R&D

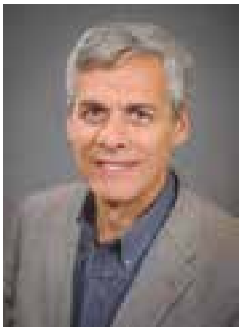
2016 GLOBAL R&D FUNDING FORECAST

WINTER 2016

A Supplement to R&D Magazine

- U.S. R&D to Increase 3.4% to $514 billion
- China R&D to Increase 6.3% to $396 billion
- Asian R&D Shift Continues with Nearly 42% Share
- Industrial R&D Continues to Drive Overall R&D Investments

Message from the IRI President



It is a privilege for the Industrial Research Institute (IRI) and *Research-Technology Management* (RTM) to partner with *R&D Magazine* in the release of this 2016 global research and development funding forecast. This invaluable resource, drawn from the expertise of leaders in industry and academia, is a public service for policy makers, educators, researchers, economists, innovation leaders and many others worldwide.

The rate of growth in R&D funding in 2015, and the location of that growth, are both significant. Trends are showing a return to growth, with only minor caveats, across most areas of R&D spending. The increase in R&D investment in Asia, particularly China, and the consecutive annual growth in R&D spending in North America indicate a period of stability, security and healthy competition across industrial sectors. Despite the insecurities in certain parts of the world, interest in scientific and technological progress marches on across developed markets. History teaches us that such investment, and such a commitment to discovery, leads to prosperity.

As an organization representing approximately 200 large R&D organizations and many U.S. federal labs, we at IRI are optimistic about global R&D spending as we head into 2016. The indicators are all there: expectations for spending increases, budgetary uncertainties in decline, attitudes towards partnerships and alliances on the rise, and the overall health of the global economy continuing to improve. The growing commitment to R&D investment in Europe and Asia lends support to our optimism. In our world of interconnected and open innovation, these global investment trends carry important implications about global quality of life.

IRI and RTM thank the many industry leaders who contributed to this year's global surveys on which this report's findings are based. Your knowledge and insights regarding R&D spending and economic health contribute significantly to our understanding and allow us to better anticipate the outlook for R&D funding.

Ed Bernstein
President
Industrial Research Institute

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Creating Innovation Leadership Solutions

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R&D Investments Continue to Grow, As Do Their Past Trends

Research and development (R&D) is defined as the process of creating new products, processes and technologies that can be used and marketed for mankind's benefit in the future. The R&D processes and their costs vary from industry to industry, from country to country and from year to year. Since January 1959, the editors of R&D Magazine have created an annual R&D Funding Forecast (U.S.-focused from 1959 to 2004 and Global since 2005) which provides a summary and future outlook for those costs. The 2016 Global R&D Funding Forecast, this year sponsored by the Industrial Research Institute (IRI), Washington, D.C., reveals that global R&D investments will increase by 3.5% in 2016 to a total of $1.948 trillion in purchasing power parity (PPP) values for the more than 110 countries having significant R&D investments (more than $100 million).

As in previous years, the growth in global R&D investments is being driven by spending in Asian countries, and in particular, China. As noted in the attached table, Asian countries (including China, Japan, India and South Korea) now account for more than 40% of all global R&D investments, with North American investments now less than 30% and European R&D only slightly more than 20%. North America (and the U.S.) and Europe continue to lose global R&D share values on a yearly basis. China's R&D investments, until recently, had annual growth figures of more than 10% since the 1990s, but these have slowed to less than 7% for 2016. This slower growth, however, is still several times the growth rates of both the U.S. and Europe whose annual growth rates are in the 2% to 3% range. The rest of the world (ROW, Russia, Africa, South America and the Middle East countries) account for a combined 8.8% of the global R&D investments with combined average growth of only about 1.5% per year.

Economic Growth

Much of the R&D growth in a country is driven by that country's economic growth, which is measured by the gross domestic product (GDP). GDP growth, as documented by the International Monetary Fund (IMF) is forecast for a 6.3% increase for China in 2016, a 2.8% increase for the U.S. and significantly smaller increases for European countries—China's GDP growth is still significantly larger than all other potential competitors for the immediate future. India has significantly larger GDP growth expectations—7.3% for 2015 and 7.5% for 2016, but its GDP is significantly less than that of China or the U.S., as are its R&D investments (less than 1% of its GDP). But India's recent strong GDP growth and commitment to R&D currently rank it as the

Share of Total Global R&D Spending

	2014	2015	2016
North America	29.1%	28.5%	28.4%
U.S.	26.9%	26.4%	26.4%
Caribbean	0.1%	0.1%	0.1%
All North America	29.2%	28.5%	28.5%
Asia	40.2%	41.2%	41.8%
China	19.1%	19.8%	20.4%
Europe	21.5%	21.3%	21.0%
Russia/CIS	3.1%	2.9%	2.8%
South America	2.8%	2.6%	2.6%
Middle East	2.2%	2.3%	2.3%
Africa	1.0%	1.1%	1.1%
Total	100.0%	100.0%	100.0%

Asian economies continue to grow faster than other parts of the world, and their investments in R&D are often at rates several times that of American and European countries. As a result, combined Asian R&D investments are growing at a faster rate than elsewhere and their global R&D shares continue to increase at almost 1% per year, while American and European R&D shares decrease, even though they also continue to increase their absolute R&D investments, just not at as fast a rate as they do in Asia.

sixth largest R&D spender in the world. India also is likely to surpass both South Korea (# 5) and Germany (# 4) in terms of total R&D investments by 2018.

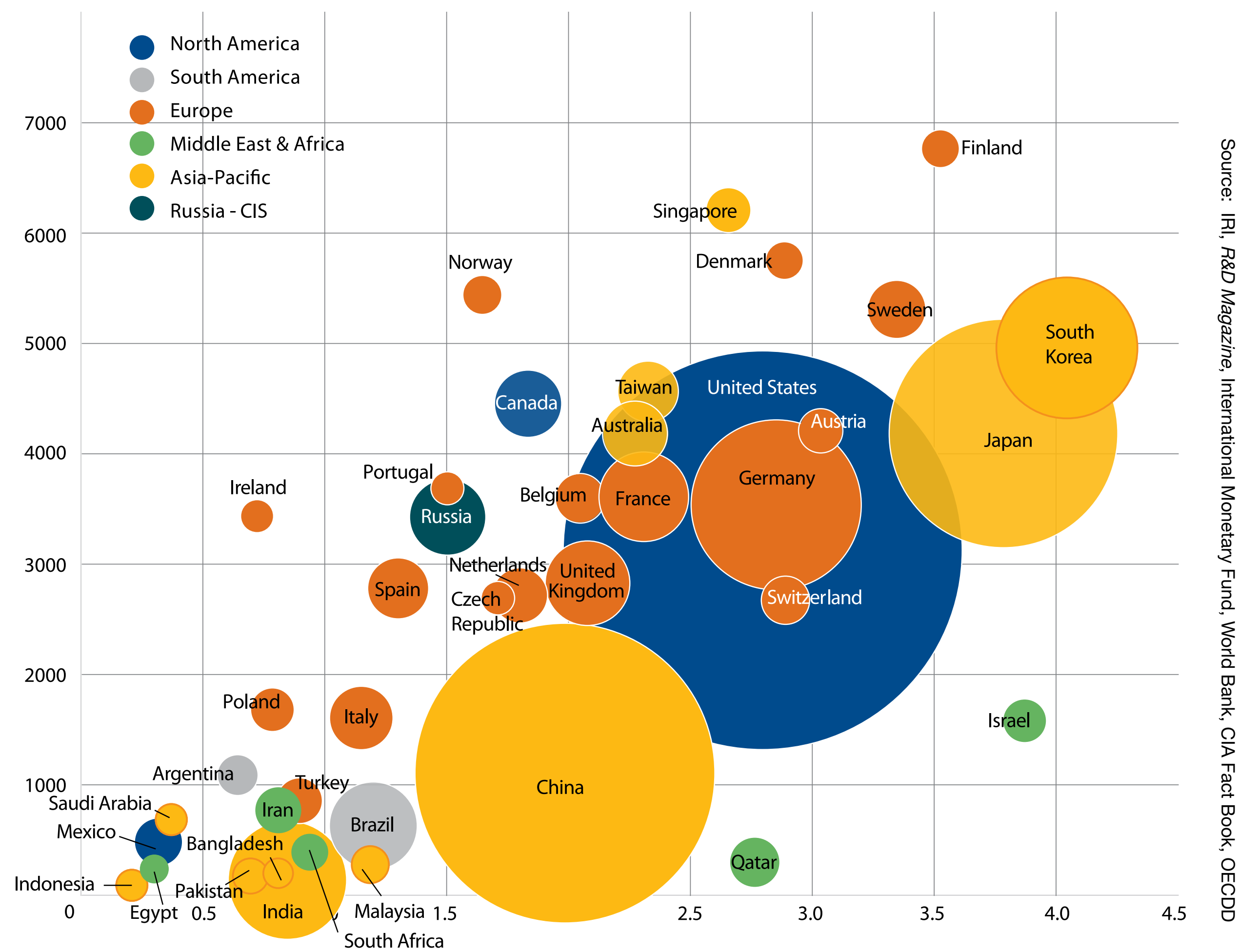
China, as well, despite its economic slowdown this past year that disrupted the world economy (to 'only' 6.8%-7% GDP growth in 2015, down from 8% or more in previous years) has a well-documented program for R&D investments (Five Year Plans) that will sustain its R&D dominance and continue to outpace other countries (including the U.S.) for the foreseeable future. It's 'Thirteen-Five' (Thirteenth Five-Year Plan 2016-2020) continues its 7% annual GDP growth targets. China is expected to surpass the U.S. in total annual R&D spending by 2026 and continue to widen the gap beyond that point in time.

U.S. R&D Dominance

For 2015 and 2016, R&D investments in the U.S. continue a series of trends started over the past five years. These include restrictions on total federal government spending on R&D, the resultant decline in federal government support of academic R&D investments (and their struggles to compensate), and the slow increase in industrial R&D spending (and its share of the total R&D "pie").

Despite these 'drags' on R&D support, the U.S. continues to be the largest single country in R&D investments with slightly more than a quarter of all global R&D spending. These R&D programs are supported by industrial (66%), federal government (25%) and academic/non-profit (7%) investments.

There are substantial changes that are being seen in the character of the U.S.'s industrial R&D makeup. Life science R&D, for more than ten years, has been the largest sector in the industrial technology arena. For 2016, many of the large players in this sector—Novartis, Pfizer, Merck, Sanofi, Astra Zeneca, Eli Lilly, GlaxoSmithKline, Bristol-Myers Squibb and more (not all are U.S.-based, but most have large U.S. instal-



Size of the circles reflects the relative amount of annual R&D spending by the indicated country. Note the regional grouping of countries by the color of the balls.

Forecast Gross Expenditures on R&D

#	Country	2014 Actual GDP PPP Bil, US$	2014 Actual R&D as % GDP	2014 Actual GERD PPP Bil, US$	2015 Estimated GDP PPP Bil, US$	2015 Estimated R&D as % GDP	2015 Estimated GERD PPP Bil, US$	2016 Forecast GDP PPP Bil, US$	2016 Forecast R&D as % GDP	2016 Forecast GERD PPP Bil, US$
1	United States	17,460.0	2.78%	485.39	18,001.3	2.76%	496.84	18,559.3	2.77%	514.00
2	China	17,630.0	1.95%	343.78	18,828.8	1.98%	372.81	20,015.0	1.98%	396.30
3	Japan	4,807.0	3.40%	163.44	4,855.1	3.39%	164.59	4,913.4	3.39%	166.60
4	Germany	3,621.0	2.85%	103.20	3,678.9	2.92%	107.42	3,741.4	2.92%	109.25
5	South Korea	1,786.0	3.60%	64.30	1,844.9	4.04%	74.53	1,909.5	4.04%	77.14
6	India	7,277.0	0.85%	61.85	7,822.8	0.85%	66.49	8,409.5	0.85%	71.48
7	France	2,587.0	2.25%	58.21	2,618.0	2.26%	59.17	2,657.3	2.26%	60.05
8	Russia	3,568.0	1.50%	53.52	3,432.4	1.50%	51.49	3,396.6	1.50%	50.95
9	United Kingdom	2,435.0	1.81%	44.07	2,500.7	1.78%	44.51	2,558.2	1.78%	45.54
10	Brazil	3,073.0	1.21%	37.18	3,042.3	1.21%	36.81	3,072.7	1.21%	37.18
11	Canada	1,579.0	1.90%	30.00	1,613.7	1.79%	28.89	1,646.0	1.79%	29.46
12	Australia	1,100.0	2.25%	24.75	1,130.8	2.39%	27.03	1,167.0	2.39%	27.89
13	Italy	2,066.0	1.20%	24.79	2,076.3	1.27%	26.37	2,099.1	1.27%	26.66
14	Taiwan	1,022.0	2.35%	24.02	1,060.8	2.35%	24.93	1,104.3	2.35%	25.95
15	Spain	1,534.0	1.25%	19.18	1,572.4	1.30%	20.44	1,603.8	1.30%	20.85
16	Netherlands	798.1	2.08%	16.60	810.9	2.16%	17.52	823.9	2.16%	17.80
17	Sweden	434.2	3.40%	14.76	445.9	3.41%	15.21	458.4	3.41%	15.63
18	Turkey	1,512.0	0.88%	13.30	1,558.9	0.86%	13.41	1,615.0	0.86%	13.89
19	Switzerland	444.7	2.90%	12.90	448.3	2.90%	13.00	453.7	2.90%	13.16
20	Singapore	445.2	2.65%	11.80	458.6	2.60%	11.92	472.4	2.60%	12.28
21	Iran	1,284.0	0.84%	10.79	1,291.7	0.90%	11.62	1,308.5	0.90%	11.78
22	Israel	268.3	4.15%	11.13	277.7	3.93%	10.91	286.9	3.93%	11.28
23	Austria	386.9	2.75%	10.64	390.4	2.84%	11.09	396.6	2.84%	11.26
24	Belgium	467.1	2.04%	9.53	473.2	2.24%	10.60	480.3	2.24%	10.76
25	Mexico	2,143.0	0.45%	9.64	2,207.3	0.45%	9.93	2,280.1	0.45%	10.26
26	Qatar	323.2	2.70%	8.73	346.1	2.70%	9.34	368.6	2.70%	9.95
27	Poland	941.4	0.80%	7.53	974.3	0.90%	8.77	1,008.4	0.90%	9.08
28	Malaysia	746.8	0.80%	5.97	782.6	1.07%	8.37	820.9	1.07%	8.78
29	Finland	221.5	3.50%	7.75	223.3	3.55%	7.93	226.4	3.55%	8.04
30	Denmark	248.7	2.90%	7.21	252.7	2.98%	7.53	257.8	2.98%	7.68
31	Pakistan	884.2	0.70%	6.19	922.2	0.75%	6.92	965.5	0.75%	7.24
32	Saudi Arabia	1,616.0	0.32%	5.17	1,664.5	0.40%	6.66	1,709.4	0.40%	6.84
33	South Africa	683.1	0.95%	6.49	696.8	0.95%	6.62	711.4	0.95%	6.76
34	Czech Republic	299.7	1.80%	5.39	307.2	1.88%	5.78	315.5	1.88%	5.93
35	Norway	339.5	1.65%	5.60	342.9	1.65%	5.66	348.0	1.65%	5.74
36	Argentina	927.4	0.62%	5.75	924.6	0.62%	5.73	925.5	0.62%	5.74
37	Indonesia	2,554.0	0.22%	5.62	1,445.4	0.30%	4.34	1,524.9	0.30%	4.57
38	Egypt	945.4	0.24%	2.27	983.2	0.43%	4.23	1,025.5	0.43%	4.41
39	Bangladesh	535.6	0.70%	3.75	571.5	0.70%	4.00	609.8	0.70%	4.27
40	Portugal	276.0	1.40%	3.86	280;4	1.50%	4.21	284.6	1.50%	4.27
Top 40		**91,271.0**	**1.91%**	**1746.05**	**92,879.4**	**1.96%**	**1823.62**	**96,531.1**	**1.95%**	**1886.70**
Rest of World		**14,486.0**	**0.39%**	**57.05**	**14,925.0**	**0.40%**	**59.05**	**15,516.9**	**0.39%**	**61.05**
Global R&D		**105,757.0**	**1.70%**	**1803.10**	**107,804.4**	**1.75%**	**1882.67**	**112,048.0**	**1.74%**	**1947.75**

Source: IRI, *R&D Magazine*, International Monetary Fund, World Bank, CIA Fact Book, OECD

- **GERD = Gross Expenditures on Research and Development**
- **PPP = Purchasing Power Parity (used to normalize R&D investments)**

lations)—are expected to reduce their large multi-billion dollar annual R&D investments. A reduction of products in the R&D pipeline, increased regulatory pressures and consumer resistance to high-priced drugs are some of the reasons that pharmaceutical companies are likely to see reduced revenues and a reduced ability to continue funding mega-scale R&D programs.

