R&D®

2017 GLOBAL R&D FUNDING FORECAST

A Supplement to R&D Magazine

WINTER 2017

INSIDE

- U.S. R&D Spending Expected to Increase by 2.9% to $527.5 billion
- China R&D to Increase Total R&D Spending by 7.1% to $429.5 billion
- Asia has the Greatest R&D Growth in the World
- Industry Continues to Drive Global R&D

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Message from the IRI President

For two years now the *Industrial Research Institute* (IRI) and *Research-Technology Management* (RTM) have been privileged to partner with *R&D Magazine* in the release of the global research and development funding forecast. Drawing on the expertise of a diverse set of industry and academic leaders, this report is a tremendous resource for researchers, economists, policy makers and many others worldwide, and we are proud to play an active role in developing it.

Looking towards 2017, we see that growth rates for R&D funding have slowed somewhat from the previous year, but optimism remains strong across many industry segments. The U.S. still holds the title of largest investor in R&D, but China is closing the gap steadily with each passing year. Turmoil in several parts of the world has created a drag on their respective R&D investments, but overall most countries continue to push forward with technological investments and discovery.

As an organization representing just under 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 2017. The indicators are all there: expectations for spending increases among industry and academic leaders, attitudes towards partnerships and alliances are lower than last year but still rising, and the overall health of the global economy continues 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 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 healthcontribute 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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Editor's Note: The 2017 Global R&D Funding Forecast™ was partially based on data collected from a series of proprietary surveys of *R&D Magazine* readers, members of the Industrial Research Institute (IRI) and associated IRI organizations. Unless otherwise noted, the sources of the data for the graphics in this report are the results of those surveys, which were distributed in June to September 2016. Specific data points and analyses in this report are proprietary to Advantage Business Media (ABM, the publisher of *R&D Magazine*) and IRI and will not be released. All inquiries regarding this report should be addressed to ABM Science Group, 100 Enterprise Drive, Suite 600, Rockaway, NJ 07866.

Global Funding of Research and Development Overview

Slowing Economies Slow R&D Investments

R&D *Magazine*'s 58th annual *Global R&D Funding Forecast* estimates that global R&D investments will increase by 3.4% in 2017 to $2.066 trillion in purchasing power parity (PPP) values for the more than 115 countries having significant R&D investments (more than $100 million). The growth rate on R&D investments has slowed in 2017 as the overall slowing global economy is being reflected in the amount of monies that are now available for R&D endeavors.

The annual *Global R&D Funding Forecast* is created by the editors of *R&D Magazine* and is sponsored by the Industrial Research Institute (IRI), Washington, D.C. This report is published as a public service for scientists, engineers and research managers in the preparation of their annual R&D budgets and the evaluation of the current R&D environment.

The overall global R&D forecast is a combination of the industrial, government and academic investments by each country. Much of the R&D investments are driven by each country's economic situation which is characterized by its gross domestic product (GDP). Our forecast is based on a combination of specific country economic values, published relationships of the country's science and technology (S&T) to its economy, and the most recent economic forecasts by organizations such as the International Monetary Fund (IMF), the World Bank, the Organization for Economic Cooperation and Development (OECD) and the U.S.'s Central Intelligence Agency (CIA).

The U.S. continues to be the country with the largest investments in R&D, a title it has held for the past 50 years. The U.S. share of the global R&D pie continues to shrink due to the higher growth rates in Asia, however at a slowing rate over the past five years. Economic turmoil in many third world countries and countries with social strife are seeing stagnating R&D investment rates, which are not keeping pace with the advanced North American and European economies and the Asian high-growth economies.

Share of Total Global R&D Spending

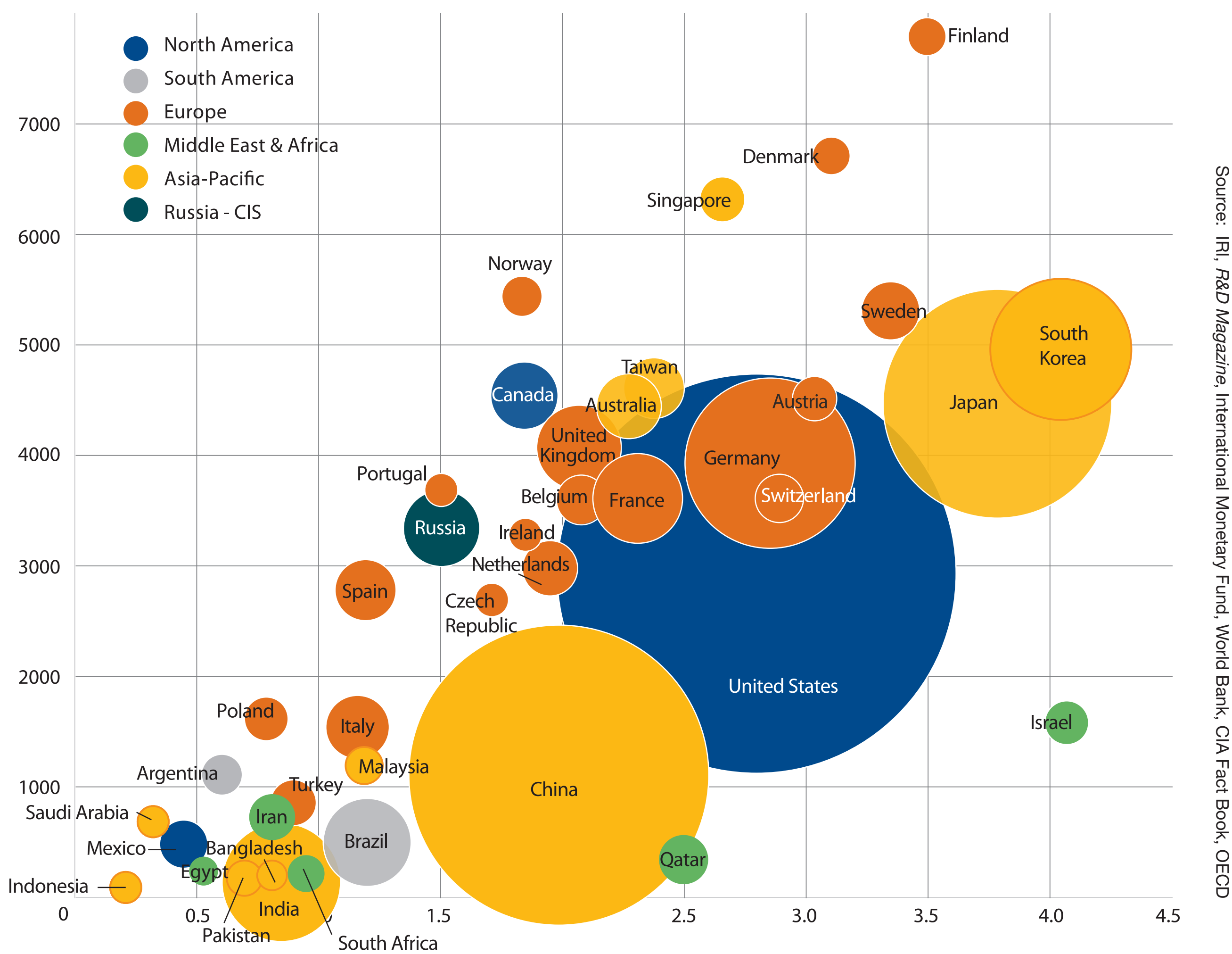
	2015	2016	2017
North America (12 countries)	27.9%	27.8%	27.7%
United States	25.8%	25.6%	25.5%
South America (10 countries)	2.7%	2.5%	2.4%
Europe (34 countries)	21.6%	21.2%	20.8%
Germany	5.8%	5.6%	5.4%
Asia (24 countries)	41.3%	42.3%	42.9%
Japan	8.5%	8.6%	8.4%
China	19.4%	20.1%	20.8%
South Korea	3.9%	4.0%	4.1%
India	3.5%	3.6%	3.8%
Africa (18 countries)	1.0%	0.9%	0.9%
Middle East (13 countries)	2.5%	2.4%	2.5%
Russia/CAS (5 countries)	3.0%	2.9%	2.8%
Total (116 countries)	**100.0%**	**100.0%**	**100.0%**

As noted in the Table, over the past ten years in these forecasts, the overall growth in global R&D investments is being driven by substantial increases in Asian countries and especially in China, which for many years increased its R&D investments by more than 10% per year. Over that many years, the Chinese rate increases are basically unsustainable and its current R&D growth rate is now in the 7% growth rate range, which is still more than twice that of the U.S. and most European countries. As noted the Table, Asia accounts for more than 42% of all global R&D investments and its share rate continues to increase each year—at the expense of all the other countries investing in R&D.

