration's request proposes a decrease in DOD R&D spending of 4.4%. Our current estimate has the FY 2011 R&D bud-



Source: Battelle/*R&D Magazine* with data from OSTP, AAAS

get reaching $78.4 billion, a 3.3% decline over FY 2010 enacted levels, but still 1.1% over the administration's budget submission. As the largest single federal sponsor of R&D, this nearly $2.7 billion decline would have a substantial impact on overall U.S. federal R&D funding.

National Institutes of Health (NIH)

The R&D budget for the NIH (the largest component of the Dept. of Health and Human Services, accounting for 98% of HHS R&D efforts) has recently stayed within 1% of the administration's request. For FY 2011, the request was $32.2 billion, an increase of 3.1% over FY 2010 and likely close to what the final FY 2011 budget will provide for NIH R&D.

Dept. of Energy (DOE)

The administration's request for DOE R&D funding of slightly more than $11.2 billion (an increase of 4.9%) continues on the combined multi-year track of doubling of DOE's Office of Science, stemming from the America COMPETES efforts and other increases in energy research. Congress has suggested a slightly lower level of overall growth. Accordingly, our estimate of $11.1 billion is slightly less than the administration's request, which still would represent an increase of 3.8% over FY 2010.

NASA

Given the evolving mission of NASA, including the cancellation of the Constellation program and the retirement of the space shuttles, the NASA R&D budget has been the subject of much debate and modification over the last few fiscal years. The administration's FY 2011 request for nearly $11 billion in R&D funding would be a substantial 18.3% increase over the FY 2011 enacted level, in part to spur the development of new space exploration technologies. This budget is potentially one of the most volatile in the FY 2011 process. Recent history and current fiscal realities make it likely that there will be some reductions in the final NASA R&D budget. While there is a slight possibility that some of the non-R&D operational cuts made to NASA's budget may be replaced, in part, with additional R&D funds, our estimate embraces the most likely scenario of a slight reduction to the administration's request. This would provide NASA with $10.3 billion for R&D in FY 2011, an increase of 10.4% over last year.

National Science Foundation (NSF)

The administration's request for the NSF R&D budget calls for a 9.4% increase as part of the doubling of basic research capacity authorized by the America COMPETES Act. According to the OSTP, in the final FY 2010 enacted budget, NSF received just under $5.1 billion for R&D (74% of the total NSF budget) which amounted to an inflation-adjusted decline of $287 million over the prior year. The request for FY 2011 would bring the total to nearly $5.6 billion. However, congressional committee actions suggest that the final appropriation might be reduced, so our estimate for NSF R&D funding for FY 2011 is $5.5 billion, an 8.0% increase over FY 2010.

Dept. of Agriculture (USDA)

The FY 2011 USDA R&D budget request amounts to a 5.5% ($143 million) decrease from enacted FY 2010 levels. Current congressional budget committee actions, on which our estimate is based, point to a budget of $2.5 billion, or a reduction of 4.5%.

Dept. of Commerce (DOC)

The DOC R&D budget has been slated for double-digit increases over the past few years due to NIST's role in the America COMPETES Act R&D doubling mandate. For FY 2011, the administration requested a 13.9% increase for the DOC R&D budget. Senate and House committee debates have bracketed this amount. We believe that while DOC will receive an increase in R&D funding, it will probably be closer to 12%, or a total of $1.7 billion in FY 2011.

Industrial R&D: Life Sciences

The life sciences segment covers the full range of related industries, ranging from pharmaceuticals to medical devices and equipment to biotechnology. While merger and acquisition activity has abated somewhat, it continues to be a defining factor in R&D investment.

Pharma and Biotech

Currently, one of the largest independent remaining biotech companies, Genzyme, is being aggressively pursued in a takeover bid by Sanofi-Aventis. Meanwhile, Genzyme is marketing itself to other pharmaceutical companies in hopes of raising its price and/or finding a better suitor. While neither firm is one of the ten largest U.S. life sciences R&D performers, they nevertheless continue the recent history of significant consolidation activities.

It is interesting to note that Roche CEO Severin Schwan has recently gone on record saying that the company has no plans to consolidate the R&D activities of Genentech with the Roche R&D operation, choosing to keep them separate to better enable innovation. Whether this model can be sustained by Roche in the long term or would be emulated by other pharmaceutical/biotech mergers remains to be seen.

Much of this recent M&A activity among pharmaceutical companies is explained by the impending 2012 patent expirations facing a number of significant drugs, including Pfizer's Lipitor™, which is first in global sales. These long-anticipated expirations have driven corporate strategies to cut costs and rebuild pipelines. We will know soon if these activities actually lead to new drugs with the demand-driven financial strength to backfill for the loss of revenue when proprietary molecules become generic.

Rationalizing R&D

Acquiring firms are typically quick to rationalize R&D activities—both existing IP and their R&D portfolios. Much has been reported about large pharmaceutical companies buying small biotech companies for their niche targets and/or agile R&D capabilities. However, there may be a reversal on the horizon for a number of pharmaceutical companies. Large holders of post-merger IP and R&D portfolios are beginning to contemplate packaging pieces of these portfolios that are outside of the company's focus and spinning them out into new companies. One company, Convergence, already has been formed out of pain therapy IP from GlaxoSmithKline, and industry observers have noted that this may be a likely strategy for Roche and others going forward.

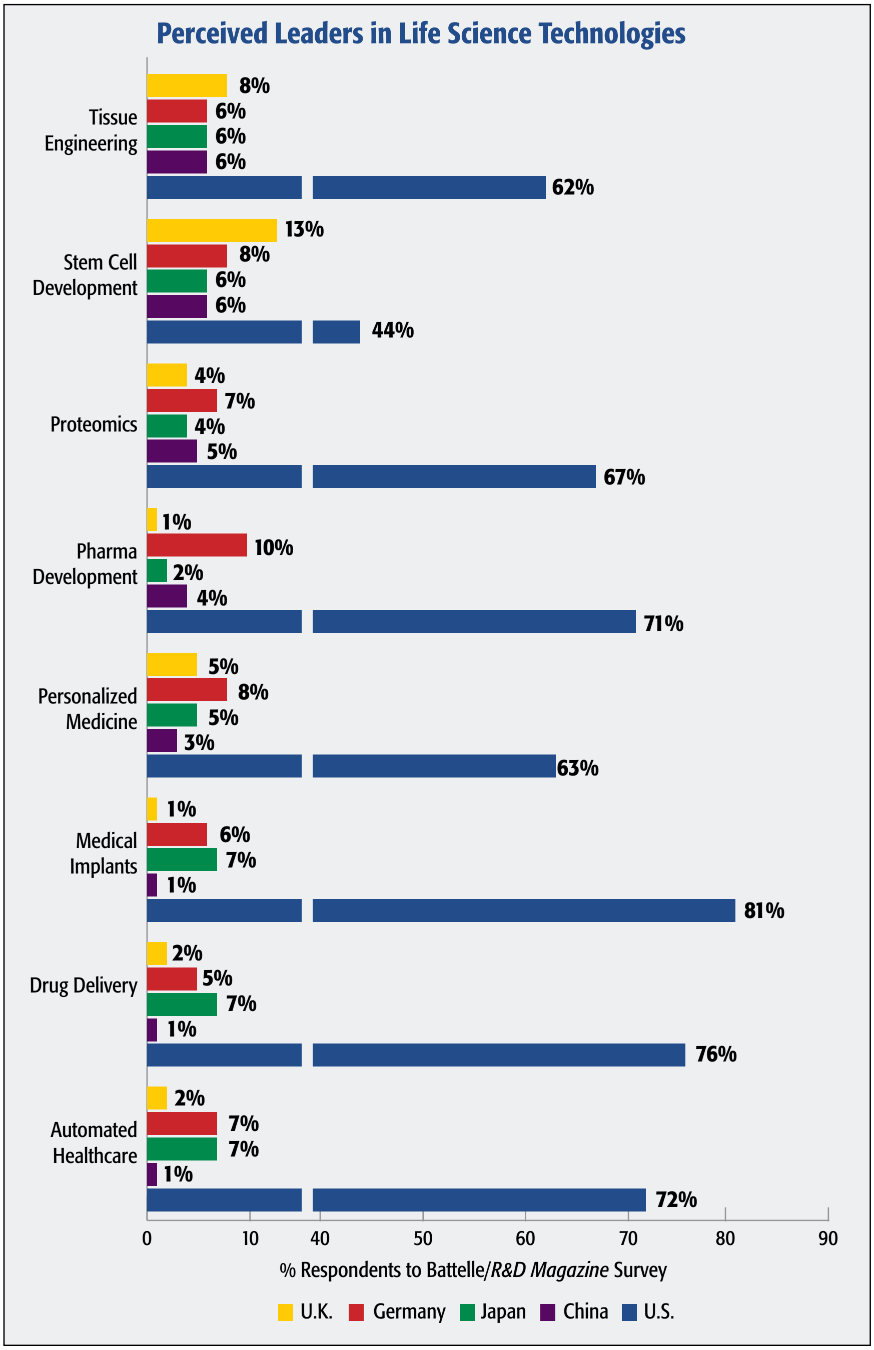
Post-merger activities, which include cutting, restructuring and streamlining overall R&D costs, will be adding further to the number of pharmaceutical jobs lost over the last five years. Some of the largest cuts still coming are from Merck (post-merger with Schering Plough), which is closing eight global R&D facilities as part of a larger operational consolidation effort. Pfizer (post-Wyeth merger) is signaling cuts of up to $3 billion in its R&D budget over the next few years. AstraZeneca has announced plans to reduce R&D budgets by $1 billion in the next four years, and Abbott Laboratories (post-Solvay acquisition) has announced plans for big cuts in R&D among more

Life Sciences	2008	2009	Q1-Q3 2010
Top U.S. R&D Spenders	Millions, U.S.$		
Merck & Co.	8,334.3	8,425.0	6,474.0
Pfizer, Inc.	7,945.0	7,845.0	6,607.0
Johnson & Johnson	7,577.0	6,986.0	4,862.0
Lilly (Eli) & Co.	3,840.9	4,326.5	3,446.1
Bristol-Myers Squibb Co.	3,512.0	3,647.0	2,556.0
Amgen, Inc.	3,030.0	2,864.0	2,010.0
Abbott Laboratories	2,688.8	2,743.7	2,667.0
Medtronic	1,335.0	1,451.0	n/a
Biogen Idec Inc.	1,072.1	1,283.1	957.8
Monsanto.	1,033.0	1,113.0	938.0

Source: Battelle/*R&D Magazine*/Company information

Total Life Sciences R&D Spending

Source: Battelle, *R&D Magazine*, EU R&D Scoreboard



Perceived Leaders in Life Science Technologies

than 3,500 job cuts globally. Roche also recently announced plans to cut 4,800 jobs globally.

From an operational perspective, a trend is quickly developing among pharmaceutical firms in reshaping their R&D operations. Three major pharmaceutical firms, Eli Lilly (back in 2008) and more recently Merck and Sanofi-Aventis, have launched significant and far-ranging development agreements with Covance, a major contract research organization. They all view the efficiencies and flexibilities gained by these agreements (including the transfer of R&D facilities and assets) will dramatically improve the returns on the affected part of their respective R&D portfolios.

The most significant and continuing R&D trend is the increasing expansion of R&D efforts in Asia. Both Eli Lilly and Sanofi-Aventis recently announced new R&D centers in China joining Merck, Novartis, AstraZeneca and others with significant China-based R&D operations. Singapore also continues to attract new pharmaceutical R&D investments, including a new Roche research center.

Beyond these individual corporate actions over the last year was the joint February announcement by Eli Lilly, Merck and Pfizer to establish the Asian Cancer Research Group (ACRG). This non-profit organization will enhance research and drug discovery efforts aimed at the most common cancers in Asia through the development of an open access pharmacogenomic cancer database of data from about 2,000 cancer tissue samples taken from around the region. The ACRG initially will focus on lung and gastric cancers.

While biopharmaceutical R&D efforts in Asia continue to be robust, the region is not immune to global restructuring activities. In October, Eli Lilly announced the closing of its recently expanded Singapore Center for Drug Discovery as part of its plans to bring focus and efficiency to its global business.

Medical Devices

With significantly lower costs to achieve regulatory approval of new products, R&D in the medical devices sector often receives less attention than pharmaceuticals. Even so, there are significant on-going M&A activities in this area as well. For example, Medtronic continues to expand its research, technical and global portfolio through the recent acquisitions of Osteotech, ATS Medical and Invatec. Given the relative scale differences between these transactions and what has been occurring in the biopharmaceutical sector, these efforts typically do not generate the same level of public attention. But implications for research and development are equally important to the the global medical device industry.