In other industrial areas, most global automotive companies (except for Volkswagen, the largest global automotive company and prior to 2015, the largest total R&D spender) are expected to grow their R&D programs due to strong technology shifts from internal combustion to electric propulsion systems, manual to automated driving systems and increasingly integrated electronic systems. Of course, these R&D enhancements are complemented (and supported) by increasing revenues from a resurgent marketplace eager to purchase new products with reduced operating costs.

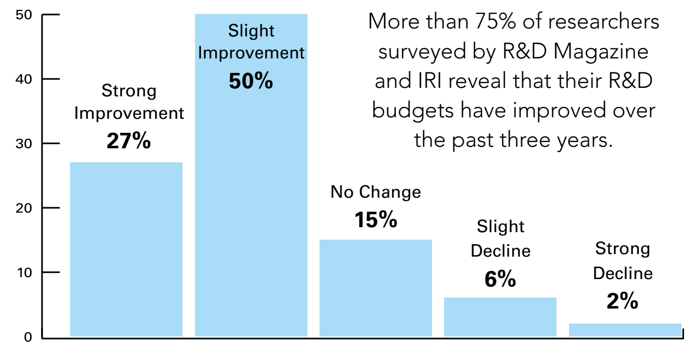
Actual Results

R&D investments, especially those for upcoming years, are based on budgets prepared by R&D managers, directors and executive committees. They're based on what these planners expect to spend, their long-term R&D and product development goals and what resources they have available to them. Based upon surveys created by R&D Magazine and the IRI, most global survey respondents (77%) noted that their R&D budgets and expenditures had improved over the past three years (since 2012) with relatively few (8%) seeing a decline in their budgets/expenditures. Many of the survey respondents (56%) also noted that their R&D increased from 2014 to 2015, while some respondents (15%) had experienced reductions in their budgets/expenditures. Nearly a third (29%) stated that they had no changes in their R&D support from 2014 to 2015.

The long-term outlook for these researchers was not as positive as you might expect with only slightly more than half (57%) expecting to see their R&D budgets improve over the next five years (by 2020). The remaining survey respondents expect to see their R&D budgets decline (11%) or stay the same (31%) as they have in 2015.

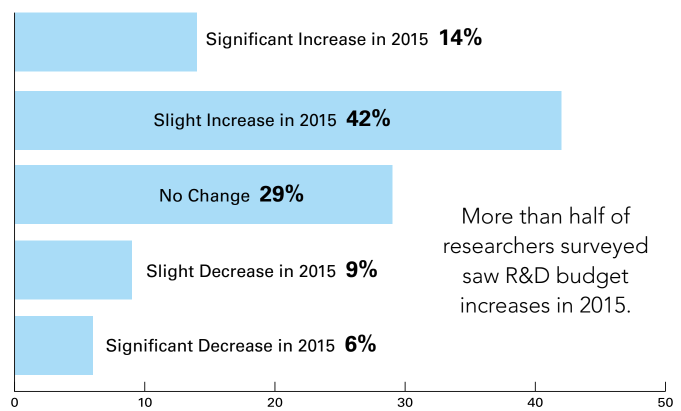
Most researcher survey respondents (75%) stated that they basically held to their formal R&D budgets in 2014, while some (15%) overspent their budgets and a few (10%) underspent their R&D budgets. Similar results were obtained from the researchers when they were asked about their current 2015 R&D budgets. These research budgets however were noted as being restricted, since nearly two thirds of the researchers stated they were limited in what research they could perform by their tight budgets – no one stated that they had excess funds, even though they might have underspent their budgets. Despite their budgets, or lack thereof, most researchers we surveyed indicated that their R&D was successful in 2014. Only a handful (6%) noted that their R&D was unsuccessful.

What Has Changed in Your R&D Budget Since 2012?



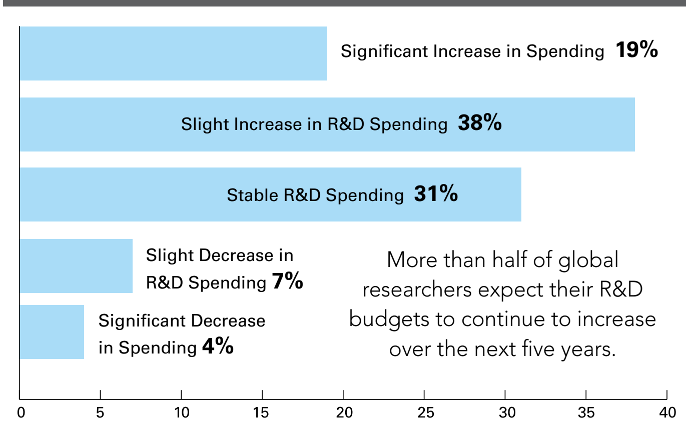
Source: IRI/*R&D Magazine*

Compare Your 2014 and 2015 R&D Budgets



Source: IRI/*R&D Magazine*

What is Your R&D Outlook for 2020



Source: IRI/*R&D Magazine*

U.S. R&D Improves, But With Limitations

For 2016, total U.S. R&D spending is expected to increase by 3.4% to $514 billion or a 2.0% increase after accounting for 2016's expected 1.5% inflation rate.

U.S. researchers—all those in government, industry and academic labs—struggled throughout 2015 with a host of uncertainties to understand how to plan for their 2016 R&D budgets. And as we close out 2015, many of those uncertainties have not been allayed. The overriding factor in 2015 was the global economy and its effects on all areas of the U.S.'s R&D environment, what measures might be employed to support it and how effective those measures might be. All types of factors that bear upon the R&D arena have become involved—politics, economics, technologies, global trade, regulatory, and more.

For 2016, total U.S. R&D spending is expected to increase by 3.4% to $514 billion or a 1.9% increase after accounting for 2016's expected 1.5% inflation rate. This is the third consecutive year of positive increases following flat R&D growth in the recession-recovery years. Factors that have influenced the 2016 U.S. R&D outlook include:

- A slowdown in China's economy to less than 7% annual growth (from traditional 8%+ levels) and the resulting effects on global stock markets.
- Multiple economic actions (lowering interest rates and easing financial restrictions for banks) by China's government to stimulate growth appeared to stabilize their overall economy by November.
- A U.S. stock market correction (>10% decline) in August from the DJIA peak in early June. By September most stocks were well below their January 1 levels.
- Lackluster jobs creation in the Fall following strong jobs growth in the first half of 2015.
- Continued restrictions on federal spending from earlier sequestration spending programs.
- Inability of the Federal Reserve Bank to decide if short-term interest rate increases were appropriate in the Fall, resulting in increased uncertainty about the current and future cost of lending.
- Continued modest growth in the overall U.S. economy and strong dollar growth compared to foreign currencies.
- A flex point in the technological development and user mind-set of electric propulsion systems for automobiles and trucks.

The Source-Performer Matrix

US$ Billions, change from 2015

R&D is funded by the federal government, industry, academia and non-profit organizations who then perform varying levels of that research, along with FFRDC (federally funded R&D centers) which are operated for the federal government by industry, non-profit organizations or academia.

Source of Funds	Federal Gov't	Industry	Academia	FFRDC (Gov't)	Non-Profit	Total
Federal Government	$43.0 1.5%	$29.0 1.8%	$38.0 1.3%	$15.0 -3.2%	$6.3 0.5%	$131.3 1.5%
Industry		$328.4 1.5%	$5.0 1.0%	$3.0 4.0%	$2.0 1.0%	$338.4 2.0%
Academia			$18.0 2.0%	$0.3 0.0%		$18.3 2.0%
Other Government			$6.5 7.0%			$6.5 7.0%
Non-Profit			$5.0 1.0%	$0.1 0.0%	$14.4 3.0%	$19.5 3.0%
Total	$43.0 1.5%	$357.4 2.0%	$72.5 2.0%	$18.4 1.0%	$22.7 3.0%	$514.0 3.4%

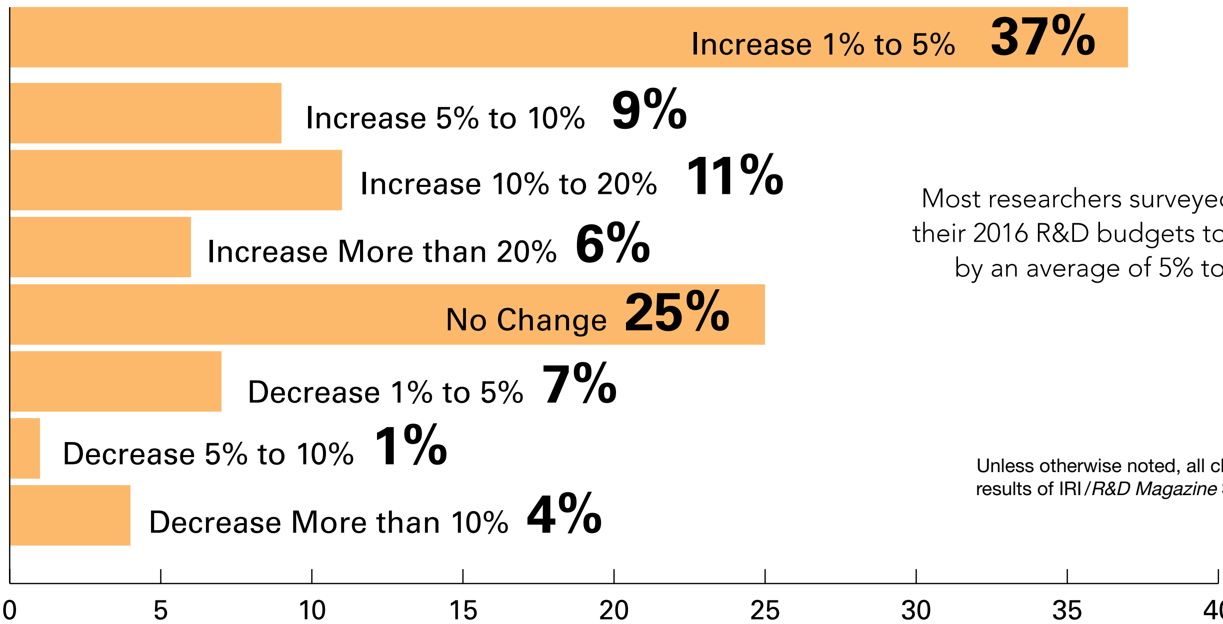
Source: *R&D Magazine*

- A flex point in the production of U.S. natural gas and oil systems allowing dramatic reductions in importation demand for foreign crude oil.
- The possibility of actually exporting U.S. natural gas/oil on the global market for the first time in more than 40 years.
- Continued evolution and increased efficiencies of alternate electric power systems (i.e., solar cells and wind turbines).
- A slight shift from massive foreign product development and production outsourcing to domestic in-sourcing.
- The resignation of House Speaker John Boehner and the resulting lack of strong established leadership.
- Distractions from Democratic and Republican political campaigns and posturing for the November 2016 General Elections.

All of these factors combined created a weaker than might be expected environment for strong fiscal growth and confidence in the U.S. However, the U.S. fares better than most other overseas economies. This strength compared to other economies can be attributed to the U.S.'s strong energy resources and the potential for both short- and long-term further improvements. Unemployment rates fell during the year to a very sustainable 5.1% and even the Federal Reserve started to feel more confident in being able to raise short term interest rates, possibly in their December 2015 general meeting. Also, many corporate stocks which saw massive losses in August had returned to respectable levels by November. As a result, our R&D forecast is possibly as still conservative due to the possible fast return to tenuous levels as you might expect.

Corporate spending on R&D continues to be the strong card in the overall mix of funding resources, especially as federal R&D investments stagnate due to fiscal spending limitation. The business confidence index (BCI) generated monthly by the OECD (Organization for Economic Cooperation and Development, Paris, France) rates the U.S. as a 99.40 for September, up slightly from it August rating, but down 1.5 points from its level in September 2014. The BCI is based on enterprises assessment of production, orders and stocks, along with its current position and expectations for the immediate future. The U.S. BCI (which hints at the level of R&D investments a company might make) is greater than that of China (98.8), but less than that of Russia (101.7) and generally slightly lower than many other established Western economies. But while the U.S. BCI might be slightly lower than other established countries, its GDP growth forecast (as forecast by the IMF) is substantially greater than that of those same established (non-Asian) countries. U.S. GDP growth is forecast to be at about the same level as that of South Korea, and substantially lower (less than half) than that of China and India.
A possible wild card in our overall U.S. R&D funding forecast is the lack of strong baseline data that historically was generated by the National Science Foundation (NSF). The

How Will Your 2016 R&D Budget Change?



Most researchers surveyed expect their 2016 R&D budgets to increase by an average of 5% to 10%.

Unless otherwise noted, all charts are results of IRI/*R&D Magazine* Surveys.

What R&D Changes Do You Expect in 2016?

	Increase	Decrease	No Change	No Activity
Applied Research	51%	6%	37%	5%
Basic Research	31%	11%	47%	12%
Development	55%	8%	31%	6%
Science/Engineering Consulting	33%	7%	47%	13%
Technical Service	35%	7%	49%	8%

Most researchers expect all types of R&D to increase or stay the same in 2016, especially their applied research and development programs.

last baseline data created by the NSF (National Patterns of R&D Resources, NSF 14-304) was created in December 2013 with data only going back to 2012, and that was listed as preliminary. The next update for this type of data is not scheduled to be created and published until Spring 2016.

Federal Carousel

Every Fall for the past several years, the approval process for the upcoming federal budget (i.e., FY2016) has gone through a series of similar political negotiations. While FY2016 was scheduled to begin October 1, 2015, a first continuing resolution (CR) was used by the Congress to extend the legal requirements to Dec. 11 to keep their agencies operating without defaulting. In previous years multiple spending extensions have gone as long as into March of the following year. Often, to expedite the overall process and get on with more current business, the CRs were finalized with Omnibus spending bills that kept spending levels at similar levels as the previous fiscal year, resulting in zero growth. The National Institutes of Health (NIH), for example, has seen its fiscal budgets frozen for so many years by these and other limiting procedures that its actual spending level is now about 20% lower in real dollars than it was 10 years ago due to the interim inflationary effects on its purchasing power and costs.

The retirement of House Speaker John Boehner (October 31) this year resulted in the creation of a new last-minute debt ceiling extension to March 2017 and an increase in discretionary spending limits by about $80 billion over the next two years (split equally between defense and domestic spending), short-cutting the limits imposed by the 2011 Budget Control Act (sequestration). This was done this year to accommodate new House Speaker Paul Ryan, so that he would not be burdened with trying to negotiate a new debt ceiling and budget issues in his first days in his new position. Just how this bill will play out with R&D spending has yet to be determined, however federal R&D is likely to be larger than that stated in some sections of this forecast.

The retirement of House Speaker John Boehner (October 31) this year resulted in the creation of a new last-minute debt ceiling extension to March 2017 and an increase in discretionary spending limits by about $80 billion over the next two years.

Academic R&D has similarly suffered over the past several years as a result of the federal government's spending limits. Nearly 60% of academic R&D funding comes from the federal government principally through grants from the NSF and the NIH. Academia has worked to increase its R&D funding sources from industrial, philanthropic and internal funding organizations, but have not been able to offset the lost federal funding.

