Advantage Business Media
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2012 GLOBAL
R&D FUNDING FORECAST

- U.S. Industry R&D Increases 3.8% to $280 Billion
- Growing Worldwide Emphasis on Basic Research
- Global R&D Spending to Increase 5.2% to $1.4 Trillion
- Increasing Importance of R&D ROI and Collaboration

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2012 Global R&D Funding Forecast:
CEO Message

Battelle and *R&D Magazine* are pleased to introduce our latest forecast of global R&D funding and related trends, including the results of our annual survey of researchers. Despite persistent challenges in the global economy, we are encouraged by the Forecast's conclusion that commitments to innovation will continue to grow in 2012.

We produce the Forecast as a public service that is intended to provide a forward-looking, global perspective on research and development.

These insights are also vital to Battelle. As the world's largest independent R&D organization, Battelle has been dedicated to advancing science and technology to benefit humankind for over 80 years, and we bring together world-class human and research assets to develop and commercialize technology and products for our clients in the Americas, Europe, the Middle East, and Asia.

Each year, the global researcher survey reveals or confirms interesting trends. Among them in 2012 is the increasing importance of R&D collaboration at all scales. From new mechanisms for open innovation in life science, to multi-national collaborations like the ITER fusion energy experiment, it is clear that collaboration has become a preferred strategy for major science and technology projects.

Globalization trends remain strong, with investment, research capabilities, and commercialization migrating to optimal locations, and new countries entering the mix of those committed to R&D as a national strategy. China's profile as the second-largest sponsor of global R&D continues to increase, whether measured in terms of funding or generation of intellectual capital.

Even so, with over $400 billion in annual R&D funding from both public and private sectors, the United States continues its historic and world-leading commitment to innovation as an essential catalyst for prosperity and growth.

Finally, each year I address the importance of STEM (science, technology, engineering, and math) at all levels of education. Among our charitable purposes, Battelle is deeply committed to STEM education as the foundation for a healthy, productive, innovation-based society. In this Forecast is a powerful statistic: between 2003 and 2007, educational output of scientists and engineers increased Asia's share of the global researcher pool from 16% to 31%. It is no coincidence that this corresponds to a period of rapid innovation and economic growth in that region, offering strong evidence that STEM education is a critical enabler of research and innovation.

We welcome your comments and suggestions to help improve next year's Forecast.

Jeff Wadsworth

Jeffrey Wadsworth
President and CEO
Battelle

R&D Spending Growth Continues While Globalization Accelerates

Global R&D spending will increase in 2012 with continued strong growth in emerging economies and stable growth in established economies.

Global R&D spending is expected to grow by about 5.2% to more than $1.4 trillion in 2012, according to an analysis performed by Battelle and *R&D Magazine*. This advance is slightly less than the 6.5% growth seen in 2011 following the end of the global recession and accompanying R&D stimulus incentives. Most of the global funding growth is being driven by Asian economies, which are expected to increase nearly 9% in 2012, while European R&D will grow by about 3.5% and North American R&D by 2.8%. U.S. R&D is forecast to grow 2.1% in 2012 to $436 billion.

The U.S., European Union (EU), and Asia continue to be the strongest regions for R&D, with a combined total of nearly 92% of all global spending. R&D growth in emerging economies has lowered the U.S. share of global funding to about 31%, although the U.S. remains dominant in absolute terms, and annual increases in U.S. R&D still exceed the total budgets of most countries.

U.S. Economic Concerns

Federal government spending on R&D in 2012 is forecast to decline by about 1.6% to $125.7 billion, while U.S. industrial spending is forecast to increase by 3.8% to $279.7 billion, and academic spending is projected to increase 2.85% to $12.3 billion. Significant government budget reductions are responsible for the drop in federal R&D spending, although R&D is likely to decline proportionally less than the overall federal budget. R&D sponsored by the U.S. Department of Defense (DOD) will see one of the biggest declines (down $2.5 billion to $75 billion forecast for 2012) for the third consecutive year.

The weak U.S. government R&D spending outlook will be partially offset by one of the strongest increases in industrial R&D spending over the past 10 years. This continues a trend of complementary shifts that has helped sustain growth in total U.S. R&D spending. For example, in 2003 and 2004, flat industrial R&D investment was offset by record federal R&D spending, while in 2005 and 2006 industry spending increased and federal government spending decreased.

Part of the 2012 industrial R&D investment can also be attributed to steadily increasing investments by U.S. companies in their offshore research facilities. The overall percentage of such R&D investments is still reasonably small, but many companies are leveraging the economic and collaborative benefits of globalization.

As evidence of the value of scientific discovery as a platform for innovation, the U.S. is targeting about 18% of all R&D at basic research programs, performed mainly in academic and industrial research laboratories. Sponsorship comes mostly from the public sector, with objectives for national scientific leadership and economic competitiveness. Efforts to double the budgets for the National Science Foundation (NSF), the U.S. Department of Energy's (DOE's) Office of Science, and the National Institute of Standards and Technology (NIST) still have supporters in Congress despite efforts to reduce overall government spending.

Share of Total Global R&D Spending

	2010	2011	2012
Americas	37.8%	36.9%	36.0%
U.S.	32.8%	32.0%	31.1%
Asia	34.3%	35.5%	36.7%
Japan	11.8%	11.4%	11.2%
China	12.0%	13.1%	14.2%
India	2.6%	2.8%	2.9%
Europe	24.8%	24.5%	24.1%
Rest of World	3.0%	3.1%	3.2%

Source: Battelle, *R&D Magazine*

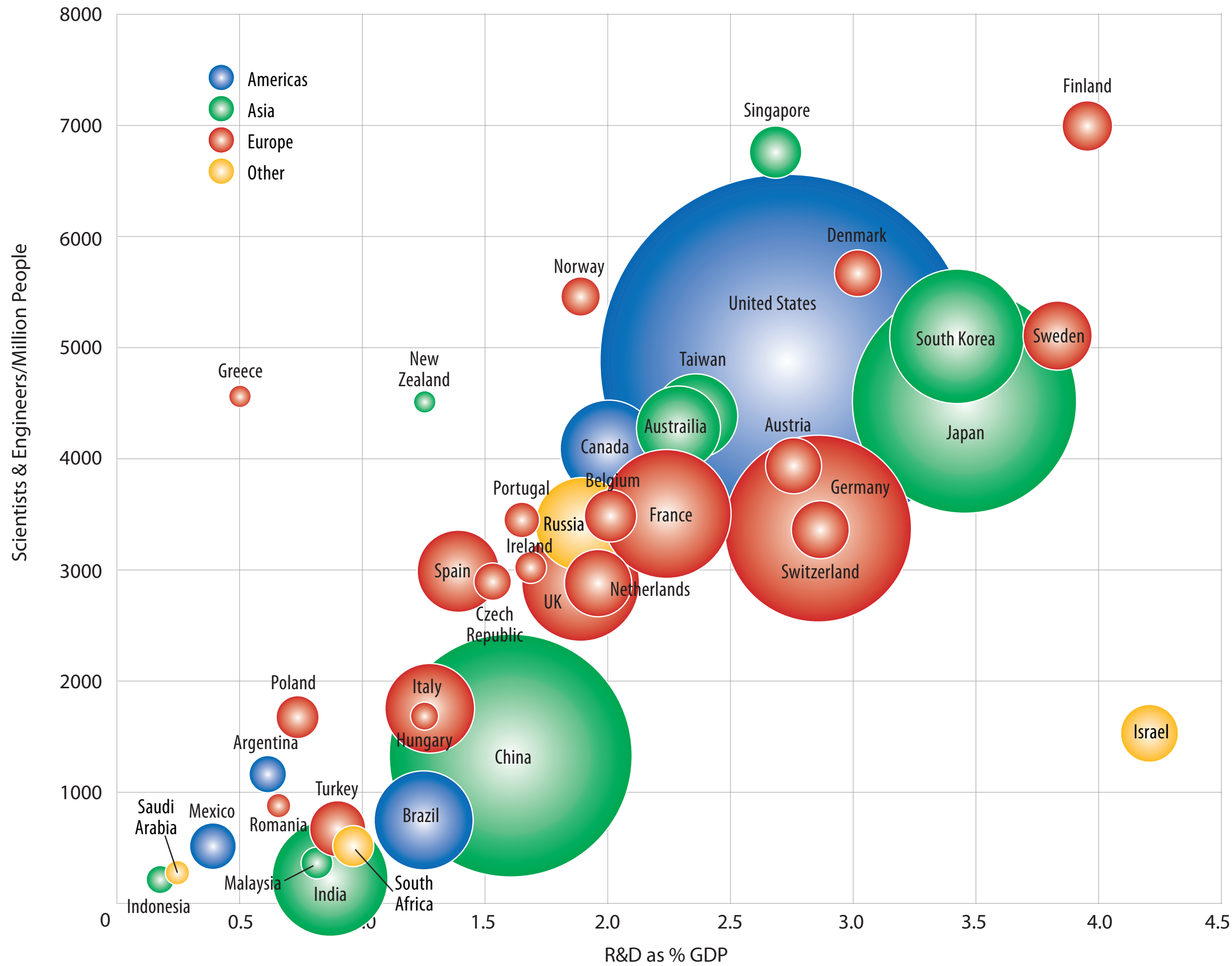
Global R&D Spending Forecast

	2010 GERD PPP Billions U.S. $	2010 R&D as % of GDP	2011 GERD PPP Billions U.S. $	2011 R&D as % of GDP	2012 GERD PPP Billions U.S. $	2012 R&D as % of GDP
Americas	473.7	2.3%	491.8	2.3%	505.6	2.3%
U.S.	415.1	2.8%	427.2	2.8%	436.0	2.8%
Asia	429.9	1.8%	473.5	1.9%	514.4	1.9%
Japan	148.3	3.4%	152.1	3.5%	157.6	3.5%
China	149.3	1.5%	174.9	1.6%	198.9	1.6%
India	32.5	0.8%	38.0	0.8%	41.3	0.8%
Europe	310.5	1.9%	326.7	1.9%	338.1	2.0%
Rest of World	37.8	1.0%	41.4	1.1%	44.5	1.1%
Total	1,251.9	2.0%	1,333.4	2.0%	1,402.6	2.0%
GERD, Gross Expenditures on R&D, PPP, Purchasing Power Parity						

Source: Battelle, *R&D Magazine*

World of R&D 2011

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



Source: Battelle, *R&D Magazine*, International Monetary Fund, World Bank, CIA World Factbook, OECD

Commercial outcomes are equally important, and U.S. industries have increased expectations for return on their R&D investment. Though only 10% of the companies surveyed several years ago calculated ROI on their R&D, more than 40% do it now, with most using improvements in product quality, competitiveness, and new product sales as key indicators.

Except for Greece, all countries in the Battelle/*R&D Magazine*'s list of Top 40 global R&D spenders are expected to increase their R&D budgets in 2012. Even economically distressed Italy, Ireland, and Portugal will see significant increases in their R&D investments. The EU continues its strong investments in R&D at the individual country level as well as through the European Commission's (EC's) Framework Programme (FP). The EC is planning to increase its eighth version (FP8) in 2014 by nearly 50% to $15 billion per year in basic R&D programs.

China, which became the world's second largest R&D investor in 2011, remains noteworthy as well. Driven by GDP growth, its rate of spending will remain strong in 2012.

Three new emerging economies joined this Forecast in 2012: Malaysia, Indonesia, and Saudi Arabia. Starting from relatively small commitments (R&D expenditures at less than 1.0% of gross domestic product), each intends to increase its funding over the next several years to reflect the R&D ratios of more innovation-oriented economies.

This report reflects the global researcher viewpoint of R&D. The multinational respondents to our survey confirm trends reported elsewhere, including expectations of future funding constraints across all R&D sectors—government, industry, and academia—as the most critical concern for researchers. It also reveals that the U.S. continues to be the recognized leader in a broad range of technologies such as aerospace, agriculture, military, materials, and life science.

Forecast Gross Expeditures on R&D (GERD)

Billions of U.S. Dollars

		2010			2011			2012		
		GDP PPP Bil, US$	R&D as % GDP	GERD PPP Bil, US$	GDP PPP Bil, US$	R&D as % GDP	GERD PPP Bil, US$	GDP PPP Bil, US$	R&D as % GDP	GERD PPP Bil, US$
1	United States	14,660	2.83%	415.1	15,203	2.81%	427.2	15,305	2.85%	436.0
2	China	10,090	1.48%	149.3	11,283	1.55%	174.9	12,434	1.60%	198.9
3	Japan	4,310	3.44%	148.3	4,382	3.47%	152.1	4,530	3.48%	157.6
4	Germany	2,940	2.82%	82.9	3,085	2.85%	87.9	3,158	2.87%	90.6
5	South Korea	1,459	3.36%	49.0	1,549	3.40%	52.7	1,634	3.45%	56.4
6	France	2,145	2.21%	47.4	2,227	2.21%	49.2	2,282	2.24%	51.1
7	United Kingdom	2,173	1.81%	39.3	2,246	1.81%	40.7	2,305	1.84%	42.4
8	India	4,060	0.80%	32.5	4,472	0.85%	38.0	4,859	0.85%	41.3
9	Brazil	2,172	1.10%	23.9	2,294	1.20%	27.5	2,402	1.25%	30.0
10	Canada	1,330	1.95%	25.9	1,387	1.95%	27.0	1,429	2.00%	28.6
11	Russia	2,223	1.03%	22.9	2,367	1.05%	24.9	2,491	1.08%	26.9
12	Italy	1,774	1.27%	22.5	1,824	1.30%	23.7	1,849	1.32%	24.4
13	Taiwan	822	2.30%	18.9	883	2.35%	20.7	938	2.38%	22.3
14	Australia	882	2.21%	19.5	917	2.25%	20.6	958	2.28%	21.8
15	Spain	1,369	1.38%	18.9	1,409	1.40%	19.7	1,440	1.42%	20.4
16	Sweden	355	3.62%	12.9	379	3.62%	13.7	398	3.62%	14.4
17	Netherlands	677	1.84%	12.5	703	1.87%	13.1	720	1.90%	13.7
18	Switzerland	324	3.00%	9.7	338	3.00%	10.1	346	3.00%	10.4
19	Israel	219	4.27%	9.4	234	4.20%	9.8	246	4.20%	10.3
20	Austria	332	2.75%	9.1	350	2.75%	9.6	359	2.75%	9.9
21	Turkey	960	0.85%	8.2	1,045	0.90%	9.4	1,080	0.90%	9.7
22	Singapore	292	2.52%	7.4	314	2.60%	8.2	331	2.65%	8.8
23	Belgium	394	1.96%	7.7	412	2.00%	8.2	423	2.03%	8.6
24	Finland	186	3.87%	7.2	196	3.83%	7.5	203	3.80%	7.7
25	Mexico	1,567	0.37%	5.8	1,663	0.38%	6.3	1,741	0.39%	6.8
26	Denmark	202	3.02%	6.1	209	3.05%	6.4	215	3.08%	6.6
27	Poland	721	0.68%	4.9	765	0.72%	5.5	796	0.72%	5.7
28	South Africa	524	0.93%	4.9	553	0.95%	5.3	579	0.95%	5.5
29	Norway	255	1.80%	4.6	265	1.85%	4.9	274	1.85%	5.1
30	Czech Republic	261	1.53%	4.0	272	1.55%	4.2	280	1.55%	4.3
31	Argentina	596	0.51%	3.0	658	0.58%	3.8	695	0.61%	4.2
32	Portugal	247	1.66%	4.1	247	1.65%	4.1	245	1.67%	4.1
33	Malaysia	414	0.64%	2.6	445	0.70%	3.1	472	0.70%	3.3
34	Ireland	172	1.77%	3.0	176	1.75%	3.1	181	1.75%	3.2
35	Hungary	188	1.15%	2.2	195	1.20%	2.3	201	1.20%	2.4
36	Indonesia	1,030	0.10%	1.0	1,120	0.15%	1.7	1,203	0.20%	2.4
37	Romania	254	0.59%	1.5	263	0.65%	1.7	275	0.66%	1.8
38	Saudi Arabia	622	0.10%	0.6	677	0.20%	1.4	708	0.25%	1.8
39	Greece	318	0.58%	1.8	314	0.55%	1.7	311	0.50%	1.6
40	New Zealand	118	1.18%	1.4	123	1.20%	1.5	129	1.22%	1.6

Source : Battelle, *R&D Magazine*, International Monetary Fund, World Bank, CIA World Factbook

Stable Growth of U.S. R&D

As 2012 approaches, U.S. investment in research has stabilized, but growth still lags previous years as a result of the sluggish economy. Given the current federal budget situation and announcements by a number of high-profile corporations regarding planned reductions in R&D spending, the stable, slow-growth trajectory that developed in 2011 will likely continue through 2012.

The Battelle/*R&D Magazine* team forecasts that U.S. R&D expenditures will grow by slightly more than 2.0%, from our final 2011 estimate of $427.2 billion to $436.0 billion in 2012. Against an estimated 2.0% inflation rate for 2012, this suggests that U.S. R&D investments will remain flat in real terms over the next year.

This detailed forecast of U.S. R&D investment is built upon data derived from the National Science Foundation's (NSF's) *National Patterns of R&D Resources*, a longitudinal database of U.S. R&D funding and performance. The most recent complete release of this database includes *estimated* data through 2008. Additional NSF data from more recent survey releases, including initial data from the Business R&D and Innovation Survey (BRDIS) and recent *InfoBriefs,* are incorporated to develop estimates through 2011. The 2012 R&D spending forecast involves information from various sections of this report, including information about federal R&D budgets, corporate R&D expenditures and plans, and the general condition of the U.S. and global economies.