Industrial R&D: Information Technologies

Like most other industries, the software industry's spending on R&D slowed during the recent recession, declining about 1.5% globally and 5% in the U.S. in 2009. Industry R&D is back on track, however, with increases in 2010 and 2011 of 4.5% to 7.5%, respectively, driven in part by increased adoption of embedded control and interface software in a wide range of applications. Telecom, automotive, energy, pharmaceutical, banking and finance, aerospace/defense and other sectors are increasingly relying on more software to simulate, design, operate and control their products, systems and manufacturing procedures. General Motors' Chevrolet Volt, for example, has more software than a state-of-the-art fighter aircraft, with up to 40% of the car's value coming from software, computer controls and sensors. Working with IBM, GM researchers developed the Volt's 10 million lines of code and control systems in just 29 months. Code now can be modified almost instantaneously (and post-production, if necessary) through each vehicle's network address.

U.S. investments in software R&D account for more than 70% of the global total. No real decline in that share has occurred over the past several years. Most of the software leaders are multinational corporations, with extensive global R&D presences in advanced and emerging nations alike.

From an R&D perspective, a number of trends have emerged, including development and implementation of cloud computing, expansion and sophistication of wireless/mobile applications, development of non-cloud IT networks, and embedding of intelligence in software systems and associated hardware. Due to the nature of software technology, many of these trends integrate and overlap.

Cloud Computing

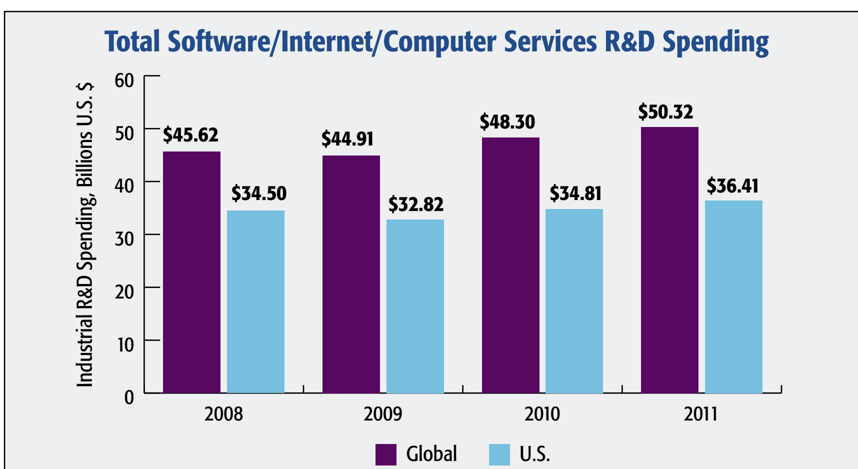
Cloud computing is basically a software implementation for increasing the capacity and capabilities of an organization's IT infrastructure without major investments in new equipment, technologies, personnel or training. Cloud computing is simply a subscription-based service performed real-time over the Internet. These services can include the use of application software, storage and virtual servers, web services, and managed services such as virus scanning.

Numerous companies are developing and marketing cloud computing services, including IBM, Google, Microsoft, Oracle, Amazon and others. IBM launched the first Cloud Computing Lab in its Hursley, U.K., facility in October 2010, making experts and technology available to remote clients from any of its 38 global Innovation Centers. In November 2010, IBM announced it is leading a joint research initiative with 14 European companies, including SAP AG, France Telecom, and Siemens AG, to develop a new type of cloud-based storage architecture. Vision Cloud (Virtualized Storage Services for the Future Initiative) aims to develop a meta-data approach to data storage that provides content-centric access to the data that varies according to those who access it. Also in November, IBM announced its Municipal Shared Services Cloud and its Federal Community Cloud for local governments and government agencies, respectively.

With the market for cloud technologies at $50 billion in 2010 and expected to

Software/Internet/Computer Services	2008	2009	Q1-Q3 2010
Top U.S. R&D Spenders	Millions, U.S. $		
Microsoft Corp.	9,015.0	8,581.0	6,766.0
International Business Machines Corp.	6,337.0	5,820.0	4,448.0
Google Inc.	2,793.2	2,843.0	2,710.0
Oracle Corp.	2,776.0	2,775.0	2,989.0
Electronic Arts Inc.	1,343.0	1,250.0	863.0
Yahoo Inc	1,221.8	1,210.2	804.4
Symantec Corp.	868.3	865.5	632.0
Activision Blizzard	592.0	627.0	366.0
Intuit	561.7	567.0	n/a
Adobe Systems Inc.	662.1	565.1	509.9

Source: Battelle/*R&D Magazine*/Company information



Source: Battelle, *R&D Magazine*, EU R&D Scoreboard

World's Top 10 Supercomputers					
	Operator	Site	Computer	Cores	Rpeak *
1	China NSC	Tianjin	Tianhe-1A	186,388	2.566
2	U.S. DOE	ORNL	Jaguar-Cray	224,162	1.759
3	China NSC	Shenzhen	Nebulae	120,640	1.271
4	Japan GSIC	Tokyo	TSUBAME	73,278	1.192
5	U.S. DOE	LBNL	Hopper-Cray	153,408	1.054
6	France CEA	Paris	Tera-100	138,368	1.050
7	U.S. DOE	LANL	Roadrunner	122,400	1.042
8	U.S. NICS	Tennessee	Kraken XT5-Cray	98,928	0.831
9	Germany	FZJ	JUGENE	294,912	0.825
10	U.S. DOE	LANL	Pleiades-Cray	107,152	0.817

* - Linpack petaflops/sec

Source: Top500.org (Nov 2010)

double by 2012, IBM has invested heavily in associated R&D. For example, in early-2010, IBM acquired Cast Iron Systems, the leader in cloud-based integration, for an undisclosed amount. IBM Software Group has acquired more than 55 companies since 2003.

Wireless Research

Wireless software applications are being driven in part by the rapid growth in traditional and smart cell phone systems. In the cell phone arena, four software operating systems dominate the marketplace, Nokia's open-source Symbian OS, with more than 400 million total mobile devices shipped, with a 37% market share; Google's rapidly ascending Android (27%); Apple's iOS (17%) and RIM (Blackberry, 15%). Microsoft only recently introduced its new Phone7 OS. This marketplace looks to become a two-player arena between Android and iOS, with Android gaining a dominating marketshare within the next year, driven through lower prices and broader availability. While the Symbian OS dominated the marketplace for the past decade and mirrored Nokia's market dominance with traditional cell phones, Nokia failed to keep pace with the development of smart phone OS technologies created by Apple and Google and lost market share in both devices and operating systems. Nokia introduced its Symbian^3 operating system for smart phones this past summer.

Apple dominated the early smart phone market with a large number of third-party developed applications; there are currently more than 250,000 applications for iPhones. Android followed suit with currently more than 100,000 applications. A big portion of Apple's R&D budget is targeted at software development, as its hardware systems are primarily built with off-the-shelf components or are designed by others. As a result, Apple is more cost-effective in its R&D investments than other similar high-tech companies.

Development of non-cloud-based IT networks is being driven by a number of scientific demands for environmental, manufacturing and security-based applications. The 2010 BP Gulf oil spill reinforced the need for extensive networks of software-driven monitoring sites throughout the Gulf. While technologies exist for these systems and isolated areas have been instrumented in Europe, there are relatively few along the U.S. coasts. That became readily apparent following the oil spill when no one had any information on the effects of the spill. Numerous academic, government, and industrial monitoring systems are being established to support R&D in these areas.

Unknown to the general public, many devices with electronic components, including some kitchen appliances, are currently being built with their own network addresses, allowing future systems to identify and communicate with them. Most sensors used in industrial settings already have data processing and communication capabilities. Passports and driver's licenses have smart chips. Smart phones with GPS capabilities can be reverse tracked, and senior citizens can be monitored simply with electronic devices in real time, minimizing the need for supervised healthcare facilities.

Strong Niches

The software segment also includes numerous companies that specialize in niche applications that dominate their marketplace with relatively strong R&D investments. SAS Institute, for example, is a privately held company specializing in statistical software for everything from pharmaceutical drug development studies to banking and finance trends. It spends about 23%, or $530 million, of its annual $2.31 billion in revenue on R&D.

SAP AG is another niche software company with a strong commitment to R&D at nearly 16% (or $2.6 billion) of its annual revenue of more than $14 billion. SAP makes enterprise software for business management.

High-Performance Computing: R&D Enabling Faster R&D

While mostly a narrow market, supercomputing also has seen substantial growth over the past several years, with China and Japan developing systems that have become the most powerful in the world. System software development is important to ensure that the new hardware can be fully leveraged. Investments in application development are even more important, since this technology enables a new era in accelerated research and development through computational modeling, simulation and engineering.

China recently unveiled its Tianhe-1A supercomputer, which immediately was listed as the most powerful system in the world in the biannual Top500 competition. The Tianhe-1A uses a combination of NUDT (China's National University Defense Technology) multicore microprocessors and U.S.-made Nvidia multicore graphics processing devices to achieve this performance. China has indicated it is developing an even more powerful supercomputer expected to launch in 2011, with all processing devices manufactured in China.

Industrial R&D: Electronics/Computers

Electronic systems and components have been in a constant state of evolution for nearly 50 years. Moore's Law—the doubling of transistor density every two years—started it all in 1965, and the trend is now expected to continue through 2015 and beyond. Current hardware technology development responds to growth in cloud computing, Internet servers, mobile computing, pervasive wireless, embedded everything, integrated power supplies, satellite-based communications, flexible circuits and displays, many-core processors, carbon nanotube circuits, printed circuits and more. Tomorrow's technologies are likely to involve human implanted sensors, controllers, displays, and microprocessors. Imaging sensors have already been implanted in the human retina, allowing blind people to see. The bio-electronics age is just beginning.

Electronics manufacturing, design, and research was one of the first high-tech industries to be fully globalized. The continual downsizing and miniaturization of integrated circuits within electronic applications has created complex manufacturing and testing requirements that are more expensive than any other volume manufacturing system on the planet. A new manufacturing plant for state-of-the-art microprocessors can cost $5 billion in the U.S. or $3 billion in a lower cost Asian site, which makes offshore manufacturing by U.S. companies very attractive, even with added support requirements. As a result, substantial infrastructures have been established in many countries for even the most complex procedures.

The complexity of electronics manufacturing requires that a substantial amount of the company's R&D be dedicated to development of the manufacturing procedures and often spent in and around the local manufacturing site. With 80% market share, Intel has become the largest manufacturer of microprocessors in the world. It recently opened a $1 billion chip assembly and testing facility in Vietnam and within two weeks opened a $2.5 billion semiconductor manufacturing plant in Dalian, China. The Vietnam facility is Intel's seventh assembly and test site. Others are located in Penang and Kulim, Malaysia; Cavite, the Philippines; Chengdu and Shanghai, China; and San Jose, Costa Rica. Intel's chip plant in Dalian uses 300-mm wafers, which cuts chip manufacturing costs by 30% over the previous generation 200-mm wafers. But of course, the equipment for 300-mm manufacture is considerably more expensive than that for 200-mm wafers.

Intel's continuing R&D and large-scale manufacturing capabilities allow it to push manufacturing efficiencies and keep its competitors at a distance due to the expensive capital equipment and entry costs.

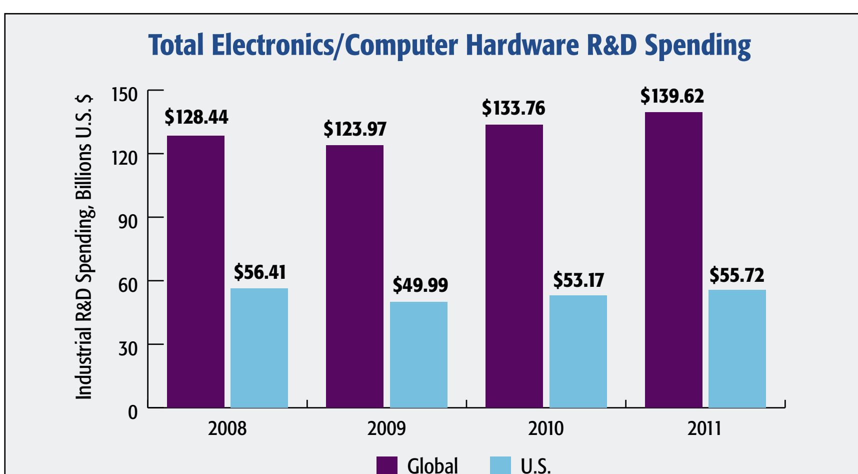
Intel has not ignored its U.S. manufacturing base and recently announced investments of $8 billion to build a new plant in Oregon and upgrade four existing plants in Arizona and Oregon.

Intel has also used its strong market position in microprocessor manufacturing to open doors for other associated ventures. The company recently partnered with the government of Taiwan to set up a multimillion dollar Internet computing research lab. Intel announced that it would work with Taiwan's National Science Council and a leading Taiwan university to establish a cloud computing research center at an estimated cost of $24 million over the next three to five years.