Spending Bill Secures FY2016 and FY2017

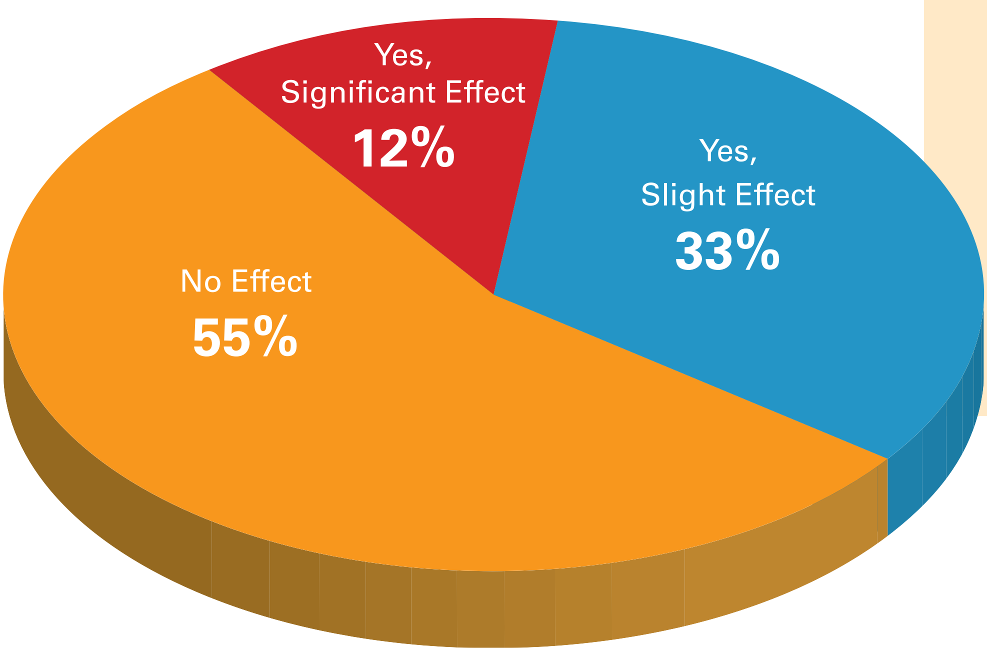
The federal government's forecast $127 billion in R&D investments for 2016 are split mostly half and half into defense and non-defense spending. At more than $60 billion, the Dept. of Defense's (DOD's) R&D budget is larger than the total R&D budgets of all but five countries—China, Japan, Germany, South Korea and India. The DOD budget is split into science and technology (approximately 17%) and technology development (approximately 80%) areas. The S&T portion is split into basic research (Category 6.1 at 17%), applied research (Category 6.2 at 38%) and advanced technology development (Category 6.3 at 45%). DARPA (Defense Advanced Research Projects Agency) is considered a stand alone R&D account within the DOD with a published budget of slightly less than $3 billion—House and Senate appropriation committees cut President Obama's request for DARPA funding this past summer by about 3%. DOD's S&T budget also includes a medical research component that declined during the DOD's peak operations in Iraq and Afghanistan, but has been recovering over the past two years to its current requested level of slightly less than $2 billion.

President Barack Obama had proposed an 8.4% increase in DOD R&D for 2016 over 2015 spending. With the expected new debt ceiling extension measure and its $80 billion increase in budgetary spending in place, Obama's request (and possibly more) is likely to be passed since the DOD is generally a favorite with both the House of Representatives and the Senate. Both the House and the Senate committees evaluating the R&D budgets passed slightly larger bills (($0.3 and $0.5 billion, respectively) for the DOD's S&T budgets (and medical research) during their appropriation meetings this past summer.

National Institutes of Health

The NIH has the second largest federal government R&D budget with a 2016 R&D appropriation request of $31.3 billion—$1.0 billion or 2.6% more than was appropriated in 2015. House and Senate appropriation committees increased that $0.1 and $1.0 billion, respectively. If the Senate measure is approved, this would amount to the largest single year increase since the end of the agency's budget doubling program in FY2003 (excluding the approximately $10 billion increase from the American Recovery and Reinvestment Act, or ARRA, in FY2009 intended to offset the great recession's economic effects).

Will Government Funding Affect Your R&D?



Reduced U.S. federal investments in R&D due to budgetary constraints are expected to be split almost 50-50 in terms of what type of an effect they have on researchers' R&D efforts.

The NIH has 21 institutes and six centers, with 11 institutes having individual R&D budgets of more than $1 billion—the National Cancer Institute (NCI) is the largest with a research budget of more than $5 billion for FY2016. The House and the Senate appropriation committees recommended varying levels of budget changes (both additions and cuts) in the individual institutes over what was proposed by the Obama Administration with no consistent trends, other than an overall increase by both Congressional bodies for the whole agency. The Senate appropriations committee, however, recommended varying levels of increases (over the Administration's proposal) in all 27 NIH organizations (including the Office of the Director, (OD)), while the House appropriations committee recommended a range of cuts in 17 of the 27 NIH organizations (over what was proposed) and varying levels of increases in the remaining 10 (plus the OD).

NASA

NASA's R&D budget proposal for FY2016 is $12.3 billion, 1.52% more than was appropriated in 2015. During appropriations meetings, the 2016 R&D budget was raised to $12.4 billion (0.6%) by the House and held status quo by the Senate, although there were serious discussions and reshuffling of specific project funds by both Congressional bodies. The House subcommittee cut earth science funding, but raised planetary science funding by mostly similar amounts (-13.6% and +14.4%, respectively). The Senate subcommittee cut planetary science, but raised astrophysics, again by similar rates. Both bodies continue to support the Space Launch System (SLS) with most funds than was proposed. The SLS is NASA's post-Shuttle next generation system for sending astronauts to Mars.

Department of Energy

The DOE has three main R&D components—defense (approximately 38% or $4.7 billion of the total $12.4 billion proposed for FY2016), general science (39% or $5.3 billion) and energy (23% or $2.7 billion). The defense sector is responsible for maintenance of the U.S.'s atomic weapon arsenal and both Congressional bodies have few problems with the R&D proposed for this section. Both bodies found some faults with the general science sector, cutting their appropriations by 4.5% and 3.7%, respectively for the House and Senate, for topics like advanced science computing research, high-energy physics and nuclear physics, among others.

The Congressional appropriations committees, however, found substantial issues with the DOE's energy R&D programs, cutting them by 16.7% and 12.0% respectively. They specifically found funding issues with the DOE's energy efficiency and renewable energy programs cutting these programs by 39% and 28%.

At more than $60 billion, the Dept. of Defense's (DOD's) R&D budget is larger than the total R&D budgets of all but five countries — China, Japan, Germany, South Korea and India.

The National Institutes of Health has the second largest federal government R&D budget with a 2016 R&D appropriation request of $31.3 billion — $1.0 billion or 2.6% more than was appropriated in 2015.

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Academic Research Revival

Academics performing R&D over the past 10 years have suffered through periods of "hot" and "cold" support from the federal government and industrial organizations. In the late-1990s, the National Institutes of Health (NIH), the agency with the largest life science focus, went through an R&D budget-doubling period that increased the NIH's R&D budget from $13.7 billion in FY1998 to $27.1 billion in FY2003. This excited NIH administrators and their life science researchers with flush budgets and provided almost more grants than they knew what to do with. But, immediately, the NIH R&D budget started shrinking in constant dollars due to slim annual increases, so that by FY2008, the NIH budget was reduced to just $23.9 billion.

The American Recovery and Reinvestment Act (ARRA) of 2009 pumped $10 billion into the NIH in FY2009 and FY2010, but traditional funding was still declining such that the NIH got only $21.1 billion in FY2013. And as inflation took its annual toll, the purchasing power of the NIH's grant system continued to decline in even larger values each year. More than 50% of the NIH's budget is funneled into principal investigator (PI)-initiated research project grants (RPGs), many of which are made to academics. As available funds declined over the past 15 years, the competition for the remaining funds increased. PIs increasingly found themselves spending more time writing RPG proposals and less time doing actual research. This frustrated researchers, and the NIH estimated more than 1,000 researchers actually resigned due to these pressures in just one year alone.

But tight government budgets have restricted academic funding in all areas, not just the life sciences. As noted in the attached chart, NIH-based life science research funding for academia is about 57% of all government funding, and about 23% of all types of funding for academia. For FY2016, this overall situation could be alleviated somewhat due to the $80 billion voted to be added to discretionary funds in the Bipartisan Budget Act (BBA) of 2015. These discretionary budget add-ons ($50 billion for FY2016 and $30 billion for FY2017, half of which is dedicated to defense and half to non-defense budget areas) were signed into law, but Congress still needs to create an overall budget by December 11. We estimate that about $2 to $3 billion could be added to the federal government's R&D coffers with this bill.

But the federal government is not the only source of R&D funding for academic research. By default, academia has become the go-to organization for performing advanced basic research and even applied research when government or industrial organizations are looking for cost-effective ways to perform a development program. For many years now, academia has performed the majority of basic research as industrial organizations have reduced their involvement in basic research. The high costs, always questionable results and increasing requirements for faster times to market made basic research a very tenuous pursuit by industrial research organizations. The strong scientific and technological expertise and knowledge available with academic research laboratories make them a much more reliable group to perform basic research programs.

The U.S. university and college systems continue to lead other countries in research, technology and innovation. Of the Top 10 universities in the world, eight are in the U.S. (Harvard, Stanford, MIT, UC-Berkeley, Princeton, CalTech, Columbia and the Univ. of Chicago) and two are in the U.K. (Cambridge and Oxford). Of the Top 20 universities in the world, 16 are in the U.S., with Switzerland's ETH and Univ. College London being the non-U.S.-based standouts—the other top U.S. universities include Yale, UCLA, Cornell, UC-San Diego, Univ. of Washington, Univ. of Pennsylvania, Johns Hopkins and UC-San Francisco. This ranking system is run by the Center for World Class Universities at Shanghai Jiao Tong Univ., China. The ranking system uses six objective

U.S. R&D Performance

	Funding	Share	Industry	Federal Govt	Academia	Non-Profit
Basic Research	$ 75 billion	16%	22%	7%	56%	15%
Applied Research	$ 87 billion	20%	61%	10%	21%	8%
Development	$ 291 billion	64%	87%	8%	3%	2%
All R&D	$ 453 billion	100%	72%	8%	15%	5%

The largest share of basic research in the U.S. is performed by academic institutions, while industry organizations perform most of the applied research and development work. Source: National Science Foundation, 2012 National Patterns

Top Universities by R&D Expenditures (Millions of U.S. Dollars)

		R&D	Fed Obligations	Share
1	Johns Hopkins Univ.	$2,169	$1,539	71%
2	Univ. Michigan, Ann Arbor	$1,375	$610	44%
3	Univ. Washington, Seattle	$1,193	$663	56%
4	Univ. Wisconsin, Madison	$1,124	$440	39%
5	Univ. California, San Diego	$1,076	$566	53%
6	Univ. California, San Francisco	$1,043	$574	55%
7	Harvard Univ.	$1,013	$459	45%
8	Duke Univ.	$993	$454	46%
9	Univ. NC, Chapel Hill	$973	$442	45%
10	Univ. California, Los Angeles	$967	$481	50%

Source: National Science Foundation

Johns Hopkins University was the first academic to surpass $1 billion in R&D and now is the first to surpass $2 billion—the bulk of which is funded by the federal government for life science research.

indicators, including the number of alumni and staff winning Nobel Prizes and Fields Medals, the number of highly cited researchers selected by Thomson Reuters, the number of articles published in the *Nature and Science* journals, the number of articles indexed in the Science Citation Index - Expanded and Social Sciences Citation Index and per capita performance of a university. More than 1,200 universities are ranked every year and the best 500 are published.

Of these Top 16 U.S. universities, six are in the Top 10 universities having the largest R&D expenditures—Johns Hopkins, Univ. of Washington, UC-San Diego, UC-San Francisco, Harvard and UCLA. These Top Six have a combined annual R&D expenditure of nearly $7.5 billion/yr, $4.3 billion of that funded by U.S. federal agencies. Baltimore's Johns Hopkins Univ. was the first school to exceed $1 billion in R&D expenditures (there are now seven), and it is the first school to exceed $2 billion, driven strongly by its federal obligations from the NIH (and not coincidentally geographical proximity to the main NIH campus in Rockville, Md.).

Harvard Univ. has become the standard by which all other research universities are judged. Its baseline ranking of 100 by the Shanghai Academic Ranking of World Universities even overwhelms the number two university (Stanford), whose ranking is only 73.3. While it ranks first overall, Harvard also ranks first in Social Science, Medical Science and Life Science categories. It ranks second in Natural Science/Mathematics (behind UC-Berkely), and 25th in Engineering where its crosstown (Cambridge, Mass.) neighbor MIT ranks first.

Globalization has affected many aspects of the overall R&D environment where the U.S. has lost its overall industrial or technology dominance over the past 15 years. However, the U.S.'s academic research system appears to have only grown stronger over the past five years, with improved overall rankings. Funding appears to be a strong driver in this revival with Harvard's endowment fund growing from $4.6 billion in 2000 to $32.7 billion today. Indeed, a ranking of the world's richest universities reveals nine of the Top 10 located in the U.S. (the lone standout being King Abdulah Univ. of Science and Technology in Saudi Arabia) with a combined U.S. wealth of nearly $200 billion (Harvard is again ranked first in this poll). Seventeen of the Top 20 in this ranking are U.S. universities (the U.K.'s Cambridge and Oxford universities being the other two standouts).

Top U.S. Federal R&D Obligations to Academia, FY2013

All Federal Agencies	$29,034
USDA	$1,136
DOC	$269
DOD	$3,365
Dept. Education	$180
DOE	$1,054
HHS	$16,839
CDC	$99
FDA	$41
NIH	$16,478
DHS	$60
DOI	$51
DOT	$127
EPA	$48
NASA	$884
NSF	$4,910

Source: National Science Foundation

The National Institutes of Health provides more than half of the federal government's investment in R&D, the bulk of which is for life science research.

INDUSTRIAL CONSIDERATIONS

In the U.S., Europe and much of Asia, industrial R&D accounts for the largest share of each country's total R&D investments. Industrial R&D differs from the other two types—government and academic—as industrial R&D is associated with products that are marketed, sold and are meant to make a profit for the organization. As a result, industrial R&D deals with various economic issues, return on investment (ROI), time-to-market, paybacks, competitive advantages, reliability, patents, lifecycles, production considerations and other aspects not generally considered in government and academic research programs.

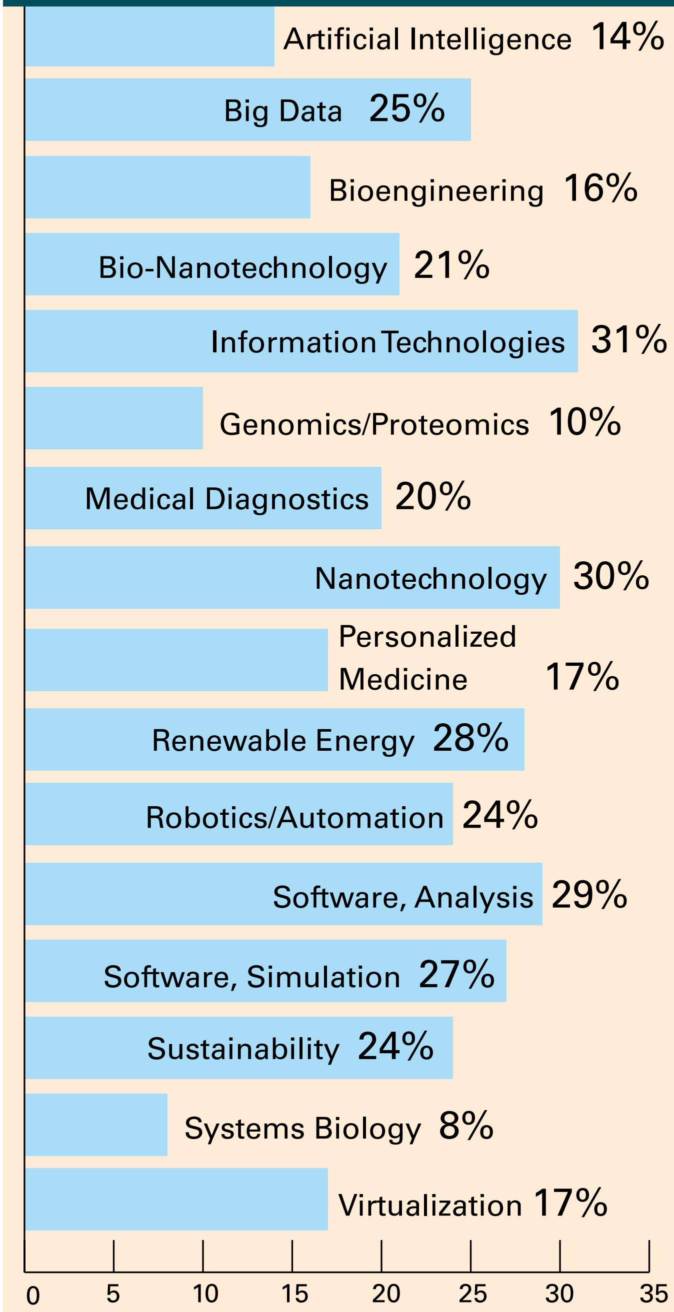
Industrial R&D is often considered a cost of doing business and, most of the time, can be deducted on a company's balance sheet and tax forms in the U.S. when Congress has put in place the R&D tax credit legislation. In the U.S., R&D tax credits aren't always a guaranteed deduction—even though many politicians and research organizations have pressed to make R&D tax credits a permanent component of the Internal Revenue Service's tax code for more than 35 years. R&D tax credits have often been established as a temporary measure with a finite life.