The Source-Performer Matrix

The Source-Performer Matrix
Estimated Distribution of U.S. R&D Funds in 2012
Millions of Current U.S. Dollars (Percent Change from 2011)

Source	Performer					
	Federal Gov't.	FFRDC	Industry	Academia	Non-Profit	Total
Federal Government	$29,152 -2.51%	$14,666 -3.69%	$37,577 -2.42%	$37,440 0.93%	$6,817 -2.29%	$125,652 -1.61%
Industry		$202 2.20%	$273,487 3.37%	$3,868 26.49%	$2,129 8.89%	$279,685 3.75%
Academia				$12,318 2.85%		$12,318 2.85%
Other Government				$3,817 2.72%		$3,817 2.72%
Non-Profit				$3,491 2.70%	$11,055 2.70%	$14,546 2.70%
Total	$29,152 -2.51%	$14,868 -2.36%	$311,063 2.63%	$60,934 2.85%	$20,001 1.55%	$436,018 2.07%

Source: Battelle, *R&D Magazine*

The U.S. forecast is presented as the source-performer matrix, detailing the flow of funds between entities that fund R&D and those that perform it. The components of the matrix are identified by the NSF through its surveys of R&D expenditures. Integration within the U.S. research enterprise is reflected by the matrix because the four key sources of R&D funding—government, industry, universities, and non-profits—also perform R&D activities. Additional funding flows to academia from other government entities (state and local). To date, the National Patterns data series has not tracked specific state and local funding to industrial R&D performers. As a result, this funding—which could come from economic development incentives, innovation grants like the State of Ohio's Third Frontier program, etc.—is not represented. A fifth set of R&D performers, federally funded research and development centers (FFRDCs), receive most of their operational funding and programmatic objectives from the federal government. Some major FFRDCs, including most of the DOE's national laboratories, are operated for the government by contractors, and also collaborate with the private sector to perform research and transfer technology.

Significant Factors and Assumptions in the 2012 Forecast

The 2012 forecast of U.S. R&D investments and performance embodied in this source-performer matrix is shaped by five principal factors.

Guarded optimism and continued stability

Industry leaders, economists, and consumers generally expect that the economy will be better in 2012 than in 2011, and definitely improved over 2010. Reflecting this view, 81% of industry survey respondents estimate that their R&D budgets will increase or stay the same for 2012 (at least in current dollars). The link between R&D performance and the national economy, however, is not as strong or direct as one might suppose. Historically, the National Patterns data have indicated stability and inertia in R&D performance. Significant economic swings are often reflected in the funding and performance data, but dampened in magnitude, with the R&D impact declining more slowly and returning to long-term growth vectors more quickly than the economy as a whole. This finding is amplified by our industrial survey respondents, only 36% of whom state that the economy has a significant effect on their R&D budgets.

Continued tightening of federal R&D budgets

As discussed in the next section, federal

R&D budgets, though more resilient than total government spending against significant budget reductions, will again see declines across many agencies. Administration and congressional support for basic research activities will likely minimize the impact on basic science agencies such as the National Institutes of Health (NIH), NSF, and the U.S. Department of Energy's Office of Science. However, the growth trajectory for these national science and innovation assets, as envisioned in the America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act (America COMPETES Act), will be subdued, limiting the research that they perform directly as well as the significant amount that they fund at U.S. universities.

Increased expectations for R&D ROI

Economic uncertainty in public and private sectors has caused R&D sponsors to pay new attention to measureable returns on research investments. One key example is the pharmaceutical industry, which faces increased scrutiny of R&D spending versus limited productivity and weak pipelines for blockbuster drugs. In response, many pharmaceutical companies are not only dampening their projections for R&D expense, but are announcing annual cuts of $1 billion or more over the next few years. The private sector is not alone in expectations for improved R&D ROI. With the difficult U.S. budget situation and the significant resources invested by the federal government in research, development, and testing activities, Congress, the General Accounting Office, the administration, and the public are demanding improved return on research investments in the form of economic and policy outcomes.

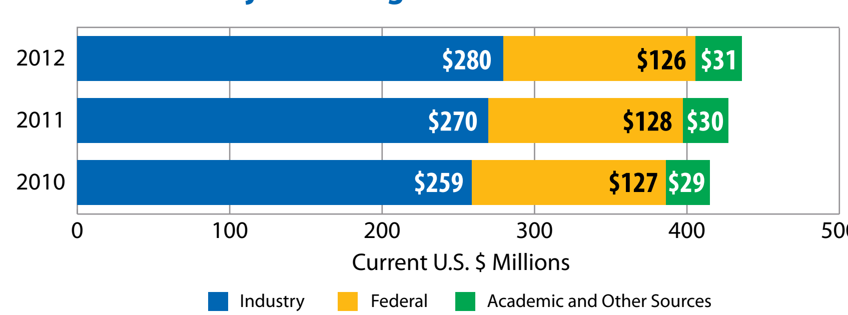
Revised federal expenditure reporting

Due to our reliance on the NSF's National Patterns data as the foundation of our estimates, significant adjustments to these data affect the levels and directions of our forecast. For example, after the release of our 2011 forecast, the NSF issued an *InfoBrief* entitled *Department of the Air Force Revises R&D Data for FY 2000–07*. This report detailed upward adjustments to the Air Force's R&D obligations, ranging from $3 billion in 2000 to nearly $14 billion in 2007. In the context of our forecast, this historical change will also reset the federal R&D funding baseline by nearly $14 billion starting in 2007. At this revised level, total U.S. R&D is also increased, which in turn increases the R&D share of the gross domestic product.

Continued effect of ARRA

Congress required that American Recovery and Reinvestment Act (ARRA) stimulus funds be committed to specific projects by the end of the government's 2010 fiscal year. However, the actual expenditure of ARRA funds by R&D performers will continue through calendar years 2011 and 2012, and is expected to continue into 2013 for some larger-scale research projects. These multi-year expenditures continue to add to the forecast's federal source line of the source-performer matrix.

Major Funding Sources of U.S. R&D



Source: Battelle, *R&D Magazine*

Details on U.S. R&D Funding Sources

The description and analysis of the 2012 forecast begin with a discussion of the major sources of U.S. R&D funding. This discussion focuses on the magnitude, nature, and distribution of these funds to the various performers.

Federal Funding of R&D

With the potential for significant reductions in discretionary budgets across the board, consideration of federal R&D funding involves finding ways to support research and innovation as drivers of growth and competitiveness, while containing costs. Philosophical disagreements are also a factor for some key research areas. Nevertheless, in the FY 2012 budget process, most of the reductions from last year's appropriations or changes from this year's administration requests have resulted from a tempering of growth rates for specific programs. This level of debate was enabled, in part, by an administration directive to reduce agency FY 2012 budgets by at least 5% and to eliminate low-priority programs and investments.

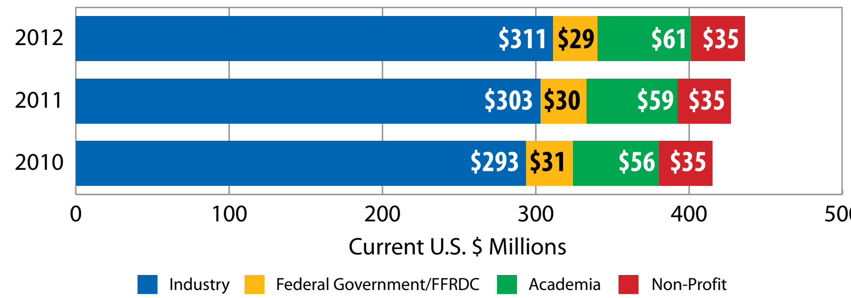
Though the federal FY 2012 budget remains a work in progress, our budget estimates lead to a forecast with federal funding reaching $125.7 billion in 2012, down 1.6% from our final estimate of $127.7 billion for 2011. With the exception of academia, which sees an increase of less than 1% in federal R&D funding, all other performers are down by more than 2% from 2011. The slight increase in academic R&D relates to ARRA expenditures, which will likely account for 10% or more of the total federal funds spent by academic institutions on R&D in 2012.

Industry Funding of R&D

Industrial funds for R&D will reach $280 billion in 2012, an increase of 3.7% over our final 2011 estimate of $270 billion. At 64% of all U.S. funding, the industrial private sector is a major driver, particularly of applied research and development. The nearly $10 billion increase in industrial funding accounts for all of the growth in the U.S. R&D enterprise from 2011 to 2012.

Of the $280 billion, 98% stays internal to industry performers, either directly or through outsourcing arrangements with other industry performers, although a small shift has begun. Based upon industry press and media accounts, we forecast a large increase (26.5%) in the level of industrial funds to academia in 2012 as firms embrace open and collaborative innovation. This amounts to an increase of $800 million, for a total of $3.9 billion in 2012. Similarly, an increase of 8.9% from 2011 to 2012 is forecast for industry funding to non-profit research institutes, amounting to $2.1 billion. Finally, industry funding to FFRDCs increases by 2.2% to $0.2 billion in 2012.

Major Performers of U.S. R&D



Source: Battelle, *R&D Magazine*

Other Funding of R&D

Beyond federal government and industry R&D funding, other sources provide important niche funding to U.S. R&D performers, especially within academia. Academic internal funds and non-profits (primarily foundations) provide research funding of $12.3 billion and $14.5 billion, respectively. Not surprisingly, these two sources are strongly engaged in intramural funding, with 100% of university funds supporting the performance of academic research and 76% of non-profit funding supporting other non-profits, including internal research funding within non-profit research institutes. With another $3.8 billion from non-federal government sources going completely to universities, these three sources combine to account for 7.0% of all U.S. R&D funding.

Details on U.S. R&D Performers

The other axis of the 2012 source-performer matrix illustrates the roles of the federal government, industry, academia, and non-profit organizations in undertaking research.

Federal Performance of R&D (including FFRDCs)

As federal resources have become more constrained over the past few years, intramural research functions have been asked to do more with less, even with the influx of ARRA funds to some federal research facilities. Intramural research is estimated to decline for the fourth consecutive year, with budget reductions (down 2.5%) exceeding overall federal R&D budget declines (down 1.5%). Total federal intramural research will reach $29.2 billion in 2012, down from nearly $30 billion in 2011.

The forecast performance level of FFRDCs is affected by anticipated reductions in federal R&D funding in 2012. The FFRDC level will reach $14.9 billion in 2012, down 2.4% from $15.2 billion in 2011.

Industry Performance of R&D

Total performance of R&D by industry will reach $311.1 billion in 2012, an increase of 2.6% over our final estimate of $303.1 billion in 2011. This growth rate is somewhat dampened by recent announcements of planned R&D reductions within the pharmaceutical industry in 2012. The majority of this funding comes from internal R&D resources, accounting for 88% of total industry R&D funding, with the growth in industry internal funding accounting for all of the increase in total industry funding. Industry will receive $37.6 billion from the federal government, accounting for the remaining 12% of funding. This amount is a decline of 2.4% over 2011 and primarily relates to reductions in DOD research expenditures.

Academic Performance of R&D

Sources of funding for academic research appear likely to continue placing a philosophical and programmatic priority on the basic and applied research performed by academia. This is demonstrated as funding for academic research will increase, albeit at different rates, across all sources of funds; even as the overall budgets of these research sponsors continue to be constrained. The performance of R&D by academia will increase by more than 2.8% in 2012, reaching $60.9 billion—a level that continues to be buoyed by ARRA-related expenditures.

The federal government, the primary funder of academic R&D, will provide less than a 1.0% increase, reaching $37.4 billion in 2012, as both NIH and NSF R&D budgets are projected to resist significant cuts in extramural funding programs. The second-largest share of academic R&D funding will come from institutions' own internal funds, including annual research and departmental budgets and endowments. The largest percentage increase to academic R&D performers will come from industry, continuing to look for open innovation partners or avenues to outsource additional, typically basic, research activities. This 26.5% increase, the only double-digit percentage increase in the 2012 U.S. forecast, will bring industry funding of academic R&D to nearly $3.9 billion in 2012.

Non-Profit Performance of R&D

Non-profit research institutions will see an increase of 1.6%, reaching $20 billion in 2012. These institutions will face similar reductions in federal funding as most other performers, with a decline of 2.3%. However, increases in both industry funding (8.9%) and internal or other non-profit support (2.7%) may offset these federal reductions.

FY 2012 U.S. Federal R&D Funding: **Continued Constraints**

We estimate that federal R&D funding will reach $140.9 billion in FY 2012, a decline of 1.8% from our estimate of actual FY 2011 R&D funding ($143.5 billion) and 4.7% lower than the administration's FY 2012 R&D funding request. Adjusting for a 2012 inflation rate estimate of 2.0%, this FY 2012 level of federal R&D funding represents a decline in real terms of 3.8% compared with FY 2011. Defense-related R&D accounts for 54% of total federal R&D in FY 2012, reaching $76.7 billion. This level of defense-related R&D represents a decline of 3.2% from FY 2011. The outlook for non-defense-related R&D is better (a current decline of less than 1.0%); yet at slightly more than $64.2 billion, it is the lowest it has been in the past four years.

These estimates are made as key FY 2012 agency budgets remain uncertain following the long delay in finalizing the FY 2011 budget and the current delay in reaching a complete agreement on the FY 2012 budget. The FY 2011 budget was completed in April 2011, through an omnibus Department of Defense (DOD) and Full-Year Continuing Appropriations Act, 2011. Hence, the federal government operated in FY 2011 for more than six months under various continuing resolutions and spending freezes. Progress is being made on the FY 2012 budget as the recent continuing resolution also included a final appropriations "Mini-Bus" bill. This bill, the *Consolidated and Further Continuing Appropriations Act, 2012,* finalizes the budgets of several agencies, most notably from an R&D perspective, the Departments of Agriculture, Commerce, and Transportation and both the National Science Foundation (NSF) and NASA. However, the overall budgets for the three largest R&D funding agencies, the Departments of Defense and Energy and the National Institutes of Health (NIH), are currently operating under the continuing resolution, until at least mid-December.

Moving forward, the total FY 2012 R&D budget is likely to be constrained, although probably less so than the overall federal budget. Significant gains are unlikely, although budget priorities and authorizations established by the America COMPETES Act will likely provide positive context for funding key basic research agencies. As discretionary spending, federal R&D budgets will continue to attract attention in the quest to reduce spending. Finally, the inability of the congressional deficit-cutting Joint Select Committee (also known as the Super Committee) to reach an agreement on budget cuts or revenue enhancements may weigh on the finalization of the remaining FY 2012 R&D budgets, and future R&D budgets may face significant reductions.

According to the Office of Science and Technology Policy (OSTP), the administration's FY 2012 request for R&D funding was $147.9 billion at the start of the budget process—an increase of less than 1% over the final FY 2010 R&D budget, but up 3.1% from our estimate of FY 2011 federal R&D spending. Under this request, the three agencies most associated with federally funded basic research—the NSF, the NIH, and the Department of Energy's Office of Science—would receive substantial increases in line with the America COMPETES Act. Additionally, the Department of Homeland Security would receive an R&D increase, taking into account that its final FY 2011 budget was dramatically below the administration's original request.

However, budget actions and other indications from Congress suggest that the R&D budget could be significantly lower than the administration's FY 2012 request. This is a fundamental assumption that we have factored into the FY 2012 forecast provided above.

The preceding estimates and observations are based on the analysis and insights of the OSTP, the American Association for the Advancement of Science (AAAS) R&D Budget Program, congressional committee reports, the Third Quarter 2011 Survey of Professional Forecasters, and other sources.

Department of Defense

Like last year, the FY 2012 defense appropriation is one of the last to be considered. As a result, DOD's FY 2012 R&D budget remains particularly uncertain. Current estimates of the ranges for DOD R&D being considered by Congress are between $73 billion and $76 billion, with the higher amount closer to the administration's request. Within this range, the final FY 2012 DOD R&D budget would decline for the third consecutive year.

Accordingly, our estimate is $75.0 billion, a 3.2% decline from FY 2011's $77.5 billion and a 7.2% decline from the FY 2009 high of $80.8 billion. At $75 billion, DOD R&D still accounts for 53% of total federal R&D funding for FY 2012, but its reduction accounts for more than 75% of the total reduction in federal R&D funding from FY 2011 to FY 2012.

National Institutes of Health

An unusual amount of debate is occurring this year regarding the NIH budget, which accounts for the majority of the Department of Health and Human Services (HHS) R&D budget. The administration requested an increase, related to the America COMPETES Act, of slightly more than $1 billion. The House Appropriations Committee proposed an R&D budget that equaled the president's request, while the Senate Appropriations Committee proposed $1.2 billion less than the president's request. This funding differential is tied to debate over the NIH's proposed development of a new National Center for Advanced Translational Science (NCATS). This new center would assume some of the functions of the National Center for Research Resources, which is slated for termination. The NCATS concept was presented as a new NIH strategic initiative after the administration's FY 2012 budget was released. Reconciliation of the House and Senate proposals for NCATS, which would involve a significant research component, will be an important factor in the total NIH budget. Our estimate for FY 2012 funding is $30.6 billion for the NIH, with a total of $31.7 billion for all of the HHS. At this level, the NIH will receive slightly less (0.4%) than our FY 2011 estimate, and the HHS overall will receive 0.6% less than in FY 2011.