Advanced Micro Devices (AMD) has

Electronics/Computer Hardware	2008	2009	Q1-Q3 2010
Top U.S. R&D Spenders	Millions, U.S. $		
Intel Corp.	5,722.0	5,653.0	4,905.0
Cisco Systems Inc.	5,518.0	4,994.0	4,233.0
Motorola, Inc.	4,109.0	3,183.0	2,156.0
EMC Corp.	3,006.9	2,829.6	1,395.9
Hewlett-Packard Co.	3,185.0	2,768.0	n/a
Qualcomm Inc.	2,373.0	2,432.0	1,953.0
Advanced Micro Devices	1,848.0	1,721.0	1,053.0
Broadcom	1,497.7	1,534.9	1,290.1
Texas Instruments Inc.	1,940.0	1,476.0	1,178.0
Apple, Inc.	1,178.0	1,416.0	1,384.0

Source: Battelle/*R&D Magazine*/Company information



Source: Battelle, *R&D Magazine,* EU R&D Scoreboard

been attempting to challenge Intel for market share for a long time, but with 20% market share, its smaller size puts it at a disadvantage. Because Intel has more money to spend on R&D (nearly five times that of AMD for 2010), it can often develop and manufacture the next generation of more complex, smaller and more power-efficient chips ahead of AMD. Being first to market means a much larger initial and even later market share for the next generation of computing systems.

AMD has not conceded the microprocessor market to Intel. It acquired ATI four years ago for $5.4 billion and has been using its R&D to develop an accelerated processing unit (APU) that combines the central processing unit (CPU) with a graphical processing unit (GPU) into one chip of 'super-silicon'. AMD's first Fusion chips were introduced this fall, ahead of the Q1 2011 target date. This device is targeted at mainstream notebooks and desktop computers. It has twice the gaming performance of existing microprocessors and graphics cards/chips at half the power requirements. The ultra-small form factor also gives it 10 times the graphics performance over existing netbook computers. Production scale-up will allow the first products to appear in early 2011. To unload itself from the massive maintenance and capital requirements, AMD spun off its chip fabrication facilities into a separate company, GlobalFoundries, Inc., in 2009.

Agile R&D as a Strategic Advantage

While Intel and AMD spend their R&D investments developing new microprocessor devices and the processes for creating them, Apple, Inc., invests in developing products that use mostly existing components. The systems they've developed over the past several years—the iPod, iPad, and iPhone, along with their line of Mac portable computers—have established whole new product lines and created demand where none existed before. This R&D strategy has fewer risks than the capital-intensive Intel and AMD have, but is much more prone to competition. Apple's response is to use the speed of R&D as a competitive advantage.

Global Electronics/ Computer Hardware Research Collaborations with Key U.S. Companies

Collaborating Author Country	Publications (2009 to Present)
UK	97
China	68
Germany	56
South Korea	50
Canada	45
Israel	41
Japan	41
France	37
Australia	28
India	28
Spain	27
Sweden	23
Italy	21
Belgium	19
Singapore	17
Taiwan	17
Brazil	15
Switzerland	15

Source: Battelle/*R&D Magazine* Analysis of Recent Publication Data from Thomson Reuters

It continuously develops upgrades that are announced on short time scales and that keep competitors one step behind. The tremendous success of this approach has allowed Apple to hire thousands of employees to support their operations (12,600 new hires over the past year) and to increase their R&D investments (up 34% or nearly $500 million over the past year) and development programs. A substantial part of this R&D investment is also targeted at software development and upgrades for each of its product lines.

It's been noted that the payback on Apple's R&D investments is substantially better than those for Intel, Cisco or even Microsoft. Apple, for example, spent $4.6 billion on R&D over the past four years. To the extent that revenue growth is an indicator of return on R&D, Apple's concomitant revenue increased from $25 to $43 billion. Over the same period, Microsoft spent $31 billion on R&D, and its revenue only rose from $44 to $58 billion. Cisco spent $19 billion on R&D, while its revenue grew from $28 to $36 billion. Intel spent $23 billion on R&D, with flat revenues over a four year period at $35 billion/year.

Targeting Product Cost

Qualcomm is another chip manufacturer that focuses its R&D investments on mobile chipsets for cell phones. It spends heavily on reducing chip costs since its applications are cost-sensitive cell phone suppliers. Qualcomm also recently announced that it was establishing an R&D center in Taiwan to help it tap into China's growing market for cell phones. The company is also creating a new data exchange format that could help it gain an edge for supporting 3D chips.

Transcending Commodities

Dell Computer, which built its business without significant R&D investments, has decided to increase R&D spending to develop higher margin computer servers, data storage, networking gear and technology services. The margins on desktop and notebook devices have recently been shrinking and are not expected to return to previous levels.

In some situations, chip-fabrication technologies have become too complex and expensive for even the largest manufacturers. Over the past decade, these situations have required the formation of pre-competitive collaborations. In October 2010, Intel, Toshiba and Samsung announced they were collaborating to develop devices with 10-nm semiconductor feature sizes by 2016. In this initiative, Japan's Ministry of Economy, Trade, and Industry is providing more than $60 million in initial funding for the R&D efforts. Toshiba and Samsung are expected to use the technology to make 10-nm flash memory chips, while Intel will make faster microprocessors that use less power. In a similar situation, IBM, Samsung, GlobalFoundries, and STMicroelectronics announced in June 2010 that they were configuring their manufacturing facilities for the production of devices with 28-nm processors developed by the four and Toshiba, Infineon and Renesas Electronics.

Industrial R&D: Aerospace/Defense/Security

No segment has a stronger connection to public R&D investment than aerospace, defense, and national security. The U.S. and many foreign governments invest massive amounts on defense and security-related R&D every year. As an illustration of the scale, the U.S. government will spend more on defense R&D in 2011 (about $80 billion) than our estimates of total R&D (government, corporate and academic) for every country in our global analysis except the top three.

The impact this funding has on companies' internal R&D budgets and activities, and the directives behind it, cannot be overstated. As a result, when budgetary concerns develop at the federal level, effects are evident throughout the defense industry.

Funding Pressure Ahead

National Defense, the magazine of the National Defense Industrial Association, summarized the situation for U.S. federal R&D spending: "The perfect storm for defense is here, for real this time." In the past, defense budgets have been minimally affected during periods of budgetary constraints. This is about to change, as multiple factors—significant budget deficits, the growing federal debt crisis and related scrutiny of discretionary spending like R&D, the sluggish economy, the changing status of the Iraq and Afghanistan wars and the evolving nature of our defense activities in general—are aligning to change the level and focus of defense spending in the future. As Secretary Gates cautioned earlier in 2010, "The attacks of September 11th, 2001, opened a gusher of defense spending that nearly doubled the base budget over the last decade … Given America's difficult economic circumstances and parlous fiscal condition, military spending on things large and small can and should expect closer, harsher scrutiny. The gusher has been turned off, and will stay off for a good period of time."

The ultimate impact on aerospace, defense, and national security R&D remains to be seen. Pentagon officials have already stated that while efficiency in R&D activities will be sought, at least the basic research budget of approximately $2 billion annually will likely be immune from the expected overall defense cuts.

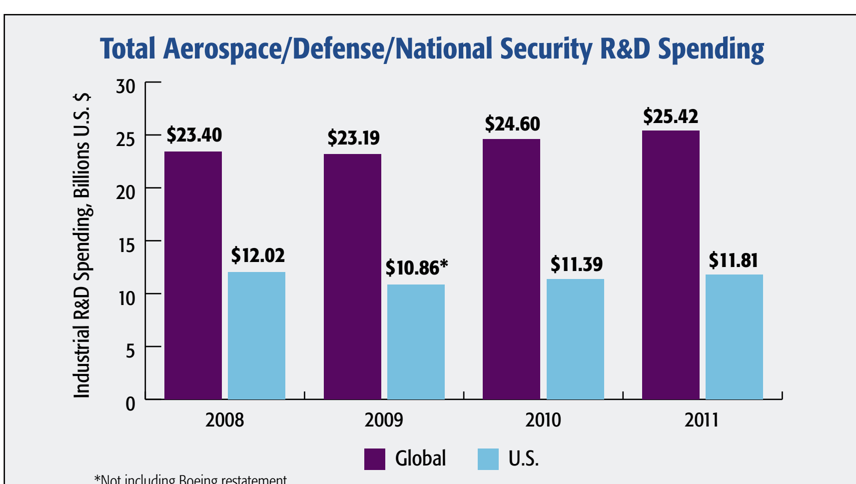
Against this backdrop of impending fiscal pressure are additional concerns over the allocations within the defense R&D portfolio. The report, S&T for National Security, issued by the JASON Program Office, describes the importance of DOD basic research, but concludes, "important aspects of the DOD basic research programs are 'broken' to an extent that neither throwing more money at these problems nor simples changes in procedures and definitions will fix them." The report identifies the main problem as a shifting focus from "long-term basic research to short-term deliverable-based research."

So where does this leave industrial R&D activities in the aerospace, defense and national security segment? Some observers see defense following the pattern of other mature industries dealing with significant cost constraints. There will be further efforts to push the development of innovations into the supply chain or to look to the private sector to find new ways to help finance innovation.

As the largest U.S. aerospace and defense-

Aerospace/Defense/National Security	2008	2009	Q1-Q3 2010
Top U.S. R&D Spenders	Millions, U.S. $		
Boeing Co.	3,768.0	6,506.0	2,987.0
Northrop Grumman Corp.	564.0	610.0	n/a
Lockheed Martin	719.0	750.0	n/a
Raytheon	517.0	565.0	n/a
General Dynamics	474.0	520.0	n/a
Textron	966.0	844.0	n/a
Rockwell Collins	393.0	355.0	n/a
B.F. Goodrich	284.0	239.0	n/a
L-3 Communications	254.0	257.0	n/a
BE Aerospace	131.4	102.6	81.2

Source: Battelle/*R&D Magazine*/Company information



Source: Battelle, *R&D Magazine,* EU R&D Scoreboard

related R&D performer, Boeing has faced a number of R&D related hurdles in recent years—though none directly connected to its defense and national security business.

Some in the R&D community might say more funding is better. In Boeing's case, this is not always true. Performance of its earliest 787 Dreamliner flight test aircraft caused it to write off $2.7 billion against R&D expense in 2009. The extent of testing and rework on the three flight test aircraft made it unlikely that they could be sold, so Boeing elected to restate their value from inventory to R&D expense. Some industry observers predict additional charges, although Boeing's guidance indicates that its 2011 R&D expenditures are likely to decline by about $500 million over earlier projections.

The other significant news for Boeing is that resolution may be near on its joint U.S. ongoing dispute with Airbus (jointly with the EU) over subsidies in the development of their respective wide-body aircraft. The WTO has ruled that both parties received illegal subsidies from their respective governments. Many anticipate that these WTO rulings will now lead to a negotiated final settlement.

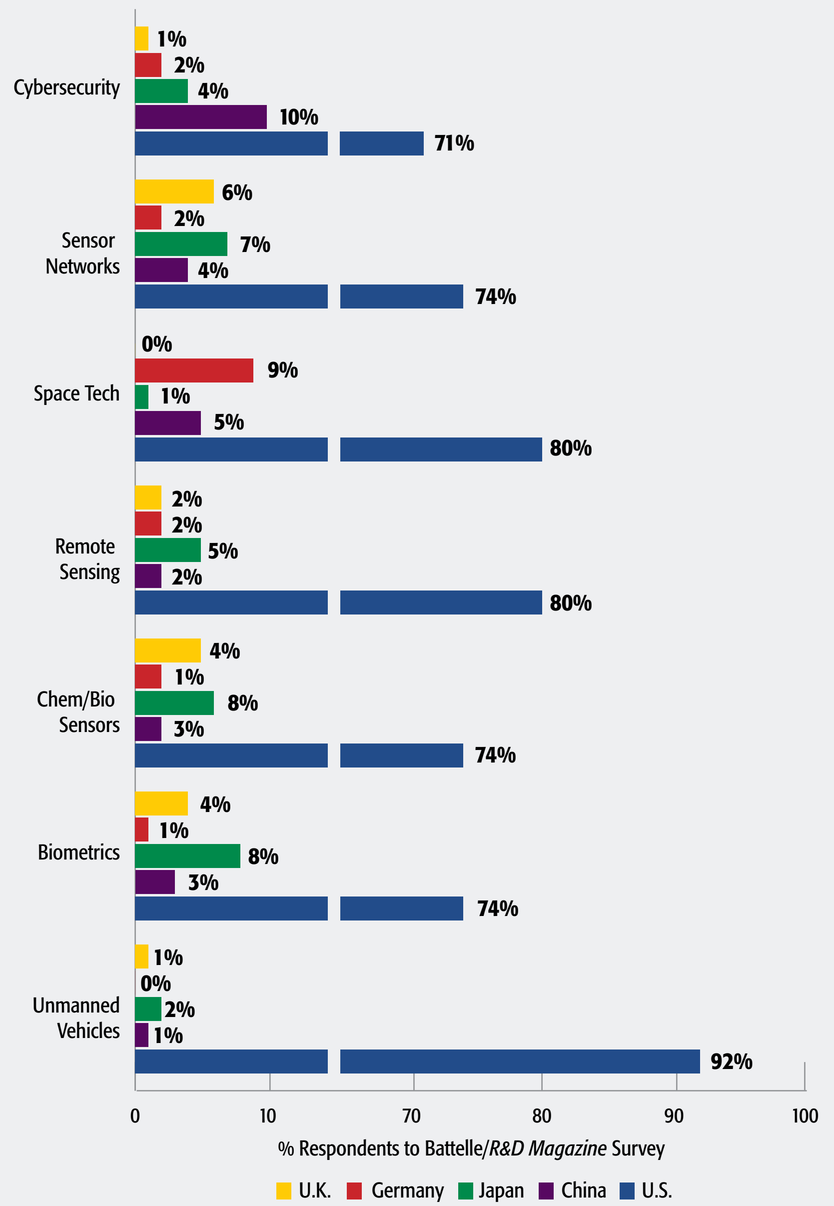
Trend Toward Collaboration

One unusual aspect of aerospace, defense, and national security R&D is collaborative and cost-sharing requirements of some federal R&D and procurement programs. For example, NASA selected Boeing, Lockheed Martin, Northrop Grumman and others to collaboratively provide R&D assistance on future aerospace vehicles.