There are numerous industries in which R&D is considered a strong and essential component in the development of new products and in which hundreds of billions of dollars in R&D monies are invested to accomplish those goals.

The six global industries whose R&D expenditures are summarized in this report are Life Science, Aerospace and Defense Systems, Advanced Materials and Chemicals, Information and Communications Technologies (ICT), Automotive and Transportation Systems and Energy Systems. These six industries account for well over half of the industrial R&D spending in the world, and have very dynamic, innovative, high-growth and profitable companies as members.

Over the past 15 years, there have been dramatic changes in each of these industries, their technologies, the way they perform their R&D, the makeup of the industry members and the overall application of their R&D. The technologies employed by the scientists and engineers in these industrial laboratories are expected to continuously evolve over the next several years, as well. The attached chart gives an overview of what technologies are expected to change the most over the next three years by 2018. There are no surprises here, just a continuing technological evolution with information technologies (IT) and nanotechnology leading the way, cited by 30% or more of the survey respondents.

Most Important Technologies by 2018



A wide range of technologies are considered to have relative importance to researchers over the next next three years.

Life Science Technologies

The global Life Science industry is one of the top two large global high-tech industries—the other being ICT. It consists of pharmaceuticals, biotechnology, medical instruments and devices, animal and agricultural bioscience and commercial research and testing. However, most of this industry's activities are driven by R&D in the biopharmaceutical sector, which accounts for about 85% of the industry's total R&D spending.

The industry is highly complex with strong ongoing M&A activities, a highly respected and established large regulatory infrastructure, a technological base which has not yet matured, a highly skilled and educated workforce and costly, yet highly profitable, research protocols. Pharmaceutical R&D is transitioning from a long-standing chemical compound configuration—which has become mostly saturated—to a biotech/biopharmaceutical configuration, along with the implementation of a sophisticated informatics and big data infrastructure.

The cost to develop a new drug continues to rise (often exceeding $1 billion per new chemical entity (NCE)), and the development process is also time consuming (nine to 12 years, including the FDA clinical testing programs).

For the global Life Science R&D marketplace, we predict a modest 1.8% increase in R&D spending for 2016, and a weak 0.6% increase in U.S. R&D spending for 2016. The Life Science industry is currently plagued with a series of concerns, one of them being a consumer reaction to the current high prices of prescription drugs. A series of media events exposing these high prices has also exacerbated these concerns.

Overall, Life Science R&D employment has fallen over the past several years as federal funding for the National Institutes of Health (NIH) R&D efforts has stagnated in current dollars and steadily fallen in real dollars since 2002. A study by the NIH found that between 500 to 1,000 NIH researchers (principal investigators or PIs) dropped out of the industry in just one year alone due to concerns/issues in obtaining NIH grants.

The stock market decline during August 2015 also hurt a number of pharmaceutical companies (Roche, Novartis, Johnson & Johnson, Merck and Astra Zeneca) whose stock did not recover and continues to lag behind its value at the beginning of 2015. On the other hand, a couple of pharmaceutical companies with FDA approvals have done well in 2015 (Eli Lilly, Bristol-Myers Squibb and Pfizer).

Corporate Restructurings

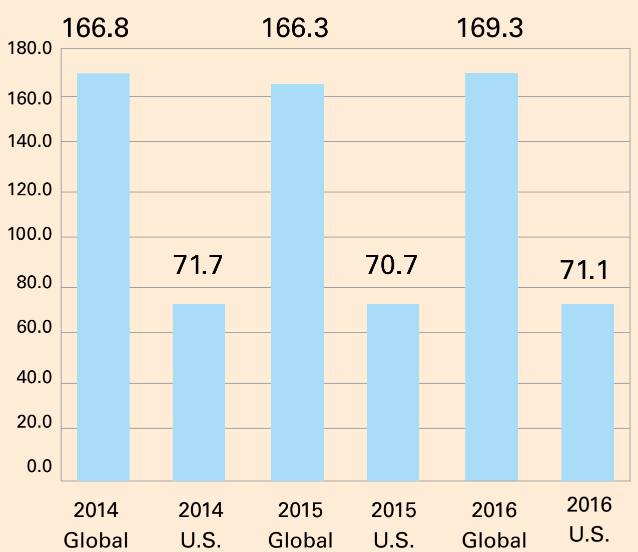
Big pharma continues to explore its options for improving its financial situation. Pfizer, one of the largest pharma companies known for creating mergers and acquisitions (M&As) to improve its overall drug portfolio (Pfizer acquired Warner-Lambert 2000, Pharmacia 2002, Coley 2007, Wyeth 2009, King 2010 and Hospira 2015) is currently in the process of acquiring Irish Allergan, with analysts noting the tax benefits that could be gained by merging with a non-U.S. company. Pfizer's record from its previous M&A activities has resulted in the layoffs of thousands of researchers in the combined company, along with substantially smaller R&D spending in the merged organization. Pfizer also had a major restructuring in 2014, reducing its R&D budget by several billion dollars. GlaxoSmithKline, Astra Zeneca and Sanofi also announced large R&D cuts in 2014 as the overall industry restructured itself. Biotech giant Amgen also cut nearly 3,000 researchers in 2014.

Outside of M&A activities, life science organizations have put a strong reliance on partnerships, collaborations, in-licensing and the enhancement of internal development capabilities. U.S. life science companies tend to favor external partnerships with other U.S. companies—most U.S.-based life science companies have no plans for foreign engagements (despite the Pfizer example noted earlier).

As big pharma transitions to more biopharmaceutical-based products, there is also the likelihood of even smaller research staffs.

Life Science R&D Spending Chart
(R&D Spending, Billions of U.S. Dollars)

While continuing to grow, the rate of overall life science R&D spending has slowed over the past several years, compared to the double and triple the current rate it experienced five to ten years ago.



Aerospace/Defense R&D

The Aerospace/Defense industry consists of numerous Dept. of Defense (DOD) suppliers like Boeing, Lockheed Martin, Northrop Grumman, Raytheon, General Electric, United Technologies (Pratt & Whitney), Rolls Royce, BAE (British Aerospace), Thales and EADS (Airbus). These same suppliers also service the commercial airline industry.

For 2016, we expect global aerospace R&D will increase 2.0% to $30.4 billion, while the U.S. portion is expected to increase 1.4% to $14.3 billion. Some major weapons programs, over the past several years, have staged a small recovery in this area, following several years of slow or no growth due to a dearth of military programs. A strong commercial airline demand for the foreseeable future is also adding strength to these programs.

An additional blip in the R&D picture is the growth of the commercial space launch component of this industry. The list of commercial spaceflight companies has blossomed since the retirement of the space shuttle system and the looming business opportunities for deep-space transport systems. The big corporate players (Boeing, Lockheed Martin, Northrop Grumman, Rockwell Collins, Raytheon and others) are well-known and have mostly growing R&D budgets. However, there also are a large number of small startup companies (and some not so small), which are mostly private and with unknown R&D budgets, but guaranteed to have strong R&D programs. These companies, most of whom are U.S., include Elon Musk's SpaceX, Richard Branson's Virgin Galactic, Orbital Sciences/Technologies, Burt Rutan's Scaled Composites, Bigelow Aerospace, SpaceDev, Sea Launch (Boeing) and others. We estimate undocumented R&D expenses from these programs in the $1 to $2 billion range.

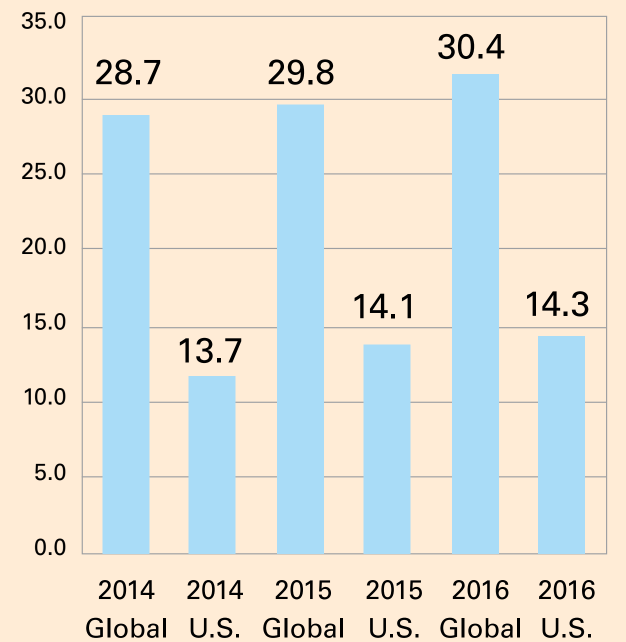
Also following the retirement of the space shuttles, the launch sites (Pads 35A and 35B) became available for commercial use, along with the shuttle servicing and support facilities, including several bays of the large four-bay Vehicle Assembly Building (VAB). These have since been taken over, modified and outfitted for future space launch vehicles and systems. An entirely new launch pad (35C) is also being constructed by NASA for use by smaller launch companies.

There are numerous DOD-funded systems that are in the beginning of their design and development stages. The F-35 advanced fighter (Lockheed Martin) is well along in its development with numerous active R&D programs for software and avionics. This is also true of the Boeing-produced Air Force KC-46A tanker. The new advanced bomber (B-3?) was just awarded to Northrop Grumman and, so, there is likely to be a large amount of design and development effort funded by the DOD in 2016.

There are also numerous commercial aircraft in development for which there are considerable dedicated R&D funds. Boeing, for example, is developing its 777X, 777-9 and 737MAX as next-generation systems for their very successful 777 and 737 aircraft. Along with these enhancements, General Electric is designing new engines, GEnx and GE9x, to power them. Airbus is following suit by developing its A330neo, A350-900 and A350XWB aircraft. Not to be outdone, the Commercial Aircraft Corp. of China, or Comac, recently released its first single-aisle twin-engine C919, which looks to compete against the Boeing 737 and Airbus A320/319. There is considerable R&D yet to be accomplished on the C919 before it's certified sometime in 2016. The Canadian aircraft manufacturer was in the process of developing its C-Series aircraft designed to compete against the Boeing 737 and Airbus A320/319, but it has run into design problems. It recently received a $1 billion bailout from the Canadian government to support continued R&D.

Aerospace R&D Spending Chart

(R&D Spending, Billions of U.S. Dollars)



The aerospace and defense industries have seen some major upticks over the past two years in space exploration and could see even more over the next two years in the defense arena depending on events occurring in global conflicts and efforts to control terrorism.

Advanced Materials and Chemicals

R&D for Advanced Materials and Chemicals includes research dedicated to developing basic chemicals, catalysts, polymers, metals, ceramics and nanomaterials. This can include research on materials sold in bulk (freight-car size), or in samples sold for hundreds of dollars per gram. Development of specialized versions of these materials is essential to the development of new products including paints, polymers, foods, adhesives, energy and metals.

We forecast that R&D for this industry will increase by about 2.1% to $44.4 billion, and by 2.6% to $12.0 billion for materials developed in the U.S. The U.S. has a strong leadership role in the development of these materials technologies. Compared to other materials' developers in Germany, Japan and China, U.S. materials developers are ranked higher by factors ranging from 2.4 to 7.3, better than the other countries.

R&D leaders in this area are dominated by 3M ($1.1 billion in annual R&D), 3M Co. ($1.2 billion in annual R&D), Dow Chemical ($1.3 billion in annual R&D), BASF ($2.2 billion) and DuPont ($2.1 billion). The U.S. companies have an R&D/sales ratio in the 2.5% to 6.0% ranges. Sumitomo Chemical has a ratio of 7.0%, and Bayer AG has a 7.75% ratio.

Nanotechnology continues to be the hot material in this industry, with strong R&D funding from a large number federal agencies as noted in the chart below .

While R&D funding has dropped a bit for nanotechnology research from $1.7 billion in 2010 to the current $1.5 billion, there continues to be strong bipartisan support in Congress and the Administration for research across 15 federal agencies.

The payback for this research is fast, and the results are seen in areas like new composites for aerospace applications, faster and safer chemical reactions (with new catalysts) in various production processes and more durable coatings and finishes for automotive applications.

Of course, the large technical and monetary advantages offered by the use of nanomaterials means many other countries will make use of them and dedicate R&D resources to them for creating new and innovative applications. Japan's National Institute for Materials Science, for example, promotes nanotechnology-based research in photonics and quantum dots. South Korea's Advanced Nano Products Ltd. manufactures and supplies chemically processed nanocrystalline materials and their chemical precursors for coating and powder processing applications.

National Nanotechnology Initiative, 2014-2016 (Millions of U.S. Dollars)

Agency	2014	2015	2016 Proposed
Consumer Protection	2.0	2.0	7.0
Dept. Homeland Security	25.0	28.4	17.0
NIST	97.8	83.6	86.3
DOD	189.6	141.7	130.4
DOE	309.4	329.7	342.2
DOT	2.1	1.5	1.5
EPA	15.5	15.1	15.3
DHHS (Total)	430.3	437.8	448.6
• FDA	9.3	15.8	14.6
• NIH	410.0	411.0	423.0
• NIOSH	11.0	11.0	11.0
NASA	22.4	19.1	15.8
NSF	464.5	413.4	416.4
USDA (Total)	15.6	15.6	14.8
• ARS	2.0	3.0	3.0
• FS	5.6	4.6	4.5
• NIFA	8.0	8.0	7.3
Total	**1,574.3**	**1,487.8**	**1,495.3**

Source: NNI

Basic materials R&D has sustained a steady growth over the past ten years, reflecting this area's strong importance in support of all other R&D efforts. Few breakthroughs are often announced, but continuing performance and production enhancements are essential to the overall conduct of R&D.

Information and Communication Technology (ICT)

Intel's co-founder Gordon Moore created "Moore's Law" 50 years ago, professing the continual evolution of semiconductor devices in their simultaneous shrinking size and expanding performance. ICT giants Intel, Microsoft, Google, Cisco, IBM and a host of others have built on this base and prospered. The non-stop computing and electronic revolution has created new devices and capabilities that change our lives on a daily basis.

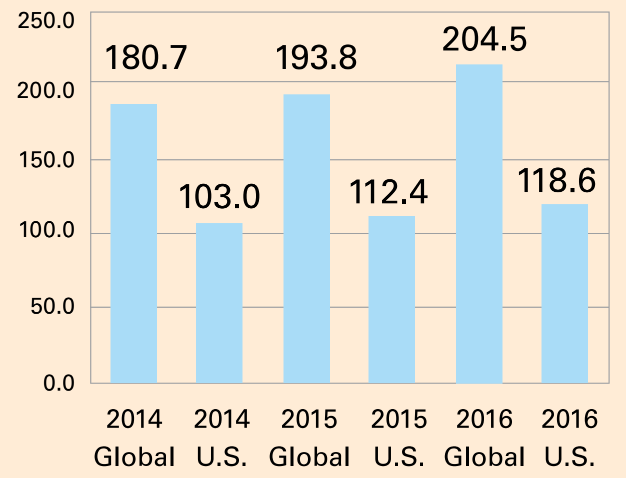
To maintain this dynamic growth for 2016, we forecast the R&D spending for the ICT industry will increase by 5.5% to $204.5 billion. The U.S. portion of this industry is forecast to grow a similar 55 .% to $118.6 billion. Being a leader in this rapidly changing industry is no guarantee for continued success. IBM was the leader for many years, with its computer mainframes, software services and a host of basic research-based laboratories around the world where Nobel Prize winners resided. But these R&D-based products were outpaced by the changing ICT landscape driven by Google, Apple and Samsung. At last count, IBM continued its record of 14 consecutive quarters of declining sales and revenues. Its global R&D is expected to drop from $5.6 billion in 2014 to $5.3 billion in 2016, just slightly ahead of the $5 billion it spent on R&D in 2001 when it was the 6th largest R&D spending company—IBM now ranks as the 18th largest. Of course, there are more than three times the number of companies in IBM's Standard Industrial Classification (SIC) codes category (7,370) investing in R&D than there were 15 years ago.