Over the past twelve months, the recovery from the 2008-2010 global recession has slowed with consecutive economic growth forecasts from the IMF that have reduced its overall outlook in a pattern of forecasts released approximately every three months. The most current IMF World Economic Outlook (October 2016) again reduced its growth forecasts for most countries from the updated report it issued in July 2016, which itself revealed a lower growth rate from the IMF's official April 2016 report. This recovery is one of the longest recovery periods on record and has negatively affected the growth rates on emerging economies. The U.S. economy continues to outpace many other Western economies with strong programs in place for ensuring continued, albeit slow, growth. Supporting this growth is a strong cadre of academic institutions, a strong organization of federal government research organizations and facilities and strong industrial organizations. Over the past two years, industrial investments in R&D appear to be increasing at a time when many federal organizations have frozen their R&D budgets and investments due to budgetary restrictions and constraints.

> The U.S. continues to be the country with the largest investments in R&D…

A number of technological trends, which include biopharmaceuticals, automation and robotics, artificial intelligence, cloud computing, autonomous transportation systems, unmanned aerial systems and advanced military and weapons systems ensure that technology will continue to drive new advances for



The 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

		2015 Actual			2016 Estimated			2017 Forecast		
		GDP *PPP Bil, US$*	**R&D** *as % GDP*	**GERD** *PPP Bil, US$*	**GDP** *PPP Bil, US$*	**R&D** *as % GDP*	**GERD** *PPP Bil, US$*	**GDP** *PPP Bil, US$*	**R&D** *as % GDP*	**GERD** *PPP Bil, US$*
1	United States	17,950.0	2.77%	496.84	18,237.0	2.81%	512.46	18,638.0	2.83%	527.46
2	China	19,390.0	1.92%	372.81	20,669.7	1.94%	400.99	21,951.3	1.96%	429.54
3	Japan	4,830.0	3.41%	164.59	4,854.2	3.55%	172.32	4,883.3	3.50%	173.36
4	Germany	3,841.0	2.92%	112.16	3,906.3	2.88%	112.50	3,961.0	2.84%	112.49
5	South Korea	1,849.0	4.04%	74.70	1,898.9	4.26%	80.89	1,955.9	4.29%	83.91
6	India	7,965.0	0.85%	67.70	8,570.3	0.85%	72.85	9,221.7	0.84%	77.46
7	France	2,647.0	2.26%	59.82	2,681.4	2.24%	60.06	2,716.3	2.24%	60.84
8	Russia	3,718.0	1.50%	55.77	3,688.3	1.50%	55.32	3,728.8	1.50%	55.93
9	United Kingdom	2,679.0	1.78%	47.69	2,727.2	1.75%	47.73	2,757.2	1.75%	48.25
10	Brazil	3,192.0	1.21%	38.62	3,086.7	1.20%	37.04	3,102.1	1.20%	37.22
11	Australia	1,489.0	2.39%	35.59	1,532.2	2.30%	35.24	1,573.5	2.30%	36.19
12	Canada	1,632.0	1.79%	29.21	1,651.6	1.80%	29.73	1,683.0	1.80%	30.29
13	Italy	2,171.0	1.27%	27.57	2,188.4	1.27%	27.79	2,208.1	1.27%	28.04
14	Taiwan	1,099.0	2.35%	25.83	1,110.0	2.40%	26.64	1,128.9	2.45%	27.66
15	Spain	1,615.0	1.30%	21.00	1,665.1	1.27%	21.15	1,701.7	1.27%	21.61
16	Netherlands	832.6	2.16%	17.98	846.8	2.10%	17.78	860.3	2.10%	18.07
17	Sweden	474.4	3.40%	16.13	491.5	3.28%	16.12	504.3	3.30%	16.64
18	Turkey	1,589.0	0.86%	13.67	1,641.4	0.92%	15.10	1,690.7	0.92%	15.55
19	Switzerland	482.3	2.90%	13.99	487.1	2.96%	14.42	493.5	2.98%	14.71
20	Singapore	471.9	2.60%	12.27	479.9	2.60%	12.48	490.5	2.60%	12.75
21	Austria	404.3	2.84%	11.48	410.0	3.00%	12.30	414.9	3.00%	12.45
22	Israel	281.9	3.95%	11.14	289.8	4.10%	11.88	298.5	4.10%	12.24
23	Belgium	494.1	2.24%	11.07	501.0	2.35%	11.77	508.0	2.35%	11.94
24	Mexico	2,227.0	0.45%	10.02	2,273.8	0.50%	11.37	2,326.1	0.50%	11.63
25	Iran	1,371.0	0.90%	12.34	1,432.7	0.75%	10.75	1,491.4	0.75%	11.19
26	Malaysia	815.6	1.10%	8.97	850.7	1.25%	10.63	889.8	1.25%	11.12
27	Poland	1,005.0	0.90%	9.04	1,036.2	0.89%	9.22	1,071.4	0.90%	9.64
28	Indonesia	2,842.0	0.30%	8.53	2,981.3	0.30%	8.94	3,139.3	0.30%	9.42
29	Qatar	319.8	2.70%	8.63	328.1	2.50%	8.20	339.3	2.50%	8.48
30	Denmark	258.7	2.98%	7.71	261.3	3.02%	7.89	264.9	3.04%	8.05
31	Finland	225.0	3.55%	7.99	227.0	3.50%	7.94	229.3	3.50%	8.03
32	Saudi Arabia	1,683.0	0.40%	6.73	1,703.2	0.40%	6.81	1,737.3	0.45%	7.82
33	Egypt	1,048.0	0.43%	4.51	1,087.8	0.60%	6.53	1,131.3	0.60%	6.79
34	Czech Republic	332.5	1.88%	6.25	340.8	1.80%	6.13	350.0	1.85%	6.48
35	Norway	356.2	1.65%	5.88	359.0	1.70%	6.10	363.4	1.75%	6.36
36	South Africa	723.5	0.95%	6.87	724.2	0.85%	6.16	730.0	0.85%	6.20
37	Pakistan	931.0	0.75%	6.98	974.8	0.60%	5.85	1,023.5	0.60%	6.14
38	Argentina	972.0	0.62%	6.03	954.5	0.58%	5.54	980.3	0.56%	5.49
39	Ireland	257.4	1.72%	4.43	270.0	1.72%	4.64	278.7	1.75%	4.88
40	Bangladesh	577.0	0.70%	4.04	616.8	0.70%	4.32	659.4	0.70%	4.62
Top 40		**97,042.2**	**1.92%**	**1,862.58**	**100,037.0**	**1.93%**	**1,931.58**	**103,476.9**	**1.93%**	**1,996.94**
Rest of World		**15,920.2**	**0.40%**	**63.90**	**16,305.8**	**0.41%**	**67.22**	**16,805.4**	**0.41%**	**69.36**
Global R&D		**112,962.4**	**1.71%**	**1,926.48**	**116,342.8**	**1.72%**	**1,998.80**	**120,282.3**	**1.72%**	**2,066.30**