Similarly, DARPA often convenes R&D capabilities of multiple firms in a combined competitive and collaborative approach. A recent example is the Triple Target Terminator (T3), an air-to-air missile designed to shoot down high-performance targets, for which both Raytheon and Boeing will receive $21.3 million cost-sharing development awards. This important role of the DOD in supporting and pushing the industry to catalyze innovation has not gone unnoticed. Recently, Russian President Dmitry Medvedev urged the establishment of a Russian agency similar to DARPA to assist in the development of new technologies for the military.

Based upon recent and planned R&D program announcements, aerospace, defense and national security R&D will likely continue along many technology fronts, including electronics (e.g., surveillance and sensor capabilities, wireless and other networking technologies; increasingly smaller navigation and guidance components and electronic warfare countermeasures); unmanned and autonomous platforms (e.g., larger scale, more robust systems and unmanned options for future manned vehicles); new long range, multi-function weapon systems; and warfighter safety and capability enhancements (ranging from lightweight armor/systems to continued development of flexible displays for battlefield use).

Perceived Leaders in Aerospace/Defense/Security Technologies



Industrial R&D: Energy

Energy R&D covers a broad spectrum, from fossil to renewable, from generation to storage, and from utility to consumer. These technologies and markets are fairly distinctive. As a result, R&D funding is not entirely fungible within the energy sector; so, we have adopted a portfolio approach to our forecast.

U.S. industrial R&D investment (see Top Ten list at right) reflects a mix of fossil, renewable and nuclear, and is driven by a combination of forces, including discovery and accessibility of fossil reserves, policy and financial incentives for renewable, etc.

R&D is enabling diversification within companies. For example, the three largest U.S. oil and gas companies are making significant investments in renewable energy—most notably, and not surprisingly, in the biofuels area where historical research, operational and infrastructure investments related to "liquid" fuels can be leveraged.

This picture of the U.S. energy R&D portfolio is also complicated by the difficulty of segmenting out R&D activities of diversified multinationals. The most important of these is General Electric (GE). While we have taken into account GE's energy R&D activities within the segment's R&D forecast chart, we have not included this estimate in the Top 10 table. At its likely current level of energy R&D, GE would undoubtedly be listed at the top, and it would stay there if it achieves its goal of doubling of energy-related R&D to $2 billion per year over the next five years.

Even so, the level of R&D spending in the U.S. energy sector is small in absolute terms and as a percent of revenue (0.3%) when compared with other sectors. For example, the total amount of private sector investment in all forms of energy research in our portfolio would likely amount to little more than half of the leading life science R&D investor, Merck, or the leading software/IT R&D investor, Microsoft, both of which invested more than $8.4 billion in R&D in 2009.

Defining Role for Federal Energy R&D

Unlike defense, outcomes and benefits from federal energy research are realized largely in the private sector. Moreover, DOE's research investment fills a critical gap in private sector innovation capacity. The relatively low level of R&D spending in the regulated, capital-intensive energy sector is unlikely to achieve the affordable, abundant, sustainable, secure energy supply that will be necessary for the U.S. to maintain global economic leadership in this century.

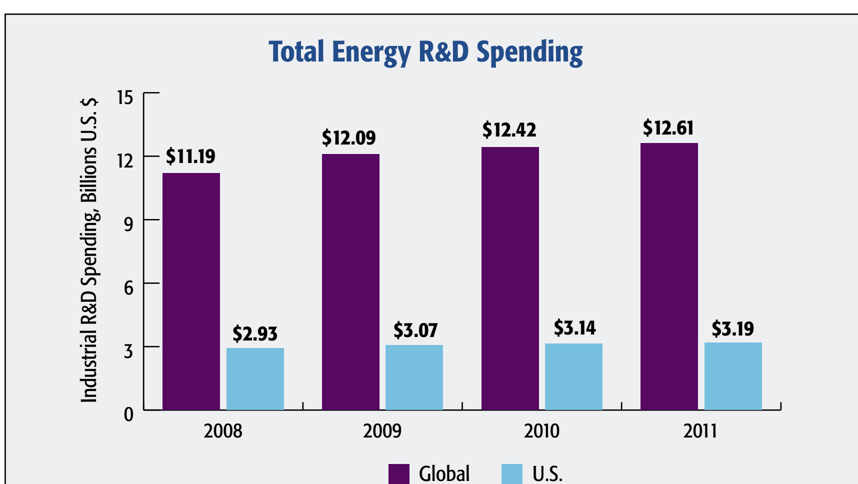
At the same time, public-private collaboration and commercialization are necessary to deploy energy innovation at scale, since the government controls little energy production or distribution capacity (except fossil reserves on federal lands).

In short, the private sector lacks the full scope of resources to do the research necessary to address growing demand and requirements for sustainability and affordability across all dimensions of energy technology. The government lacks the means to deploy energy innovation at a large scale to achieve policy goals and public benefits. Collaboration and commercialization are the essential bridges.

Recognizing the importance of the federal R&D engine in this sector, the American Energy Innovation Council (AEIC) has called for a tripling of invest-

Energy	2008	2009	Q1-Q3 2010
Top U.S. R&D Spenders	Millions, U.S. $		
Exxon Mobil	847.0	1,050.0	n/a
Chevron	702.0	603.0	n/a
ConocoPhillips	209.0	190.0	n/a
USEC	110.2	118.4	80.3
First Solar	33.5	78.2	67.2
Cree	66.9	75.1	66.6
McDermott International	40.1	54.2	n/a
A123	37.0	48.3	27.9
SunPower	21.5	31.6	n/a
FuelCell Energy	21.6	20.2	n/a

Source: Battelle/*R&D Magazine*/Company information



Source: Battelle, *R&D Magazine,* EU R&D Scoreboard

ment to $16 billion per year. It would be a significant challenge at a time when federal budgets are under pressure, particularly discretionary spending such as R&D. AEIC acknowledged the shortfall of energy R&D spending relative to energy's role in the economy (10% of GDP) and the significant decline, in real terms, of federal energy R&D investment since 1979-80.

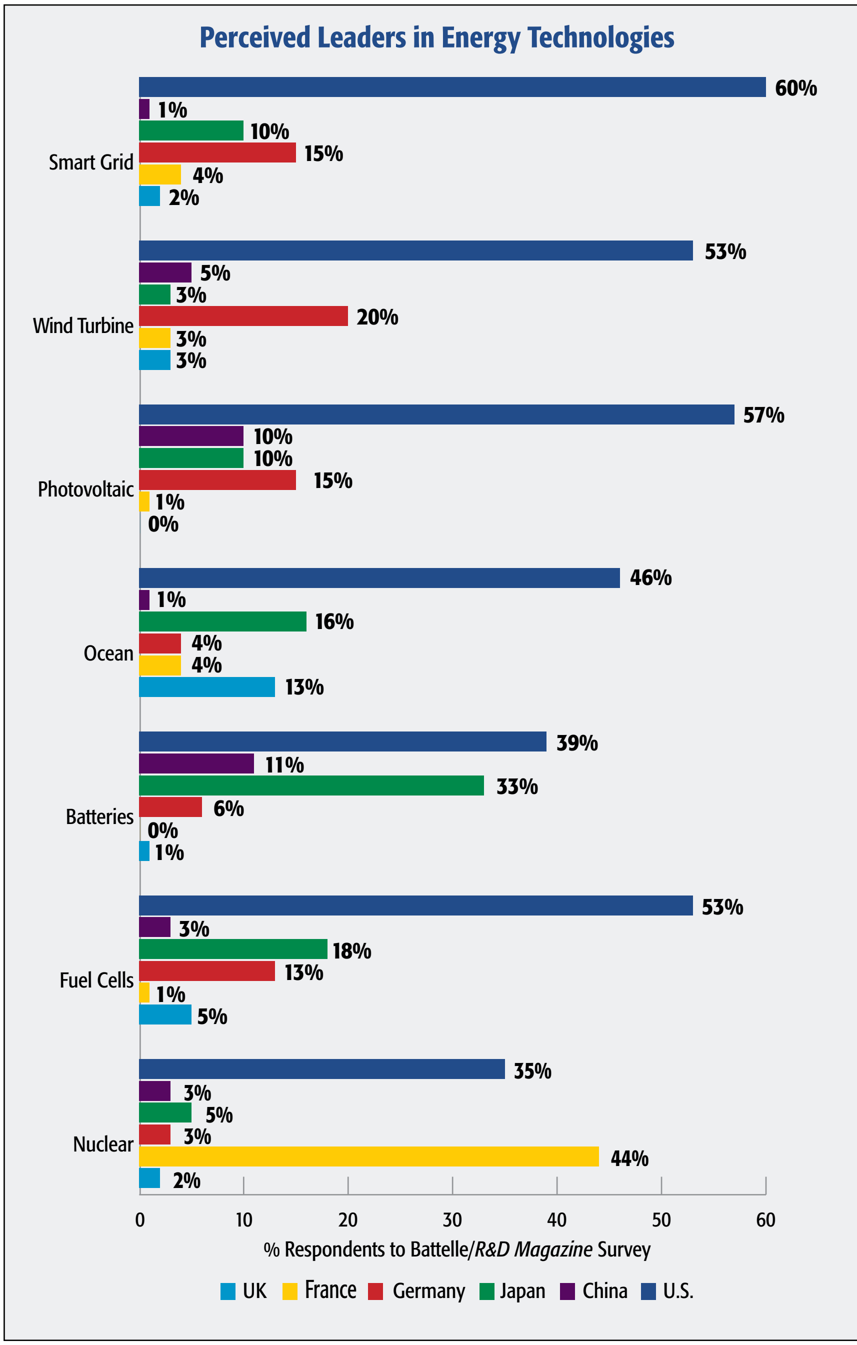
Proposed AEIC Energy R&D Model Budget	Billions, U.S. $
Basic Energy Science	$2.6
Nuclear Fission	$1.0
Nuclear Fusion	$0.4
Energy Efficiency	$2.1
Renewable Sources	$2.4
Fossil Energy (Clean Coal)	$1.3
Electricity Transmission and Distribution	$1.2
ARPA-E	$1.0
Pilot/Demonstration Projects	$2.0
Clean Energy Deployment Administration	$2.0
Total, Model Budget in 5 years	$16.0

In addition to the direct impact of increased federal spending on energy R&D like that recommended by AEIC, some suggest that it could stimulate increased levels of private sector investment in addition to increased collaboration with federal research activities.

Cleantech/Smart Grid Opportunities

As with other segments, the energy industry is affected by continued globalization and M&A activity. Unlike many of these segments, the U.S. is an attractive, somewhat untapped market for foreign renewable energy-related investment. From an R&D perspective, the most notable recent example is Vestas' continued investment in the U.S., including a new R&D center to be located in Colorado. Within M&A activities, we may be starting to see actions that reflect the drive toward larger corporate scale in clean tech. For example, the recently announced plans for United Technologies Corporation (UTC) to acquire Clipper Windpower might signal the start of renewable technology operations being brought into large multinational corporations that have the potential to contribute to a dramatic increase in scale in overall energy R&D.