Moore's Intel has lately prospered. It is now the third largest corporation investing in R&D, behind Volkswagen and Microsoft. Intel is expected to increase its R&D from $11.5 billion in 2014 to $13.5 billion in 2016, which is actually ahead of the $13.3 billion Microsoft is expected to spend on R&D in 2016 (an increase from $11.7 billion in 2014). Intel's R&D is 22% of its sales, while Microsoft's is 13% and IBM's is 5.6% (5.3% in 2001). Supporting these systems developers and implementers are a long string of strong equipment and basic technology fabricators. One of the leading semiconductor device equipment manufacturers, Applied Materials, is expected to increase its R&D from $1.4 billion in 2014 to $1.6 billion in 2016.

ICT is, and has been, a global business for many years. Highly automated, multibillion dollar semiconductor fabs dot the countryside of emerging countries, along with those in the U.S., Japan and China. Operating and maintaining these sophisticated manufacturing facilities on a 24/7 basis often is a concern for some ICT companies with headquarters and large research staffs thousands of miles away. Some companies must consider whether to continue operating these far-flung facilities or return some of their production to their home country.

Information and Communication

(R&D Spending, Billions of U.S. Dollars)



ICT is considered the strongest R&D industry and the one most integrated (with software and hardware products) into all other industrial R&D areas. It also is expected to have about twice the R&D growth rate in 2016 of all other industries.

The technological evolution of semiconductor devices is obviously continuing with many manufacturers stating they've seen significant technology changes just in the past year alone. As noted earlier in this section, half of the most important technologies recognized by our survey respondents over the next three years are based on ICT. The top two—information technologies and nanotechnology—are drivers for the development of future ICT devices. Big data, analysis software and artificial intelligence (AI) are similarly noted as strong drivers for these future technologies.

Indeed, futurists and current technology leaders like Prof. Stephen Hawkings, SpaceX/Tesla's Elon Musk and Google's Larry Page have all cautioned over the past year about the potential problems with having too strong of an AI-based ICT infrastructure—it could lead to a non-reversible situation where humankind is put at risk. The systems being created by the evolutionary technologies developed and manufactured by Intel, IBM, Google, Microsoft and Samsung could potentially get ahead of our ability to control them.

The Automotive Industry in Transition

Few industries have seen such a wide range of changes over the past year as those involved in the Automotive industry. The current largest R&D spender (and largest automotive manufacturer in the world), Volkswagen (VW), is struggling to weather a storm of controversy over the falsification of environmental testing protocols that threatens to cost the company as much as $80 billion in product corrections, fines and lawsuits to rectify the situation. VW was expected to increase its R&D spending from $14.0 billion in 2014 to $17.4 billion in 2016. Those forecasts were made before VW encountered the testing issues in early 2015. The company initially put $6 billion into a "war chest" to buffer some of its liabilities, which likely won't be enough.

Other changes occurring over the past year include the rapid and mostly unexpected implementation of self-driving cars; the emergence of electric cars, which could supplant a significant portion of fossil fuel-powered vehicles in a relatively short period; and the availability of large amounts of fossil fuels at prices not experienced in more than 20 years.

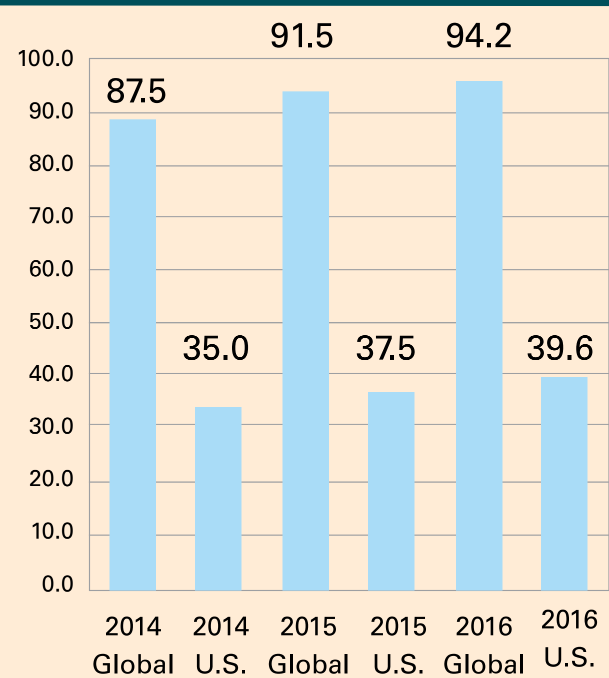
All of these changes, including those at VW, are keeping the R&D laboratories at automotive manufacturers busy, and going far beyond traditional annual cosmetic changes. Indeed, a continued economic recovery has also been instrumental in creating a boom in automotive sales. As a result, we forecast the global Automotive industry will increase its R&D spending in 2016 by 3.0% to $94.2 billion (not including the exaggerated VW figures noted earlier), while R&D spending in the U.S. is expected to increase 5.6% to $39.6 billion in 2016. Indeed, before this year's events, most automotive manufacturers were forecast to have the most stable R&D plans—this included Toyota, GM, Ford, Daimler, Nissan and Honda, all companies with corporate R&D investments from $4 to $8 billion and in the overall Top 30 listings.

The electric car revolution and transition has been driven mostly by the success of the Tesla, Toyota's Prius hybrid, the Chevrolet Volt hybrid and, to a much smaller degree, the Nissan Leaf. Indeed, electric hybrid vehicles have become a strong market segment from entry level vehicles and SUVs to luxury brands with their own dedicated parking spots in public garages. These vehicles have prospered in an era of declining costs and increasing availability of fossil fuels due to several reasons. First, the Tesla has shown that it is a high-performance vehicle capable of outperforming any other vehicle on the road, from the high-speed Bugati Veyron to the Chevrolet Corvette. While still costly, the Tesla provides the consumer with an immediate view of the future. Second, Tesla's engineers continue to develop the technology with better performing and improved battery technology, more affordable vehicles and an increasing range of models. Third, Tesla has created an infrastructure for recharging its vehicles across the country. Finally, Tesla is not content with the status quo and has demonstrated, in 2015, a self-driving option, which, while not perfect, is advanced technology that one didn't expect to see for several years. It was made available to "early access" customers in mid-August.

It's been noted that Tesla loses thousands of dollars on every vehicle it makes. However, the company continues to increase its volume, and is constructing a $5 billion battery factory in Nevada, which will supply Tesla and other automotive companies and non-automotive companies as well, with a strong future supply of rechargeable lithium batteries. From a marketing standpoint, Tesla is also positioning itself as the most technologically advanced and smartest vehicle on the planet. Tesla Motors is expected to increase its R&D spending from $464 million in 2014 to $695 million in 2016, a CAGR of more than 20%.

Automotive R&D Spending

(R&D Spending, Billions of U.S. Dollars)



Often considered to be a very cyclical R&D area, the outlook for continued strong R&D growth over the next five or more years is very positive with an emphasis on alternative (electric) energy sources, automated driving systems (artificial intelligence), and minimizing emissions driving the growth in R&D.

The Energy Industry

Twenty-five years ago, we were told annually that we'd soon run out of fossil fuel to power our ever-increasing hunger and passion for cars. Saudi Arabia was the king of oil, and the U.S., with its ever increasing oil imports, was being driven into an ever-increasing negative balance of trade situation. Fast forward to today, there's an oil glut on the world market, gas prices are where they were 25 years ago, Saudi Arabia could go into bankruptcy in as little as five years because of low gas prices and the U.S. has considered exporting crude oil from its shale oil reserves.

Big oil companies like Exxon, Chevron, Dutch Shell, Total and BP are struggling economically as oil prices continue languishing from their $100/barrel levels from a year ago to their current $40 to $50/barrel levels. To strengthen their struggling economies, Russia and Saudi Arabia also continue pumping and marketing oil at near record volumes (and at low prices), and in the process are keeping those prices at a low level. All of this has little to do with R&D investments, but it does affect the monies available to invest in R&D. Historically, energy companies invest a relatively small portion of their revenues (0.3%) in R&D; however, they do have comparatively large revenues compared to other industries.

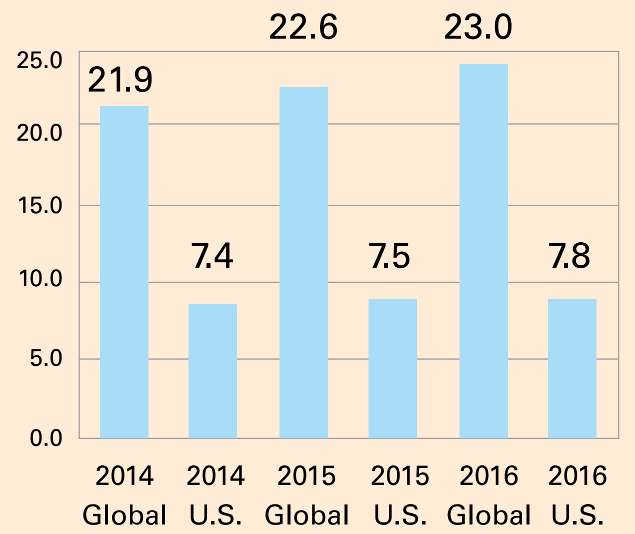
As a result of these events, we forecast the amount of R&D invested globally in the energy industry to increase slightly by 1.8% in 2016 to $23.0 billion. In the U.S., R&D investments are expected to increase by 4.0% to $7.8 billion in 2016.

Many of the initial energy industry R&D forecasts were made based on energy forecasts that were more positive. Indeed, Exxon has already reduced its R&D investments from $971 million in 2014 to an expected $898 million in 2016—a reduction of 7.5%. Similarly, Royal Dutch Shell cut its R&D from $1.2 billion in 2014 to $1.1 billion in 2016, a 1% reduction. And BP reduced its R&D by 2%. With its more optimistic long-term view, PetroChina has become a leader in the energy industry and is expected to increase its R&D spending from $2.1 billion in 2014 to $2.2 billion in 2016. French Total, China Petroleum & Chemical, Petrobras Argentina, and Chevron are all expected to increase their R&D spending in 2016.

Solar-powered technologies continue to be a relatively small sector of the overall energy industry that is populated by comparatively smaller technology companies (other than oil refiners). Most of these small energy companies, with strong future market forecasts, expect to increase their R&D spending in 2016. Solar cells, power converters and associated hardware continue to improve in overall efficiencies, while dropping slightly in overall prices. Many of the new higher efficiency semiconductor-based photovoltaic cells are based

Energy R&D Spending

(R&D Spending, Billions of U.S. Dollars)



Investments in energy R&D are being limited by the reduced revenue streams imposed by the current glut in petroleum energy supplies, a situation that is forecast to continue through at least the end of 2016.

on relatively rare materials in short supply. An increased amount of R&D has been dedicated to sourcing these or replacement materials to provide an adequate supply for future demands. The other solar component, installation, also is holding steady on pricing while more reliable installers are now available, creating a more competitive marketplace.

Driving some of this market growth is the increasing acceptance and installation of solar panel systems within industrial buildings. Increasingly, governmental organizations are demanding that new public buildings have at least a modicum of renewable energy (solar panels) systems installed. Energy credits are also still available from some governmental organizations, which offsets some of the costs to purchase and install these systems.

Wind turbine farms continue to be installed at a mostly steady pace with evolutionary technologies that continue to evolve and improve. While most of these systems are manufactured from mature technologies, relatively small improvements in their R&D investments can be expected.

As noted in the Automotive industry section, Elon Musk is building a $5 billion lithium-ion battery factory in Nevada, which is expected to supply batteries for automobiles, computers and his new Energy-Wall system, which can be integrated with a solar-panel system for small industry and consumer uses. Second-generation lithium-ion batteries are also expected to be developed and manufactured at Musk's battery plant. A second battery plant is expected to be designed and built in California.

INTERNATIONAL R&D OVERVIEW

Global and international research and development are, of course, synonymous. More than 60 countries in the world annually perform more than a billion dollars each of R&D and their numbers are growing. The number of researchers—scientists and engineers—has expanded dramatically over the past 20 years in most countries and, except for economically distressed regions, their R&D expenditures have similarly expanded, especially over the past five years. R&D investments have recovered since the global Great Recession of 2008-2009, and most countries find themselves in fiercely competitive positions for creating new technologies, processes and products to grow their economies. The headlines are filled every day with the announcements of new scientific breakthroughs, discoveries and developments. The countries where these events occur are no longer of any significance, importance or even newsworthiness—they can occur anywhere since information and technology is now distributed globally. Whether R&D managers like it or not, most global scientific and technological capabilities are now shared around the world.

This, of course, is not to say that R&D capabilities, knowledge and science and technology (S&T) wealth are equal throughout the world. Many emerging countries are playing S&T "catch-up" with the established countries and many regions outspending (on a percentage basis) the established S&T leaders to increase their competitive S&T positions. China and other countries are on fast tracks to build basic science infrastructures that equal or even exceed those of the U.S. and Europe. For example, while many countries used to launch their in-house developed space monitoring or communication satellites on U.S., European or Russian space launch systems, many now build their own launch vehicles, increasing again their basic technology capabilities. And while U.S. R&D has a strong standing in many areas as noted on the attached table, it doesn't always dominate specific technologies. Other countries have nearly as strong technological capabilities in some areas. For example, Germany and Japan are equally strong in automotive, environmental and instrumentation areas.

Academic R&D capabilities are still dominated by U.S. and European institutions and, as noted in the academic R&D section in this report, that advantage may even be growing due to a number of innovative and established methodologies. About one in three universities which are ranked in the top 500 universities in the world are located in the U.S. The academic capabilities of non-U.S. and non-European countries are increasing, but to jump start their capabilities, the emerging countries often create educational partnerships with the strong, established educational institutions, which benefits both parties.

U.S. researchers have dominated the Nobel Prize Awards, both

Technology Sector Leaders

	U.S.	China	France	Germany	Japan	Russia	Korea	UK	Other
Advanced Materials	59%	15%	1%	12%	7%	1%	2%	2%	2%
Agriculture/Food	68%	10%	3%	5%	2%	1%	1%	1%	10%
Automotive	22%	6%	1%	29%	32%	0%	8%	0%	2%
Commercial Aerospace	62%	3%	10%	6%	1%	13%	1%	2%	2%
Communications	57%	13%	0%	2%	13%	0%	4%	4%	6%
Energy	49%	10%	3%	20%	7%	1%	1%	1%	8%
Environmental	37%	1%	6%	26%	8%	1%	2%	6%	12%
Instrumentation	41%	9%	1%	14%	22%	1%	9%	1%	2%
Life Science/Healthcare	43%	2%	7%	18%	7%	0%	2%	9%	12%
Military/Defense	78%	6%	1%	1%	0%	11%	1%	1%	2%
Pharmaceutical/Biotech	56%	4%	3%	16%	5%	1%	1%	7%	8%

The U.S. continues to dominate most of the technological sectors, with the exception of automotive where it shares the lead with Germany and Japan. Electric automotive research is being driven by several U.S. leaders including Tesla and the U.S. Dept. of Energy which could lead to a resurgence in this area by the U.S.

long term and in the 21st century, as well, with 356 awards overall and 102 since 2000. The country with the second most awards is the United Kingdom with 116 overall and 18 since 2000. Japanese researchers won 16 awards since 2000 and 24 overall, while French researchers won 10 since 2000 and 67 overall. Chinese researchers have won five Nobel prizes since 2000 and nine overall. The Nobel Prizes, awarded since 1901, have gone to researchers in 73 countries.

A recent report by the Economic Intelligence Unit updated their 2011 Global Talent Index with ratings for 2015. The U.S. and northern Europe countries outpaced all other countries in both rankings (actually improving slightly in 2015) with their ability to produce and attract working talent. As noted above, the excellence of the U.S. universities was noted in the report as a major factor in this performance. The high quality of the U.S. workforce also plays a role in the U.S.'s Talent Index in terms of its adaptability, innovation and meritocratic environment. Countries which have risen the most in the rankings between the two reports include Canada, Chile and Turkey. Countries which have fallen the most in the rankings include Azerberbijan, Greece and Venezuela.

China R&D

China is the world's second largest investor in R&D with a forecast spending of $396.3 billion for 2016. In purchasing power parity (PPP) values, China already has a larger economy (gross domestic product or GDP) than that of the U.S. with $18.8 trillion in 2015 compared to the U.S.'s $18.0 trillion for 2015. In current, non-PPP prices, China's GDP is $11.4 billion (Source: IMF). China's 2016 R&D is an increase of 6.3% over the $372.8 they're estimated to spend in 2015, which is down from the 8.4% increase they experienced from 2014 to 2015.