Department of Energy

The administration requested nearly $13 billion for DOE R&D funding in FY 2012, an increase of nearly $2.8 billion. This involves the multi-year track for doubling funding of the Office of Science according to the America COMPETES Act, as well as sizable increases in funding for research performed by the National Nuclear Security Administration and the Office of Energy, particularly for the latter in the fields of energy efficiency and renewable energy. Congress to this point has indicated a preference to scale back the growth in the Office of Science and hold many areas outside the Office of Science to budget levels similar to FY 2011. Our estimate projects that "basic research" funding will be subject to the most compromise, yielding a final DOE FY 2012 R&D budget of $10.6 billion, $2.3 billion less than the request, but 3.8% more than in FY 2011.

NASA

The total NASA budget, and therefore its R&D budget, continues to be a matter of scientific and policy debate. Unlike most agencies and departments, NASA is likely to experience the largest budget cuts to its R&D efforts. The administration's request for a slight increase in NASA's overall FY 2012 budget actually included a slight decrease in R&D funding, primarily within aeronautics. The most significant congressional debate revolved around the future of the James Webb Space Telescope, the shifting of resources to a new Space Technology Directorate, and reprioritization (and budget changes) among other R&D areas. The final NASA FY 2012 R&D budget is set at $9.2 billion, which included significant support for the most highly debated investments. This level marks a decline of 6.6% from the FY 2011 level of $9.9 billion, and is the lowest level in at least five years.

National Science Foundation

Basic research funding, the mainstay of the NSF, has typically received strong bipartisan support. This support, while still evident, is faced with the realities of the current budgetary situation. The NSF has seen substantial increases in its R&D funding, with more than 20% growth from FY 2007 to FY 2011 due to both congressional and administration support through America COMPETES and other initiatives. For FY 2012, the administration requested an increase of roughly 15% over the previous year. The congressional compromise budget, while an increase, does not reach the administration's request. The final NSF FY 2012 R&D budget reaches $5.8 billion, an increase of 6.7% over our final FY 2011 estimate of $5.4 billion.

Department of Agriculture

USDA R&D efforts are carried out primarily through the Agricultural Research Service and the National Institute of Food and Agriculture. Both of these were slated for slight increases in the administration's FY 2012 request, among overall cuts and redirection of resources. The congressional conference budget reduced the R&D funding for both somewhat in a final USDA FY 2012 R&D funding of $2.0 billion, down 5.2% from our estimate of $2.1 billion in FY 2011.

Department of Commerce

The DOC FY 2012 R&D budget, like other budgets connected with America COMPETES, was likely to increase over final FY 2011 budgets, but not at the level requested by the administration to continue the "doubling" budget trajectory. For FY 2012, the administration's request for DOC R&D, including the National Oceanic and Atmospheric Administration (NOAA) and the National Institute of Standards and Technology (NIST), was $1.7 billion. The final DOC FY 2012 R&D budget is set by the appropriation bill at $1.4 billion. Compared with FY 2011, this level includes a slight decrease in NOAA R&D funding and a significant increase in NIST R&D funding. The increase in NIST R&D funding stems from increases in the Scientific and Technical Research and Services budget and the mandatory Public Safety Innovation Fund. At this level, the DOC FY 2012 R&D budget constitutes an increase of 10.9% over our final FY 2011 estimate.

Department of Transportation

For FY 2012, the administration requested a DOT R&D budget of $1.2 billion, an increase of 15% over our final FY 2011 estimate. In general, congressional budget actions have complied with the administration's request, including a likely 20% increase in the Federal Highway Administration's R&D budget, though increases overall are much more constrained. The final DOT FY 2012 R&D budget is set at $1.1 billion, an increase of 1.3% over our FY 2011 estimate.

Industrial R&D—Manufacturing

In the next sections we examine, through survey and secondary data, five technology-intensive industries chosen for their overall importance in terms of U.S. corporate R&D, U.S. federal R&D, and global industry R&D. Besides these industries, a more diverse set of manufacturing firms and industries—including automotive, heavy equipment, consumer products, and food—also perform significant R&D activities in the U.S. We provide a snapshot of the R&D investment level of these manufacturers, but limit it to leading public companies for which R&D investment data are available. The U.S. is also home to key private companies that are R&D leaders such as General Atomics and Chrysler Group, LLC. To highlight the significance of R&D within U.S. and global manufacturing (including information and communication technologies, or ICT), the chart on the opposite page portrays the 50 largest public companies in global R&D spending.

Leadership in Manufacturing R&D

With 18 U.S. corporations among the top 50 firms according to R&D spending, the U.S. remains dominant in manufacturing R&D. Translating this level of R&D and innovation into output, products, and jobs is the challenge faced by both U.S. corporations and government. Depending on the economic measure (direct output value or estimated purchasing power parity) used, China either has surpassed the U.S. in total manufacturing output or will in the next few years. However, from a manufacturing R&D perspective, the U.S. is the leader in investments, but China is gaining ground. Our 2012 estimate of U.S. R&D funded and performed by industry reaches $273 billion, a level surpassing all R&D investments in China. This is the case even when discounting that share of U.S. corporate R&D investments made outside the U.S. China's surge in R&D, though possibly overstated based on R&D investment estimates, is getting noticed—33% of the Battelle/*R&D Magazine* survey respondents believe that the U.S. currently leads in manufacturing R&D, but 31% believe that the leadership has shifted to China.

Survey respondents were also asked to comment on what role the federal government should play in assisting the R&D efforts of U.S. manufacturers. Two-thirds of the respondents stated that tax credits and incentives should be key components of federal support. This response reflects the significant concern that the federal government has failed to provide a long-term, stable, and globally competitive R&D tax credit for U.S. corporations.

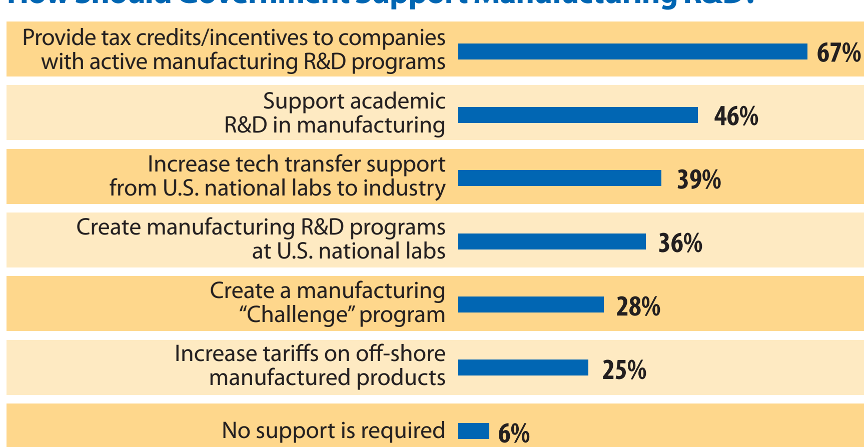
R&D Return on Investment

Because the ongoing issue of R&D tax credits affects corporate investment decisions, the return from these investments is also a key determinant. Calculating and tracking a return on investment (ROI) for R&D expenditures is becoming more common across manufacturing, as operation budgets tighten across corporations of all types. Among survey respondents, 52% of manufacturers said R&D ROI was important in calculating their R&D budget. Currently, 45% of the respondents calculate R&D ROI in some fashion. Though still a minority of respondents, this is a significant increase

Key Diverse Manufacturers	2009	2010	Q1-Q3 2011
Top U.S. R&D Expenditures	Millions, U.S. $		
General Motors (e)	6,051.0	6,962.0	5,713.2
Ford Motor (e)	4,700.0	5,000.0	4,005.6
Procter & Gamble	1,907.0	1,975.5	1,531.7
Caterpillar	1,421.0	1,905.0	1,693.0
Deere (e)	993.3	1,085.7	915.8
Kraft Foods (e)	466.0	583.0	470.1
Whirlpool	489.0	516.0	386.5
PepsiCo (e)	414.0	488.0	391.0
Navistar International	434.0	484.0	417.0
Eaton	395.0	425.0	316.0

Source: Battelle/*R&D Magazine* and Company Information; (e) = estimated

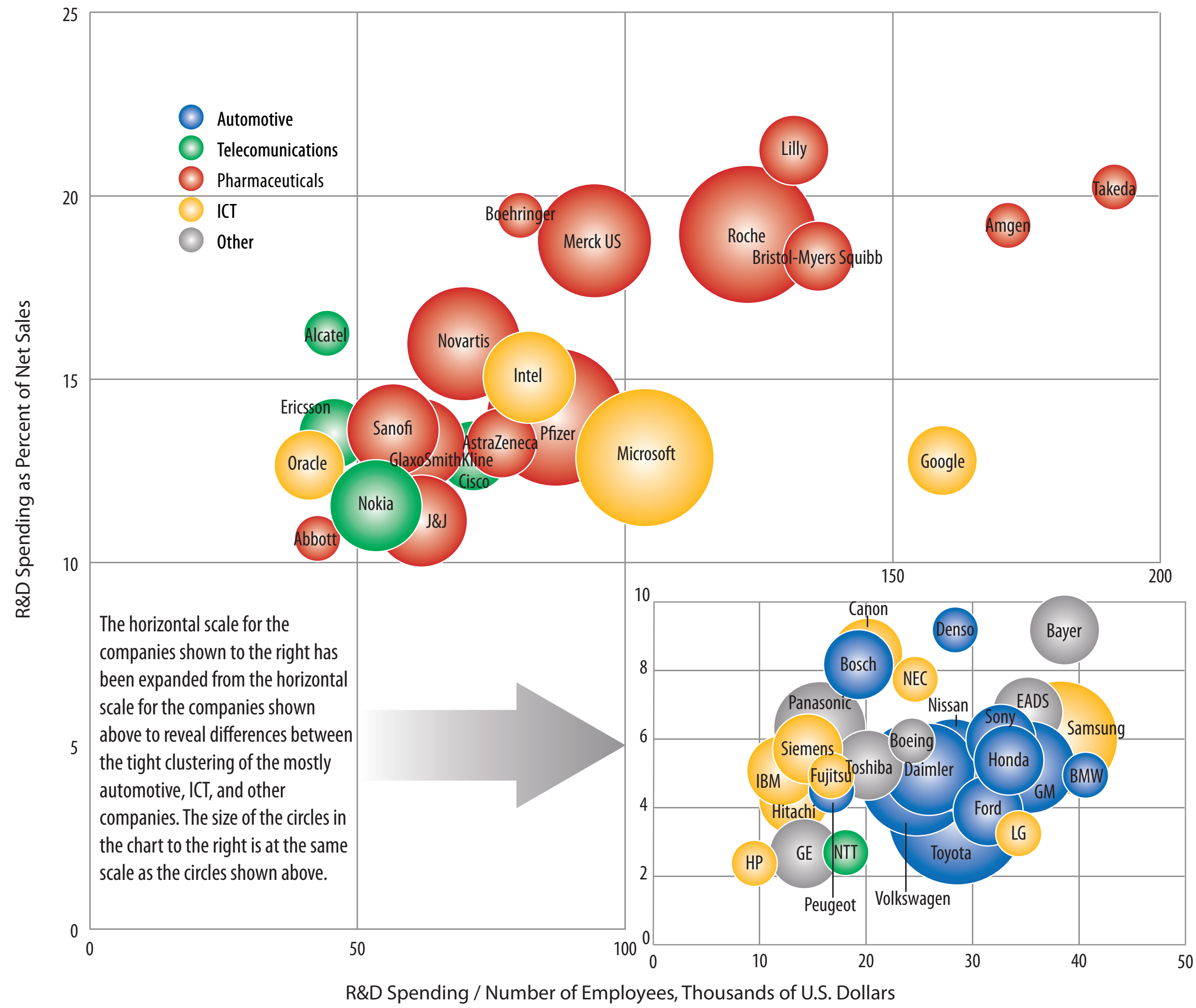
How Should Government Support Manufacturing R&D?



Source: Battelle, *R&D Magazine* Survey

World of Industrial R&D 2010

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



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

over levels from a couple of years ago.

ROI and effects of manufacturing R&D investments are measured in various ways related to the corporate "bottom line," according to survey respondents. The level of specificity in measuring ROI, however, remains a broad and somewhat elusive target. About 55% of the respondents cited broad concepts such as improved competitiveness, improved product quality, and market success of new products as indicators of effective R&D. Improved profitability was cited by 53% of the respondents, improved productivity by 45%, and reduced product development costs by 35%.

Collaborative R&D

Throughout this forecast, we are examining the role that collaboration is playing in R&D efforts. Fully 81% of U.S. manufacturing survey respondents indicated their involvement in some type of collaborative R&D activity. Collaborations with academia were noted by 54% of the respondents, with 48% also involved in collaborations with other U.S. companies. Involvement with federal laboratories, contract research organizations, and non-U.S. companies was considered a somewhat less viable option for manufacturers, with only about 29% of the respondents involved with each of these. The overall importance of collaboration is also recognized by U.S. manufacturers. More than 60% viewed these technology collaborations as important to the growth of their organizations, with 39% planning to expand their collaborative efforts beyond existing levels. The results that companies expect from these collaborations vary, with knowledge sharing (71%), shorter development cycle (49%), and availability of proprietary technologies (47%) key among the respondents.

Industrial R&D—Life Science

The life science segment includes diverse firms such as multinational pharmaceutical corporations, large medical device and instrument companies, and both large and small biotechnology firms. Though primarily engaged in human healthcare, firms in this segment are also involved in animal health and agricultural biosciences, and many operate in multiple areas. Eight of the top 10 U.S. firms in life science R&D are in biopharmaceuticals, with only Medtronics, in medical devices, and Monsanto, in agricultural biosciences, also making the top 10.

As pharmaceutical companies continue to rationalize their R&D activities and deal with financial and investor pressures, budget and employment reductions have become more strategic, undertaken to reduce costs and renew focus and efficiency to their R&D operations and portfolios. For some firms, such as Novartis, cuts in some areas have led to additional positions in higher-priority technical areas, though these new positions are often in lower-cost global locations. Such geographic migration to lower both production and R&D costs has been a trend for at least a decade, and is likely to continue for the foreseeable future. Among U.S. medical device manufacturers, R&D activities have continued to be focused within the U.S., even as device or component production is moved to lower-cost locations.

Reconfiguring Pharma

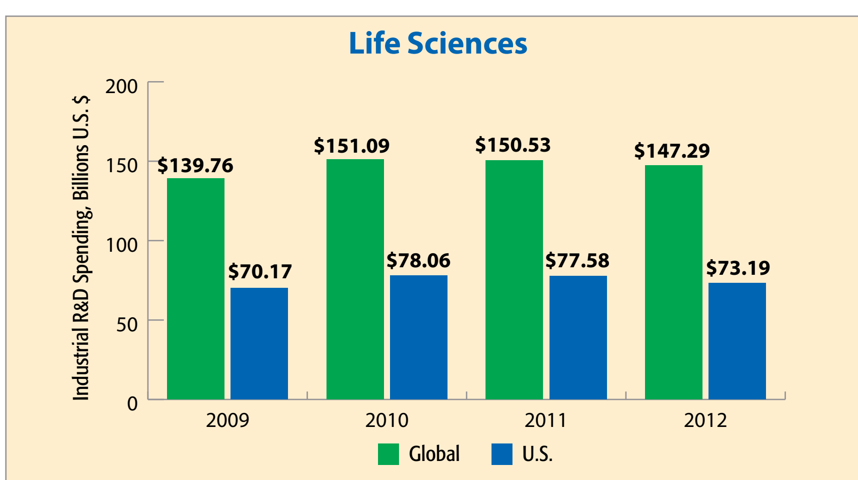
In many recent large mergers, the combined company experienced a period of reduced R&D productivity due to the process of rationalizing research budgets, pipelines, and staff. This makes further large-firm mergers less likely, though not impossible, over the next few years. It remains probable, however, that the remaining large pharmaceutical firms will still seek to acquire smaller firms with de-risked molecules and target-specific R&D capabilities. The rate of future consolidation is up for debate. Some expect it to accelerate over the next few years, leaving a biopharmaceutical industry with two types of firms—(1) those specializing in innovative, higher-value treatments (often targeted to smaller sub-populations) that can manage the cost structure accompanying the required development work or (2) those with significantly lower-cost structures that compete on a larger scale with mass-market and generic drugs. This two-pronged structure is interesting to note, especially in conjunction with Abbott Laboratories' recent announcement that it will split the company into two components somewhat along these lines.

Changing R&D Strategies

Due to impending patent expirations and the widely reported decline in productivity in the development and approval of significant new medicines, many in the pharmaceutical segment have evaluated, reevaluated, and restructured their R&D operations. Specific efforts have been made recently to reduce the costs and improve the return associated with their R&D activities, to focus their internal R&D on a smaller portfolio of diseases, and/or to modify their overall R&D approach. Pfizer recently announced that it plans to reduce its overall R&D budget to between $8.1 billion and $8.4 billion in 2011 (down from

Life Sciences	2009	2010	Q1-Q3 2011
Top U.S. R&D Expenditures	Millions, U.S. $		
Pfizer	7,845.0	9,402.0	6,516.0
Merck & Co.	8,425.0	8,669.0	6,048.0
Johnson & Johnson	6,986.0	6,844.0	5,393.0
Lilly (Eli) & Co.	4,326.5	4,884.2	3,665.5
Abbott Laboratories	2,743.7	3,724.4	2,978.2
Bristol-Myers Squibb Co.	3,647.0	3,566.0	2,831.0
Amgen	2,864.0	2,894.0	2,318.0
Medtronic (e)	1,451.0	1,491.0	1,147.5
Biogen Idec	1,283.1	1,248.6	880.7
Monsanto	1,113.0	1,241.0	1,084.0

Source: Battelle/*R&D Magazine* and Company Information; (e) = estimated



Source: Battelle, *R&D Magazine*

$9.4 billion in 2010) and to $6.5 billion in 2012. This may be the strongest sign yet that the enormous R&D budgets of the pharmaceutical companies are coming to an end. However, the cost of R&D is not the only issue facing the industry.