Energy distribution, efficiency and control technologies in the broad category of "smart grid" is an area of strong R&D interest to a number of key global multinational firms (including GE, IBM, Siemens and others) as well as emerging growth companies. It also drives M&A activity involving larger acquiring firms such as ABB, Cisco and Honeywell. Grid-related opportunities have even attracted major defense companies, such as Boeing, which was awarded an $8.6 million ARRA grant for a smart grid project in 2009.



Industrial R&D: Advanced Materials

Industrial materials and chemical companies are involved in a broad range of R&D activities where users must rely on a mix of proven technologies and materials applied in new and/or unique ways. New materials must meet continuing performance improvements in terms of strength-to-weight ratios, cost-effectiveness, sustainable manufacturing, low or zero greenhouse gas (GHG) processing emissions and availability in critical applications. Across all industries, including automotive, aerospace, oil and gas exploration and consumer packaging there is a common need for lighter, more efficient systems that reduce energy consumption, while delivering on the intended mission.

Materials for Energy & Climate

PPG Industries has been supplying fiberglass to the wind turbine industry for more than 15 years. In 2010, with more than $700 thousand in ARRA funds, Pittsburgh-based PPG partnered with MAG Industrial Automation Systems in Erlanger, Ky., to research advanced materials and processes that could result in more reliable wind turbine blades. This research is aimed at reducing production variability that could result in premature failure in the turbine blade. "Everything now is about reducing the cost of renewable energy," says Cheryl Richards, PPG global marketing manager.

With R&D supporting its corporate and M&A strategies to move up the specialty value chain, Dow Chemical has developed a solar shingle that would bring the largest U.S. chemical manufacturer into an entirely new and lucrative market. These shingles use copper indium gallium diselenide solar modules—made by Global Solar Energy, Inc.—that are wrapped in a proprietary Dow plastic. Dow received a $20 million grant from the U.S. Dept. of Energy to develop these shingles. The resulting product has the potential to be installed on an average home for about $6,000 and could supply about half of the homeowner's electrical power. Dow estimates it could earn about $1 billion in revenue from this product by 2015.

Materials for Aerospace & Defense

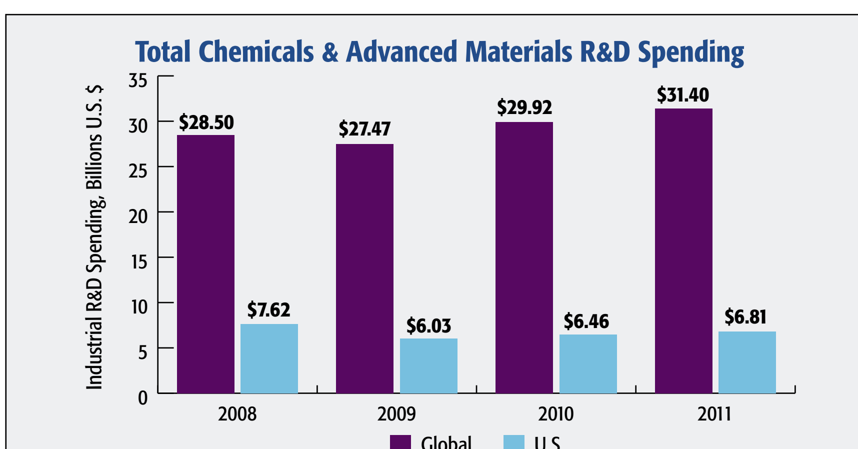
Aerospace manufacturers, such as EADS and Boeing are moving into higher use of composite materials, metal hybrid additive manufacturing processes (3-D printing), and powdered metal manufacturing to save weight and reduce fuel requirements for their commercial aircraft. Boeing is in the final stages of qualifying its 787 Dreamliner, which should set the stage for future aircraft construction technologies. Airbus is following with its development of its A350 XWB, a similar carbon-fiber reinforced polymer composite aircraft, which Airbus claims will be even more fuel efficient than the 787.

Shortages May Spur Innovation

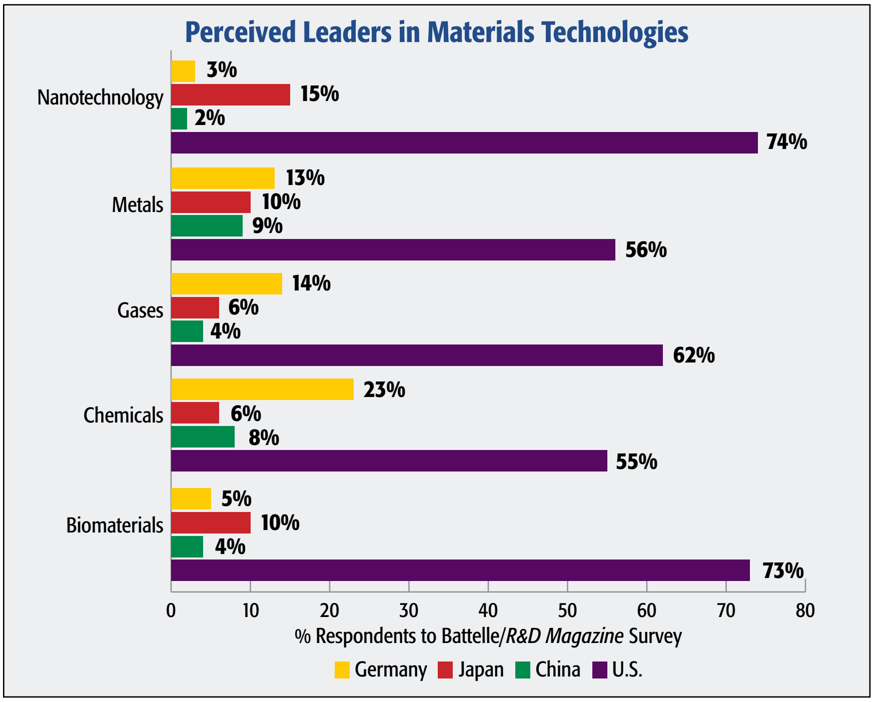
A recent report by the Organization of Economic Cooperation and Development (OECD Global Forum on Sustainable Materials Management) focused on a number of materials research areas, including critical materials, wood, aluminum and plastics. In the critical materials area, the focus was on antimony, beryllium, palladium and platinum—materials used extensively in mobile phones that are exposed to potential supply risks and subject to supply restrictions. It was found that the use and supply issue of

Chemicals & Advanced Materials	2008	2009	Q1-Q3 2010
Top U.S. R&D Spenders	Millions, U.S. $		
3M Co.	1,404.0	1,293.0	1,046.0
DuPont	1,393.0	1,378.0	1,178.0
Dow Chemical	1,310.0	1,492.0	1,217.0
PPG Industries	451.0	388.0	290.0
Lubrizol	220.9	212.1	160.3
ALCOA	246.0	169.0	124.0
Huntsman International LLC	154.0	145.0	111.0
Eastman Chemical Co.	158.0	137.0	115.0
Air Products & Chemicals Inc.	134.2	110.3	87.5
Praxair	97.0	74.0	56.0

Source: Battelle/*R&D Magazine*/Company information



Source: Battelle, *R&D Magazine,* EU R&D Scoreboard



these critical materials are closely connected to innovation and the transboundary movement of hazardous wastes.

The Nanotech Phenomena

Nowhere else is materials research so strong in 2010 and 2011 as in nanotechnology. "With nanotechnology, almost every material property can be changed and tailored, electrical, mechanical magnetic, or optical," says Ray Johnson, Lockheed Martin SVP and CTO. Nanotech started as a three-year pilot investment for Lockheed Martin and is now is entering its fifth year because of its high payoff potential.

The National Nanotechnology Initiative (NNI) continues to get bipartisan support in Congress and the Administration, with more than $1.7 billion in annual government funding across 15 government agencies from the Dept. of Energy and NASA to the Dept. of Justice. Beyond the $1.7 billion in total NNI investments in 2009, ARRA provided an additional $511 million for nanotech research and infrastructure investments from 2009 through 2011.

Research on fundamental nanoscale phenomena and processes is the largest program area of the NNI, with $484 million proposed for 2011. Combined with $342 million for nanomaterials research, this basic research component of the NNI portfolio represents just under half of the total NNI funding request. Other areas of R&D that are supported by the NNI include nanoscale devices and systems ($435 million); instrument research, metrology and standards ($91 million); nanomanufacturing ($76 million); major research facilities and instrumentation acquisition ($178 million); environment, health and safety ($74 million); and education and societal dimensions ($37 million).

The U.S. Food and Drug Administration (FDA) and the Consumer Product Safety Commission (CPSC) are joining the NNI budget crosscut for the first time in 2011. The Dept. of Justice's investment in nanotechnology furthers the Department's mission through sponsoring research that provides objective, independent, evidence-based knowledge and tools to meet the challenges of crime and justice. DOJ continues to view nanotech as an integral component of its R&D portfolio.

One of the main goals of the NNI is that government multidisciplinary research centers partner with industry and economic development organizations. "The National Science Foundation, the National Institutes of Health, and other major supporters of multidisciplinary nanotechnology-focused research centers should explicitly support, maintain, and strengthen cross-sector linkages."

A significant amount of advanced materials R&D involves the development of instrumentation that can characterize and test these materials, including nanoscale materials.

NNI Budget, 2009 to 2011 (US $ in millions)

	2009 Actual	2009 ARRA	2010 Estimated	2011 Proposed
Dept. of Energy	332.6	293.2	372.9	423.9
National Science Foundation	408.6	101.2	417.7	401.3
National Institutes of Health (HHS)	342.8	73.4	360.6	382.4
Dept. of Defense	459.0	0.0	436.4	348.5
Dept. of Commerce (NIST)	93.4	43.4	114.4	108.0
Environmental Protection Agency	11.6	0.0	17.7	20.0
NIOSH (HHS)	6.7	0.0	9.5	16.5
NASA	13.7	0.0	13.7	15.8
Food and Drug Administration (HHS)	6.5	0.0	7.3	15.0
Dept. of Homeland Security	9.1	0.0	11.7	11.7
Dept. of Agriculture	15.3	0.0	15.8	14.3
Consumer Protection (CPSC)	0.2	0.0	0.2	2.2
Dept. of Transportation	0.9	0.0	3.2	2.0
Dept. of Justice	1.2	0.0	0.0	0.0
Total	1,701.5	511.3	1,781.1	1,761.6

Source: National Nanotechnology Initiative

The Globalization of R&D

U.S. research and development is so large compared to R&D performed in the rest of the world that its individual components are mostly larger in funding and structure than the entire spending of most other countries. R&D spending by the U.S. Dept. of Defense, for example, is larger in absolute spending than all countries except China and Japan and nearly 20% larger than that of Germany. Only China, Japan and Germany have R&D infrastructures at a scale comparable to the U.S.

However, globalization of R&D is slowly altering the dominance that the U.S. has maintained for the past 40 years. The economies of China, Korea, India, Russia and Brazil, and their investments in R&D, are expanding at rates substantially higher than that of the U.S., Japan, and Germany. As a result, emerging economies are starting to challenge the technological and discovery capabilities of the historic R&D leaders.

China's R&D investments are growing at a rate that closely matches its 9% to 10% annual economic growth (and about four times that currently of the U.S. in both categories). But in absolute dollars, the growth is roughly the same as that of the U.S.—about $10 billion per year. So, the U.S. is maintaining growth parity for now. If the U.S. and China keep investing in R&D at the same rates, it will take China 20 years to reach the U.S. level. But that may be unlikely. China has many other demands on its capital, while the U.S. R&D growth is currently at unusually low levels. Moreover, wages in China and India keep rising, which will eventually reduce their cost advantages in the performance of R&D among other areas of international competition.

R&D investment in Japan and Germany, however, are not keeping pace with Asia, as they struggle to recover from last year's economic downturn.

The 2008-2009 recession also helped level the distribution of global R&D. Some emerging nations were less affected by the recession and could continue to invest in their R&D infrastructures at relatively high levels. Meanwhile, the recession seriously affected the world's advanced economies such that most reduced their R&D spending in 2009 from 2008 levels. They also are investing at more conservative levels in 2010 and 2011. Most advanced economies are still not investing in R&D at their pre-recession levels.

Globalization of R&D can be illustrated by multinational corporations, which are decentralizing their R&D organizations across advanced and emerging economies. This strategy optimizes the balance of cost and capability access (and often access to natural resources as well), and also provides synergy with commercial development of a wider range of local markets.

The growing strength of the emerging nations and their high-tech organizations has also created a reverse flow of R&D investments from the emerging nations to the advanced nations. China's Huawei Technologies, for example, has made substantial investments outside of China to become a global telecom leader. India's pharmaceutical companies also have made substantial acquisitions of European generic drug companies to gain market share of this growing industry.