China's economy and R&D have both seen yearly rate declines over the past several years, which has caused some analysts considerable concerns. Indeed, when announcement of China's annual economic growth dropped below its 7.0% target to 6.9% in the summer of 2015, the global stock markets tanked and lost several trillion dollars of value in just a few weeks. Investors had become used to the large annual growth figures for the world's second largest economy. The vast size and population of China and its traditional economic growth were economic targets for many other countries. But the high rates of China's economic growth and R&D growth were realistically unsustainable. The current values of 7.0% GDP growth and 6.3% R&D growth are similarly questionable growth values for the long term, especially in a country that historically has been prone to corruption and dubious auditing and banking practices.

China's R&D investments have resulted in surprisingly strong results. China is very aggressive in applying for technology patents with 825,136 patent applications in 2013 compared to 571,612 for the U.S. in the same year. Its output of papers indexed in Thomson Reuters' Web of Science has steadily increased from about 50,000 papers in 2003 to 200,000 in 2013, and is continuing to grow at about the same rate (increase of about 20,000 papers/year). China has a particularly strong emphasis in the chemical sciences having nearly a 25% world share of technical papers in this area (U.S. researchers have a 20% share in chemical sciences). The country also has an 18% share of highly cited papers in materials science technology fields.

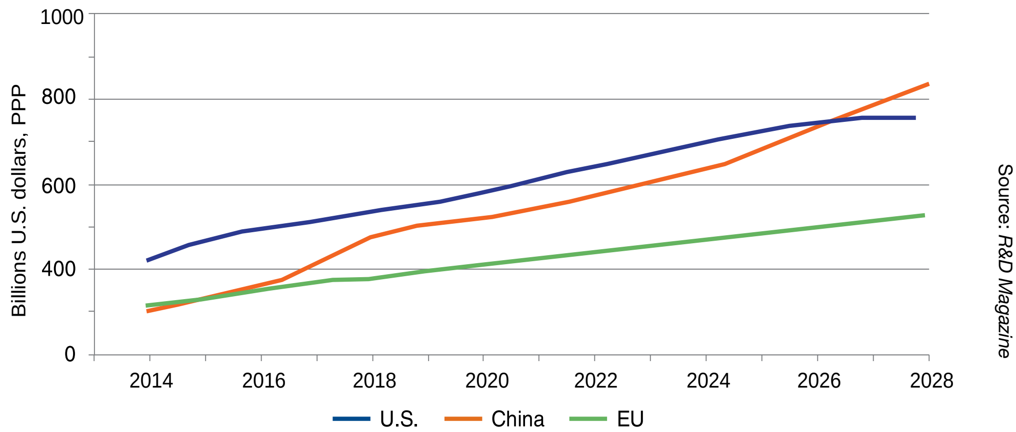
China's share of R&D performance per OECD (Organization of Economic Cooperation and Development) reports reveal 69% of their R&D is performed by government researchers, 21% by industrial researchers and the remaining 10% by academic researchers. This is in stark contrast to how the U.S. distributes its R&D where the shares are 11% (government),

How Does U.S. and China R&D Compare?

	U.S. Superior	China Superior	Both the Same
Overall R&D Investments	40%	40%	20%
R&D Quality	68%	8%	24%
R&D Productivity	51%	24%	25%
R&D Basic Research	54%	15%	31%
R&D Applied Research	42%	23%	34%
R&D Development	46%	21%	33%
R&D Trends	43%	21%	36%

U.S. and Chinese investments in R&D are considered equal, however the quality of the R&D work performance is overwhelmingly biased in favor of the U.S.

Annual R&D Budgets



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71% (industry) and 18% (academia). China's R&D is dominated by its government, while the U.S.'s R&D is dominated by its industrial sector.

These distributions play out in how the R&D is perceived and realized. While Chinese and U.S. overall investments are considered to be similar by researcher respondents to our 2015 surveys, the R&D quality, productivity, basic research, applied research, development activities and overall trends are considered to be vastly superior in the U.S. than in China by factors of two to eight as shown in the attached table.

The economic changes seen in China in 2015 have slightly changed the structure of its R&D enterprise. While China's economy has mostly caught up and (has or will shortly depending on how you measure it) surpass that of the U.S. to move it into the largest economy in the world, its financial investment in R&D continues to lag behind that of the U.S. despite a significant larger CAGR. A couple of years ago, China's GDP and R&D investment rates were growing at significantly larger rates than they are today, even though they still both exceed that of the U.S. The cross-over date where China would surpass the U.S. in R&D investments at that time was about 2022-2023. Due to the slower GDP/R&D rates, this point has now moved out to the 2025-2026 time period as shown on the attached chart. This assumes that U.S. R&D investments will continue at a historically suppressed level of 3 to 4% annual increases and China's R&D investments will continue at their elevated 6 to 7% rates. Historically, U.S. R&D has been in the 6% annual level range, but current government austerity measures make it unlikely to get to that level anytime soon unless dramatic industrial increases are made, which also is unlikely. China's technology administrators have been very patient and consistent in their R&D investments over the past 20 years, so it's likely their investment rates will remain at their current levels.

It was noted this past summer by the fDi Markets Div. of the *Financial Times* that China has caught up with the U.S. in attracting foreign investment in their R&D with a Greenfield investment of $1.2 billion in 2014 compared to just $300 million in the U.S. Also, the number of companies with headquarters in China represented by Strategy's Global Innovation 1000 list grew from eight in 2005 to 114 in 2014.

China's R&D administrators are playing catch-up to western technology/R&D infrastructures in a number of areas. Cases in point include their recent proposals to build two new supercolliders which would dwarf the 27-km Large Hadron Collider at CERN in Europe. China's 52-km $3 billion "Higgs" factory would be built by 2028 and could be financed completely by China (or supported by other countries as well). Physicists state that such a machine is within the technological grasp of scientists and is actually considered conservative in scope and cost. European and U.S. researchers have considered such a machine, but the costs and development/administrative struggles meant that such a machine could not become a reality before 2035.

China has also constructed a 500-m aperture spherical telescope similar to the 305-m Arecibo Observatory in Puerto Rico operated by SRI International, USRA, UMET and the NSF. Construction on China's telescope was started in 2011 and is scheduled to be completed by September 2016. The Arecibo Observatory has been operational since 1963.

China has also already launched multiple astronauts into orbit and housed them in orbiting modules for short periods. Its large modular Tiangong 3 Space Station is in the planning stages and scheduled to be launched by about 2020. A smaller Tiangong 2 space laboratory is scheduled to be launched in 2016. The Tiangong 3 is planned to be used to evaluate life support and power systems similar to those used on the Russian MIR and the ISS.

Asian R&D

As noted earlier, Asia is the leading R&D region in the world with $813 billion invested annually in R&D and a 41.8% share of the global R&D. While China is the largest member of that region, the non-China Asian sector will still create $417 billion of R&D investments in 2016 for a 21.4% share of the global R&D. The non-China Asian R&D group actually invests 2% more in R&D than the combined 24 countries in the European R&D group. Ten of the Top 40 R&D spending countries are in Asia. They include Japan, South Korea, India, Australia, Taiwan, Singapore, Malaysia, Pakistan, Indonesia and Bangladesh. Other Asian countries spending more than $1 billion annually (but not in our Top 40) include Thailand ($3.2 billion in 2016 R&D), New Zealand ($2.1 billion), Vietnam (1.8 billion) and the Philippines ($1.2 billion).

As noted in the China R&D section, Asian R&D is perceived and realized as not up to the quality level of U.S. and European R&D efforts. While Asian and U.S. overall investments are again considered to be similar by researcher respondents to our 2015 surveys, the R&D quality, productivity, basic research, applied research, development activities and overall trends are considered to be vastly superior in the U.S. and Europe than in other Asian countries. This disparity is not as large as the one noted in the China-U.S. comparison noted earlier likely due to the higher quality of R&D performed in Japan, Singapore and South Korea.

The amount of R&D performed by Japan is only exceeded by the U.S. and China, having been surpassed in R&D spending by China about five years ago. Japan has experienced an economic slowdown, which has affected its R&D investments since the 1990s with growth that's threatened by a large aging population, high national debt and the impact of recent crises and natural disasters (the Fukushima Daiichi earthquake, tsunami and nuclear failures). Japan's R&D distribution is dominated by industrial spending (similar to the U.S. model) which account for about 77% of the total GERD. Its overall ratio of R&D to GDP is one of the most intense in the world at 3.39%

As part of Prime Minister Abe's massive long-term Revitalization Strategy introduced in 2014, the government vowed to promote innovation in science and technology and develop an infrastructure that links innovation technologies with new businesses through the establishment of a "National System" that reforms Japan's institutes to link universities with business and allows researchers to hold concurrent posts at universities and R&D institutes.

Numerous technology programs were also launched as part of the Revitalization Strategy. This included a five-year plan with a "Robotic Revolution Initiative Council" to address social challenges and realize new industrial robotic technologies. Japan also launched a Brain Mapping by Integrated Neurotechnologies for Disease Studies (BrainMINDS) to compete with the similar U.S. BRAIN Initiative and European Human Brain Project. Another project launched in connection with Revitalization Strategy by Japan's Ministry of Education, Culture Sports, Science and Technology (MEXT) was the Program for Promoting the Enhancement of Research Universities where enhanced funding would be given annually over the next 10 years to 22 universities to lead the country's efforts in advancing S&T. MEXT also selected 37 universities to become Super Global Universities providing an annual subsidy from $100 to $400 million each over the next 10 years for personal training, recruitment of international researchers and the improvement of the universities facilities. MEXT also launched academic personnel exchange programs with other East Asian nations for hosting 30,000 researchers in Japan and having 150,000 Japanese researchers study outside of Japan.

South Korea is the fifth largest country investing in R&D with $77 billion forecast to be spent in 2016, a 3.5% increase over the $74.5 billion estimated to be spent in 2015. Korea's R&D is split similarly to that in Japan with 78% of it from industrial sources, 12.5% from government and 9.5% from academia. Of the industrial portion of the R&D, about three-quarters of it came from large corporations, with the remainder from small- and medium-sized enterprises having relatively equal shares. Korea's largest R&D industrial sector is its automotive industry with the most R&D spending and the largest R&D workforce. Similar to China's five-year plans, Korea's government is currently involved in its Third Basic Plan for S&T which runs from 2013 to 2017. The plan includes five major strategies, expanding and improving the efficiency of national R&D investments, developing national strategic technologies, enhancing mid- to long-term creative capabilities, supporting the creation of new industries and creating more S&T jobs. With these programs and substantial government investments, the government is hoping to raise Korea's R&D investment as a ratio GDP from its current 4.04% to 5.0%.

According to a recent OECD report, Science, Technology and Industry Scoreboard 2015, Korea has a medium score in the number of technical papers published in scientific journals over a 10-year period, ranking 12th of the scoreboard behind Australia. The country also ranked lower than the worldwide average for international science cooperation. However, Korea ranked high on disruptive technologies including data transmission and human interface technologies. Korea accounted for more than 14% of the international patents in the areas of the Internet of Things, big data, quantum computing and telecommunications.

India is the sixth largest country in the world investing in R&D (N.B. – four of the top six R&D spending countries are located in Asia) with $71.5 billion forecast to be spent in 2016, a 7.5% increase over the $66.5 billion estimated to be spent in 2015. India has long been recognized for its strong IT infrastructure and educational resources. However, over the past several years, more multinational technology conglomerates have been setting up ambitious R&D projects within India, in part to serve the large Indian market with its 1.3 billion population, but also with an eye to creating and delivering new products faster to the global marketplace. Microsoft, for example, recently announced it was setting up three new large data centers in India and would spend $15 billion on them. Multinational automotive and pharmaceutical companies are setting up large R&D centers within India. Multinationals that have set up R&D units recently in India include Kellogg, Dell, Daussalt Systemes, BASF, Broadcom, Xiaomi and Twitter.

Like China, India is expanding its research presence globally with an increasing number of published technical papers, expanding its output at nearly three times the global average over the past decade. Of course, India started from a relatively low output level and so still has a relatively small share of the total global output, from 21,269 Web of Science (Thomson Reuters) papers in 2003 to 45,639 in 2012.

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R&D Development	41%	21%	38%
R&D Trends	37%	23%	41%

As in the U.S.-China R&D comparison, the level of R&D investments is similar between the U.S. and most Asian countries, however the quality of the work performed is favored in the U.S. about to the same level as in the China-U.S. Comparison.

European R&D

Sixteen of the European Union's 28 member countries are included in our Top 40 R&D spending countries. The only two EU countries not included in our R&D analysis are Malta and Cyprus, both with comparatively small R&D programs. The EU's 26 members, plus eight non-members, are included in our global R&D analysis (34 total) for an R&D forecast investment in 2016 of $408.37 billion (R&D to GDP ratio of 1.87%, GDP of $21,868 billion). Europe's share of the total global R&D investment in 2016 is 21.0%, down from 21.5% in 2014, which declined as a share due to the Asian R&D investment shares which are rising faster. Europe's R&D actually increased by 3.6% in 2015 from 2014 levels and is forecast to increase by 1.9% in 2016.

When comparing U.S. R&D to European R&D, while U.S. R&D is considered superior in overall R&D, R&D quality, productivity, basic and applied research, development and R&D trends, the two regions are more comparable than that seen when comparing U.S. R&D to Asian and China R&D.

When comparing the top companies in the world with regard to R&D, the comparisons are close to equal with 19 of the Top 50 corporations in the world being in Europe, 19 in the U.S. and 12 in Asia, according to the European Commission's Survey on Industrial R&D Investment Trends. The Top 10 technology-based companies in Europe include Volkswagen (Germany), Novartis (Switzerland), Roche (Switzerland), Daimler (Germany), BMW (Germany), Sanofi (France), Robert Bosch (Germany), GlaxoSmithKline (U.K.), Airbus (Netherlands) and Ericsson (Sweden).

Three of the Top 10 R&D investing countries in the world include the EU's Germany, France and the U.K., with 2016 R&D forecasts of $109.25 billion, $60.05 billion and $45.54 billion, respectively. Their R&D/GDP ratios are 2.92%, 2.26% and 1.78%, respectively.

Five of the Top 10 in the Economic Intelligence Unit's 2015 Global Talent Index are also in Europe—Denmark, Finland, Norway, Sweden and Switzerland. (The same countries as were in the Top 10 for the 2011 version of the Index.) The U.S. was number one in both versions of the Index. The Nordic region of Europe is noteworthy as it has four of the top five countries in the talent index. The Nordic region as a whole has high government spending, as a percentage of GDP which is maintained throughout all stages of education, right through to universities, which explains why it has outperformed so many prominent rivals in the developed world in the overall index. The linguistic and technical skills of the Nordic countries' working population are also particularly strong.

Turkey was noted as a European country with a particularly dramatic improvement in the talent index, while Austria and Greece were noted for their particularly dramatic declines in the index rankings. Turkey is ranked 43rd out of 60 countries, while Austria and Greece are ranked 20th and 33rd, respectively. Overall, Western Europe was ranked second behind North America, while Eastern Europe was ranked sixth.

Regarding technical publishing, 15 of the Top 20 countries in the world with the most cited documents and scientific leading authorship over the past 10 years are in Europe. These include, in order, the Netherlands, U.K., Switzerland, Denmark, Austria, Sweden, Belgium, Finland, Germany, Ireland, Norway, Italy, France, Spain and Portugal. The overall global share of European technical published papers, however, has declined 3% as a global share of all published paper over the past ten years to 38.5%, according to a recent

How Does U.S. and European R&D Compare?