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

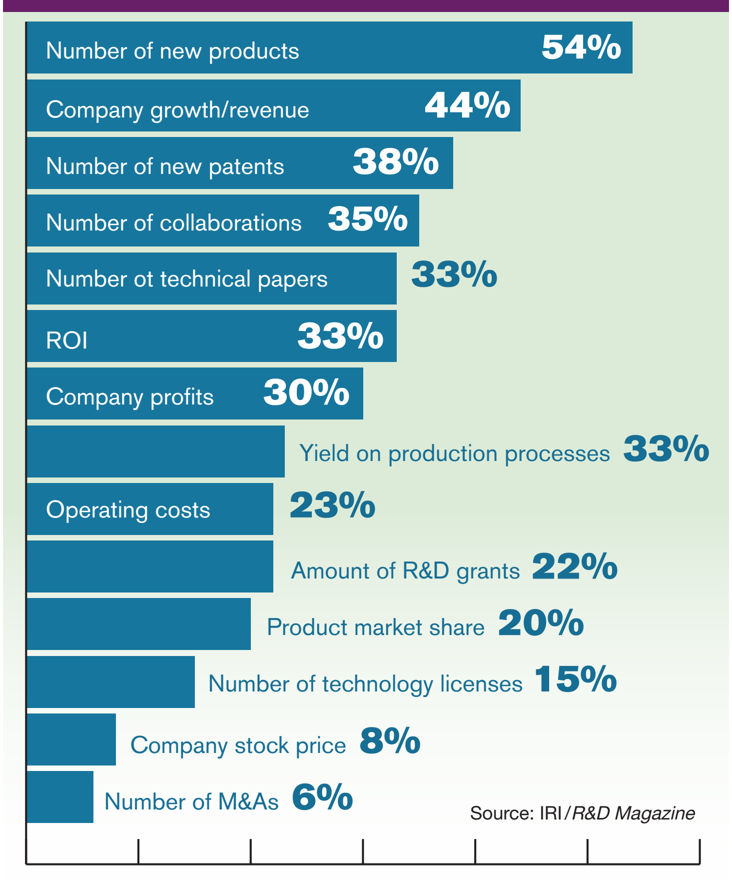
• GERD = Gross Expenditures on Research and Development

• PPP = Purchasing Power Parity (used to normalize R&D investments) the next five years and beyond. Global warming, energy resources and food production do not appear to have insurmountable challenges.

Global demographics also appear to be driving technological demands, economic and R&D funding hurdles as well as possible future research staffing issues on a global basis. Most countries, and especially Japan and China, are facing an increasing rate of aging populations that directly impact these challenges.

Global warming, energy resources and food production do not appear to have insurmountable challenges.

How Do You Measure R&D Innovation?



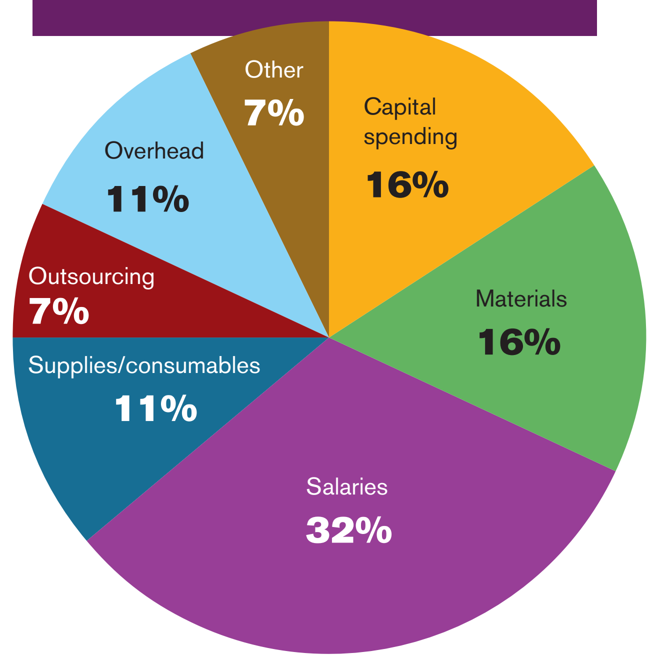
Source: IRI / *R&D Magazine*

R&D Budgetary Changes in 2017

	Survey Respondents		
	Increase	**Same**	**Decrease**
Total R&D expenditures	43%	41%	16%
Capital spending on R&D	24%	57%	19%
R&D / sales ratio	18%	66%	16%
Participation in alliances	27%	63%	10%
Participation in consortia	21%	67%	12%
Acquistion of IP through M&A	23%	64%	13%
In-bound IP licensing	17%	69%	14%
Out-bound IP licensing	12%	77%	11%
Grants with academia	24%	63%	13%
Contracts with government labs	24%	61%	15%
Contracts with non-profit labs	21%	66%	13%

Source: IRI / *R&D Magazine*

Distribution of 2017 R&D



Source: IRI / *R&D Magazine*

U.S. R&D: Slow Growth and Opportunities

The U.S. economy grew in 2016, albeit slowly. U.S. GDP is only forecast to grow 1.6% in 2016, considerably below the robust 2.6% growth in 2015, according to the International Monetary Fund (IMF). However, U.S. GDP is expected to rebound a small amount in 2017 to 2.3%. How much a country invests in R&D is loosely linked to that country's economy. For 2017, President-elect Donald Trump's policies are added factors that also could affect overall R&D investments. Few of those policies will be able to have much of an impact on early 2017 R&D investments due to the momentum of ongoing R&D created in 2016, but some Trump programs could affect R&D spending by mid- to late-2017.

> There are numerous indications that the U.S. economy will expand in 2017 and possibly beyond.

President-elect Trump is likely to put many of his programs in place within his first 100 days in office (January 20, 2017 to April 30, 2017). Some of those early programs affecting R&D operations and investments include 1) the scale-back of some parts of the H-1B visa program; 2) refocusing of some NASA space programs (decisions on Mars, asteroid and Moon astronaut landings, climate change); 3) repealing of the Net Neutrality Act; 4) implementation of a one-time repatriation of corporate profits being held overseas; 5) injection of free-market policies into healthcare systems; and 6) an overall review and reinforcement of cyber security policies.

For 2017, total U.S. R&D spending is expected to increase by 2.9% to $527.5 billion or a 1% increase after accounting for 2017's expected 1.9% inflation rate (EIU/OECD). The 2017 R&D growth forecast is down slightly from the 3.1% growth seen in 2016 over the R&D spent in 2015. This is the fourth consecutive year of R&D spending growth, following flat R&D growth during the recession and recession/recovery years.

Factors Influencing U.S. R&D Outlook

There are many factors that affect a country's investment on R&D. Some of these factors (both positive and negative) that have influenced the 2017 U.S. R&D outlook include:

- The data revealing researcher interests and plans in this report reflect researcher attitudes and recollections during the summer of 2016–prior to the U.S. presidential election. The election results and comments made since then are unlikely to have any substantive effect due to their highly speculative nature.
- The global economy is in a continued slowdown, including that of China, which is now forecast to grow about 6.2% in 2017, its slowest annual growth since 1990 when its GDP was about $400 billion.
- Some of the post-Presidential election polls on economic growth have shown a slight improvement in both U.S. and global economic growth for 2017 and 2018 from similar forecasts provided before the U.S. presidential election. The head of one of these polls, the Organization for Economic Cooperation and Development (OECD), stated in the release of their report that the global economy could be at an "inflection point" with these latest growth forecasts.
- There have been record-high stock market valuations following the U.S. Presidential election which produces more monies available for R&D investments.