European R&D Fails to Meet Goals

About five years ago, several EU countries and organizations set goals to increase their R&D spending as a share of GDP to match or exceed that of the U.S. and Japan (2.7% to 3.0%) by 2010. That was before the global recession of 2008-2009, the banking failures, and the massive support potentially required by Greece, Spain and Ireland. And even before the economic problems, R&D funding growth remained flat during 2006 and 2007. The average for R&D spending as a share of EU GDP has remained at 1.9% for five years. Surprisingly, even before the global recession took hold, there was a lack of governmental action to attempt to reach the "3% by 2010" goal. Coming into 2011, there has been no apparent interest in updating or revitalizing this goal.

Real GDP growth in the EU has been lower than in the U.S. and the gap could widen over the next decade according to analysts. In actuality, that growth is estimated to be less over the next five years than it was over the past five years, even ignoring the global recession period. The EU is set to diverge over the next decade, with the four southern European states having the slowest growth in the European area, while even the northern states are forecast to have substantially lower growth than in the U.S. over the next decade.

Part of the problem in the EU is relatively high labor costs, which according to a recent study represent more than 70% of typical R&D costs in Europe. In the U.S., labor costs represent about 45% of the R&D budget. In Asia, labor costs are less than 30% of the cost of R&D (except Japan, which is similar to the U.S.).

The southern and eastern European countries, initially attractive because of the lower labor costs and economic incentives, have seen mixed results over the past several years. Some countries, such as Poland, have seen substantial growth in their R&D infrastructures, while others, like Greece and Romania, have seen weak local demand for R&D and are less likely to grow. The smaller Slavic countries of southeastern Europe have relatively lower outputs for patents, research collaborations and scientific publications than the more established western and northern European countries. Economic and R&D growth in the southeastern European countries remains in the 1.5% to 2.5%

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range, with R&D and a share of GDP holding in the sub-1% region. Another revealing statistic is that the productivity gap between the U.S. and Europe appears to be widening. U.S. productivity, for example, rose by 2.5% in 2009, while Europe fell by 1.0%. This difference is expected to remain even during the economic recovery, according to analysts.

On the other hand, a promising area for European R&D is an active environment for collaborations with emerging economies, such as China and India.

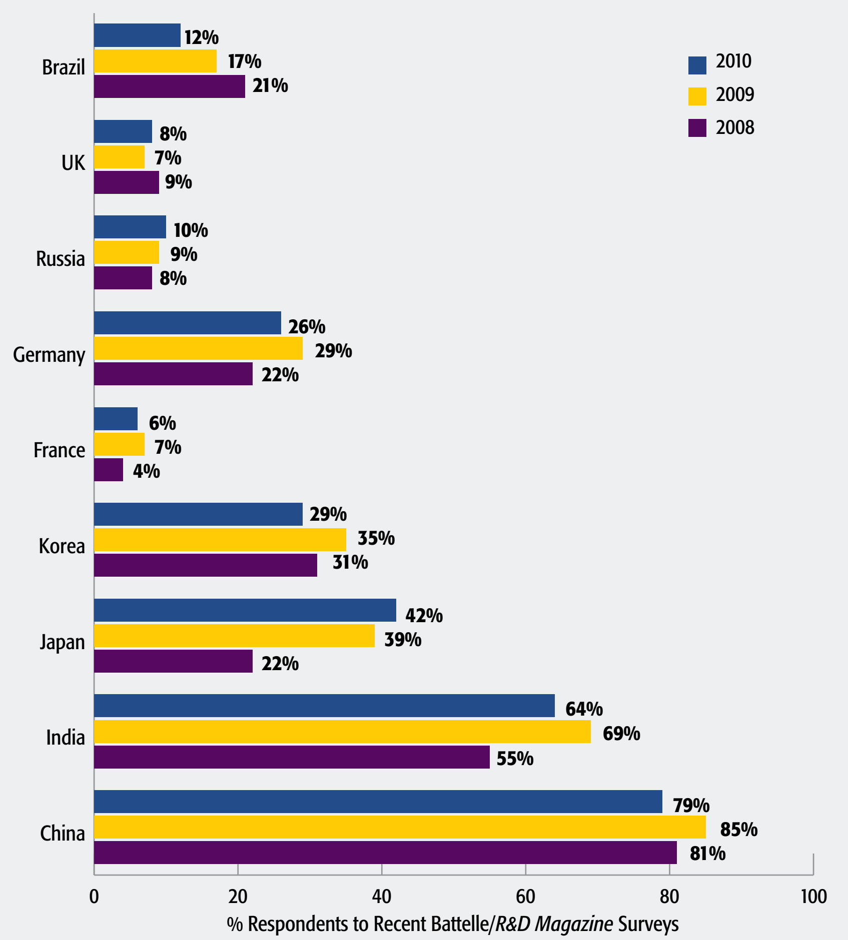
European Leader

Germany is the fourth largest R&D investor in the world, trailing the U.S., China and Japan and spending 55% more annually on R&D than South Korea. Germany contributes about a quarter of the EU-27's total Gross Domestic Expenditure on R&D (GERD) and nearly 20% of its GDP. Its projected GDP growth of 2% for 2011 is a little better than the overall EU average. Germany and the UK compete for leadership in the number of technical papers published, with Germany having a 7% advantage.

Germany has a strong research infrastructure, with stable, growing industrial leaders in the automotive, aerospace, chemical, pharmaceutical and energy industries. The top R&D-spending company in the EU is Volkswagen, with nearly $8 billion invested in R&D in 2009, according to the 2010 EC Industrial R&D Investment Scoreboard. Five of the top 10 R&D companies in the EU are German, each having substantial R&D-to-sales ratios [Volkswagen (5.7%), Siemens (5.6%), Daimler (5.3%), Robert Bosch (9.4%), and Bayer (9.5%)].

Germany also emphasizes development of clean technologies and generates a respectable 16% of its electricity supply coming from renewable sources. At 14.6 GWp, Germany has the world's largest photovoltaic energy capacity. It also accounts for Europe's largest share of installed wind capacity, at more than 25 GW. The German Federal Government expects renewable energies to account for 35% of Germany's electricity mix by 2020 and 80% by 2050.

Which Countries Will Make the Largest Tech Gains by 2015?



India's Road to Competitiveness

India's economy is projected to grow between 7% and 9% annually over the next five years, well ahead of the projections for most countries, but still behind China, which continues to grow at 10% or more. Like China, India is becoming very active in collaborating and doing business with established R&D leaders. Russia and India have had strong partnerships in the past on military hardware, whereas there have been no Russo-Chinese contracts in more than five years. Russia is also building 12 nuclear reactor power plants for India over the next 10 years [China is building more than 15 of its own with French and U.S. (Westinghouse) support in the same time period.] Russia has also provided space technology support to India over the past several years.

The November 2010 visit by President Obama to India was targeted at increasing U.S.-India technology collaborations in the areas of counter-terrorism, climate change, clean energy, civilian space and defense, addressing some areas of Russo-Indian partnership in the past.

India's record for R&D investments has not always been robust. While setting goals for the past several years to increase its R&D to GDP ratio to more than 1%, its actual performance has seen a stable ratio over the past several years at 0.9%. Of this

Continued on page 29

China's R&D Growth Engine

Huawei Technologies, a Chinese telecom founded in 1988, has grown to become the third largest manufacturer of mobile infrastructure equipment in the world and the fifth largest telecom maker overall, behind Cisco, Ericsson, Nokia Siemens and Lucent-Alcatel. Starting primarily as a domestic company, the company has expanded globally over the past decade. Huawei grew partially because of its low-cost manufacturing and government support, but it has now established R&D centers in Dallas, Bangalore, Moscow and Stockholm, and has established joint ventures along the way with other multinationals. Another secret to its success is that more than half of its 60,000 employees work in R&D, on which it spends about 10% of its annual revenues.

Huawei is just one of many Chinese companies making the transition from a domestic to a multinational business strategy. China's high-tech design and manufacturing abilities are growing in nuclear energy, commercial aircraft, satellite and spacecraft, automotive, renewable energy, supercomputers, and genetics.

China's leadership understands and emphasizes R&D. Eight of the nine members of China's Standing Committee of the Political Bureau, including China's current President Hu Jintao, have engineering degrees. Of the 15 U.S. cabinet members, only one, Secretary of Energy Steven Chu, has a technical degree—a doctorate in physics.

While over the past decade, many of the high-tech products produced in China were created by multinationals with manufacturing sites in China, the Chinese government has established an indigenous innovation policy to encourage Chinese companies to originate and own technologies (see Academic sidebar). The success of the growth of its educational system (and the size of its labor pool) is revealed by Shanghai-based outsourcing company, Bleum Inc., which uses an IQ screening test for its Chinese employees with a cutoff at 140. The same test used for hiring in the U.S. has to lower the cutoff to 125 because of the smaller labor pool.

The policy in place in China for the past decade is designed to encourage tech transfer from abroad and force foreign companies to transfer their R&D operations to China in exchange for access to China's large volume markets.

According to Edward Tse, Booz and Company's Chairman for Greater China, in his book, *The China Strategy*, "There have been signs of a more hands-on industrial policy in China [by the Chinese government]. Industries that the state deems strategic will continue to remain largely off-limits to foreign companies—and to non-state-owned Chinese companies as well."

China's growing R&D capabilities and its large domestic market are strong attractions for many companies, either independently or in partnership with Chinese companies or research institutes. Many multinational companies have already done this, including IBM, Intel, Samsung, and a number of pharmaceutical companies, including Novartis, which moved from India, and Eli Lilly which has been divesting its large Indianapolis R&D facilities for several years to Covance. Recently, Lilly closed an R&D lab in Singapore and then announced the construction of a new Shanghai lab that will focus on diabetes in China, which has a different molecular structure than diabetes elsewhere in the world and which has reached epidemic proportions in China.

Chinese R&D Distribution

	Industrial Firms	Research Institutes	Academia
R&D expenditures	63%	26%	11%
Basic research	9%	53%	38%
Applied research	26%	45%	29%
Technology development	77%	19%	4%
Patent applications	64%	14%	22%
Government funding	62%	20%	18%

Source: OECD

Part of the foreign direct investment going into China is for building R&D and manufacturing facilities. That investment was $90 billion in 2009 and was up about 10% for the first half of 2010 over 2009.

Long-Term Commitment to Growth

11.6 million Chinese students took university entrance exams from 1977 to 1978, setting a historical record. By 2006, Chinese university enrollments had surged to 5.5 million, five times that of 1998, and enrollments continue to grow. Universities have become more accessible to many Chinese people. In 2007, it was estimated that more than 55% of candidates were successful in their university enrollments. In Beijing and Shanghai, the rate is more than 80%.

In the 1970s, China began to send students overseas to study advanced technologies and communications, with the rest of the world. It began with just 860 Chinese nationals in 1978, and by 2006 that figure had grown to more than 130,000, six times that of 1999, the dawn of China's second expansion. Besides those sponsored by the government or companies, more Chinese nationals have managed to study abroad via scholarships from overseas universities. This is not an easy task, since most are

China's C9 League

In 1998, Chinese president Jiang Zemin stated a need for China to improve its universities to a position considered to be top-class at the international level. To this end, Project 985 was created. Named after the day it was announced—1998 in the fifth month—the project originally included just nine universities that received funding for the next three years. By the end of the first phase, 34 universities were sponsored and five more were added by the end of the second phase. In 2007, the administrators announced that no additional universities would be added, leaving the total number at 39.

The C9 League comprises the original top nine universities of 985 and is roughly equivalent to the U.S. Ivy League (See table for participants). Peking and Tsinghua universities are the top-ranked universities in China. Shanghai Jiao Tong Univ. is known for its engineering program, while the Harbin Institute has close ties to China's space program and military industry.

China's C9 League

	Founded	Students *	Province
Fudan University	1905	26,700	Shanghai
Harbin Institute of Technology	1920	37,700	Heilongjiang
Nanjing University	1902	22,100	Jiangsu
Peking University	1898	30,100	Beijing
Shanghai Jiao Tong University	1896	33,000	Shanghai
Tsinghua University	1911	26,700	Beijing
University of Science and Technology	1958	16,600	Anhui
Xi'an Jiao Tong University	1896	32,000	Shaanxi
Zhejiang University	1897	39,000	Zhejiang
* – Undergraduates + postgraduates			

Source: *R&D Magazine*

The most important principle of C9 is interconnectedness. There are eight main areas listed in the founding agreement that support strengths and share resources, including undergraduate credit recognition, exchange programs and collaboration in postgraduate education. Another vital principle of mutual support is the establishment of an annual conference of graduate schools to serve as a forum for higher education development.

Despite a global recession, Project 985 and C9 have succeeded with help from large endowments in the name of scientific research. In 2007, 985 universities each received about $92 million, with several as much as $132 million. A measure of China's success in scientific research comes in the number of scientific papers published. Before 985 was announced, the top 34 universities published a combined 2,000 scientific research papers, whereas in 2007, the top four C9 universities each published 2,300 papers.

required to take graduate entrance exams.