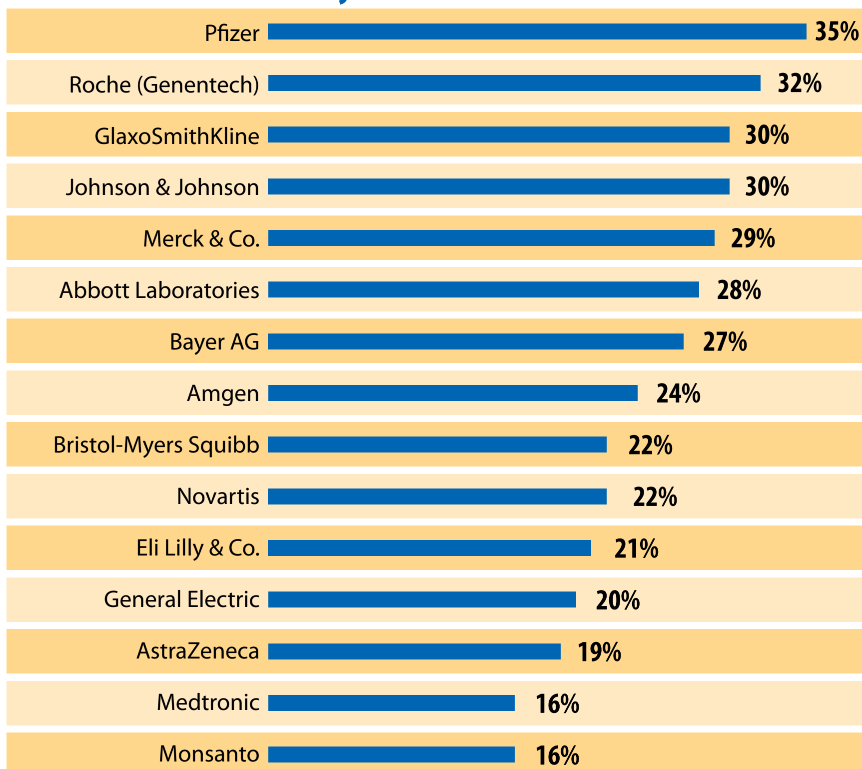
In a recent report, KPMG calls for a significant change in how global pharmaceutical companies capture and manage the returns on their R&D investments and improve their ability to justify these R&D expenditures. The report states that pharmaceutical industry returns on research expenditures have fallen from an ROI of 17% in 1990 to just over 10% in 2010. This concern over ROIs is magnified by the substantial revenue that many large pharmaceutical companies will lose because of patent expirations.

In addition to streamlining global R&D infrastructure, many pharmaceutical companies are rationalizing their pipelines. For example, as Pfizer announced its R&D budget cuts, it revealed a continued focus on oncology and inflammatory conditions, among others, but a shift away from areas such as urology and internal medicine.

Open R&D

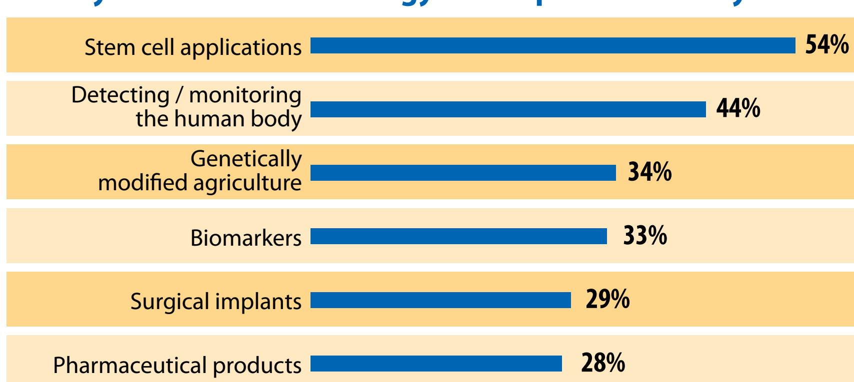
The retrenchment of pharma's conventional model has created significant R&D opportunities for universities, non-profits, and the government. Continuing to consider the Pfizer example, while reducing internal R&D, it has expanded its presence in Cambridge, Mass., specifically to have better collaborative access to the great research institutions of the area and to adopt an open innovation posture. In a larger example intended to accelerate drug development, GlaxoSmithKline, Novartis, Pfizer, and Eli Lilly have joined the Structural Genomics Consortium, a public-private partnership that supports the discovery of new medicines through open access research. Yet another open model is "*One Mind for Research*," an effort to build a global repository of relevant data, imaging, and patient information for collaborative neuroscience and brain disorder research.

Global Industry Leaders in Life Science R&D



Source: Battelle, *R&D Magazine* Survey

Key Life Science Technology Development Areas by 2014



Source: Battelle, *R&D Magazine* Survey

At the same time, the federal government has become oriented to a larger role in early-stage drug R&D with initiatives like the afore referenced National Center for Advancing Translational Sciences, and the National Institute of Health's (NIH's) Common Fund. Foundations are also taking a more active role in funding and R&D toward treatments for the often difficult diseases in which they have an interest.

This convergence of public and private life science R&D toward open innovation and open source information—especially in areas needing considerable fundamental research—is a major change in the approach to funding and performing life science R&D.

Industrial R&D—ICT

Over the past 20 years, information and communication technologies (ICT) have been a key innovation enabler in many domains and have dramatically changed social behavior around the globe. In the past decade, the fortunes of many ICT companies have evolved significantly. And over the past two years, ICT-related manufacturing has been particularly volatile, with leading companies like Nokia, Motorola, Google, Apple, Microsoft, and Hewlett-Packard experiencing commercial dynamics following the introduction of new products arising from their R&D decisions.

As these companies illustrate, success in the ICT marketplace cannot be maintained by being the current market leader and making large R&D investments alone. A clear vision of long-term technology goals aligned with a competitive marketing strategy is essential. For example, Nokia led the cellular market for most of the past 10 years by creating low-cost, reliable handsets. But when the market evolved to more upscale and technologically significant products, Nokia failed to develop a strong smart phone product, a competitive operating system, or a strong industry collaboration. Its market share and position in the upper echelon of all global companies (with about $7 billion investment in R&D, at #11 in our list) could be in jeopardy as a result.

Apple's success, on the other hand, has been well publicized. With lean R&D investments of about $2 billion in 2011, Apple's R&D as a percent of sales is only 2.7%—less than a quarter of that spent by Nokia. But smart investments and a clear market vision by the late CEO Steve Jobs helped Apple rise within the past five years to become, briefly, the first or second largest industrial company in the world. Apple succeeded with smart R&D, close attention to the marketplace and the user, and an emphasis on quality—not just relying on large amounts of R&D or a position as technological leader.

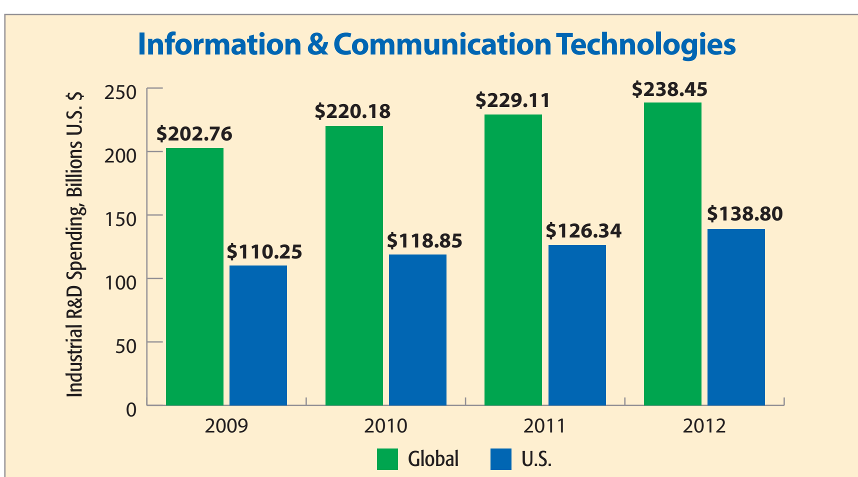
While Nokia and Apple demonstrate some extremes of R&D investment and outcomes, they also illustrate the range of strategies available for R&D in ICT, where product cycles are fast and innovation-driven.

U.S. ICT Strength at Risk?

In its latest *ICT R&D Policy Report*, The Telecommunications Industry Association (TIA) urges U.S. policymakers to take action to reinvigorate investment in ICT innovation. Noting that the U.S. has long been the unrivaled leader in ICT, the report cites a growing gap in basic ICT research funding in the U.S., an inadequate (and uncertain for all industries) R&D tax credit, and the need for greater ICT industry input into U.S. federal agency funding priorities. The report recommends simplifying the R&D tax credit, funding the Wireless Innovation Fund (WIF), doubling the basic science budget by 2015, promoting policies to stimulate

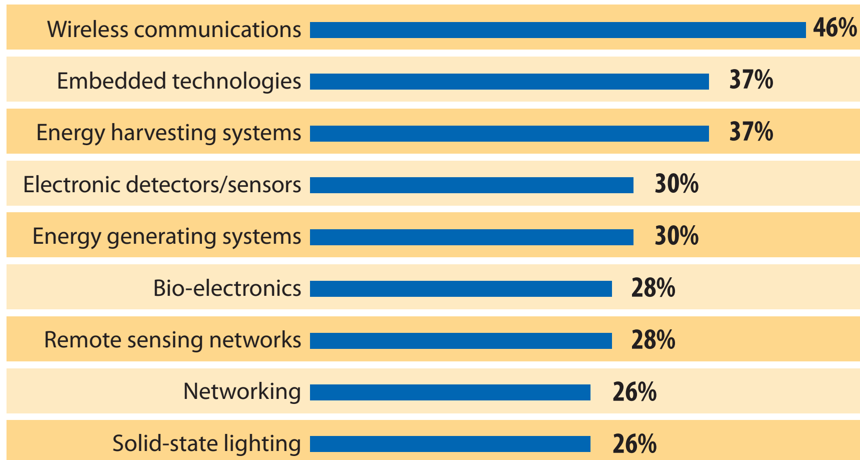
Information & Communication Technologies	2009	2010	Q1-Q3 2011
Top U.S. R&D Expenditures	Millions, U.S. $		
Microsoft	8,581.0	8,951.0	6,991.0
Intel	5,653.0	6,576.0	6,042.0
International Business Machines	5,820.0	6,026.0	4,702.0
Cisco Systems	4,994.0	5,711.0	4,371.0
Oracle	2,775.0	4,108.0	3,347.0
Google	2,843.0	3,762.0	3,864.0
Hewlett-Packard Co.	2,768.0	3,076.0	2,440.5
Qualcomm	2,432.0	2,624.0	2,348.0
Apple	1,416.0	1,959.0	1,854.0
EMC	1,627.5	1,888.0	1,589.0

Source: Battelle/*R&D Magazine* and Company Information; (e) = estimated



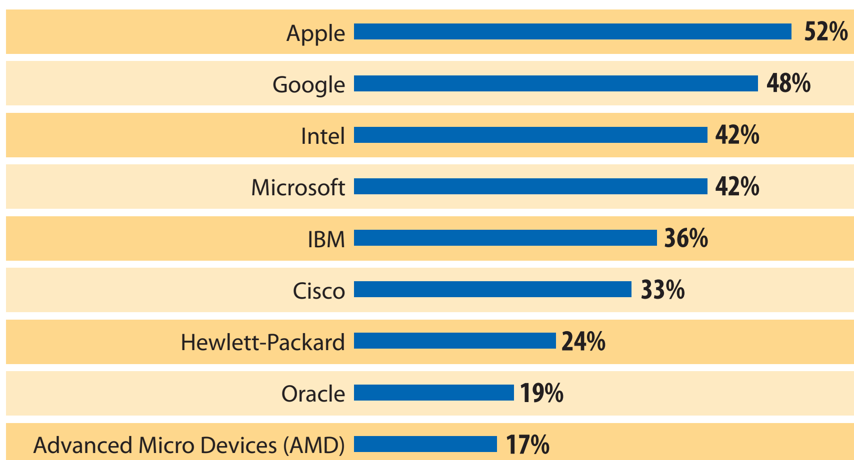
Source: Battelle, *R&D Magazine*, EU R&D Scoreboard

Key ICT Technology Development Areas by 2014



Source: Battelle, *R&D Magazine* Survey

Global Industry Leaders in ICT R&D



Source: Battelle, *R&D Magazine* Survey

broadband deployment, and encouraging cooperation and information sharing with other nations.

The Economic Intelligence Unit (EIU) affirms that the U.S. remains the world's most competitive country in ICT, but notes that developing nations are beginning to close the gap. Sponsored by the EIU, a report by the Business Software Alliance (BSA)—*Benchmarking IT Industry Competitiveness, 2011*—ranks the U.S. first overall in ICT (over #2 Finland), first in ICT R&D (over #2 Israel), first in human capital (over #2 China), a close second to Australia in ICT legal environment, first in IT industry environment (over #2 Canada), but ninth in IT infrastructure.

The U.S. and Japan make up nearly 70% of all global ICT R&D investments, according to a recent study by ZDNet. While China is excelling in many other industries, Huawei Technologies is the only Chinese company in the top 30 firms ranked by ICT R&D spending.

R&D in the Cloud

At slightly more than $9 billion in R&D spending, Microsoft is the leader in ICT R&D spending, outspending #2 Samsung by more than $1 billion. In early 2011, Microsoft President Jean-Philippe Courtois announced that the company would be spending 90% of its research budget, or more than $8 billion, on improving cloud computing technologies. With the U.S. government alone currently estimated to spend more than $20 billion in cloud computing, this investment by Microsoft may not be as risky as some analysts initially noted. A Microsoft internal marketing study also indicated that 40% of all small and medium businesses (SMBs) would adopt cloud-based computing systems within three years.

One new product outcome of Microsoft's R&D is Office 365, a collaboration and productivity tool delivered through a cloud computing interface for a monthly fee. Office 365 competes directly with the Google Apps cloud-based email and collaboration suite, which was selected by General Motors for more than 100,000 of its employees.

ICT IP

U.S. leadership in ICT intellectual property may be weakening. According to a World Intellectual Property Organization (WIPO) 2011 report, the most global Patent Cooperation Treaty applications have been filed by Japan's Panasonic, China's ZTE, the U.S.'s Qualcomm, and China's Huawei Technologies, respectively. Six of the top 20 rankings (based on number of applications filed) are from Japan, four are from the U.S. (Qualcomm # 4, 3M #16, Hewlett-Packard #18, and Microsoft #20), and five are from European Union (EU) countries.

The EU recognizes that its development of ICT intellectual property has lagged the rest of the world. In reports preparing for its Framework Programme 8 (FP8, the EU's premier R&D initiative of more than $120 billion scheduled to run from 2014 to 2020), the EU notes that many ICTs will have matured over the next 15 years, becoming even more widely adopted and integrated in diverse technology platforms. Many of the FP8 research programs will emphasize ICT to build economic advantage for the EU's member states and companies.

Industrial R&D—Aero/Defense

The resources invested in aerospace, defense, and national security R&D continue to dominate U.S. federal funding and constitute an important part of overall global R&D. U.S. federally funded defense R&D will reach nearly $75 billion in 2012, exceeding every other country's total R&D except that of China, Japan, and Germany. With the defense R&D of these leaders and others, global defense R&D will likely account for more than $150 billion in 2012 or nearly 10% of all global R&D. Of U.S. corporate R&D, the sector as a whole, at $13.8 billion, will account for less than 5% in 2012, though key prime contractors are investing substantial funds in R&D activities.

It is important to consider that corporate R&D decisions and investments in this sector are often driven by the directives and future mission requirements tied to the federal government funding that these companies receive for both research services and procurement. Thus, corporate aerospace, defense, and national security R&D is more strongly tied to federal budget priorities than any other sector.

Continued Funding Pressure

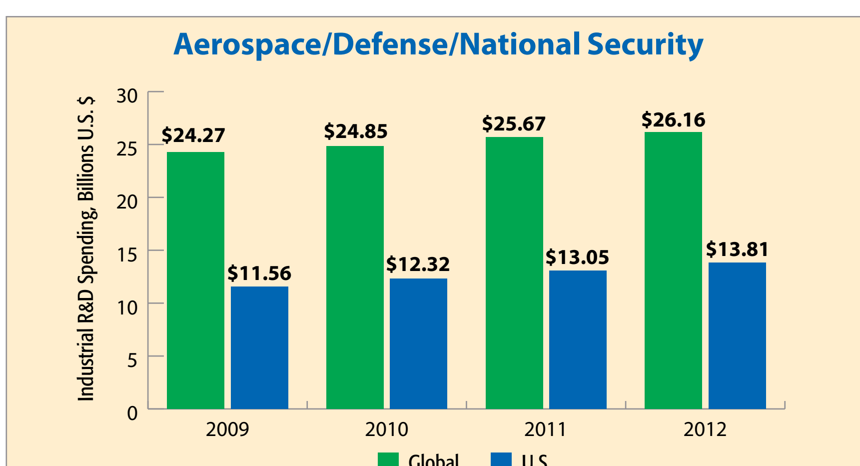
During federal budget belt-tightening, it is not surprising that the U.S. Department of Defense (DOD) and other national security funding, the largest component of the "discretionary" federal budget, faces significant pressures. Historically, administration and congressional support has often shielded the defense budgets, especially the DOD R&D budget, from sizable cuts. This situation has changed as federal funding for DOD R&D is likely to decline for the third consecutive year. The challenges for federal defense-related funding are likely to continue, and potentially change in structure, if the automatic sequester budget cuts in the Budget Control Act of 2011 go into effect in 2013. While these dramatic cuts are seen as unlikely for many reasons, they have initiated considerable examination of spending and priorities, including within R&D efforts, which will likely exert pressure to reduce funding for the DOD and the defense industry.