2017 U.S. Source-Performer Matrix

Billions, US$/Percent changes from 2016

Source of Funds	Federal Gov't	Industry	Academia	FFRDC (Gov't)	Non-Profit	Total
Federal Government	$43.2 0.5%	$30.0 3.4%	$38.5 1.3%	$15.5 3.3%	$6.0 -0.5%	**$133.2** **1.4%**
Industry		$336.8 2.6%	$5.2 4.0%	$3.6 23.3%	$2.1 5.0%	**$347.7** **2.7%**
Academia			$19.0 5.6%	$0.3 0.0%		**$19.3** **5.5%**
Other Government			$7.0 7.7%			**$7.0** **7.7%**
Non-Profit			$5.5 10.0%	$0.1 0.0%	$14.7 2.1%	**$20.3** **4.1%**
Total	$43.2 0.5%	$366.8 2.6%	$75.2 3.7%	$19.5 6.0%	$22.8 0.4%	**$527.5** **2.9%**

Source: *R&D Magazine*

- Restrictions on federal spending from earlier sequestration spending programs are continuing. The presidential election results had no effect on these laws.
- Throughout 2016, the Federal Reserve Bank has continued its hesitance to enact additional short-term interest rate hikes, although there are signs at the time of this writing that these rates will be increased at the Fed's December 2016 meeting. The rate increase, if it occurs, is still expected to be relatively minor–likely equal to the rate imposed in 2015. The Fed's hesitance in putting these rate increases in place has been to minimize their effect on slowing potential economic growth.
- The U.S. dollar has seen continued strong growth. The resultant effects of a strong dollar is to lower trade (U.S.-produced products are more expensive in foreign markets) and the interest paid on foreign debt is more expensive, which is especially troublesome for smaller countries with large long-term debts tied to the dollar.
- There is a continued growth in the exploitation of U.S. natural gas resources and an increased ability to export it, which provides a positive trade balance. The U.S. became a net exporter of energy resources in late 2016 for the first time in nearly 60 years.
- Federal funding for academic R&D continues to shrink each year; however, there are indications that this trend may soon reverse.
- Strong federal support of defense spending and defense R&D is likely to be continued with the new administration and congress. There are indications from the new administration that spending in these areas could be slightly enhanced.
- There is considerable uncertainty about President-elect Trump's plans other than a repealing of Net Neutrality, scale-back/elimination of the Affordable Healthcare Act, dramatic scale-back/deportation of illegal immigrants and the creation of infrastructure spending goals. Trump also discussed several times, during his campaign that he wanted to rewrite or even eliminate many previously created treaties including that for climate change.
- Another concern over Trump's statements has been on his trade protectionism stance and its overall effect on global trade. As witnessed in the past, any overtures for putting new trade tariffs or taxes on foreign-produced imports are often met with equal actions on U.S. produced exports. These trade-war actions result in higher consumer costs and a further slowing of global economic growth. While the purpose of putting tariffs in place is to protect or create more home-based jobs, the actual result has often been just the opposite.
- Most of Trump's budgetary and program proposals are likely to face little or weak opposition in light of the strongly Republican-controlled Congress and marginally controlled Senate. The polarization seen during the presidential election is likely to continue in congressional debates with strongly motivated minority discussions and actions, with little net effective results.

The U.S. became a net exporter of energy resources in late 2016 for the first time in nearly 60 years.

All of these factors create an environment with mixed messages for R&D investments. A growing economy is the strongest indicator for R&D growth and there are numerous indications that the U.S. economy will expand in 2017 and possibly beyond. Limitations on government spending act to restrict R&D growth and

Importance of R&D Operations

	Survey Respondents		
	High	Medium	Low
Attract, retain R&D staff	55%	30%	15%
Balance short/long term R&D	46%	43%	11%
Build an innovation culture	57%	34%	9%
Comply with regulations	50%	35%	15%
Management technology support	38%	44%	18%
ID disruptive technologies	40%	40%	20%
Improve efficiency	58%	34%	8%
improve knowledge management	50%	41%	9%
Improve sustainability	41%	42%	17%
Integrate tech planning & business	42%	43%	15%
Develop leadership	37%	47%	16%
Manage global innovation	24%	40%	36%
Measure R&D value	30%	52%	18%

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

Changes in the Type of R&D for 2017

	Survey Respondents		
	Increase	Decrease	No change
Applied research	37%	12%	51%
Basic research	24%	20%	56%
Development	49%	8%	43%
Science/engineering consulting	27%	12%	61%
Technical Service	25%	12%	63%
Average	32%	13%	55%

the current laws that limit deficit spending are not likely to be overturned, even with a new administration. Funding of academic research have slowed over the past several years, especially by the federal government, and since academia is the key organization that performs basic research (two-thirds of all basic research in the U.S. is performed in academia) that innovation engine has been at risk.

While increasing in absolute terms, the federal government's share of R&D investments has been declining since the Budget Control Act (BCA) of 2011 was enacted. The BCA limits growth of discretionary spending of which most R&D investments consist. Industries are the source of roughly two-thirds of the total R&D investments and as government shares have decreased, the industrial share has increased. The annual share changes between government and industry-sourced investments have been relatively modest, but consistent over the past several years.

Federal Funding

The 2016 national elections delayed finalization of the FY2017 Federal Budget (which was scheduled to begin on October 1, 2016). Congress did pass a continuing resolution (CR) in September 2016 that extended the federal budget (to keep federal agencies from shutting down) through December 9, 2016 at an annualized level of $1,066.7 billion. This is $3 billion below the FY2017 discretionary spending cap, but $1.6 billion above the non-defense discretionary cap and $4.6 billion below the defense discretionary cap.

The CR was passed with an attachment for $1.1 billion for Zika-virus response efforts (non-R&D) administered by the Department of Health and Human Services (HHS). CR's have been used every year for more than 15 years, as Congress finds it impossible to agree on the specific funding details before the official beginning of the federal government's new fiscal year on October 1st. In the past, some CR's have been renewed several times, with budget finalization not occurring until March of the following year.

The problem with CR's is that when extended several times, the resulting federal budget often result in an all-encompassing omnibus budget bill that renews the new fiscal budget at basically the same level as the previous year's fiscal budget with little or no accommodation for inflationary adjustments. This has hurt organizations such as the National Institutes of Health (NIH/HHS), which has seen its research budgets frozen for so many years by these fiscal instruments that its actual spending level is now more than 20% lower in actual dollars than it was 10 years ago due to the accumulated inflationary effects of its purchasing power and escalating costs.

Congressional discussions following the national elections have not resulted in any decision as of this writing on what will occur following expiration of the December 9th CR for the FY2017 budget. Congress wants to extend it again into March 2017, while some Senators want to complete it in the current (114th) session of Congress, which ends January 3, 2017.

Compounding the FY2017 budget finalization is the need to renew the federal government's debt ceiling in March 2017. This is the deadline for an extension created in October 2015, which was coupled with an increase in discretionary spending limits by about $80 spread out over FY2016 and FY2017 (split equally between defense and domestic spending). This bill short-cut the FY2016 limits imposed by the 2011 BCA (sequestration). Few people have considered the effects on R&D of this bill in the past year (nor was it ever mentioned in the national campaign dialogues), which will again come into full view in March 2017.

The Source-Performer Matrix

The Table identifies the total R&D invested in the U.S. with information on the sources of the funds and the relationships of the organizations performing the R&D. These breakdown relationships are as follows:

	Sourcing Share	Spending Share
Federal Government	25.5 %	8.2 %
Industry	65.8 %	69.5 %
Academia	3.6 %	14.3 %
Other Government	1.3 %	3.7 %
Non-Profit	3.8 %	4.3 %

Federal Government: End of R&D Status Quo

U.S. government R&D is very "big business" investing more than the total R&D (government, industrial and academic combined) of every country in the world except Japan and China. The top four government R&D spending agencies–the Department of Defense (DOD), Health & Human Services/National Institutes of Health (NIH), Department of Energy (DOE), and NASA–combined account for about 90% of that investment.

And while overall federal discretionary R&D spending is limited in growth due to the Budget Control Act of 2011 (BCA), its expected growth in 2017 is still forecast to be nearly $2 billion, well beyond the total growth for all but five countries in the world.

Department of Defense

The DOD has the largest R&D budget in the government, accounting for nearly half of the total R&D budget of $133.2 billion in FY2017. Much of this is allocated toward the development of weapons systems, while about 20% (or $12 billion) of the DOD's nearly $60 billion total budget is focused on science and technology, including basic research.