For much of the past 30 years, China has focused on building its physical infrastructure. Factories needed to be modern, the roads world-class, the ports vast, and the airports efficient. All of these were built on a scale and speed never seen before. Now China is targeting higher quality goods and services, and its government recognizes the need to invest in human capital with the same determination used to build roads. Since 1998, Beijing has tripled the amount of GDP devoted to its expansion of education. In that period, the number of colleges has doubled and the number of students quintupled, from 1 million in 1997 to 5.5 million in 2007. China has identified its top nine universities and singled them out as its version of the U.S. Ivy League. At a time when universities in Europe and state universities in the U.S. are suffering the impact of budget cuts, China is now moving in the opposite direction.

What does this unprecedented investment in education mean for China? Nobel Prize-winning economist Robert Fogel of the Univ. of Chicago estimates that in the U.S., a high school-educated worker is 1.8 times as productive and a college graduate 3 times as productive as someone with a ninth-grade education. China is massively expanding its supply of high school and college graduates. And although China lags behind India in the services sector, as its students learn English and train in technology, Chinese firms will enter this vast market as well. Fogel believes that the increase in high-skilled workers will substantially boost China's annual growth rate for a generation, taking its GDP to more than $120 trillion by 2040.

In China, all top-ranked academies, including universities, are owned by the government. Universities educate five million students, among them about one million research students. Universities are an important driving force for technology innovation in China since they serve a major role in fundamental research by being actively engaged in application research due to the close university-industry linkage and technology transfer. In the past five years, half of the national awards for scientific research have been received by universities; 70% of the papers indexed by SCI/EI/ISTP are from universities. A recent Thomson Reuters study found that China's academia contributes a significantly higher proportion of patent applications to the national total compared to many other countries—16% compared to 1% in Japan, 4% in the U.S., and 2% in Korea. The same study found that the only other country with a high contribution is Russia. Both China and Russia are ruled by centralized governments, where R&D project selection and funding are predominantley determined and controlled by the government. Furthermore, the government also plays a significant and direct role in Chinese enterprises. In 2007, the government investment in about 150 of China's centrally administered state-owned enterprises was more than $14 billion—27% of the national total.

China's research universities are not only the center for education, but also the center of scientific and technological R&D. An important character of China's research universities is their industrial cooperation. About half of the research funds obtained by the universities are from industry. Many of these R&D results are directly transferred to industries

Many industrial companies have joint labs with universities. Tsinghua Univ. has 63 joint industrial labs, including 20 from foreign companies. A large amount of university research funds from industry is for tech transfer. University spin-offs are also becoming active parts of China's high-tech industry, and university science parks are important high-tech industrial incubators. International cooperation of research universities with multinational companies is also a fast growing sector.

Most basic research is performed within academia, both in the U.S. and in China. In 2009, basic and applied research, according to the National Bureau of Statistics of China, constituted 4.7% and 12.6% of total R&D expenditures in China, dropping from 2000 levels of 5.2% and 17% respectively. The Chinese government has pledged to beef up these ratios, setting a basic research spending ratio of 15% of total R&D expenditures by 2020. According to the report basic research should be about 10% of GDP in 2010.

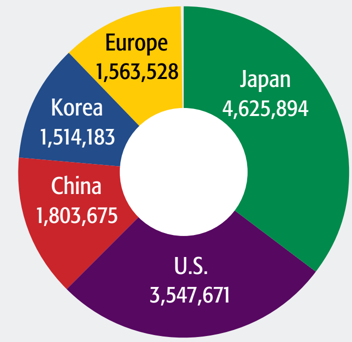
spending, 0.61% is attributable to government R&D investments, which have been increasing over the past several years. Industrial investments in Indian R&D have risen 10% over the same period. The current total target for R&D as a share of GDP is 1.2% by 2012.

Also, India graduates almost twice as many college graduates each year as China. But only 2% to 5% of those graduates have basic vocational skills, compared with 96% in Korea, 75% in Germany and 68% in the U.S., according to Indian government reports. Similarly, only about 25% of the engineers graduated in India have the language skills, practical knowledge and cultural attitudes to work for multinational companies.

India has also acquired a significant amount of technology knowledge through its industrial acquisitions. Before Tata Steel's acquisition of Corus, Europe's second largest steel producer, the Indian steelmaker did not hold any U.S. patents. The Corus takeover brought with it more than 80 patents and 1,000 researchers, thus giving Tata immediate access to the technological capacity of the acquired firms.

India's 11th Five-Year Plan for 2007-2012 stipulates a 220% increase for science and technology investments over the 10th Five-Year Plan. Part of this plan has resulted in the establishment of 30 new central universities, which will be owned and managed by the central government.

Total Patent Volume, 2003 to 2009



Source: Thomson Reuters

Sixteen of these universities will be located in the 16 states that did not have a central university before. The other 14 will become world-class universities established across the country, starting in 2010, to build "disciplinary foci" and drive R&D. Each of these world-class universities will focus on one specific issue of significance to India, such as urbanization, environmental sustainability and public health.

Two private companies have also indicated they will build world-class universities of their own, with one company donating $1 billion to start the program.

Key Indicators on World Researchers

	Researchers (thousands)		World Share Researchers (%)	
	2002	2007	2002	2007
World	5,811	7,209	100.0%	100.0%
Developed countries	4,048	4,478	69.7%	62.1%
Developing countries	1,734	2,697	29.8%	37.4%
Americas	1,628	1,832	28.0%	25.4%
Asia	2,065	2,951	35.5%	40.9%
Europe	1,871	2,124	32.2%	29.5%
U.S.	1,342	1,426	23.1%	20.0%
China	810	1,423	13.9%	19.7%

Source: UNESCO Science Report 2010

The Indian government has also committed to doubling the number of Indian Institutes of Technology to 16 and establishing 10 new National Institutes of Technology, three Indian Institutes of Science Education and Research, and 20 Indian Institutes of Information Technology.

India has also adopted a policy permitting foreign universities to enter the higher education system in India by establishing their own campuses or joint ventures with existing universities.

India's technology strength is dominated by its services sector; 60% of its "knowledge-intensive production" comes from this area, according to the Indian Central Statistics Organization.

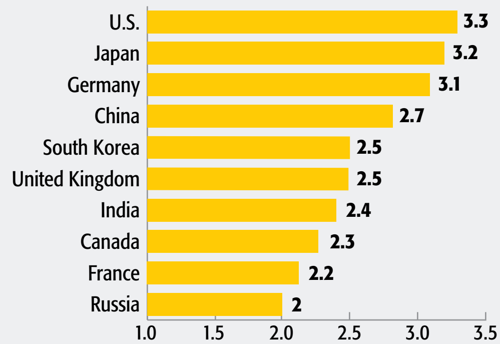
India's exports are dominated by low-tech products; less than 20% of the value of its exports are classified as high-tech. However, India is still the world's largest exporter of information technology products. India also has a strong pharmaceutical sector, with more than $20 billion in annual revenues, ranking it third behind only the U.S. and Japan, with a 10% share of the world market.

There are more than 5,000 pharmaceutical firms in India, employing about 340,000 people. The pharmaceutical industry is also one of the most innovative industries in India in terms of R&D spending and the number of patents granted in both India and abroad.

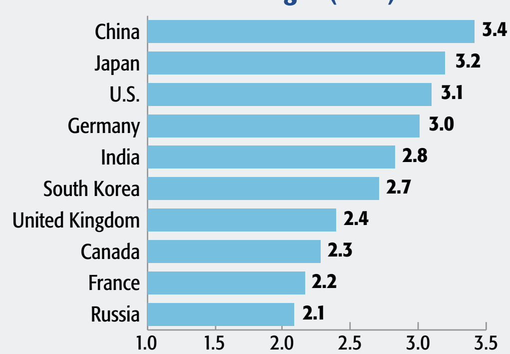
India accounts for about 25% of the world's generic drug production and has 25% of the drug master files with the U.S. Food and Drug Administration. India also has the highest number of FDA-approved production facilities of any country in the world.

India's strength and weakness is its population. At 1.1 billion and with few population controls, it's expected to surpass China within 10 years. Its literacy rate of 61% also compares unfavorably with many of its potential outsourcing competitors (China 97%, Singapore 92%, Taiwan 96%, U.S. 99%). There are more illiterate people in India than there are people in the U.S.

Perceived Country by Country Technical Strength (2010)



Perceived Country by Country Technical Strength (2015)



Ratings (1 = Weak to 5 = Strong) by Respondents to Battelle/*R&D Magazine* Survey

Korean Growth and Challenges

South Korea ranks fourth in R&D investments among OECD nations and fifth overall in the world. About 75% of Korea's R&D investment comes from industry, higher than in China (72%), the U.S. (71%), and Germany (70%). The Korean government's R&D spending has grown 10.5% annually since 2002, outpacing the overall national budget growth rate of 6.5%. At 3.0%, Korea also has the fifth highest R&D to GDP ratio of all countries (behind Israel, Japan, Sweden and Finland). The number of research papers submitted by Korean scientists also is the fourth largest in the world.

In its current S&T Framework, the Korean government has established goals for increasing its R&D as percent of GDP, from its current 3.2% to 5% by 2012. It also expects to nearly double the government's investment in R&D, from $35 billion in 2007 to $66 billion in 2012. Another goal is to increase the number of researchers per 10,000 citizens, from 53 in 2007 to 100 by 2012.

From 2003 to 2009, more than 40 laws relating to S&T innovation were enacted by the Korean government. There is a limit, however, that is being reached, according to an official from the Ministry of Knowledge Economy. "The number of the world's best selling products from Korea is decreasing and despite more investment in R&D, the performance is not resulting in the creation of new industries and markets," he said. The number of product categories in which Korea is a global leader dropped from 87 in 2000 to 53 in 2008, while China increased from 698 to 1,128 products over the same time period.

Japan's Declining Dominance

Until this year, Japan was the world's second largest economy and the world's second largest R&D spender, behind the U.S. In both categories, it is now the third largest, yielding to China's continuing ascendancy. While other Asian countries are generally referred to as emerging countries, Japan has been grouped with Europe and the U.S. as an established advanced economy and technological power. Toyota Motors is the world's largest industrial R&D investor at more than $11 billion/year and the world's largest automotive manufacturer by revenue and by number of cars manufactured. Japan also has the second highest R&D to GDP ratio at 3.4, just behind #1 Israel.

The Japanese economy stagnated throughout the 1990's and 2000's. Growth in 2011 is forecast by the IMF at a very moderate 1.5%, joined by a moderate $2 billion increase in R&D spending. Economic growth—and R&D spending—has mirrored that of the U.S. and Germany over the past three years and is going through a slow recovery.

Many Japanese universities are experiencing financial problems due to their semi-privatization in 2004, the recent recession, and reduced government funding. Many relied on government funding for up to half their operating expenses. Smaller institutions have not succeeded in closing the gap with donations and R&D grants, although the big institutions have prospered. With the 18-year old population declining along with these decreased funding sources, it's expected that many private universities will be forced to close or merge with others.

Japan's future growth as a technological power is also hindered by an aging population. It has the highest population percentage in the world of people over 65, with more than 25% now and 30% by 2020. Japan also remains challenged by its slow economy and steadily increasing wage rate. Many products are now being outsourced to other Asian countries for manufacture to remain competitive, thus lowering the manufacturing content of the economy.

The Russian Solution

Following its transition to a market economy and transformation of its political system near the turn of the century, Russia experienced strong economic growth. When the global recession hit, Russia developed a national recovery package to cushion the recession's social cost, maintain a strong financial system, and support key industrial sectors. This $88 billion bailout represented about 9% of Russia's 2009 GDP.

This, combined with other pressing health issues, an aging population, and energy and food security, have strained the government's ability to continue to provide its traditional 65% share of the GERD for Russia. Industry funding has fallen from a 30% to 29% share over the past five years and is not expected to replace any loss of government R&D support.

Academia continues to be supported by the government, with nearly 60% of Russia's 1,134 universities being government operated. Seven new large federal universities are now planned to become key educational centers for macro-regions across Russia. However, academia contributes less than 7% to the national GERD, about half the level of that in the U.S.

Another problem affecting Russian R&D is that a large portion of the equipment used by researchers is old; 25% is more than 10 years old and more than 12% is more than 20 years old, according to HSE Research. Many aging Russian Academy of Sciences research facilities were also scheduled to be updated by 2008, but by 2010 the program still had not been completed. Moreover, the average age of Russia's researchers is 49 years, with 40% over 55 years old. The number of researchers 70 years old has also doubled in the past six years, while the number under 30 has risen 18%.