Research Shift in Federal Funding

The potential combination of two trends—(1) tightening federal budgets and (2) fairly strong bipartisan support for federal involvement in basic and early-stage research—may bring about increases in the shares basic (6.1) and applied (6.2) research receive from federal defense-related resources. Discussion and debate go on regarding the need to both improve and enhance the level of basic research funded by the DOD. Some indications of this shift, though subtle, may be impacting FY 2012 appropriation efforts. Overall DOD R&D funding is likely to be reduced by slightly more than 3% from FY 2011 to FY 2012. However, within this reduction, basic and applied research are likely to see a 6.0% to 7.5% increase (depending on final FY 2011 figures). At nearly $7 billion in FY 2012, DOD-funded basic and applied research will still account for less than 10% of the total federal defense R&D budget, with the balance funding development-phase

Aerospace/Defense	2009	2010	Q1-Q3 2011
Top U.S. R&D Expenditures	Millions, U.S. $		
Boeing	6,506.0	4,121.0	3,005.0
General Electric - Aviation (e)	705.4	817.8	646.8
UTC - Aviation (e)	654.4	715.9	681.0
Lockheed Martin	724.0	638.0	537.6
Raytheon	565.0	625.0	454.0
General Dynamics	520.0	508.0	377.0
Honeywell - Aviation	463.1	469.3	370.3
Northrop Grumman	465.1	459.7	321.9
Textron	401.0	403.0	334.5
Rockwell Collins	352.5	347.5	266.3

Source: Battelle/*R&D Magazine* and Company Information; (e) = estimated



Source: Battelle, *R&D Magazine*

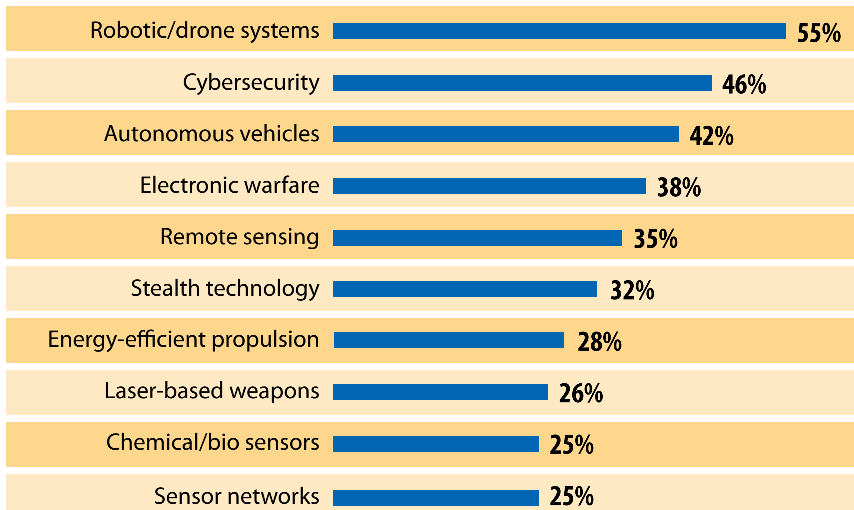
activity. However, the increased budget for research, among the other reductions, may signify changes in the overall landscape of defense R&D as most basic and applied R&D is performed outside the corporate environment. This shift in resources, some observers suggest, may reduce overall development costs and improve program outcomes.

Mission Directed R&D

The increasing importance of and reliance on unmanned and autonomous vehicles and real-time situational awareness and sensor systems continue to change the aerospace, defense, and national security R&D landscape. The unmanned aerial vehicle (UAV) sector alone is forecast by Teal Group to reach $2.6 billion in global R&D in 2011 and to more than double in less than a decade. Likewise, the autonomous underwater vehicle (AUV) market is growing rapidly, at a rate currently estimated by Booz & Co. of nearly 13% per year, with R&D investments mirroring this projected market growth. These systems, by their nature and scale, provide system-level R&D opportunities that historically were limited to major prime contractors with large manufacturing capacities. Larger corporations such as Boeing, Lockheed Martin, and Northrop Grumman are indeed engaged in developing and producing UAVs and AUVs. One of the largest and best known developers of UAVs is General Atomics Aeronautical Systems, a private corporation and manufacturer of the well-known Predator UAV. These larger companies likely dominate the R&D expenditures, but many smaller companies are also engaged both as subcontractors and primes in significant efforts in these technological areas. Kaman Aerospace, whose annual aerospace R&D investment is less than 1% of its partner Lockheed Martin, has developed key components of the K-MAX autonomous helicopter platform recently selected for full deployment. As in other industries, the R&D capabilities inherent in these small to mid-sized firms make them attractive acquisition targets for larger corporations. Airborne Technologies, a small UAV developer and manufacturer, was acquired by L-3 Communications last year as L-3 sought to broaden its capabilities.

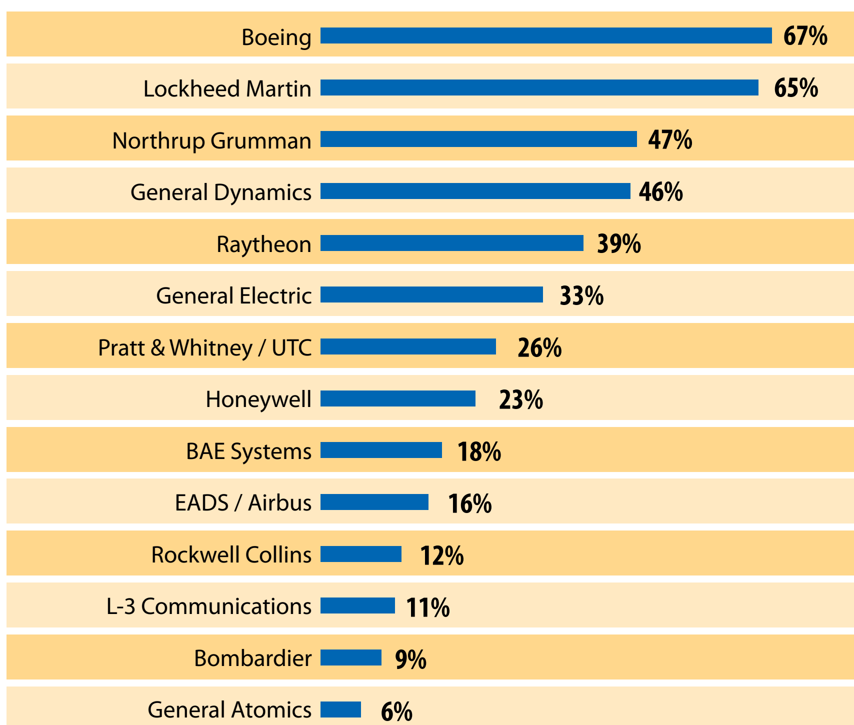
Early-stage R&D efforts in these technologies, along with efforts in other sensor and monitoring technologies, cybersecurity, nanotechnology and advanced materials, biofuels, and medical technologies, will see continued defense R&D funding, for which numerous smaller firms may see a more level playing field over the next five to 10 years.

Key Aerospace/Defense Technology Development Areas by 2014



Source: Battelle, *R&D Magazine* Survey

Global Industry Leaders in Aerospace / Defense R&D



Source: Battelle, *R&D Magazine* Survey

Industrial R&D—Energy

Industrial R&D in the energy sector comprises a broad portfolio of technologies, including fossil, nuclear, and renewable generation; smart grid or other transmission and distribution; and energy-efficiency technologies. Energy-related research sponsored by U.S. utilities, manufacturers, and technology providers will reach nearly $6.7 billion in 2012. This remains a much smaller level of investment than other innovation-based segments of the economy, and it is also small in comparison to energy's major role in U.S. GDP and national security. Even so, industrial energy R&D investment is growing, and it will continue to be shaped by external forces including federal policies and energy investments, supply and demand in the global energy market, and technology developments.

Blueprint for U.S. Energy R&D

At least as much as any other sector except perhaps life science, federal research, funding, regulation, and energy policy have a significant influence on industrial energy R&D. In September 2011, the U.S. Department of Energy (DOE) released a review panel's findings on prioritizing energy R&D and programmatic efforts. This report, the *Quadrennial Technology Review* (QTR), provides a blueprint for the direction and future of U.S. energy R&D. The *QTR* identified six key R&D areas where DOE program and investment can play a significant development role, including a number where DOE has historically underinvested. The six areas address both energy supply and demand and relate to both stationary power (deploying clean electricity, modernizing the grid, and increasing building/industrial efficiency) and transport power (deploying alternative hydrocarbon fuels, electrifying the vehicle fleet, and increasing vehicle efficiency). The *QTR* calls on DOE to "maintain a mix of analytic, assessment, and fundamental engineering research capabilities in a broad set of energy-technology areas" while seeking to "balance more assured activities against higher-risk transformational work." The *QTR* also notes that these efforts must be relevant to the private sector, while recognizing that "(t)here is a tension between supporting work that industry doesn't—which biases the Department's portfolio toward the long term—and the urgency of the Nation's energy challenges."

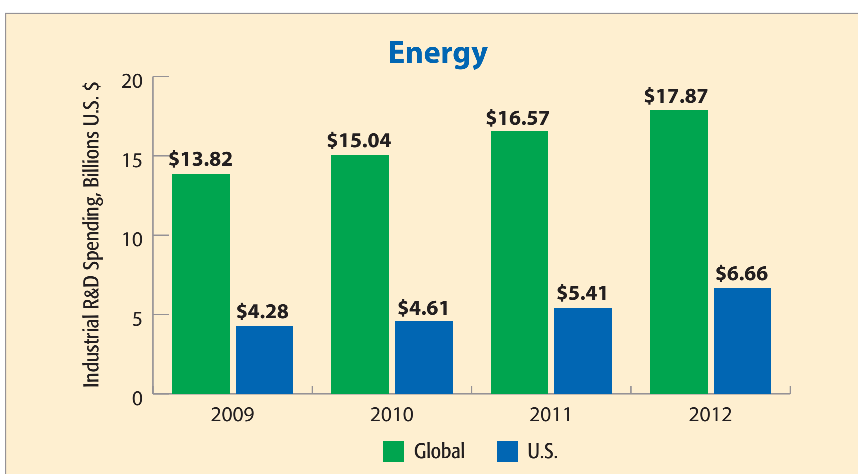
Utilities' Role in R&D

In this 2012 assessment of energy industry R&D, we have included public electrical power utilities (also known as electric investor–owned utilities or IOUs). Unlike most public companies that engage in R&D activities, public utilities have different financial reporting requirements. As a result, they do not detail the level of their R&D activities, making it more difficult to describe these firms' efforts versus public technology companies or DOE energy investments.

To gauge the size of public utility R&D activities, we estimated the overall recent R&D expenditures by public electric utilities. This estimate is constructed using data reported in the *Electric Light & Power* journal nearly a decade ago, yet still among the

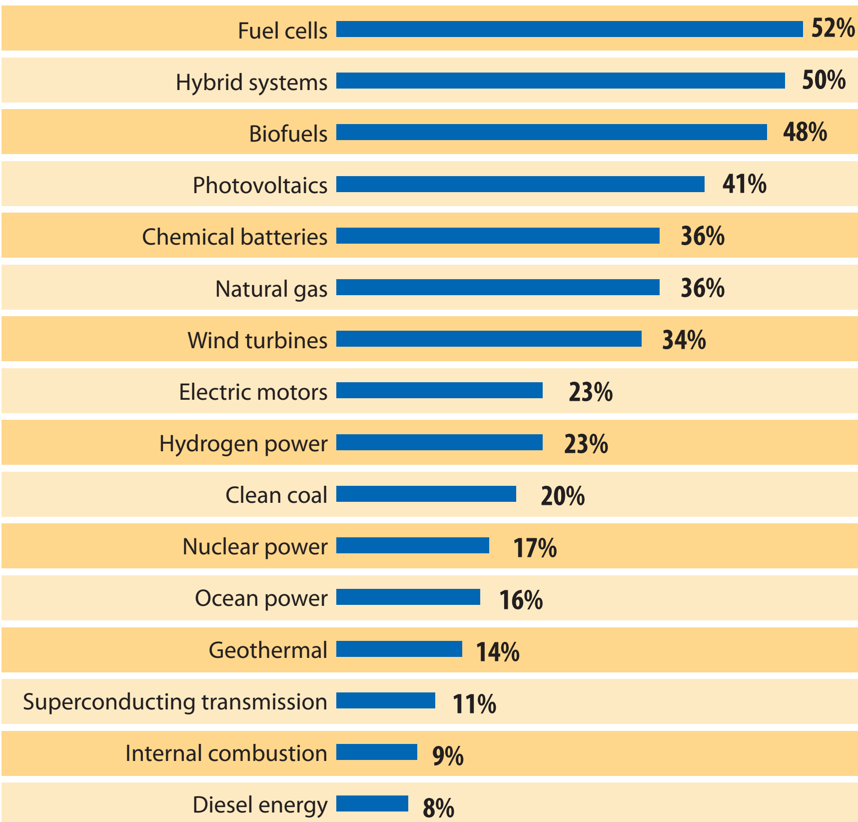
Energy	2009	2010	Q1-Q3 2011
Top U.S. R&D Expenditures	Millions, U.S. $		
GE - Energy Infrastructure (e)	1,531.1	1,741.3	1,425.3
Exxon Mobil	1,050.0	1,012.0	963.4
Chevron	603.0	526.0	497.2
ConocoPhillips	190.0	230.0	218.6
Itron	122.3	140.2	120.0
USEC	118.4	110.2	86.2
Cree	75.1	95.9	95.5
First Solar	78.2	94.8	102.6
Babcock & Wilcox	53.2	69.2	74.5
A123	48.3	60.7	57.0

Source: Battelle/*R&D Magazine* and Company Information; (e) = estimated



Source: Battelle, *R&D Magazine*

Key Energy Technology Development Areas by 2014



Source: Battelle, *R&D Magazine* Survey

2012 EPRI Research Portfolio	Millions, U.S. $
Environment	$35.2
Including research into water and ecosystems, air quality, global climate change, and other environmental issues	
Generation	$55.9
Including major component reliability, environmental controls, advanced coal plants, carbon capture/storage, renewables, and other generation issues	
Power Delivery & Utilization	$58.6
Including transmission lines, distribution, energy utilization, grid operations and planning, and other power delivery issues	
Nuclear	$129.2
Including materials degradation and aging, equipment and fuel reliability, NDE and material characterization, advanced nuclear technology, and other nuclear issues	
Total	$278.9

Source: Battelle, *R&D Magazine*

most recent regarding electric IOUs' R&D investment. These data, combined with both historic and current data on the utilities' net income, provide some perspective on investment levels. Based on available data, we estimate that electric IOUs currently invest between 1.5% and 2.2% of net income on R&D activities. By applying these investment levels to 2009 industry net-income data (the most recent available from the Energy Information Administration), our estimate of R&D investment from the public electrical power utilities ranges from $478 million to $701 million.

We also wanted to promote understanding of the many energy-related R&D activities in which utilities participate. Though little information is available from the individual utilities, an examination of the planned 2012 Research Portfolio of the Electric Power Research Institute (EPRI) provides some insights. EPRI conducts R&D related to the generation, delivery, and use of electricity, with membership representing more than 90% of the electricity generated and delivered in the U.S. It was founded to allow utilities to pool their resources in order to perform industry-relevant R&D. With a total budget of $279 million, EPRI represents, according to its annual Research Portfolio, a likely significant share of overall industry R&D. EPRI is also partnering with the DOE's Advanced Research Projects Agency-Energy (ARPA-E) to provide test-bed facilities relating to transmission and distribution research and electronics/smart grid component testing.

Private-Sector Renewable R&D

As shown in the Top U.S. companies table, GE Energy Infrastructure leads all U.S. firms in energy-related R&D. With its substantial investments in wind and solar technology, GE also likely leads the U.S. in private-sector investment in specific renewable energy technologies.

Beyond GE's Energy Infrastructure segment, there are other U.S. firms reporting significant growth in R&D relative to their size. First Solar, one of the three largest global pure-play renewable energy companies in terms of R&D efforts, will significantly exceed its 2010 R&D investments. In fact, it had already surpassed its 2010 investments by nearly $6 million through the first three quarters of 2011. Both A123 and Advanced Energy Industries are also on track to substantially exceed their 2010 investments. This growth in U.S. private-sector renewable R&D, combined with significant research efforts within the DOE national laboratories and academia, keeps the U.S. among the global leaders in renewable energy R&D and innovation. As with other research intensive segments of the economy, commercializing this research activity into a competitive domestic manufacturing capability, and ultimately deploying the technologies to diversify U.S. energy inputs is the ultimate challenge.

Industrial R&D—Chemicals/Materials

The development of new and advanced materials is often the driver for other industries, such as those involving semiconductors, composites, thin films and coatings, medical devices, chemical and environmental processes, energy systems, and biopharmaceutical products. R&D for these materials involves developing new characteristics, properties, processing capabilities, and entirely new chemical families that could create whole new industries.

Added recently to this list of research priorities is the creation of alternative sources or processes to adjust for naturally or artificially diminishing supplies of materials for existing essential products. The case in point is China's recent export limits on rare earth metals for politically motivated reasons—to maintain supplies for local industries and to limit development of competitive non-Chinese manufacturers.