While potential antagonists, such as China and Russia, are fielding advanced technologies the U.S. defense establishment fears it may have fallen behind in some weapons technologies and so has increased its R&D funding for advanced technologies that can be deployed in about five years to address emerging near-term threats. But while Russia has an advanced infrastructure for designing, developing and producing top-end weapons systems, its overall R&D budget is considerably weakened by the country's dire economic situation. Russia's GDP growth in 2017 is forecast by the IMF as only 1.1%, about half that of the U.S. On the other hand, China has a strong economy that can support multiple weapons systems development. Its infrastructure is not as strong as that in the U.S. or Russia, but China is being very aggressive in building its weapons development infrastructure to be on a par with any other country in the very near future.

President-elect Donald Trump's election on November 8, 2016, is expected to have an influence on many government agencies and subsequently have an effect, either direct or indirect, on their R&D programs as well. It is expected that his administration will support a slight enhancement of DOD R&D, especially in the cyber warfare arena.

National Institutes of Health

The NIH has the second largest R&D budget in the U.S. government with an expected authorization level of $33.0 billion–about 2.1% better than what was authorized in FY2016. The NIH received a substantial 6%, $2 billion R&D increase in its FY2016 budget, due in part to a one-time $80 billion overall discretionary increase linked to the October 2015 federal debt extension to March 2017. The Congress and the Senate both passed R&D authorization bills in the summer of 2016, which were larger than that proposed by the Obama Administration. No significant changes are expected in the NIH's R&D funding from the Trump administration. The President-elect's focus on healthcare will be primarily on the Affordable Healthcare Act (repeal), drug prices, lower corporate taxes for biopharma (and others), fewer regulations and increased M&A activities.

Department of Energy

The DOE's R&D spending was expected to increase by about 4.2% in 2017, but the focus of that research may change due to policy directives from the Trump administration. The actual increase approved by Congress could also be significantly less that that initially proposed–the DOE R&D amounts approved for the FY2016 budget were below the inflation rate.

U.S. Federal Agency R&D Budgets

	FY2016	FY2017
Federal Agency	**Actual Billions US$**	**Forecast* Billions US$**
Dept. of Defense	$72.2	$73.7
National Institutes of Health	$32.3	$33.0
Dept. of Energy	$14.4	$15.0
NASA	$13.3	$13.2
National Science Foundation	$6.1	$6.0
USDA	$2.7	$2.6
Dept of Commerce	$1.9	$1.8
Dept. of Interior	$1.0	$1.0
Dept. of Transportation	$0.9	$0.8
Dept. of Homeland Security	$0.6	$0.6
Veterans Administration	$1.2	$1.3
Other	$1.6	$1.6
Total	**$148.2**	**$150.6**

* R&D Forecast as of 11/01/2016

The Obama administration's plan to double energy research over the next five years is not likely to happen due to the Republican control of the White House, Congress and the Senate. Trump stated several times during the election campaign his intent to renew the coal industry and is likely to support research in that area at the expense of renewable energy research and the Paris climate change accords. Trump voiced opposition several times during his campaign to the Paris Climate Change Treaty, which is also likely to be repealed.

NASA

NASAs FY2017 R&D budget is expected to be $13.2 billion, about the same as was allocated for FY2016. However, the program focus of the R&D budget is now forecast to change, according to comments within the proposed Trump administration. The proposed asteroid landing program is likely to be canceled. A moon landing is also expected to be introduced. The Mars landing program may be delayed or shifted to the support of private Mars landing efforts. NASA's Space Launch System (SLS) is likely to be continued to develop the infrastructure needed for deep space programs.

NASA's earth science programs, and especially its climate change research programs, are likely to be scaled back or eliminated in favor of more research programs focused on deep space research. Trump has stated that climate change research can more effectively be handled by other government organizations such as the National Ocean and Atmospheric Agency (NOAA) and the Environmental Protection Agency (EPA).

National Nanotechnology Initiative Millions, US$

Agency	FY2015 Actual	FY2016 Estimated	FY2017 Proposed
Consumer Prod Safety Com	$2.0	$2.0	$4.0
Dept. of Homeland Security	$28.4	$21.0	$1.5
Dept. of Commerce – NIST	$83.6	$79.5	$81.8
Dept. of Defense	$143.0	$133.8	$131.3
Dept. of Energy	$312.5	$330.4	$361.7
Dept. of Transportation	$0.8	$1.5	$1.5
Environmental Protection Agency	$15.1	$13.9	$15.3
Health & Human Services (total)	$385.8	$405.0	$404.4
Food & Drug Admin.	$10.8	$12.0	$11.4
National Institutes Health	$364.0	$382.0	$382.0
National Inst Occup. Safety/Health	$11.0	$11.0	$11.0
NASA	$14.3	$11.0	$6.1
U.S. Dept of Agriculture (total)	$21.1	$21.5	$21.0
Agricultural Research Service	$3.0	$3.0	$3.0
Forest Service	$4.6	$4.5	$4.0
Natl Inst of Food and Agriculture	$13.5	$14.0	$14.0
Total	**$1,496.3**	**$1,434.7**	**$1,443.4**

Source: ww.nano.gov

Other Government Agencies

Outside of the top four R&D spending agencies noted, there is expected to be a slight change of -$0.3 billion for the seven agencies noted in the Table in FY2017 R&D authorizations from that authorized in FY2016. The National Science Foundation (NSF), the Department of Agriculture (USDA), the Department of Commerce/National Institutes of Standards and Technology (NIST) and the Department of Transportation (DOT) are each forecast to have -$0.1 billion reductions in their total R&D authorizations. The Veterans Administration (VA) will see a gain of $0.1 billion in its R&D authorizations and the Department of the Interior (DOI) and Department of Homeland Security (DHS) will each have similar R&D funding authorizations in FY2017 to those received in FY2016.

Nanotechnology is a cross-cutting technology that has seen independent, non-partisan R&D authorizations since FY2001. Created during the Clinton administration, the National Nanotechnology Initiative (NNI) has seen a cumulative R&D investment of more than $21 billion since then. NNI provides R&D authorizations for more than 10 federal agencies to conduct science, engineering and technology R&D in nanotechnology areas outside of their individual R&D budgets. The federal agencies with the largest NNI-based R&D investments include the NIH, NSF, DOE, DOD and DOC/NIST. The FY2017 NNI proposal was increased 0.6% from its FY2016 R&D budget to $1.443 billion.

When queried by *R&D Magazine*, researchers and engineers consistently rank nanotechnology at the top of the list for specific technologies which will have the most significant effect on future emerging product development and research. The NIH is consistently the agency with the largest NNI R&D funding authorizations ($0.4 billion in FY2017), with nanotechnology having a strong relationship in the study of genomics, proteomics, stem cells, viruses and other microcellular mechanisms. NNI R&D funding for the DOE (the second largest NNI-funded agency) includes the combined budgets of the DOE's Office of Science, the Office of Energy Efficiency and Renewable Energy, the Office of Fossil Energy and the Advanced Research Projects Agency for Energy (ARPA-E). The DOE saw a 9.5% increase ($31 million) in proposed NNI R&D funding for FY 2017 from FY2016 levels.

The relatively small nature of the NNI investments has not yet been mentioned by the Trump administration for any potential changes.

Academia Continues as Nation's Basic Research Hub

Academic R&D is a strong and essential component of the total R&D environment, and while only performing about 14.3% of the U.S.'s total 2017 R&D work, the sector performs nearly 60% of all of the basic research in the U.S. And while being a critical component in the performance of R&D, academia is also an invaluable resource for research staff in industry and government labs, along with leaders in government and industry through its graduate and post-graduate programs. Additionally, through its basic research work, it becomes a resource for new scientific and engineering discoveries, furthering advances in the quality of life. Academia has become a country's long-term investment in the future of their economy and society.