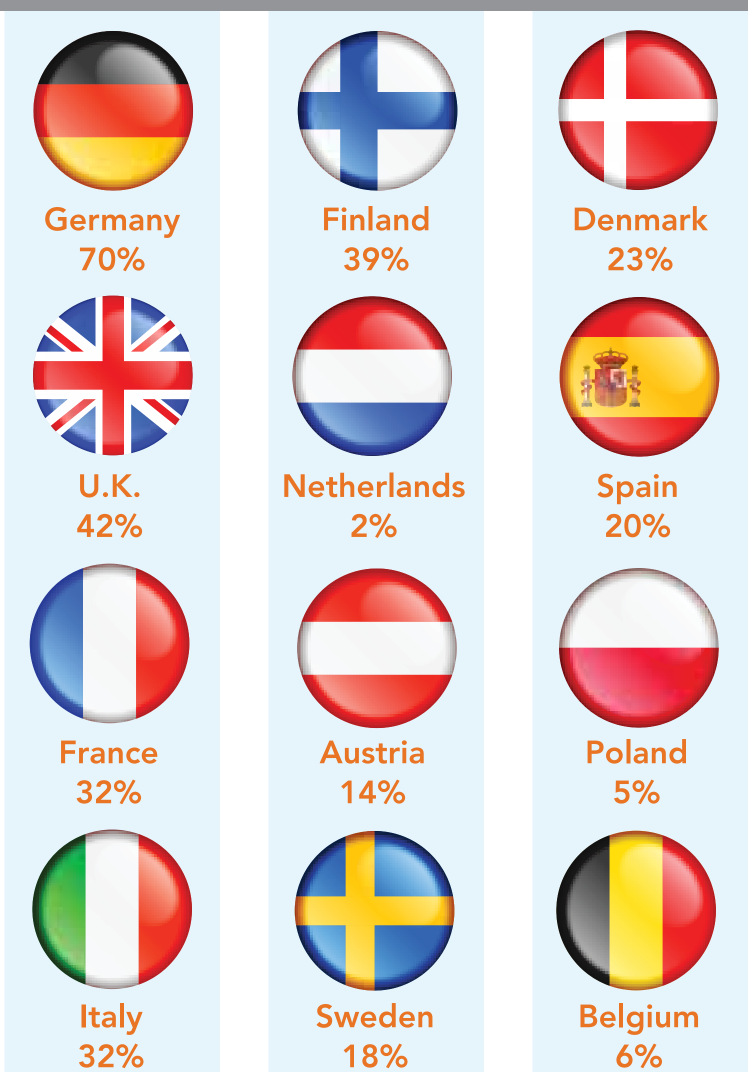
	U.S. Superior	Europe Superior	Both the Same
Overall R&D Investments	43%	18%	39%
R&D Quality	34%	16%	50%
R&D Productivity	47%	12%	41%
R&D Basic Research	36%	17%	46%
R&D Applied Research	46%	17%	37%
R&D Development	42%	15%	43%
R&D Trends	32%	19%	49%

U.S. R&D investments are considered to be superior to those made in European countries, many of which are economically depressed. The quality of the work performed is also considered, in general, to be superior to that performed in Europe.

report by Thomson Reuters. The top fields for European researchers by world share of highly cited papers, over the past 10 years, were astronomy and astrophysics (37% global share in Germany alone), plant and animal sciences, physics, geosciences and clinical medicine. By comparison, only astrophysics and astronomy ranked in the top five for the U.S. by the same indicator. Most European technical paper share losses have been attributable to the rapid rise of technical paper publishing in China.

Germany is the leading country in Europe for economic strength, GDP ($3.741 trillion forecast for 2016), R&D, industrial R&D and manufacturing production, technical paper publishing and patents. Its output of technical papers indexed in Thomson Reuters Index of Science over the past 10 years has risen from 70,000 in 2004 to 95,000 in 2012. Germany has particularly strong performance in the technical output and impact across physical and biological sciences, revealing the presence of a well-balanced S&T portfolio. Germany also has the global leadership in automotive technology with a strong R&D infrastructure at Volkswagen, Daimler, Audi, Porsche, Robert Bosche and BMW.

Attractiveness of European Country for R&D



Germany is overwhelmingly considered the most attractive location for R&D in Europe due to its strong engineering and academic credentials.

Three of the Top 10 R&D investing countries in the world include the EU's Germany, France and the U.K., with 2016 R&D forecasts of $109.25 billion, $60.05 billion and $45.54 billion, respectively. Their R&D/GDP ratios are 2.92%, 2.26% and 1.78%, respectively.

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Rest of World R&D

Eliminating the 56 countries from the Asian, U.S. and European regions of global R&D spenders that we've discussed in this International R&D section leaves 55 countries that split $212 billion of the remaining global R&D pie. The geographical regions this ROW includes are North America, South America, the Middle East, Africa and Russia/Confederation of Independent States (CIS). In terms of R&D spending the leading countries in each of these five regions are shown in the attached table. These five leaders are all in the Top 40 R&D spending countries for which economic details are provided in the earlier sections of this report. While the ROW R&D spending countries account for about half of the global R&D spending countries in this report, they are only responsible for about $26.346 trillion (or 23.5%) of the global R&D spenders' economy (GDP). This then relates to an average R&D/GDP ratio of 0.81%, less than half of the average 1.74% ratio for all 111 countries.

As seen in the attached tables, Canada, Brazil and Russia dominate their respective regions in terms of their R&D spending. Middle East R&D spending is more distributed among Iran, Israel, Qatar and Saudi Arabia who together contribute 88.9% ($39.85 billion) of their region's R&D. Similarly, South Africa, Egypt and Nigeria together contribute 65.7% ($14.66 billion) of Africa's total R&D spending.

The overall ROW distribution has not changed dramatically over the past decade. There has been a slight increase in the overall R&D/GDP, but the overall rankings of the ROW countries has not shifted. Canada, Russia, Brazil and South Africa have maintained their relative positions in the overall global R&D rankings for more than six years. Iran broke into *R&D Magazine*'s Top 40 rankings in 2013, primarily with a more detailed examination of their military/defense R&D spending.

For 2016, the ROW countries have mixed growth prospects. Russia's economic problems (and its strong R&D dominance in its region) will contribute to forecast a 0.8% decline in R&D spending from the $53.92 billion the region is estimated to spend in 2015. Again, Brazil's dominance in its region and its own internal economic slowdown will contribute to a muted R&D growth of only 1.0% in 2016. Brazil's massive spending on the 2016 Summer Olympics may also have a further detrimental effect on its ability to fund its 2016 (and beyond) R&D programs.

The Middle East region is expected to have strong R&D growth of 3.5% in 2016, driven by the region's strong long-term growth policies amid a slowdown in petroleum-based revenues limiting its overall economic growth. These countries, however, are constrained by a weak R&D infrastructure and the ability to recruit experienced scientists and engineers from outside their region. Africa is also expected to have strong 4.0% R&D spending growth in 2016 as the region's government develop longer-term policies to increase their overall competitiveness. Like the Middle East region, though, Africa's R&D growth is limited by under-developed R&D capabilities and recruitment abilities, except in South Africa.

Canada, which drives the non-U.S. North American region's R&D spending, is expected to grow its R&D by about 2.0% in 2016, although a recent administration

Rest of World R&D Regions

	Countries	Forecast 2016 R&D	Global Share
North America/Caribbean	9	$41.33 billion	2.0%
South America	11	$50.30 billion	2.6%
Middle East	13	$44.84 billion	2.3%
Africa	17	$22.30 billion	1.1%
Russia/CIS	5	$53.49 billion	2.8%
Total	**55**	**$212.26 billion**	**10.8%**

Rest of world R&D investments are spread evenly among five regions making up about 11% of the total global R&D spending, or $212 billion of the total $1.95 trillion.

Leading Countries in ROW R&D Regions

	Leading Country	Forecast 2016 R&D	Regional Share	Global Rank
North America	Canada	$29.46 billion	71.3 %	11
South America	Brazil	$37.18 billion	73.9 %	10
Middle East	Iran	$11.78 billion	23.4 %	21
Africa	South Africa	$6.76 billion	30.3%	33
Russia/CIS	Russia	$50.95 billion	95.2 %	8
Total R&D		**$136.13 billion**	**64 % of 55 ROW countries**	

Five countries in the five ROW regions are responsible for nearly two-thirds of the $212 billion in R&D invested in these areas.

change and very topical changes in its petroleum production and potential exports may limit its economic growth in 2016, thereby limiting its R&D growth as well.

Mexico also offers a stark contrast to the traditional R&D model. Despite its proximity to the U.S. and the U.S.'s leading-edge R&D infrastructures, Mexico's R&D intensity has languished in the sub-0.5% (R&D/GDP) for more than 20 years. Mexico's economy continues to grow at a reasonable pace (3.3% forecast for 2016), its economy is large ($ 2.3 trillion) and it has strong petroleum and mineral resources on which to build. But, Mexico has shown relatively few political incentives for building its R&D infrastructure. It also provides production support to the U.S. for many of its automotive and other high-technology industries on which it has failed to build an internal S&T infrastructure for growing its future capabilities. Mexico's overall S&T and academic infrastructures are not well-suited at this point in time to support R&D growth.

It is indeed difficult for the mostly emerging economies in the ROW R&D spenders to keep up with the massive spending programs exhibited in China and even the U.S. China is, of course, an anomaly in terms of R&D spending with even other strong Asian regional players like South Korea, Japan and Singapore unable to implement competitive spending and R&D growth programs. The McKinsey Global Institute has forecast slowing global economic growth in the next decade with reduced capital supplies by 2030. This is especially important for the ROW economies with already limited R&D infrastructures, which could then be further limited in their R&D growth ambitions.

ROW countries are mostly caught in a Catch-22 dilemma in that they often have strong aspirations for innovation-based growth, but they lack the strong diversity of talent, the internal S&T infrastructures and markets and the will or ability to invest at the level needed to increase their R&D standing. Many emerging ROW countries, like Mexico, have the components needed to build a strong R&D environment—economic size, population, geographical positioning and connectivity—yet they lack one or more of the essential components like political priorities to move forward. Other countries, like Qatar and Belgium, invest similar levels of R&D as Mexico, but with much smaller economies, populations and political limitations.

Like China in Asia, Russia in the ROW group of R&D investing countries is a standout exception, but in a different direction from China. It ranks eighth in the overall ranking of R&D spending countries, has a strong S&T infrastructure and has scientific leadership in many industries including aerospace, military/defense, manufacturing/production and materials/resources. Russia, however, has a political infrastructure and aspirations that have limited its R&D abilities since the downfall (and before) of the Soviet Union. Its economy is in turmoil amid falling oil prices and politically inspired trade restrictions by Western countries. It also suffers from an increasing level of national corruption that limits its overall abilities to perform both rationally and increase its long-term technological capabilities. Its S&T staffing abilities have suffered for 20 years with restricted pay, recruiting limitations, falling morale and a failing R&D infrastructure (facilities and equipment). The problem is that during its Soviet Union days, scientists and engineers had a strong standing in the S&T community, it traditionally had researchers who won Nobel Prizes on a regular basis and contributed globally to the enhancement of S&T. That does not happen now and external organizations are increasingly hesitant to partner, collaborate or work with Russian S&T organizations.

THE GLOBAL RESEARCHER

Effective R&D has many different aspects and components, including innovation, funding, technologies and the scientists and engineers who make up the R&D staff. How those researchers feel about their work and their R&D environment makes up this section of the *2016 Global R&D Funding Forecast*.

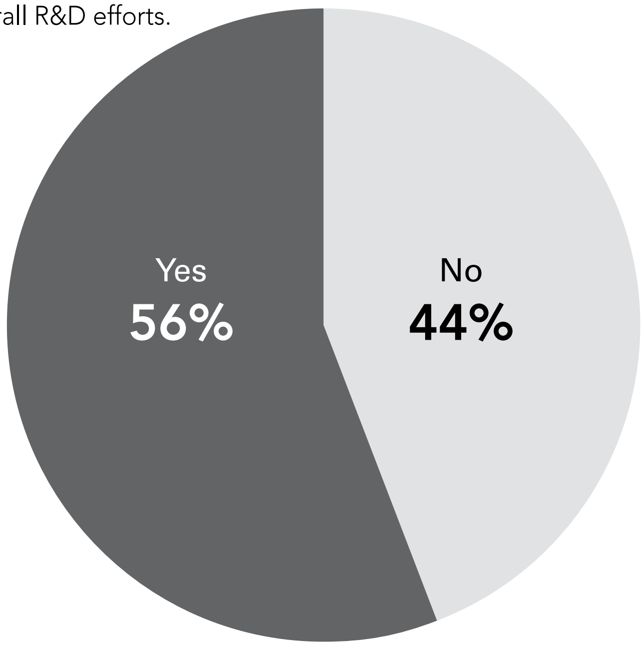
Innovation is considered one of those key aspects that drives the development of new and successful product development. In the various surveys we performed to create this report, one of the questions we asked our researchers was if the level of innovation within their organization was adequate. Surprisingly, more than half (56%) stated the level of innovation within their organization was not adequate. In the 20th century, the U.S. had become the undisputed leader in innovation and was responsible for nearly a quarter of the world's economy, while only having about 5% of its population. Since 2000, globalization has rapidly distributed technologies throughout the world, and the U.S. has lost some of its leadership, although it continues to rank highly in a number of innovation measures. Indeed, a report from the *Atlantic Century*, after reviewing 16 innovation characteristics—including the number of scientists and engineers, corporate and government R&D, venture capital, productivity and trade performance—noted the U.S. has made no progress since 1999 in its competitiveness.

Having a strong innovation environment within your R&D organization and environment results in creating a very competitive product development. According to the 2015-16 Global Competitiveness Report by the World Economic Forum (WEF), the U.S. now ranks third in innovation-based competitiveness, behind Switzerland and Singapore. Other countries making up the Global Top 10 in WEF's Competitiveness Index include (in order) Germany, the Netherlands, Japan, Hong Kong, Finland, Sweden and the United Kingdom. China ranks 28, the same ranking as it had in the WEF's 2014-15 report.

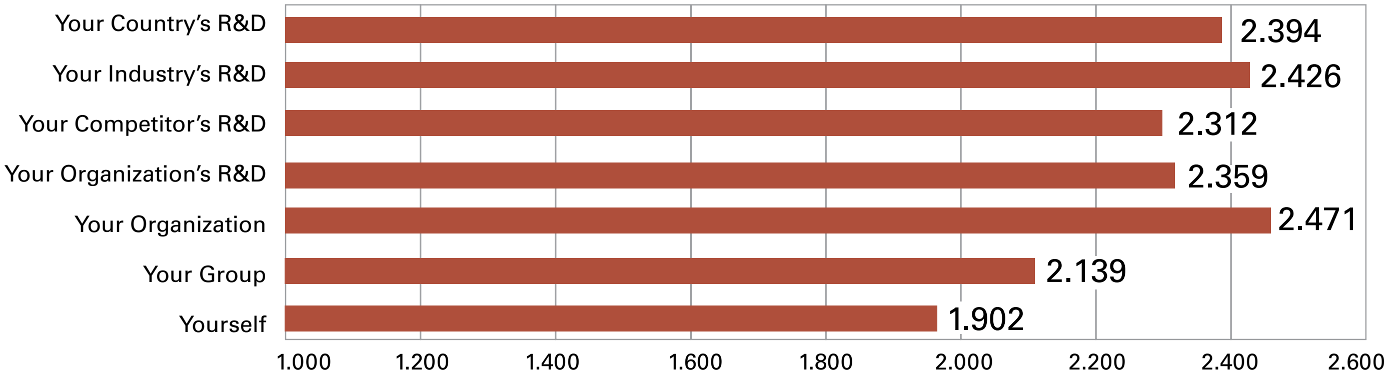
When the researchers were asked about the innovativeness

Is the Level of Your Organization's Innovation Adequate?

There is a slight bias by researchers in their organizations not having an adequate level of innovation for their overall R&D efforts.



How Do You Rate Your Innovation?



Researchers considered their individual R&D efforts significantly more innovative than their organization's, industry's and country's R&D efforts. 1=Highly Innovative, 5=Not Innovative of their own personal work, their company, industry and country, more than 40% of the survey respondents stated they were personally very innovative, while only ranking their group, organization, organization's R&D, competitors' R&D, industry's and country's innovativeness in the 18 to 26% range for being very competitive. Looking at a composite of these rankings on the attached chart, with 1.0 being very innovative and 5.0 not being innovative, the average rankings reveal the disparities between the different groups.

The R&D Budget

Nearly two-thirds of the researchers we surveyed stated they had larger R&D budgets in 2014 than they did in 2013 by an average of about 7%. About 20% stated they had similar budgets, and the remaining researchers (16%) stated they had smaller budgets in 2014 than they had in 2013, again by about 7%. Most of those researchers (75%) stated they held to their budgets, while about 15% overspent their budgets and the remaining 10% underspent their budgets.