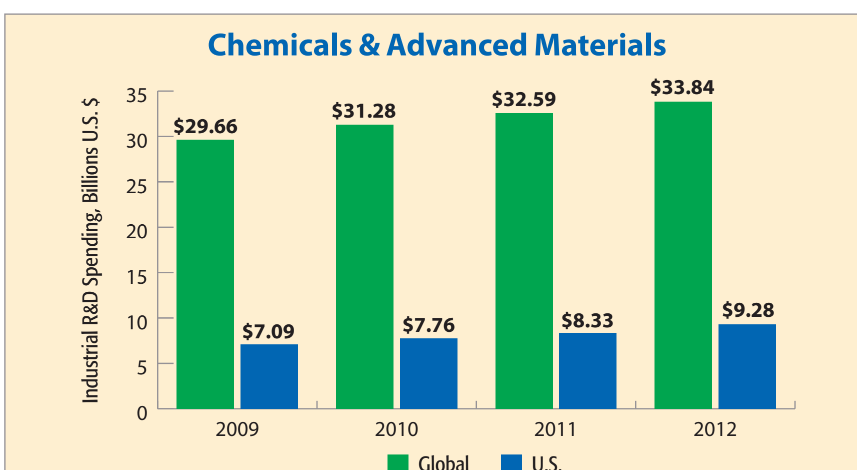
Sole Source Problems

Rare earth metals, such as lanthanum, cerium, praseodymium, neodymium, samarium, europium, terbium, dysprosium, and yttrium are essential materials used in state-of-the-art magnets, batteries, lighting-based phosphors, and for national defense applications. Product developers spent billions of dollars and tens of years on these products whose performance relies on the incorporation of rare earth metals. The majority of these metals are currently mined in China, following the closure of alternative non-Chinese sources over the past 15 years due to China's significantly lower-cost structures. Several federal R&D programs, mostly at the U.S. Department of Energy (DOE) have been established to address the component, end-use, economic, and technology innovation stages of rare earth metals. These programs range from basic research to large-scale technology deployment and span the entire innovation pipeline. In FY2010, for example, the DOE's Office of Science and the Advanced Research Projects Agency-Energy (ARPA-E) provided $15 million for research on rare earth metals and possible substitutes for magnets. ARPA-E spent another $35 million on next-generation battery technologies that do not require rare earth metals. In the industrial sector, closed non-Chinese rare earth mines are being re-opened; however, the environmental requirements for operating these mines have increased since they closed, making additional R&D and capital expenditures necessary to develop new and improved processing programs.

The European Union (EU) and countries including Japan, South Korea, Australia, and Canada, have instituted active R&D programs associated with rare earth metals sourcing. These programs include substitution research; increased material efficiency programs; use of renewable materials; processes for recycling depleting materials; the study of consumption patterns; in-depth studies of rare earth metallurgy, properties, and basic chemical sciences; and the development of innovative mining processes. For its part, China has further prohibited foreign

Chemicals & Advanced Materials	2009	2010	Q1-Q3 2011
Top U.S. R&D Expenditures	Millions, U.S. $		
Dow Chemical	1,492.0	1,660.0	1,213.0
DuPont	1,378.0	1,651.0	1,418.0
3M Co.	1,293.0	1,434.0	1,191.0
PPG Industries	388.0	394.0	321.0
Goodyear Tire & Rubber	337.0	342.0	328.0
Honeywell - Advanced Materials (e)	178.3	207.6	185.8
ALCOA	169.0	174.0	136.0
Huntsman International LLC	145.0	151.0	123.0
Eastman Chemical Co.	137.0	145.0	116.0
Air Products & Chemicals	110.3	116.7	89.6

Source: Battelle/*R&D Magazine* and Company Information; (e) = estimated



Source: Battelle, *R&D Magazine*

involvement in rare earth mining, created rare earth production quotas, and placed a moratorium on new rare earth mining permits. China also briefly curtailed all rare earth production to maintain high pricing levels when the mid-2011 economic slowdown reduced demand for the materials.

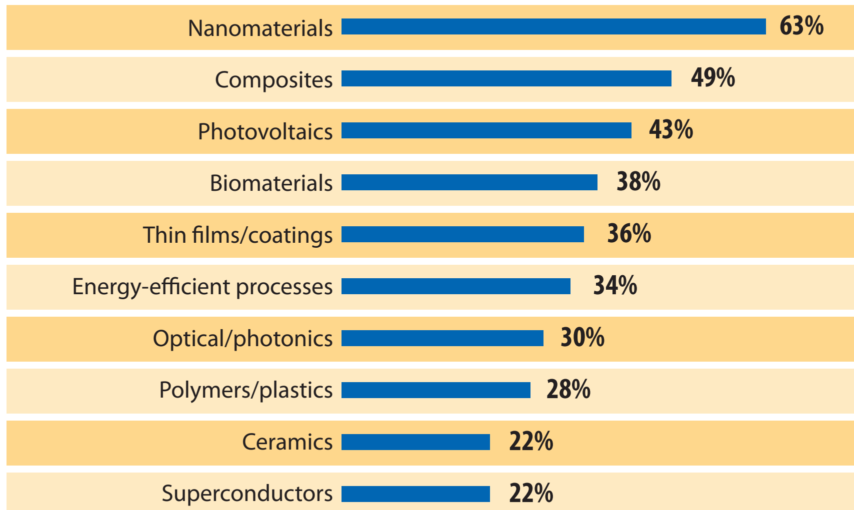
Nanotech Opportunities

Nanotechnology and its applications continue to pervade all industrial applications, with biomedical applications beginning over the past two years. The Alliance for Nanotechnology in Cancer of the National Cancer Institute (NCI), for example, recently created a public-private industry partnership—Translation of Nanotechnology in Cancer, or TONIC—to promote translational R&D opportunities of nanotechnology-based cancer solutions. An immediate consequence of this effort is the formation of a consortium involving government and pharmaceutical and biotech companies. This consortium will evaluate promising nanotech platforms and facilitate their successful translation from academic research to clinical environment, resulting in safe, timely, effective, and novel diagnoses and treatment options.

Continued research investments by more than 15 agencies of the U.S. government are led by the DOE ($611 million), NIH ($465 million), NSF ($456 million), DOD ($368 million), and NIST ($116 million) accounting for nearly 95% of the total $2.13 billion proposed for FY2012. These investments are spread out over the study of fundamental phenomena and processes (24%), nanomaterials (21%), nanoscale devices (27%), instrumentation research (4%), nanomanufacturing (6%), facilities (9%), environmental (6%), and education (3%).

The National Nanotechnology Initiative (NNI) oversees the guidance and monitoring of these investments. In FY2011 and again in the FY2012 budget, the Obama administration identified three signature initiatives as deserving increased R&D funding—nanotechnology for solar energy collection and conversion ($126 million in R&D funding in FY2012), sustainable nanomanufacturing ($84 million), and nanoelectronics for 2020 and beyond ($98 million).

Key Materials Technology Development Areas by 2014



Source: Battelle, *R&D Magazine* Survey

As a small part of the last initiative, the Semiconductor Research Corporation (SRC) recently joined with the NSF to announce $20 million in funding for nanoelectronics research. The goal of this research is to discover and develop a new switching mechanism using nanoelectronic innovations as a replacement for the current transistor. Along with 12 interdisciplinary research teams at 24 participating U.S. universities, the following companies will participate in this program: Global Foundries, IBM, Intel, Micron Technology, and Texas Instruments. These companies assign researchers to interact with the university teams. Such interaction will be instrumental for the Nanoelectronics Research Initiative to reach its goal of demonstrating feasibility in simple circuits during the next five to 10 years.

Additional Avenues

The NSF recently expanded its Materials Research Science and Engineering Centers (MRSEC) with the addition of centers at Columbia University (nanoscale composites), the University of Texas at Austin (metal oxides), and the University of North Carolina at Chapel Hill (polymers). These combine with nine existing NSF-sponsored MRSECs that focus on such areas as spintronics, liquid crystals, and programmable assembly of soft matter to foster active materials research collaborations among universities, international collaborators, industry, and national labs. These centers are designed to promote next-generation materials and phenomena for national needs in sustainability and innovation.

These and other research initiatives provide continuing support for strong U.S. materials science innovations. As an indicator of that excellence, the latest Thomson Reuters ranking that identifies the world's top materials scientists lists 50 U.S. researchers. The ranking is based on those scientists who achieved the highest citation impact scores for their articles and reviews over the past 10 years. U.S. researchers accounted for eight of the top 10 materials scientists in this study and 18 of the top 25.

Though the U.S. dominates in the criteria of this particular ranking, its overall share of all materials science publications has dropped from 28% in the early 1980s to 15% now, according to Thomson Reuters studies. China has grown from insignificance in 1981 with less than 50 papers published, to become the largest single-country producer, overtaking Japan and the U.S., and currently challenging the combined output of the EU-15 group of well-established European research economies.

Links to Basic Research

About 18% of all R&D performed in the U.S. is basic research, with academia having the largest share (60%). For the past 50 years, academia has had the largest share of basic research work. However, in the past, industry and government researchers each had about a 10% larger share of this work than they do now. Industrial basic research laboratories like Bell Laboratories and Xerox have long since shut down or scaled back, and the federal government has also cut back on intramural R&D in favor of contracts and grants to universities and companies. Surprisingly, the amount of basic research performed in the U.S. (as defined by the NSF) has about doubled as a share of all R&D over the past 50 years. U.S. R&D managers now rely on academia to an even larger degree for the breakthrough innovation that will lead to next-generation products and entirely new industries.

		R&D Performance				
	Share of All R&D	Industry	Federal Government	Academia	Non-Profit	Total
Basic Research	18%	20%	7%	60%	13%	100%
Applied Research	22%	72%	8%	13%	7%	100%
Development	60%	91%	6%	1.5%	1.5%	100%
All R&D	100%	72%	8%	16%	4%	-

Source: NSF, 2008 National Patterns

U.S. & Europe Dominate Rankings

Considering the increased importance of academia as the majority performer of basic research, the quality of universities in each region is critical to understanding the global R&D landscape.

U.S. and European universities top *The Times Higher Education World University Rankings, 2011–2012*. These scores of the top 400 universities were developed with data from Thomson Reuters and expert input from academic leaders in 15 countries. The rankings employed performance indicators covering teaching, international outlook, income from industry, research, and citations. Of the top 50 universities in this year's rankings, 30 were from the U.S., 11 from Europe, four from Asia, and three from Canada—essentially unchanged from last year. Topic-targeted rankings had similar distributions with slight differences reflecting current technology trends and regional technology strengths. Of the top 50 engineering and technology schools, the U.S. had 22, Europe had 11, and Asia had 13. Of the top 50 life science schools, the U.S. had 27, Europe had 17, and Asia had four. And, of the top 50 physical science schools, the U.S. had 21, Europe had 18, and Asia had eight.

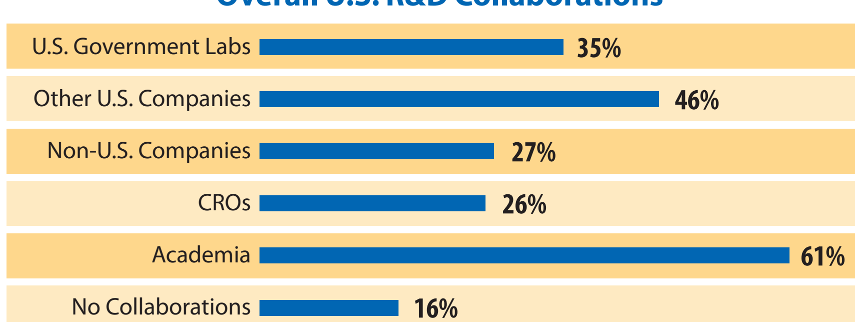
Research capacity does not always correlate with the *Times* ranking—Johns Hopkins University consistently has the largest R&D budget ($1.9 billion in 2009), but was ranked #14, behind #13-ranked UCLA, which had the fifth-highest R&D budget with $890 million. Of the top 20 university R&D spenders, UC-Berkeley had the highest *Times* ranking (#10), but was ranked #17 in R&D spending with $652 million.

Asian Aspirations

Of the top 400 universities in the *Times* rankings, Asia had 50, with the University of Tokyo the highest ranked (#30) and only four in the top 50 (University of Tokyo, University of Hong Kong, National University of Singapore, and Peking University). China had 10 universities in the top 400 (along with six from Hong Kong), and India had only one (Indian Institute of Technology, Bombay).

China has made great efforts to enhance its academic program, especially in basic research, with its "973 Program," first approved by the Chinese government in 1997. Details of China's 12th Five-Year Plan (2011 to 2015) were released this past summer and noted that one of the government's key programs over the next five years is to provide more sophisticated, higher-level education with an emphasis on scientific achievement. Its seven Strategic Emerging Industries (SEIs), are closely linked to basic and applied research investments in academia and include clean energy technologies, next-generation IT, biotechnology, high-end equipment manufacturing, alternative energy, new materials, and clean energy vehicles. Also a key target is the raising of the number of patents it produces from these innovations from the current level of 1.7 patents per 10,000 people to 3.3 patents by 2015.

Overall U.S. R&D Collaborations



Source: Battelle, *R&D Magazine* Survey

R&D in a Globalized World

The following long-term developments are shaping the global distribution of R&D:

- Emerging economies are increasing their global technological presence
- Economic issues in established economies limit their ability to support R&D
- Established economies are losing their unique tech-opolies
- Sustainability is becoming a competitive advantage
- Energy has created new technology opportunities and hazards
- Rapid technology innovation is creating a more knowledge-intensive world
- Product and technology sourcing has created new techno-politico issues.

Leveling the Playing Field

As noted throughout this report, the newly emerging economies are developing homegrown technologies that often rival—and sometimes exceed—those of established economies. Flush with revenues from manufacturing low-cost, high-value products for the established economies, these emerging economies are slowly increasing their annual investments in R&D infrastructures, education, and intellectual properties. Ten years ago, established economies were dealing with the globalization of manufacturing capabilities to emerging economies, while R&D operations seemed fairly stable. Five years ago, established economies were becoming concerned about R&D outsourcing issues with rationalizations posited to support the development of local markets in the emerging economies. Today, established economies are realizing the negative effects of their globalization efforts in the form of deficit balance of trade, high energy use, and increased government spending. These deficits limit the ability to invest in infrastructures and restrict long-term growth.

This globalization is now expanding to even smaller emerging economies such as Malaysia, Saudi Arabia, Indonesia, Thailand, Vietnam, Mexico, and others who look to ramp up their R&D spending and infrastructures. They note that the fastest way to develop long-term growth capabilities is to build a strong R&D infrastructure. Among new trends being established are limitations imposed on previously readily available resources and commercial markets. Examples include China's export restrictions of rare earth metals for which it has a near-monopoly and the development of captive sources for high-technology products that include commercial aircraft, high-speed trains, and spacecraft and space launch vehicles.

Debt Limitations

The economic debt-based problems of the U.S., the EU, and Japan put their R&D establishments and, by direct result, also their country's economic growth prospects in both short-term and long-term peril. In 2012, these three countries will struggle to increase their overall R&D budgets by 2% to 3%. China once again will easily increase its R&D investments by more than 10%; India and Brazil will both increase their R&D spending by nearly 8%; and even Russia is expected to increase its R&D spending by more than 7%.

It is well noted that the U.S. outspends all others in R&D, but the rate differences noted above have continued consecutively for the past five years and reflect the growth in technology prospects that can be expected from China and India in the not-too-distant future. The five-year outlook for emerging versus established global R&D investments also does not show any significant situations that would alter these trends.

Lost Dominance

As noted in this and previous reports, the U.S. and other established economies have a number of well-established high-tech industries that dominate the R&D global landscape. Some of these are supported and maintained by the high quality of universities in these economies, many of which have been in place for more than a century. Other industries are dominated by industrial market leaders, such as the ICT's Intel, Microsoft, Google, Apple, and Cisco. Still others, such as the aerospace and defense industries are dominated by strong government R&D support to Boeing, Airbus, Lockheed Martin, and others.

But, in industries such as chemicals, metals and steel, photovoltaics, nuclear energy, food products, and textiles, production capabilities have been lost to emerging economies, along with their integral R&D, technology, and intellectual property constituents. Still other industries, including pharmaceuticals (which just 10 years ago had unquestioned dominance by U.S. firms), supercomputing, automotive, software, and polymers are in a state of transition with the outcomes still to be decided.

Sustainability is Good

Certain facts—that we live in a world with more than 7 billion inhabitants, with

World's 2,500 Largest Public Corporations by Region

	2000	2005	2010
U.S. and Canada	1,050	1,050	750
Western Europe	750	650	600
Japan	350	300	150
Other Mature Economies	200	300	350
China	0	0	250
Brazil, Russia, India	50	50	150
Other Emerging Economies	100	150	250

Source: Booz and Company

distinctly limited material and financial resources, a changing global environment, and contamination found in every part of the planet—all point to creating living and working environments that are sustainable, and that includes R&D in all its aspects.