Forecast Gross Expenditures on R&D

	Funding Share	Industry	Federal Govt	Academia	Non-Profit
Basic Research	16%	22%	7%	56%	15%
Applied Research	20%	61%	10%	21%	8%
Development	64%	87%	8%	3%	2%

Source: National Science Foundation

World University Rankings 2016-2017

Rank	University	Research Value	Research Rank**
1	Univ. of Oxford, UK	99.1	1
2	California Inst. of Technology	95.7	6
3	Stanford Univ.	95.9	5
4	Univ. of Cambridge, UK	97.2	3
5	Massachusetts Inst. of Tech.	92.3	8
6	Harvard Univ.	98.3	2
7	Princeton Univ.	88.4	15
8	Imperial College London, UK	86.6	18
9	ETH Zurich, Switzerland	93.7	7
10*	Univ. of California, Berkeley	96.1	4
10*	Univ. of Chicago	89.1	12
12	Yale Univ.	87.8	16
13	Univ. of Pennsylvania	88.9	14
14	Univ. of California, Los Angeles	89.0	13
15	Univ. College London, UK	90.0	9
16	Columbia Univ.	78.9	30
17	Johns Hopkins Univ.	84.3	23
18	Duke Univ.	80.0	28
19	Cornell Univ.	86.5	19
20	Northwestern Univ.	85.0	22
21	Univ. of Michigan	86.1	21
22	Univ. of Toronto, Canada	86.3	20
23	Carnegie Mellon Univ.	84.0	24
24	National Univ. of Singapore	86.9	17
25	London School of Economics, UK	74.7	33

Source: The Times Higher Education, Rankings are based on 13 performance indicators of 980 global univerisities. Indicators include teaching, research, international outlook, citations and industrial income.

*Tie ** Rank by research value of 980 schools

Funding Sources

Federal and state governments are the largest sources of funds for academic research, together providing about 60% of their total R&D funding. In the U.S., academic R&D is split into science (79%), engineering (16%) and non-science & engineering (S&E) (5%) fields. Academic science research consists of computer sciences (3.6% of the science R&D portion), environmental sciences (6%), life sciences (71.9%), mathematical sciences (1.2%), physical sciences (8.7%), psychology (2.2%), social sciences (4.3%) and general science (2%).

Academic engineering R&D efforts are distributed somewhat equally in U.S. academia in the engineering disciplines of aeronautical, bio- and biomedical, chemical, civil, electrical/electronic, mechanical, materials and general engineering areas. Non-S&E R&D is relegated to research in business and management, communications, education, humanities, law, social and the performing arts.

Life sciences is the largest application of academic research, accounting for more than 56% of all academic R&D funding. This sector is broken down further into agricultural sciences (8.9% of the total life science share), biological sciences (30.2%), medical sciences (55%) and general life sciences (5.9%). Academic Life Science R&D is supported by the NIH/HHS, with nearly 83% its total funding, which also is 46% of all federal funded academic R&D. This one funding category also accounts for about 53% of the NIH's $33 billion total budget. Other academic R&D categories funded to a significant degree (in excess of $100 million each) by the NIH include chemistry, psychology, sociology, general science, biomedical and bioengineering research, education and social work.

The second largest federal government funder of academic R&D is the NSF with about 13.5% of all of academia research grants (with about 85% of its total $6 billion FY2017 budget). The DOD is also a large funder of academic R&D, investing about $5.1 billion (or about 6.9% of its total $73.7 billion FY2017 R&D budget). The DOD splits its academic R&D investment with about 51% going into science categories and 48% going into engineering R&D categories (about 40% of that going into the electrical engineering subcategory). The DOD, NSF and NIH combined account for about 80% (or $30 billion) of all government funded academic R&D work.

Federal funding of academic research declined in FY2015 in both current and constant dollars for the fourth consecutive year, according to data from the Higher Education R&D Survey by the National Center for Science and Engineering Statistics within the NSF. When adjusted for inflation, federal funding for academic R&D declined 1.7% between FY2014 and FY2015 and has fallen nearly 13% since its peak in FY2011.

This decline continues the longest multi-year decline for federal funding of academic R&D since the beginning of the data collection for this series in FY1972 (42 years). Non-federal funding for academic R&D rose by 5.3% between FY2014 and FY2015, resulting in a net increase of 2.2% for academic R&D. The non-federal funding sources included state and local governments (-1.2% change), institution funds (5.9% increase), industry (7.5% increase), non-profit organizations (6.9% increase) and other sources (6.4% increase). Also according to the NSF, federal funding for academic R&D between FY2013 and FY2014 actually increased 6% from $59.2 billion to $62.9 billion.

Academic Spending on R&D

		Total R&D	Science	Engineering
		millions U.S.$		
1	Johns Hopkins Univ.	$2,106.2	$1,233.4	$859.6
2	Univ. of Michigan	$1,322.7	$1,026.6	$221.1
3	Univ. of Wisconsin-Madison	$1,169.8	$916.8	$113.7
4	Univ. of Washington	$1,109.0	$961.2	$104.2
5	UC-San Diego	$1,073.8	$939.2	$126.1
6	UC-San Francisco	$1,032.7	$1,032.7	$0.0
7	Duke Univ.	$1,009.9	$946.2	$58.6
8	UC-Los Angeles	$1,003.4	$898.9	$70.8
9	Stanford Univ.	$903.2	$722.4	$131.4
10	Columbia Univ.	$889.5	$788.6	$59.2
11	Univ. of Pittsburgh	$899.0	$866.0	$33.0
12	Univ. of North Carolina	$884.8	$860.8	$4.0
13	Univ. of Pennsylvania	$847.1	$767.4	$45.8
14	Univ. of Minnesota	$826.2	$715.8	$91.0
15	Massachusetts Inst of Tech	$824.1	$405.2	$365.2
16	Cornell Univ.	$802.4	$711.9	$87.9
17	Harvard Univ.	$799.4	$706.0	$48.0
18	Pennsylvania State Univ.	$767.7	$485.1	$298.8
19	Ohio State Univ.	$766.5	$570.7	$149.3
20	UC-Berkeley	$730.3	$524.5	$172.4
21	UC-Davis	$713.3	$621.9	$83.1
22	Washington Unvi. St. Louis	$706.4	$668.9	$20.1
23	Univ. of Florida	$697.0	$562.1	$87.9
24	Texas A&M Univ.	$693.4	$413.9	$256.1
25	Georgia Tech	$688.9	$201.1	$482.8

Source: BestColleges.com

Leading Institutions

The U.S, leads the world in terms of the number of leading academic institutions, the level of the research performed in these institutions and the quality of the researchers educated therein. There are several rating organizations that annually rank global academic institutions for various criteria. The Times Higher Education (THE) World University Rankings for the 2016 to 2017 academic year shown on the Table has been created annually for the past seven years ranking 980 of the top universities in the world. The rankings are based on a survey itemizing 13 performance indicators and are audited by Pricewaterhouse Coopers (PwC). The academic institutions are located in countries classified as advanced emerging, secondary emerging and frontier by the Financial Times Stock Exchange (FTSE) and include the BRICS nations of Brazil, Russia, India, China and South Africa.

Federal Expenditures in Academia, FY2015

(in millions of U.S. dollars)

Department of Defense	$5,095
Department of Energy	$1,713
Health & Human Services	$ 20,025
NASA	$1,419
NSF	$5,114
USDA	$1,114
Others	$3,398
Total	**$37,877**

Source: National Science Foundation

In the current World University Rankings, 17 of the top 25 universities are located in the U.S. with five located in the UK (Oxford, Cambridge, Imperial College London, University College London and the London School of Economics), one in Canada, one in Switzerland and one in Singapore.

Other ranking systems, such as ShanghaiRanking's Academic Ranking of World Universities (ARWU) utilize six indicators: number of alumni and staff winning Nobel Prizes and Field Medals, number of highly cited researchers selected by Thomson Reuters, number of published articles in Nature and Science, number of articles indexed in the Science Citation Index and per capita performance for a university. In this rating system, 19 of the top 25 universities are located in the U.S., while four are based in the UK (Cambridge, Oxford, UCL and Imperial College of S&T), one in Japan (Univ. of Tokyo) and one in Switzerland (ETH).

In each of these two ranking systems, the indicator values are submitted into a formula. Not surprisingly, about 80% of the ranked universities in both of these ranking systems appear in similarly ranked positions.