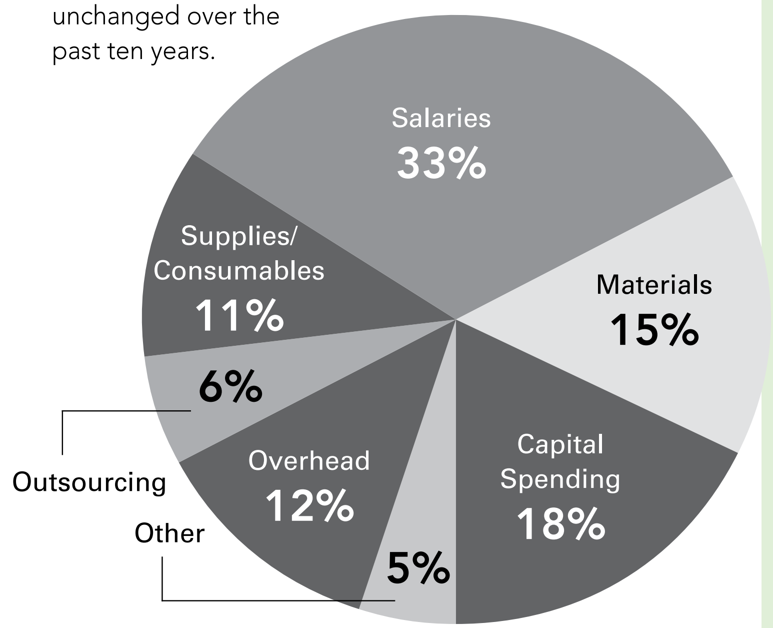
While the majority of these researchers had larger budgets in 2014 than they had in 2013, they still stated they were limited in what they could do by a shortage of R&D funds. Most of the researchers (74%) stated their R&D in 2014 was successful. Only 6% of the survey respondents stated their R&D was unsuccessful—only 2% said it was extremely unsuccessful, while the other 4% said it was only slightly unsuccessful. The ratios were quite similar when looking at the researchers' 2015 versus 2014 R&D budgets. Again, nearly two-thirds (62%) said they had larger R&D budgets in 2015 than they had in 2014, 20% had similar budgets and 15% had smaller R&D budgets in 2015 than they had in 2014. The larger R&D budgets for 2015 averaged about 6% larger, while the reduced R&D budgets for 2015 were about 5% smaller. Very few researchers (3%) had budgets that were more than 10% smaller than in 2014, while a considerable number of researchers (12%) stated that their 2015 R&D budgets were more than 10% larger than in 2014.

Our *2016 Global R&D Funding Forecast* surveys were deployed in the third quarter of 2015, and asked about how the researchers expected to work with their current 2015 R&D budgets. As noted on the attached chart, more than two-thirds (69%) of the survey respondents indicated they would hold to their stated 2015 budgets, while about 21% said they would exceed their 2015 budgets and only 10% said they would underspend their 2015 R&D budgets. Again, these statistics mirrored the results that researchers held to for each of the last two years of their R&D operations.

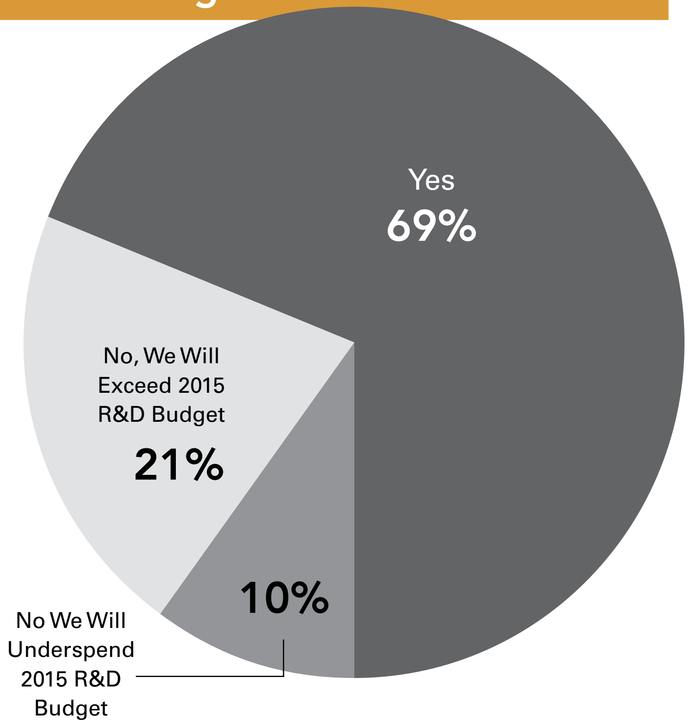
Looking at how researchers distribute their R&D budgets, the largest portion of the R&D "pie" is dedicated to staff salaries (33%). This is consistent with R&D funding reports we've created in the past. Capital spending takes up the next largest

Distribution of R&D Budget – 2015

The distribution of an organization's R&D budget dedicates a third to salaries and another third to capital spending and materials. These ratios are basically unchanged over the past ten years.



Will You Hold to Your 2015 R&D Budget?



Most researchers expected to hold to their established 2015 R&D budgets when our survey was conducted in the August 2015.

share at 18%, and this accounts for new research laboratory designs, construction and renovations; new large instrumentation and equipment purchases; and the creation of specialized testing structures and systems. Often, the capital expenditures assigned to the organization's R&D budget are of a lower scale, while larger structures and systems are assigned to capital budgets in the operational side of the organization. In that regard, the cost for a new NMR system might be allocated to the R&D budget, while the cost of a relatively massive structure for housing that same NMR would be allocated to the organization's operations budget.

The bulk of the remaining R&D budget is comprised of materials (15%), supplies and consumables (11%), overhead (including utilities, maintenance and support (12%)) and outsourcing (6%). A 5% "other" category for the R&D budget can accommodate things like licensing, legal fees, transportation, training, recruitment and emergency activities and systems.

The cost increases involved for the R&D operations of our 2015 survey respondent researchers are about equal to their 2015 R&D budget increases, according to nearly half of the survey respondents. About 30% of the remaining respondents stated the 2015 cost increases were more than their 2015 R&D budget increases, while the final 20% stated their 2015 R&D cost increases were less than their 2015 R&D budget increases.

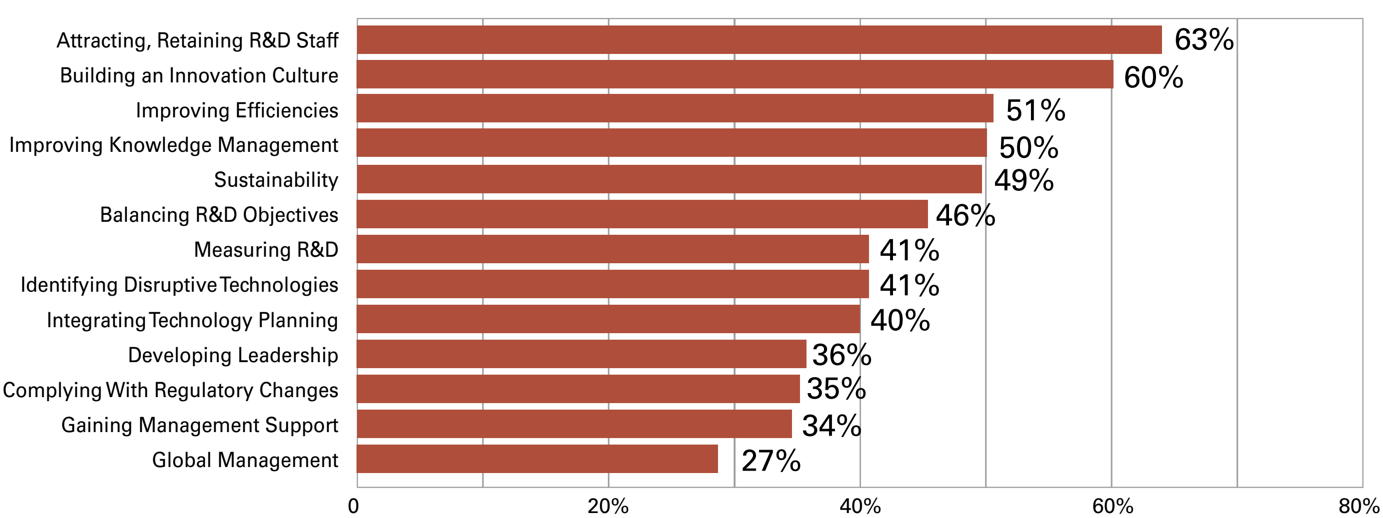
What are the Funding Sources for Your R&D?

Two thirds of an R&D organization's R&D funding comes from internal sources, while about a third comes from external grants. A rating exceeding 100% is shown due to multiple responses.

Prioritizing R&D Operations

From 2014 to 2015, there have been a number of changes that have affected the R&D operations of organizations. Some of these are continuing trends, while others are new or enhanced to the organization. Increasing costs and competition are the two biggest continuing trends that R&D managers now have to cope with. More than half of our survey respondents said that from 2014 to 2015 their R&D costs have increased, while less than 4% said they decreased. More than 40% of the survey respondents also stated that over the past year, their competition has increased while only 5% said it decreased.

What's Most Important in Your R&D?



Attracting and retaining R&D staff is the most important item for researchers and research managers, vastly outweighing technology areas.

Other changes in the R&D environment over the past year include increased time-to-market demands (34% of the survey respondents), increased staffing requirements (34%), increased collaborations/partnerships/alliances (34%), increased creation of intellectual property (IP) (32%), increased time-to-market performance (26%), increased outsourcing requirements (24%), new spinoffs based on developed technologies (22%), increased patent requirements (22%) and increased participation in consortia (19%). On the flip side, but to a lesser extent, there have been decreases seen by researchers over the past year associated with their R&D operations. The largest of these decreases include decreased grants and contracts for academic R&D (15% of the survey respondents), decreased contracts with government research laboratories (14%) and reduced staffing requirements (13%).

Finding the Money

Researchers are unlike many traditional employees in that they can get funding for their work from a variety of areas. The attached chart reveals where much of these funds come from—the responses for this question in our surveys allowed multiple responses, so the sum of the responses shows a larger number than 100%. As noted, the largest fraction of researchers get funding for their research operations from internal sources, be that for industrial, government or academic types of operations. The second largest source of funds (36%) comes from external grants, such as those from the NIH or NSF for academics or biopharmaceutical researchers, or from the DOD or National Institute of Standards and Technology (NIST) for industrial or aerospace organizations.

R&D funding from external contracts (32% of the survey responses) is the third largest source of funds for R&D organizations. These contracts include the work funded by the federal government to industrial R&D organizations and between industrial companies for contract research work. Crowd sourcing is a popular method of obtaining research funding, but still within the smallest category of funding sources (6%).

Finding the money for R&D is important for creating a strong, innovative R&D environment. As noted above, the largest component of an organization's R&D budget is the part dedicated to scientists/engineers salaries (33% of the overall budget). The highest importance within the R&D environment, according to our survey, is that component responsible for attracting and maintaining an adequate

How U.S. Technology Changed Over the Past Year

	U.S. Gained Advantage	U.S. Lost Advantage	No Change
Advanced Materials	47%	25%	27%
Agriculture/Food	26%	27%	47%
Automotive	29%	37%	34%
Commercial Aerospace	39%	28%	34%
Communications	48%	22%	29%
Computing/IT	45%	27%	28%
Energy	48%	31%	21%
Environmental	37%	29%	34%
Instrumentation	33%	27%	41%
Life Science/Healthcare	44%	26%	29%
Military/Defense	47%	23%	30%
Pharmaceutical/Biotech	43%	22%	34%

U.S. R&D organizations have gained more advantages than they've lost advantages in a wide range of technology areas by a margin of nearly two to one.

R&D staff—nearly two-thirds of the researchers surveyed indicated this component as having the highest importance for their R&D. Money is obviously just one component for maintaining and attracting researchers, but it is likely the most important component. Tied closely to creating a strong research staff is the creating of an innovation culture within the R&D organization, according to our survey results.

As a carry-over from the lessons learned in the Great Recession of 2008-2009, many R&D organizations still run a lean operation. “Our biggest concern for our 2016 R&D budget is a decreased R&D budget due to limited or declining sales,” noted one survey respondent. “Our biggest concern for our 2016 R&D budget is our business performance, which is driven by currency exchange rates and soft industrial markets,” said another researcher. Economics as applied to funding R&D operations and, to a much lesser degree, R&D staffing concerns dominated the concerns of our survey respondents.

Technology Changes

As noted earlier, U.S. R&D organizations had dominated most of the major technology-based industries until 2000, when globalization of technology, production expertise and production economics transformed the product development landscape. Since then, specific U.S. industries have worked to become more productive, efficient and innovative. Over the past year (from 2015 to 2014) U.S. industries have gained and lost competitive advantages in a number of industries as noted in the attached table. In the automotive arena, the U.S. has lost the technology and competitive advantage many years ago and, over the past year, they lost more advantage (37%) than they gained (29%), according to our surveys.

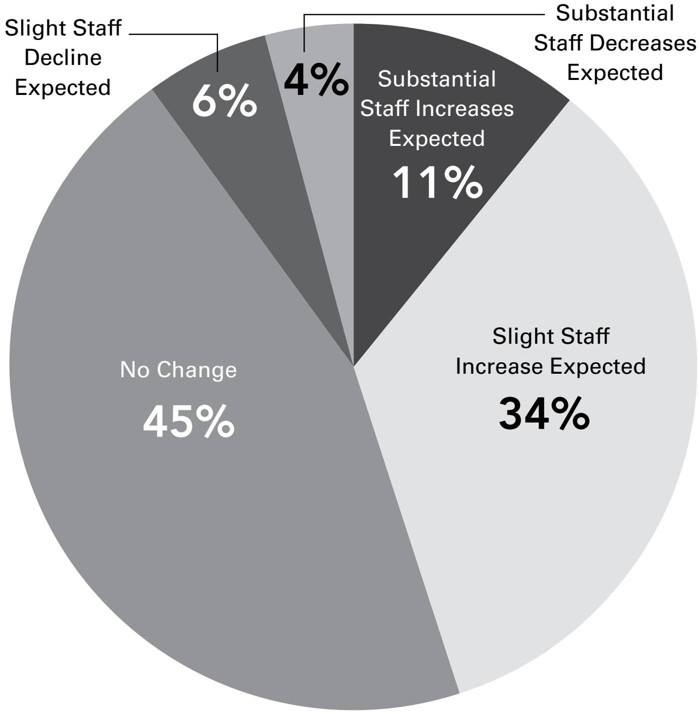
In most other areas, specific U.S. industries gained more technological advantage than they lost. This includes advanced materials (47% gain, 26% lost), commercial aerospace (39% gain, 28% lost), communications (48% gain, 22% lost), computing/IT (45% gain, 27% lost), energy (48% gain, 31% lost), environmental (37% gain, 29% lost), instrumentation (33% gain, 27% lost), life science (44% gain, 26% lost), military/defense (47% gain, 23% lost) and pharmaceutical/biotech (43% gain, 22% lost).

In the agricultural/food industry, there was an even split in that 26% of the survey respondents said the U.S. gained a technological advantage over the past year, while 27% of the respondents stated that U.S. industries had lost the technological advantage over the past year. And, in the instrumentation industry, while the U.S. gained a slight technological advantage over the past year, the number of survey respondents who actually saw no change over the past year was larger than either those who said they saw the U.S. gain an advantage or those who said they saw the U.S. lose an advantage.

These survey responses and implied trends are not surprising. They basically reinforce established technological strengths, although the ratios of gained advantage by U.S. companies versus their lost advantage over the past year might be a bit smaller than in previous years, which is a reflection of the technological gains being made in the global marketplace.

What R&D Staffing Changes Do You Expect in 2016?

Nearly half of the researchers surveyed expect to see R&D staff increases in 2016, while only 10% of those survey respondents expect to see R&D staff reductions.



The Future

We noted that one of the most important issues facing managers is maintaining, retaining and recruiting skilled scientists and engineers for the R&D laboratory. Expected R&D staffing changes in 2016 can come about through overall staff reductions based on the organization’s economic situation and required staff increases due to expansion, growth or replacements for normal staffing turnover/reorganizations. Our surveys reveal only 10% of our reader researchers expect to see staff reductions in their R&D organizations in 2016. Nearly half (44%) of the researchers expect to see either slight staff increases (34%) or substantial staff increases (34%) in their R&D groups in 2016. Slightly less than half (45%) expect no R&D staffing changes in 2016.

RESOURCES

The following web sites are good sources of information related to the global R&D enterprise. Information shown in this report was derived from these sources.

ANPEI – National Association for Research and Development of nnovative Companies
www.anpei.org.br

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

Australasian Industrial Research Group
www.airg.org.au

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

Industrial Research Institute (IRI)
www.iriweb.org

International Monetary Fund (IMF)
www.imf.org

Japanese Research Industries and Industrial Technology Association
www.jria.or.jp/HP/EN

Korean Industrial Technology Association (KOITA)
www.koita.or.kr

McKinsey & Company
www.mckinsey.com

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 *(NSF)www.nsf.gov*

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

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