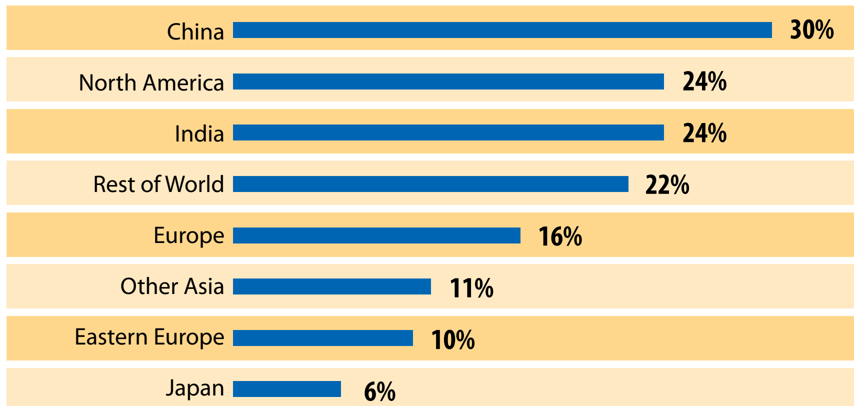
Five years ago, a sustainable approach might have been considered as just being a "good citizen"; today it's considered an essential operating scenario that if sustainable components are not directly required by law, they likely will be soon.

However, the sustainability requirements put in place in established economies often differ from the requirements put in place in emerging economies. Short-term, this disparity creates a potential cost disadvantage for the established economies, favoring the emerging economies. Additionally, the absolute cost differences between sustainable and unsustainable products and operations have yet to be resolved by R&D of new materials and technologies—it remains cheaper in the short-term to conduct unsustainable operations.

Energy Rules

Although U.S. energy consumption is consistent with its share of global GDP, on a per-capita basis, the typical U.S. family uses substantially more energy than that used by the rest of the world. In the U.S., each person uses the energy equivalent of 57 barrels of oil per year, while in China that number is 10 barrels; in Japan, 30 barrels; and in Mexico, 12 barrels. The absolute amount of oil imported in the U.S. has actually dropped slightly each year over the past several years, indicating our reliance on renewable energy, along with increased development of U.S. oil and natural gas sources. It has been noted that with the existing programs in place, the U.S. has become a net energy exporter in 2011. These programs include exporting coal and natural gas to China; the increased development of shale gas sources in the northern plains region of the U.S.; and increased R&D in biofuels, photovoltaics, and wind turbine energy sources.

Where U.S. Firms Plan to Expand R&D Operations



Source: Battelle, *R&D Magazine* Survey

The U.S. energy programs appear to be in place to satisfy, albeit partially, the rest of the world's fair share of the energy sources available.

The Technology Spiral

Of note is the ideal that technology development breeds an ever-increasing flood of new technologies. That scenario is evident in the electronics and ICT industries, with Apple, Intel, and other companies scheduling new product releases based on the expected development and efficient manufacture of new and enhanced product technologies. It is also apparent in the biomedical arena as medical practices and technologies improve, but not on the same time scale as in the ICT industry.

This trend helps established economies, since their R&D organizations are inherently involved in the development of these new technologies, establish product time scales and early on become aware of potential problems and issues. These rapid technology cycles are not so easy for emerging economies. By the time they solve these problems in these rapid technology cycles, and by the time they work out these problems in typical product development, the technology may have been switched to a different operating system, system protocol, or regulatory standard. Technology "windows of opportunity" may have been missed and whole generations of new technologies obviated.

A New Weapon?

Throughout history, withholding essential materials has often been used as an economic weapon to provide an unfair competitive product advantage. Patents, technology licenses, and production agreements are established for situations such as these. Companies that relied on China as their sole source of rare earth metals for their high-technology products, and are now hampered by the recent export restriction, likely should have known better. Japanese automotive companies who relied on sole-source suppliers found themselves in a similar situation when the earthquake and resulting tsunami disabled their sensitive supplier networks.

In a globalized network, the lack of essential components can disrupt supply chains in both manufacturing and R&D environments (although to an admittedly smaller degree with regard to R&D). The loss of thousands of research lab rats housed in the flooded basements of Houston's medical research complex during Tropical Storm Allison in 2001 irreparably damaged specific R&D programs, which took years to recover.

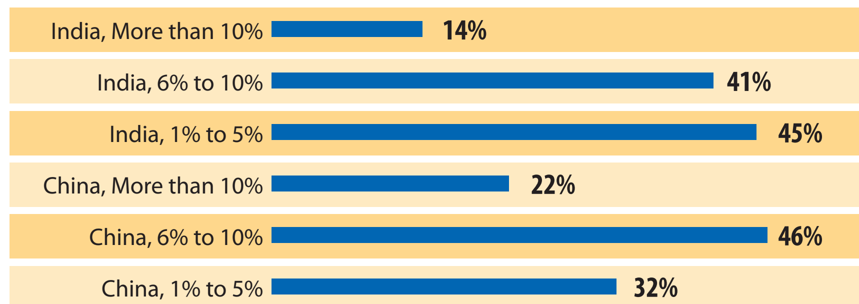
Overall, globalization of R&D should push technology forward at reduced costs and with greater quality and value to the user. Globalization will bring about changes, and the status quo is likely to be altered to the detriment of those who are not properly prepared for the change.

China's R&D Momentum

The media seem to be filled with two perspectives on China's R&D capabilities: (1) comments on its technology accomplishments and (2) attempts to put those accomplishments into perspective. Indeed, China has accomplished much over the past decade. Its spending on R&D has increased steadily from about 0.6% of GDP in 1995 to about 1.6% in 2011. R&D as a percent of GDP has remained fairly stable over the past five years for the U.S. (2.7%), Japan (3.2%), and the total Organization for Economic Cooperation and Development or OECD (2.2%). The U.S. and Japan are members of the OECD.

While China's economy has steadily grown by 9% to 10% over the past several years, its R&D investments have increased annually by about 12%—about seven times the annual percent increase in the U.S. Several years ago, China announced a goal of increasing its R&D as a percent of GDP to 2% by 2010 and 2.5% by 2020. However, its GDP is growing sufficiently fast that even with impressive increases in the rate of R&D spending, investments presently lag the goals that China had set forth.

Expected 2012 R&D Changes



Source: Battelle, *R&D Magazine* Survey

Intellectual Capital Marks Progress

China is making significant gains in intellectual capital as measured by the total volume of patents and in the number of published scientific papers and articles, according to a report by Thomson Reuters. Japan and the U.S. hold the #1 (35%) and #2 (27%) positions, respectively, for the largest combined number of patents granted by the patent offices in the U.S., Japan, Europe (European Patent Office), South Korea, and China (which together administer 75% of all patents worldwide). But China has steadily increased its number of granted patents at these five offices, doubling the number granted to Europe and South Korea, countries with which it held a similar ranking just five years ago.

The technology profile of China's patent portfolio is similar to that of other major patenting countries. Japan, the U.S., Europe, and Korea have similar ratios of patents in IT, audio-visual technology, electrical devices, consumer goods, analysis instruments, agriculture, telecommunications, and chemical engineering. Japan and the U.S. compete for the top two spots in these categories, except for chemical engineering where the U.S. is #1 and China is #2. For its part, China focuses its patents (in declining order) on digital computers, telephone and data transmission systems, broadcasting, radio and line transmission systems, natural products and polymers, and electro-(in)organic materials.

The Chinese government provides a fertile environment for increased patent filings by allowing greater and easier tax deductions for R&D expenses, increasing government-backed loans and discounting interest rates for R&D investments. Also, local city governments have made large monetary grants to the owners of invention patents that had been successfully registered in foreign countries, with a lesser amount paid for patents registered in China.

At the same time, the volume of filings tells an incomplete story. Controversy exists over the depth of innovation typically involved in Chinese patents. An August 2011 report in *The Wall Street Journal* noted that "more than 95% of the Chinese applications were filed domestically with the State Intellectual Property Office, with the vast majority covering innovations that make only small changes on existing designs." The report also noted that China is significantly weaker on patents granted outside of the China patent office.

Publish or Perish

The health of a national research enterprise is a key qualitative factor in projecting future R&D capacity and funding, as well as relative global R&D competitiveness. Publications are an important current and leading indicator.

The Chinese Academy of Sciences (CAS) is equivalent to the U.S. National Academy of Sciences in terms of supporting research within China. Founded in 1949, the CAS has a staff of 54,600 academics with branch offices in 11 cities and more than 100 affiliated institutes throughout China. The CAS is the world's largest science and technology research organization with close to 100,000 staff, technicians, and students conducting research in basic and applied sciences. Despite increasing domestic and international competition, the CAS is contributing more primary research than ever before, according to an article in *Nature*, the international weekly journal of science.

China has increased its annual output of scientific papers to more than 120,000 annually, second only to the U.S. with its 340,000 annual publications. In 2006, China surpassed the scientific papers from Japan, the U.K., and Germany, who have plateaued at about 80,000 publications per year. There have been publicized efforts by the Chinese government to calibrate standards for academic publishing more consistent with Western standards. At most scientific journals, the academic level is not high enough, as Li Dongdong, vice director of the General Administration of Press and Publication (GAPP), noted in a recent article in *Science* magazine. The GAPP regulates China's publications. China publishes about 4,700 scientific periodicals and, though the number of articles published ranks China second, it ranks last in a list of 20 countries polled in citations for articles, with an average of only 1.5 citations per article, according to reports by Elsevier.

The incentive provided to patent holders noted above also applies to lead authors who attain an article impact of at least 15. The incentive is the equivalent of $47,000, but the goal has not yet been attained by a Chinese journal.

R&D > Commercialization > Innovation

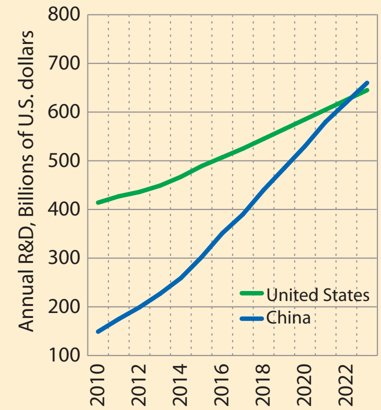
Effective commercialization is essential for establishing sustainable R&D funding and for achieving contemporary expectations for R&D ROI discussed elsewhere in this report. In fact, commercialization funding is a natural part of the funding continuum that begins with investments in basic research and leads to the economic impact of innovation.

Last summer, China's Ministry of Finance announced that it had allocated about $125 million to promote the application of China's R&D results into the commercial sector. The goals were to accelerate the transfer of S&T achievements into production, promote corporate technology innovation, and speed up economic reforms. The allocation is expected to be directed toward projects in key mechanical components and low-carbon, environmentally friendly industries this year. The average subsidy for each project is about $1.2 million, up about 20% from similar allotments last year. The maximum subsidy for any single project can now approach about $7 million.

A recent report by the CAS noted that reform of its research funding system is vital to the growth of innovation in China. The management of government-funded research projects should also be reformed, according to State Councilor Liu Yandong. Liu stated that reform, innovation, and cooperation should be the keys for China's S&T work over the next five years, when the government will increase funding for research in new strategic industries that include new energy, biomedicine, and high-end manufacturing. Over the past five years, China's government spending on S&T has grown annually by about 20%. However, despite the large increases, some researchers complain that problems in the funding system hinder innovation and progress. Inflexibility in the management of government funds allows researchers little freedom to adapt their projects to new developments in their research fields.

The success of China's high-tech commercialization efforts are exemplified by the continued growth of Huawei Technologies, which is now the world's third-largest manufacturer of mobile infrastructure equipment and the fifth-largest manufacturer of telecom equipment. With substantial government support, low manufacturing costs, and strong R&D investments, Huawei has built up a global infrastructure that consists of more than 30,000 R&D employees; R&D centers in Dallas, Bangalore, Moscow, and Stockholm; and established joint ventures with Symantec and Siemens. Huawei is being closely followed by other Chinese manufacturers who also want to grow their global capabilities.

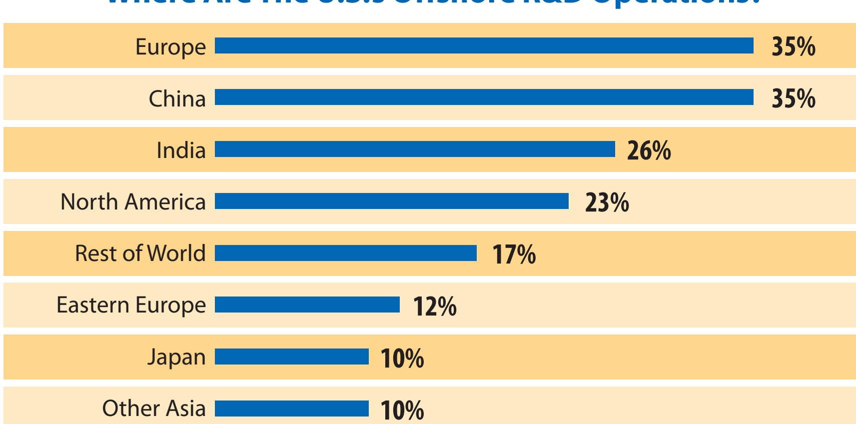
U.S. - China Annual R&D Spending



Source: Battelle, *R&D Magazine*

China's double-digit growth in R&D spending is expected to match and surpass that of the U.S. by about 2023, if several forecasting criteria are maintained. This forecast is based on continued Chinese R&D growth averaging 11.5% per year and U.S. R&D growth averaging about 4.0% per year for the next 13 years. Present U.S. R&D annual growth is only about 2.1%, but has been more than 6% over the past 15 years. China's R&D growth over the past 15 years has consistently exceeded 10%.

Where Are The U.S.'s Offshore R&D Operations?



Source: Battelle, *R&D Magazine* Survey

The Asian Machine

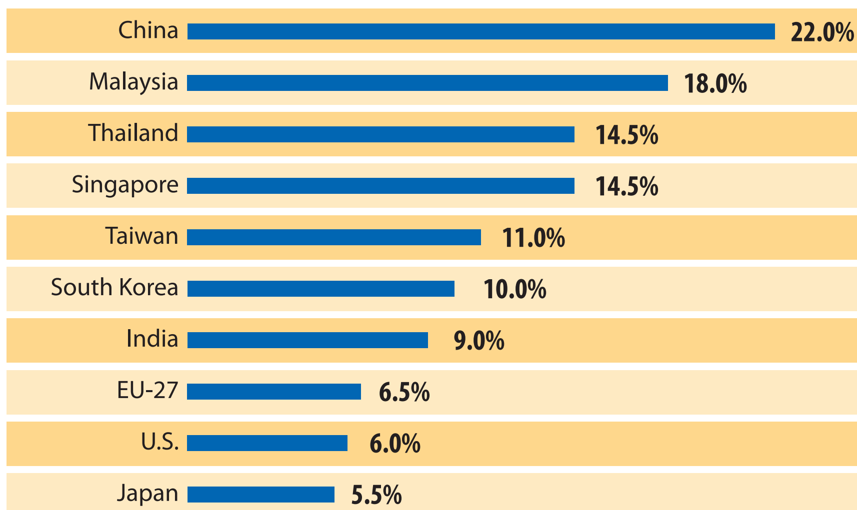
Many people call this the Asian Century because of the rapid economic, population, and technology growth in this area and the trends forecast for the next several decades. Asia has the world's largest regional gross domestic product (GDP), with its share currently at about 38% and increasing at about 1% per year. Its population is expected to continue driving GDP growth, with nearly two-thirds of world population expected to live in Asia by 2025. Also, led by China's double-digit annual R&D spending increases, the region's share of the world's R&D investment is expected to surpass that of the Americas—the current global region leader—in 2012 without slowing down. This R&D growth reflects spending by domestic and foreign firms, along with public spending.

The growth in Asian R&D also reflects the output of scientists and engineers from its growing educational system. The combined number of researchers from South Korea, Taiwan, China, and Singapore increased from 16% of the total number of global researchers in 2003 to 31% in 2007. Over the same period, the U.S. share dropped from 51% to 49%, and Japan's share dropped from 17% to 12%.

Publication of scientific papers and articles is also increasing, with annual growth rates from the eight largest countries in Asia increasing by about 9% annually and 16% in China—U.S. and European increases in the publication of scientific papers and articles is only about 1% per year.

The 16 members of the Association of Southeast Asian Nations (ASEAN)—consisting of Indonesia, Malaysia, the Philippines, Singapore, Thailand, Brunei, Myanmar (Burma), Cambodia, Laos, and Vietnam; ASEAN+6, consisting of China, Japan, South Korea, India, Australia, and New Zealand—now represent the world's largest economic bloc and have instituted inter-Asian free-trade agreements that are forcing the EU and the U.S. to reconsider their own trade agreements.

Average Annual R&D Growth, 1996 to 2007



Source: Battelle, *R&D Magazine*

Trying Harder

As a full member of the Asian community, Japan has the third-largest economy in the world (it was #2 until it was overtaken by China in 2010) and the third-largest total R&D investment (overtaken by China in 2011). Japan's R&D infrastructure is also on a par with that in the Americas and Europe, with a continued R&D investment as a share of GDP of about 3.3%—a full half point higher than that spent in the U.S. and consistently higher than that of all other countries in the world except Israel. Of course, Japan has had national-scale challenges that affected its overall ability to grow its technology investments. First, its economy stagnated from the early 1990s to the present. Then its population demographics shifted to a larger ratio of senior citizens. Finally, the 2011 earthquake, tsunami, and resulting nuclear plant issues that occurred disrupted manufacturing and research, as well as national infrastructure. Still, its investments have continued, demonstrating that Japan recognizes value in both long- and short-term product development.

Some smaller, newer-emerging Asian economies, recognizing the inherent value of creating a domestic R&D infrastructure, have made strong commitments to building their R&D capabilities. For example, nine of the 16 member countries in the ASEAN+6 are in the list of the Top 40 R&D spending countries. The average annual R&D growth from 1996 to 2007 for at least seven of the 16 ASEAN+6 countries (India, South Korea, Taiwan, Thailand, Singapore, Malaysia, and China) exceeded that of the U.S., the EU-27, and even Japan. These spending trends are expected to continue through at least 2020.