In the U.S., the NSF creates a variety of rankings of academic institutions based on their R&D expenditures. The top ten universities in the NSF's latest listing all spend in excess of $1 billion on R&D–Johns Hopkins University (JHU) actually spent $2.3 billion in 2015. The bulk of this R&D is NIH-funded and focused on Life Science applications. JHU's close proximitry (Baltimore, MD) to NIH headquarters in Bethesda, MD, allows close relationships between researchers and sponsors.

Industrial R&D Continues to Evolve

In the U.S., two-thirds of all of its R&D is invested and performed by industrial organizations. Industries in Europe and Asia similarly support and perform between 50% and 75% of their countries' total R&D. Industry is what drives the majority of global R&D throughout the world. The globalization of R&D through its industrial activities has leveled the technological playing field making each company in each country more competitive than they ever were in the past.

Still, specific companies can create their own advantages within their industries by investing in the "right" technologies at the "right" time. There also are obvious leaders within each industry which have been created through tradition, innovation, administrative leadership, in-house-generated (and legally protected) intellectual property (IP) and aggressive marketing, risk-taking and confidence.

There are numerous new technologies in play for many industries. These include the ever-increasing information and communications technologies (ICT), nanotechnologies, bio-technologies, artificial intelligence, mobile computing, smart software, intelligent computing and more. Each of these technologies build on each other and the industries they are integrated into. Add to these the scientific and engineering expertise of the R&D staffers and the educational and informational resources they have access to–and you create the six leading industries that are profiled in the next several pages–life science, aerospace/defense, advanced materials, ICT, automotive and energy. These six industries account for well over half of the industrial spending in the world.

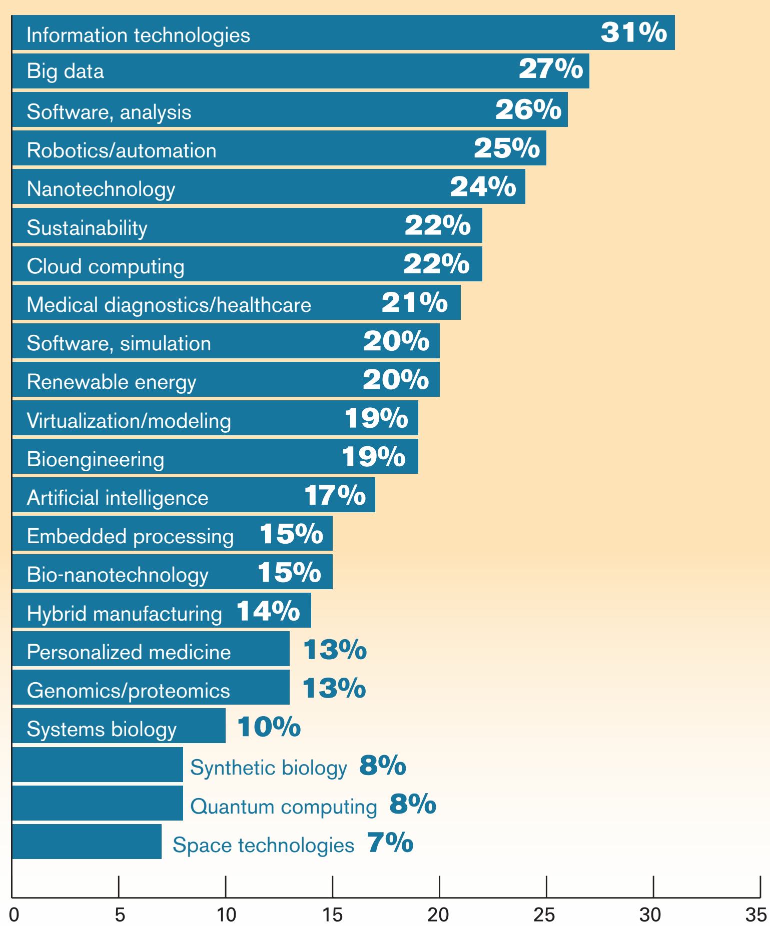
And just as advanced technologies evolve, so too the industries utilizing them have to evolve. Companies merge and are acquired, new facilities are created, outdated ones are upgraded or shuttered, technologies and proprietary processes wither and fail while advanced procedures are created or purchased. For long-established firms, making substantial changes or reinventing themselves to keep pace with the changing technologies can be traumatic, but it is what's needed to survive.

The list of technologies in the Table was created from a survey by *R&D Magazine*. It provides a picture of those technologies expected to be of major importance to all industries by 2020. There should be no surprises in this table for experienced scientists and engineers working in successful companies. What may be revealing is how fast some of these technologies have moved up in the rankings.

The generation of large amounts of data, or Big Data, for example, has been acknowledged for many years, but to be the second-most important technology by 2020 may belie its importance to some researchers. Similarly, nanotechnology has been noted by some as the most important new technology, and while it still retains a comparatively high ranking, it has shifted down in importance to other, more currently relevant technologies. And robotics and automation have been relatively highly ranked in the past, but are moving up in the rankings as they become more integrated into all aspects of research endeavors.

Specific companies can create their own advantages within their industries by investing in the "right" technologies at the "right" time.

What will be the Most Important Technologies by 2020?



Truly Global Life Science R&D

The life science industry consists of manufacturers of pharmaceuticals, biotech products, medical instruments and devices, animal and agricultural bioscience products and commercial research and testing. Life science R&D investments are driven by the expansive biopharmaceutical sector which accounts for about 80% of the industry's total R&D spending. The companies involved in this sector are well-known and well-established. Over the years, they've acquired numerous smaller life science enterprises and smaller start-ups and integrated them into the larger bio-pharm entity.

The life science R&D industry is truly global, more so than most other industries. Of the top 50 life science organizations, 36% are headquartered in the U.S., 36% are headquartered throughout Europe, 22% are headquartered in Asia and the remaining 6% are headquartered in Africa, Canada and the Middle East. These top 50 bio-pharms invest, on average, about 18% of their revenues in their R&D programs. Their overall organizations are spread throughout the world with about 20% of their R&D budgets being spent outside of their home country, according to a recent study by PhRMA (Pharmaceutical Research and Manufacturers of America).

> The life science R&D industry is truly global, more so than most other industries.

Global R&D spending in the total life science industry is forecast to increase 4.5% to $177.6 billion in 2017, according to R&D Magazine. The U.S. portion of the life science industry is forecast to increase 3.5% to $74.6 billion in 2017.

Challenges to overcome

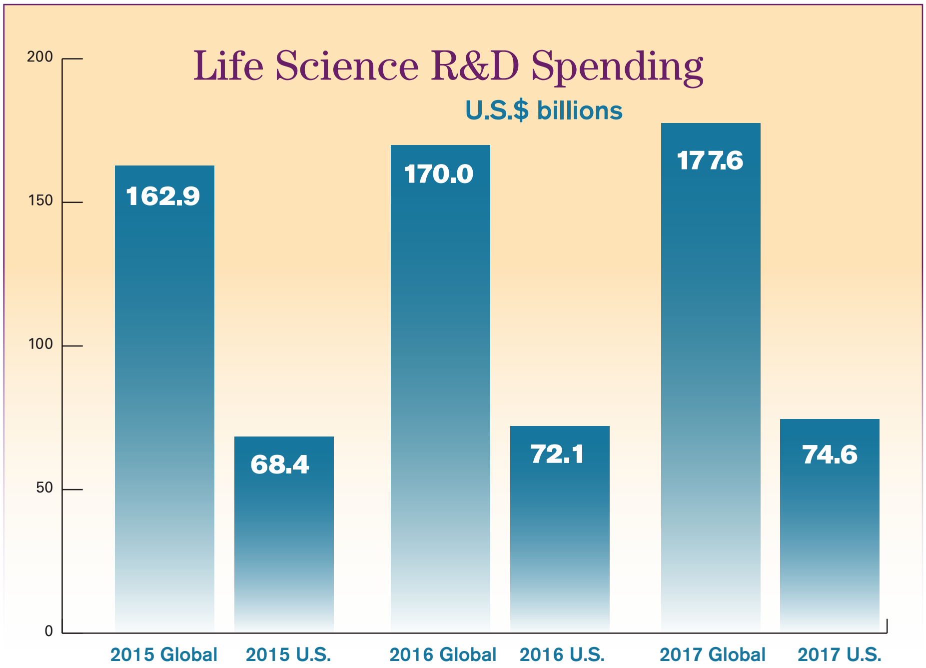
The life science industry has a number of challenges threatening their R&D funding resources. One, of course, is that there is significant backlash in government and public circles to biopharmaceutical pricing. President-elect Donald Trump has stated that he doesn't like what has happened to drug prices and he is going to bring them down. No specifics were included about how he was going to lower drug prices. But the reaction in the stock market was quick, with stock prices for bio-pharms dropping. Two of the vehicles mentioned in the Trump campaign for lowering drug prices were to allow Medicare to negotiate drug prices or import drugs from outside the U.S. The transition team also mentioned that the new administration would "reform the U.S. Food and Drug Administration (FDA) to put a greater focus on the need of patients for new and innovative medical products."