On the industrial side, President Dmitry Medvedev created the Skolkovo government-sponsored science park in Kiev to emulate the Silicon Valley, California, model and attract high-technology firms to diversify Russia's economy based on oil and gas reserves. Nokia and Microsoft have both recently indicated their interest in building research centers in Skolkovo. Established in 2010, the Skolkovo administrators are using tax cuts and other perks to attract foreign firms, while indicating that the park's rules are designed to reduce paperwork—113 laws have been passed to support the innovation economy—and prevent the creation of administrative corruption.

Latin Leader

Brazil is the largest and most populous country in Latin America, with about 190 million people. It also has the largest economy that grew 27% from 2002 to 2008. However, its GERD has progressed more slowly, growing just 10% in that same period to just under 1% as a share of overall GDP. Restrictions to R&D growth in Brazil include problems accessing capital due to high interest rates, poor logistics that hamper exports and an inadequate education system that penalizes social development and the availability of skilled researchers, especially in engineering disciplines. The rate of doctorates to inhabitants in Brazil is about 15% lower than in Germany and only a third of that in South Korea.

In terms of undergraduates only 16% of those 18 to 24 years are enrolled in universities, a third the rate of those enrolled at the low end of OECD countries. Despite these low academic statistics, Brazil's share of the world's scientific publications has grown from 0.8% in 1992 to 2.7% in 2008, thanks to a growing number of PhDs granted in Brazil. Most go to work in academic settings, and few go into industrial research firms. Also, 60% of the articles generated originate from just seven universities, of which four are in the State of Sao Paulo, indicating a lack of homogeneity in the regional distribution of academic staff.

Federal funds supply about 38% of Brazil's GERD, with industry supplying 45% and state funding 17%. A number of R&D-based foreign direct investments aimed at supporting local marketing efforts continue to drive R&D growth in Brazil. General Electric, for example, recently announced it fifth R&D center in Brazil, citing geographical advantages, tax breaks and the opportunity to receive government contracts to help grow the economy. The latest GE R&D center is expected to cost $150 million and house 300 engineers, making it the second largest R&D center outside of the U.S. Brazil also supports a growing life science sector, with more than 250 companies focusing on health (31%), agriculture (18%), reagents (16%), animal health (14%) and the environment and bioenergy (12%).

Given Brazil's geography, moderate climate and agriculture potential, a number of external organizations, including BP, are targeting their biofuel production and research plans on sugar cane in Brazil and energy grasses in the U.S., delaying other global biofuel investments for now. BP is examining a mega-million dollar investment in Brazil's Carradinho ethanol group and other firms.

Global Researcher Survey

With our annual assessment of the overall U.S. and global R&D enterprise, annual federal budget review, and detailed industry forecasts, we decided to illuminate this year's global R&D funding forecast through a discussion with the global research community. This represents an R&D constituency beyond our traditional reach through our surveys to the *R&D Magazine* readership and the internal Battelle community.

For this survey effort, we focused on researchers engaged in recent collaborative projects. To keep the survey manageable and better reflect the readership of *R&D Magazine,* we primarily focused on researchers from the private sector but also included researchers from national laboratories and research institutes from across the globe. The survey was not about their organization's specific plans, but was aimed to develop a picture of what issues and challenges respondents face as researchers, regardless of discipline, organization or country.

As with any new endeavor, there were some challenges in its implementation, but for a completely "cold" Internet survey, we ended up with a fairly respectable 3.3% response rate or 378 respondents. The respondents range from CEOs to laboratory analysts, and are located in 38 different countries. Of course, given the nature of the survey, slightly more than half (53%) came from the U.S. The results, however, include respondents from the UK, Japan, India, Russia and China.

The respondents are involved in R&D activities across a range of technologies and from a wide variety of organizations. The largest share of the respondents, 38%, comes from the broadly defined life sciences technology domain. The second largest share comes from the energy generation and technology domain, accounting for 12% of the global respondents. The third largest share, from a broadly defined advanced materials (including chemicals) domain, represents 10% of the respondents. The remaining 40% come from a number of segments spanning electronics, IT, transportation, agriculture/food production and environmental technologies. Within the respondents are researchers from many of the global firms mentioned elsewhere in this forecast.

The group as a whole has a fairly optimistic view of research in the future, with only 20% expecting decreases in their industrial R&D funds in 2011 and just 23% expecting decreases in their government R&D funding.

We asked the researchers about their most critical R&D challenges as researchers, not their specific scientific and technical challenges. The results provide some unique insights into the global research community. While it may not be surprising, there is significant unanimity among the research community both here and abroad in the issues they face; however, no single issue is an overarching concern in the entire global research community.

Overall issues of importance are very similar, but there are some interesting differences worth mentioning. The most critical challenge across the board was dealing with budget limitations, but U.S. researchers expressed this issue as being a critical challenge at a higher rate than their non-U.S. counterparts. A similar result also is found in the overall availability of development time. The ongoing concern in the U.S. regarding the outsourcing of R&D activities also is reflected in the findings, with a larger share of U.S. researchers concerned about the challenges involving outsourcing. Interestingly, a slightly higher share of non-U.S. researchers felt that both intellectual property issues and skilled worker shortages are going to be critical challenges for them in 2011. Finally, though a much lower concern overall, U.S. researchers reported legal issues will be a critical challenge for them in 2011 at twice the rate of non-U.S. researchers.

We also asked our respondents whether certain global issues or concerns had any direct bearing on their future R&D efforts.

Most Critical R&D Challenges in 2011

Area	U.S. Researchers	Non-U.S. Researchers	All Researchers
Limited Budget	41%	33%	37%
Development Time	37%	30%	34%
Competition	35%	31%	33%
Collaboration	31%	33%	32%
Cost-Savings Requirements	30%	28%	29%
Intellectual Property	22%	24%	22%
Skilled Worker Shortages	16%	19%	17%
Technology Solutions	17%	18%	17%
Globalization	15%	14%	15%
Outsourcing	17%	10%	13%
Product Prioritization	13%	15%	13%
Product Qualification	9%	11%	10%
Legal Issues	12%	6%	9%
Cost of Instrumentation	6%	9%	7%
Product Safety	6%	8%	7%
Energy Use	6%	6%	6%
Inflation Costs	2%	5%	3%

Source: Battelle

Key Global Issues of Importance Impacting Future R&D Efforts
U.S.
Healthcare for the Aging
Demand for Renewable/Sustainable Energy
Global Population Growth
Growth in Consumerism in Emerging Markets
Threat of Global Pandemics
Non-U.S.
Demand for Renewable/Sustainable Energy
Global Population Growth
Climate Change/Global Warming
Healthcare for the Aging
Environmental Clean-up/Remediation

Source: Battelle

In this area there were marked differences between U.S. and non-U.S. researchers. Three areas, Healthcare for the Aging, Demand for Renewable/Sustainable Energy and Global Population Growth, made the top five for both respondent groups.

U.S. researchers, perhaps reflecting both a market orientation and a significant biomedical representation in the respondent set, elevated both Growth in Consumerism in Emerging Markets and the Threat of Global Pandemics into their top five. Non-U.S. respondents, perhaps reflecting a larger environmental industry presence among them, included Climate Change/Global Warming and Environmental Clean-up and Remediation among their top five.

Finally, we asked the global researcher community to provide its insights into what countries were doing leading edge R&D work (across all performers) by asking them to select their top three leading countries in each of nine technology areas. The overall top five is fairly consistent regardless of whether the respondents were U.S. or non-U.S. researchers. One unique point worth noting is that non-U.S. researchers often included as their "third" best country, examples that often were not mentioned by U.S. researchers.

Global Researcher Views of Leading Countries in R&D by Technology Area

Agriculture & Food Production	Healthcare, Medical, Life Science & Biotech	Composite, Nanotech, & Other Adv. Materials	Energy Generation & Efficiency	Military, Defense & Security	Instruments, Electronics & Computer Hardware	Software & Information Management	Automotive & Other Motor Vehicle	Aerospace, Rail, & Other Non-Auto Transport
USA	USA	USA	USA	USA	USA	USA	Japan	USA
China	UK	Japan	Germany	Russia	Japan	India	USA	Japan
India	Germany	Germany	Japan	China	China	China	Germany	China
Brazil	Japan	China	China	Israel	South Korea	Japan	China	Germany
Japan	China	UK	UK	UK	Germany	Germany	South Korea	France

Source: Battelle

2011 Global R&D Forecast – **An Overview**

Global Spending

Following cuts in total R&D spending by most advanced economies during the global recession in 2008 to 2009, R&D spending growth resumed, albeit at reduced levels, in 2010 and is again forecast for 2011. Rapid growth in R&D spending in emerging Asian nations only slowed slightly during the recession and is forecast to continue growth that is several times that of the advanced economies.

Western Economic Struggles

While American, European and Asian nations all created economic stimulus programs during the recession to support their economies, the American and European countries continued to struggle with weak economies and high unemployment, along with the implications of having to pay for the economic stimulus programs in the future. Low interest rates, enhanced regulatory rules and other incentives have been mostly unsuccessful in returning confidence in the Western nations' economies and enticing corporations to make strong R&D investments. Europe is experiencing particular difficulties as it works to support failed economies in Greece and Ireland.

Continued Globalization

The globalization of R&D continues, as industrial organizations from around the world decentralize their R&D organizations and build new R&D facilities in offshore locations. These changes are mostly being done at the expense of the home organization's R&D infrastructure. In a small way, a few strong organizations in China and India are also starting to globalize their R&D activities to build their global marketing and sales support presence.

Narrowing Scientific Gap

While the corporate R&D structure is becoming more level on a global basis, so is the scientific output. The growth rates of patent applications and scientific publications in emerging economies are several times that of advanced economies. In some cases, the scientific output from emerging nations in specific technologies actually exceeds that of similar output from advanced economies.

Chinese R&D Position Grows

China continues to dominate R&D investment growth over all other countries, including many of those in Asia. Its double digit growth in R&D investments tracks its economic growth. Few expect this high rate of growth to slow in the near future, and some suggest that it actually may accelerate.

Accelerating Academia

U.S. and European academia have been the foundation for basic research advances for decades, with this area continuing to experience the strongest growth in these regions in 2010 and again in 2011. This trend also has been observed in the emerging and transitional economies, which are investing large amounts in new academic facilities and programs. These investments have gone so far as to even encourage offshore academic institutions to form alliances with the new schools.

R&D Collaborations

One of the primary tools emerging economies are using to build their S&T infrastructure and knowledge base is to form collaborations with other global leaders in specific technologies. In most cases, this has worked well, with both sides gaining expertise. But in some situations the collaborator from the advanced nation has found itself competing with the organization from the emerging nation a very short time later after the latter has gained sufficient expertise.

Challenges in U.S. R&D

The federal government's role in R&D funding is going through changes due to current and long-term budget restraints and a change in Congressional leadership from the November 2010 elections. The ultimate outcome of these changes remains speculative for 2011, but it could trigger R&D spending reductions in Dept. of Defense budgets and flat budgets in many other agencies.

Industrial R&D

In life science R&D, most indicators are positive for both U.S. and global growth over the next several years. Government and industrial R&D investments in these areas will continue to grow to maintain strong competitive positions. In IT, the continuing technological advances in this industry will drive strong double-digit R&D growth, as companies and countries work to keep pace with the technologies. In electronics, countries are working to keep costs under control, as former outsourcing sites now find themselves outsourcing manufacturing and R&D to lower costs.

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Resources

The following Web sites are good sources of information related to the global R&D enterprise. Much of the information in this report was derived from these sources, which are certainly not all-inclusive.

American Association for the Advancement of Science
www.aaas.org

American Energy Innovation Council
www.americanenergyinnovation.org/

Battelle Memorial Institute
www.battelle.org

Booz & Co.
Global Innovation 1000
www.booz.com

China Ministry of Science and Technology
www.most.gov.cn

Chinese Academy of Sciences
english.cas.cn

Economist Intelligence Unit
www.eiu.com

European Commission Research
ec.europa.eu/research/index_en.cfm

European Industrial Research Management Association (EIRMA)
www.eirma.org

European Union Community R&D Information Service (CORDIS)
cordis.europa.eu/en/home.html

International Monetary Fund
www.imf.org

Japan Science and Technology Agency
www.jst.go.jp/EN

Organization for Economic Cooperation & Development (OECD)
www.oecd.org

R&D Magazine,
Advantage Business Media
www.rdmag.com

Schonfeld & Associates
www.saibooks.com

Thomson Reuters
www.thomsonreuters.com

The World Bank
www.worldbank.org

United Nations Conference on Trade and Development
www.unctad.org/diae

United Nations Educational, Scientific and Cultural Organization (UNESCO)
www.unesco.org

U.S. National Science Foundation
www.nsf.gov

U.S. Securities & Exchange Commission (EDGAR database)
www.sec.gov/edgar.shtml

White House Office of Science & Technology Policy
www.ostp.gov

World Economic Forum
www.weforum.org

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