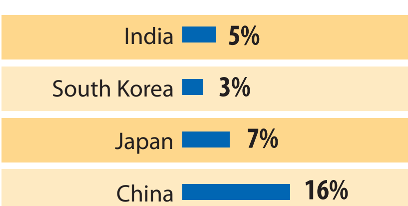
Along with increasing their overall R&D investments, emerging Asian nations are creating incentives for domestic and foreign organizations to perform research in their countries. Indonesia, for example, has regulated benefits including tax incentives, trade incentives, or technical assistance for businesses, whether private companies, state-owned companies, or cooperatives, that allocate a portion of their profits to research. Indonesia has set a long-term goal of increasing its R&D investment from less than 1% of its GDP to 3%.

Many Asian countries admit that "continued annual investment increases of 8% to 10% is a very tough job," according to Taiwan's President Ma Ying-jeou. Taiwan is a good example of a nation dependent on innovation for growth. Despite Taiwan's shortage of natural resources and frequent natural disasters such as earthquakes and typhoons, it needs to make this level of investment to avoid falling behind in the Asian region as well as the world.

Lowering Risks

Partnering with research organizations in other countries has proven to be advantageous for Asian emerging economies and for companies in established economies as well. South Korea and the U.S. recently agreed to collaboratively develop research in green transportation systems, smart

Percent of U.S. Firm's with Asian R&D Collaborations



Source: Battelle, *R&D Magazine* Survey

grid technologies, energy efficiency, renewable energy, and energy storage systems. The expected exchange in scientific and technical research will promote and advance joint investigations and development projects through organized workshops and direct bilateral cooperation.

The joint initiative and increased economic ties will work to accelerate development of lithium battery manufacturers in South Korea, who have been growing their market share and competing with Japan for global leadership in this technology. Interestingly, some of these investment funds could come from the recent U.S. American Recovery and Reinvestment Act for grid modernization, of which $4.5 billion was allocated, along with $185 million for energy storage and demonstration. The Chinese government also developed a long-term stimulus plan to invest in smart grid technologies and electrical power infrastructure projects.

The U.S. is also collaborating with India on development of clean technologies by setting up a joint R&D center, the first by the U.S. DOE with a foreign country. R&D at the center is expected to focus on building efficient solar energy systems and advanced biofuels, again the first of this kind made by the DOE with a foreign government. Obvious concerns need to be overcome in this type of program, especially where the government presently restricts sourcing of solar energy systems for India from outside the country. Solving these types of restrictive issues is important for India because its energy requirements are estimated to increase 40%—from a current 23.8 quadrillion BTU in 2010 to 33.1 quads in 2020.

For its part, China has established thousands of science and technology collaborations and partnerships, many with the EU and its member countries. These collaborations cover the gamut of R&D fields, including automotive, aerospace, pharmaceuticals, materials, electronics, and basic research.

Nature Publishing Index – Asia-Pacific

Rank	Country	Count*	Articles
1	Japan	164	254
2	China	66	149
3	Australia	38	124
4	South Korea	25	68
5	Singapore	11	41
6	New Zealand	6	26
7	Taiwan	3	17
8	India	1	9
9	Bangladesh	1	1
10	Thailand	1	7

* Corrected measure for multiple authors/countries
Source: *Nature* magazine

Malaysia and Indonesia

In this forecast, Malaysia and Indonesia are new to the Battelle/*R&D Magazine* listing of Top 40 Global R&D spending countries. While both countries have relatively small investments in R&D (Malaysia, 0.7% R&D as a percent of GDP, and Indonesia, 0.2%), they have identified R&D as the main driver for developing their economies. Malaysia is banking on technology, either home-grown or imported, to help realize added economic value from its vast natural resources. It has singled out biotechnology as the key strategic area for development and investment and has established the Malaysian Biotechnology Corporation to support these efforts. With the largest economy in Southeast Asia and the world's fourth-largest population, Indonesia, a member of the G-20 major economies, has also targeted R&D as its key economic driver. Its national R&D efforts were severely reduced following its financial crisis in the 1990s and have hardly increased since then. However, President Yudhoyono noted that the current R&D investment is twice what it was five years ago and that the government will continue to increase its R&D budget ratio to reach more than 1% of its GDP.

Euro Research Keeps Pace

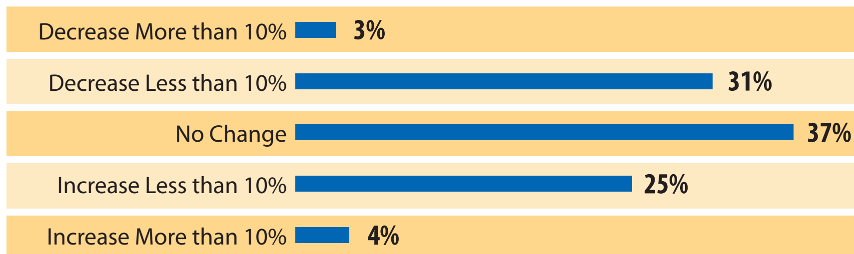
The European Union (EU), one of the "R&D Triad" regions along with the U.S. and Asia, consists of 27 countries and three candidate countries (Croatia, Macedonia, and Turkey). The EU and 11 other countries all participate in the European Commission's (EC's) Seventh Framework Programme (FP7) for Research and Technological Development—which runs from 2007 to 2013 with a budget of about $10 billion per year. The success of these research programs is expected to result in extended funding of about $15 billion per year for FP8, which is scheduled to run from 2014 to 2020, and for which planning is now proceeding. The EU expects FP8 to grow the region's annual gross domestic product (GDP) by more than $100 billion and create about 175,000 short-term jobs and nearly 450,000 long-term jobs, while keeping pace with research activity in the U.S. and China. Launched in 1984 to fund European research, each FP has been larger and more comprehensive than its predecessors.

R&D Programs

The EU's biggest-ever R&D funding package, consisting of nearly $10 billion of FP7 grants, was made this past summer to about 16,000 recipients, with special attention for small and medium enterprises. The EU has generally been successful with research programs, which include the European Space Agency, the European Laboratory for Particle Physics (CERN) and the Large Hadron Collider, the European Molecular Biology Laboratory, and the European Science Foundation.

Even as the EU itself is threatened by the weak economic conditions globally and within some member states, the turmoil does not seem to have affected R&D funding. While the EU has the smallest share of the Triad's global R&D investments (24%), it has the largest proportion of Top 40 R&D spenders (21). Even EU countries that are economically stressed or have had EU-sponsored bailouts are members of the Top 40 (Ireland, Greece, Portugal, and Italy). To be sure, there are large variations in research intensities in the EU, from 0.5% gross expenditure on research and development (GERD)/GDP ratios (Bulgaria, Slovakia, and Cyprus) to 3.5% (Finland) and 3.64% (Sweden).

Expected Change in 2012 European R&D



Source: Battelle, *R&D Magazine* Survey

R&D Distribution

Europe's structure of R&D funding and performance is different than that in the U.S. Varying according to the degree of socialization in various regions of the Europe, about 36% of the total R&D funding comes from government sources, ranging from just 22% in Switzerland, where 70% is provided by industrial sources, to 62% in Romania, where just 33% comes from industrial sources. Performance of R&D in government laboratories also varies greatly, from just 2% in Switzerland to 36% in Poland. While most of Europe's R&D is performed in industrial laboratories, this share also varies, from just 24% in Turkey, where nearly 70% is performed in academia, to 74% in both Sweden and Switzerland.

Consistent with trends in international collaboration discussed elsewhere in this report, the EU is expanding its collaborations with Asia, with more than 30 major R&D agreements now in place with China and more than 200 R&D projects per year. The China–EU Science and Technology Partnership Scheme (CESTYS) was signed in Prague in 2009 to provide the foundations for co-funded research projects. Other China–EU agreements include the joint energy development programs with China's Ministry of Science and Technology (MoST) and the Directorate General for Research (DG-RTD) research programs on ICT, life sciences, materials, and geosciences. Strategic China–EU summits on various topics are held several times each year. The EU has also signed numerous science and technology agreements with Russia. All of these collaborations are made to strengthen intercountry cooperation and facilitate the two-way flow of students and scientists.

In 2000, EU leaders set a goal for investing 3% of their combined GDP in their total R&D spending by 2010. While this goal was constantly focused on for several years, it became readily apparent by 2006 that it would not be met. Indeed, the actual ratio for 2010 was only 1.91%. The successful and growing FP and the somewhat limited industrial-academia research institute Joint Technology Initiatives (JTI) have created the start of a balanced investment portfolio of small (FP) and large (JTI) research programs. Initial JTI research involves medical, computer, energy, environment, and materials programs.

Engaging the Global Researcher

This year we again approached the global researcher community, as identified through recent science and engineering publications, armed with an improved survey and sampling methodology to further clarify the nature of global R&D activities from the perspectives of the researchers themselves.

Global Respondent Profile

We received completed surveys from 713 respondents representing 63 countries, compared with 38 countries last year. Similar to last year, the U.S. respondents were the single largest responding group. However, this year they represented only 41% of the respondents, compared with 53% of the 378 respondents last year. Except for the U.S., the larger responding countries included Canada, China, Germany, India, Japan, South Korea, Sweden, and the U.K. Our responses from the Russian Federation declined somewhat this year, but our responses from the Middle East and South America increased. Considering both language and Internet/Web-related issues, the respondent base compares favorably with the list of leading R&D countries detailed earlier in this forecast.

The respondents represented all types of research organizations. Fully 40% came from the global academic community. Corporate researchers accounted for 39% of the respondents. Of this 39%, nearly two-thirds were with a multinational corporation (25% of all respondents), with the remaining corporate respondents working for a domestic corporation. Research institutes and other research organizations accounted for 14% of the respondents, and government researchers accounted for 7%.

Beyond the global distribution of researchers, we also examined the nature of the research activities they performed. More than half (54%) of the respondents described their research as applied research, and 23% described their activities as basic research. Only 12% described their R&D activities as primarily development. Finally, an additional 12% described their involvement as more of a consulting, technical service, or other R&D supporting function (such as statistics or informatics). Our survey revealed one unique perspective from the respondents: though academia accounted for the largest share of all basic

Critical R&D Challenges for 2012 by Institution Type

Challenges	Total, All Researchers	Academia/ University	Research Institute	Government	Domestic Corporation	Multinational Corporation
Limited external funding	33%	46%	28%	44%	31%	16%
Limited internal budget	33%	32%	28%	44%	34%	35%
Acceptable R&D ROI	21%	13%	21%	17%	23%	33%
Interdisciplinary research	21%	25%	24%	21%	17%	14%
Skilled worker shortages	21%	23%	17%	23%	18%	20%
Development time	20%	15%	15%	21%	26%	29%
Competition	19%	17%	15%	10%	23%	26%
Cost-savings requirements	18%	13%	22%	29%	13%	24%
External collaboration	17%	19%	23%	25%	18%	9%
Technology solutions	15%	11%	14%	10%	22%	18%
IP protection	13%	11%	13%	8%	15%	15%
Ability to measure R&D ROI	12%	9%	11%	4%	8%	22%
Cost of instrumentation	12%	17%	11%	13%	10%	6%
IP management	10%	9%	8%	2%	14%	12%
Internal collaboration	9%	7%	11%	13%	9%	13%
Globalization	8%	7%	9%	2%	9%	11%
Open innovation efforts	8%	7%	10%	2%	6%	13%
Product prioritization	7%	2%	4%	4%	9%	17%
Inflation costs	6%	5%	7%	10%	7%	4%
Outsourcing	5%	3%	5%	4%	7%	9%

Source: Battelle Survey

Key Global Issues of Importance Impacting Future R&D Efforts by Technology/Research Area

Agriculture/Food Production	Global food supply	Governments' understanding of science & technology issues	Sustainable development
Automotive/Other Motor Vehicle	Demand for renewable & sustainable energy	Carbon constraints and CO_2 capture/management	New/Replacement transportation infrastructures
Commercial Aerospace, Rail, & Other Non-Auto. Transport	Sustainable development	Climate change/ Global warming	Demand for renewable & sustainable energy
Military Aerospace, Defense & Security	Global terrorism	Governments' understanding of science & technology issues	Border security
Composite, Nanotech, & Other Advanced Materials	Demand for renewable & sustainable energy	Governments' understanding of science & technology issues	Sustainable development
Energy Generation & Efficiency	Demand for renewable & sustainable energy	Carbon constraints and CO_2 capture/management	Availability and advanced recovery of fossil fuels
Environmental & Sustainability	Climate change/ Global warming	Demand for renewable & sustainable energy	Sustainable development
Healthcare, Medical, Life Science & Biotechnologies	Healthcare for the aging	Governments' understanding of science & technology issues	Healthcare for infants
Information & Communication (ICT)	New/Replacement communication infrastructures	Governments' understanding of science & technology issues	Demand for renewable & sustainable energy
Instruments & Other Non-ICT Electronics	Governments' understanding of science & technology issues	Citizens' understanding of science & technology issues	Ocean pollution

Source: Battelle Survey

research performers (71%), the majority of academic researchers within our respondents identified themselves as performing primarily applied research (54%).

The largest share (33%) of respondents identified themselves as being involved in the broad field of healthcare, medical, life science, and biotechnology R&D. The next two largest respondent categories were (1) composite, nanotech, and other advanced materials and (2) environmental and sustainability, each accounting for 11%.

Critical R&D Challenges & Issues

When asked about the most critical challenges to performing their R&D activities, the majority of respondents stated that limited external and internal funds continue to be the two largest for the global researcher community. Not surprisingly, limited external funding was seen as the largest challenge among basic researchers. Among applied researchers, limited external funding and limited internal budgets were statistically even as the largest challenges. For development-stage researchers, limited internal budgets (and with a high correlation, development time) were the most critical challenges. Among U.S. and non-U.S. researcher groups, external and internal funding were the two largest challenges, but both measures were identified by 5% more researchers in the U.S. More interesting is that except for the top two challenges, the two researcher groups diverged in their critical challenges. Rounding out the top five R&D challenges, demonstrating acceptable R&D return on investment (ROI), competition, and development time ranked high among U.S. researchers; interdisciplinary research efforts, skilled worker shortages, and collaboration with external organizations ranked high among non-U.S. researchers.

As ROI becomes increasingly common in the R&D lexicon (especially within industry), we note that within the automotive/other motor vehicles research/technology area, demonstrating acceptable R&D ROI was the most cited critical R&D challenge (53% of the respondents). Within commercial aerospace, rail, and other non-automotive transport, the ability to measure R&D ROI was tied with product prioritization (33% of respondents each) as the most critical R&D challenge. Finally, demonstrating acceptable R&D ROI was the third largest challenge (after internal and external funding) for the healthcare, medical, life science, and biotechnology research area (24% of respondents).

We asked researchers whether various global issues and concerns would affect the direction of their future research. Across all 28 issues, the average response (on a scale of 1 to 5) from non-U.S. researchers was higher than their U.S. counterparts on each issue—averaging 0.77 points higher overall. Our only interpretation of this striking finding is that non-U.S. researchers appear somewhat more engaged in allowing current global issues and concerns to impact their future research. Many in the global research community rated their government's understanding of science and technology issues as having substantial or extreme importance. However, beyond this issue, the research/technology area was most important in determining key issues.

Collaborative R&D

In this year's survey, we explored the collaborative nature of R&D. We asked researchers to identify the type of organizations that

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

Agriculture & Food Production	Automotive & Other Motor Vehicle	Commercial Aerospace, Rail & Other Non-Auto. Transport	Military Aerospace, Defense & Security	Composite, Nanotech, & Other Advanced Materials	Energy Generation & Efficiency	Environmental & Sustainability	Healthcare, Medical, Life Sci. & Biotech	Information & Comm. (ICT)	Instruments & Other Non-ICT Electronics
U.S.	Japan	U.S.	U.S.	U.S.	U.S.	Germany	U.S.	U.S.	U.S.
China	Germany	China	China	Japan	Germany	U.S.	U.K.	Japan	Japan
Germany	U.S.	France	Russia	Germany	China	Japan	Germany	China	Germany
Brazil	China	Germany	U.K.	China	Japan	U.K.	Japan	India	China
Japan	South Korea	Japan	France	U.K.	U.K.	China	China	Germany	U.K.

Source: Battelle Survey

they collaborate with other than their own. An extraordinary 78% of all respondents stated that they have collaborated with an academic researcher in the past year, and half (50%) have collaborated with a research institute investigator. From the perspective of research/technology area, research institutes rated as the second highest collaborating entity behind academia for all but the automotive/other motor vehicle segment, which replaced it, not surprisingly, with multinational corporations.

We also examined the locations of our respondents' principal collaborators. To gain a better perspective on multicountry collaboration, we controlled for in-country collaboration by focusing on the difference between a country's share of total respondents and its share of all collaborator countries identified. By this measure, the collaboration involvement of eight countries—the U.S., the U.K., Germany, France, Japan, China, Canada, and, somewhat surprisingly, Belgium—exceeded their share of total respondents by 3% or more.

Views of R&D Leaders

To complete our survey of global researcher views, we asked respondents to provide their opinion on what countries' researchers (including both government and industrial researchers) were leading global R&D efforts across 10 research/technology areas. Except for environmental and sustainability, which was a new area this year, the results were very similar to last year. In two areas, healthcare/medical/life science/biotechnology and composite/nanotech/other advanced materials, the top five countries were exactly the same as last year. In four other areas, the top five were the same, but with a reordering of the third through fifth countries; in three areas (agriculture/food production, military aerospace/defense/security, and instruments/other non-ICT electronics), a new country replaced one of the top five countries this year.

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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

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

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

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

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