Another aspect of the drug pricing concerns was voiced by the FDA in that this agency would prioritize and expedite their review of applications for first generics, making sure that the first applicants for generic alternatives to high-priced drugs are moved to the head of the queue and given priority reviews. The same is holding true for the development of biosimilars.

Public pressure on price hikes for drugs is also taking its toll. Amgen's recent 20% price hikes for its cholesterol drug Enbrel were found to be non-sustainable, according to analysts. Amgen stock has recently fallen by more than 11% on their pricing news.

The more traditional challenge which has reared its head in 2016 was the failure in clinical trials of a widely anticipated Alzheimer drug. Patients using Lilly's solanezumab did not experience a statistically slowing in cognitive decline compared to patients treated with a placebo. Lilly's clinical failure was a bellwether for other drug developers who were working on similar drugs.

Additionally, some drug developers, such as Allergan, are scaling back on the number of drugs they are developing to focus on those drugs they have the most experience in and fit better into their overall drug pipeline.



Building State-of-the-Art Aerospace/Defense Technologies

Aerospace and defense-based technologies have been well-recognized for utilizing the most leading-edge technologies to go faster, higher, more efficiently and safer than the products developed in previous generations. Many of these technologies have been the beneficiaries of defense-based applications which makes them no less innovative. And with nearly $60 billion in dedicated federal R&D funding (about half of the government's total R&D budget), the U.S. Dept. of Defense (DOD) invests more in the development of aerospace and defense-related technologies than all but a handful of countries do in their entirety.

Industries build on their government's R&D investments to support those products and to create commercial spin-offs. According to *R&D Magazine*'s global funding survey, the global industrial aerospace/defense R&D sector is expected to decline slightly in 2017 by -0.3 % to $29.8 billion with the U.S. portion of that actually increasing 1.3% to $15.1 billion.

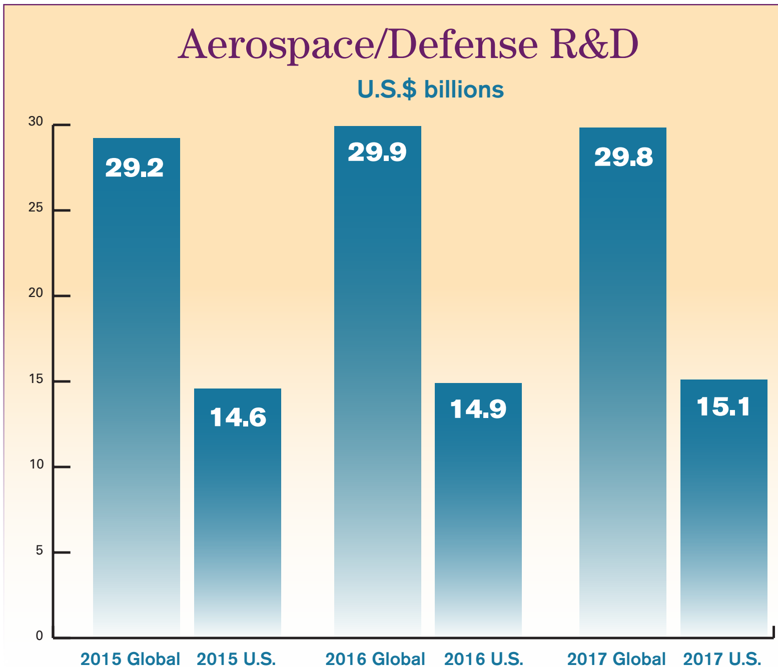
However, even this level of R&D funding limits the development of advanced systems and components, according to a recent *R&D Magazine* survey focused on the aerospace/defense R&D sector. System complexity, regulations and safety are also strong limitations, but funding is the top limitation. The systems and components in this sector push state-of-the-art by themselves as products, but the materials they are made of, the processes they require to be fabricated, and the intensity of the testing they are required to go through to be validated are all complex and costly but push state-of-the-art R&D development of systems in other industrial sectors.

Early indications from the President-elect Donald Trump administration are that federal funding of DOD R&D, which is currently scheduled to increase about 2.1% in the FY2017 R&D budget, may get a slight increase. Similar messages for federal support of industrial R&D in the aerospace/defense sector reveal that this particular funding may decline slightly.

Major U.S. industrial aerospace/defense suppliers, such as Boeing, Lockheed Martin, United Technologies, Raytheon, Northrop Grumman and others, are being relatively conservative in their current budgeting for R&D efforts especially in 2017 due to the new administration's pending restrictions on system budget overruns. Newer suppliers, such as SpaceX and Orbital ATK, are continuing their modest R&D investments to push their acceptance as lower cost suppliers of aerospace systems and components.

Automation and autonomous systems are seeing the greatest innovation growth in the industrial aerospace/defense sector. The closely interrelated software and artificial intelligence (AI) areas are also expected to see substantial R&D growth to support the overall cost and technology goals for this sector. Numerous unmanned, autonomous aircraft and vehicle systems dedicated to aerospace/defense applications are seeing the integration of software, AI and automation technologies for existing and future systems.

> Automation and autonomous systems are seeing the greatest innovation growth in the industrial aerospace/defense sector.



Foreign suppliers of aerospace/defense systems and components, including China, India and Russia, are continuing their strong investments in R&D (5% to 10% growth) to ensure long-term growth as the leading suppliers in this market. China in particular is intent on becoming the sole supplier of military aircraft, engines and subsystems for potential future export trade. Russia is supporting its aerospace/defense R&D for rebuilding and support its own internal infrastructure. India is supporting its aerospace/defense R&D to create a strong dedicated aerospace/defense industry, while continuing to purchase state-of-the-art systems and technology from Russia and the U.S.

M&As Driving Chemicals & Advanced Materials R&D

The development of new advanced materials and chemicals by themselves have relatively little value. These developments, however, are often enabling technologies that find strong applications in many other industries. New composites enable the development of advanced aircraft and fuel efficient automobiles. New polymers and thin films enable the packaging of longer lasting foodstuffs. New biomaterials enable the implantation of biostructures into the human body that support the growth of replacement tissues for damaged or diseased body parts.

An analysis by *R&D Magazine* of the chemicals and advanced materials R&D environment reveals that global R&D investments will decline 9.9% to $41.7 billion in 2017, while the U.S. component of those R&D investments are projected to decline 9.6% to $11.3 billion in 2017.

The big news for the 2016 to 2017 timeframe was the announcement of three mega-deals, all of which are still undergoing reviews by various government agencies from various countries. All three are expected to be finalized in 2017:

- State-owned ChemChina's (China) $43 billion bid for Syngenta (Switzerland)
- Bayer's (Germany) $66 billion bid for Monsanto (U.S.)
- The DuPont-Dow $60 billion merger of equals (both U.S.)

All three appear that they will be approved. President-elect Donald Trump has stated that he will not stop the DuPont-Dow merger. The likely outcome of these mergers/acquisitions is that the combined R&D efforts will be smaller than the additive sums of the individual enterprises.

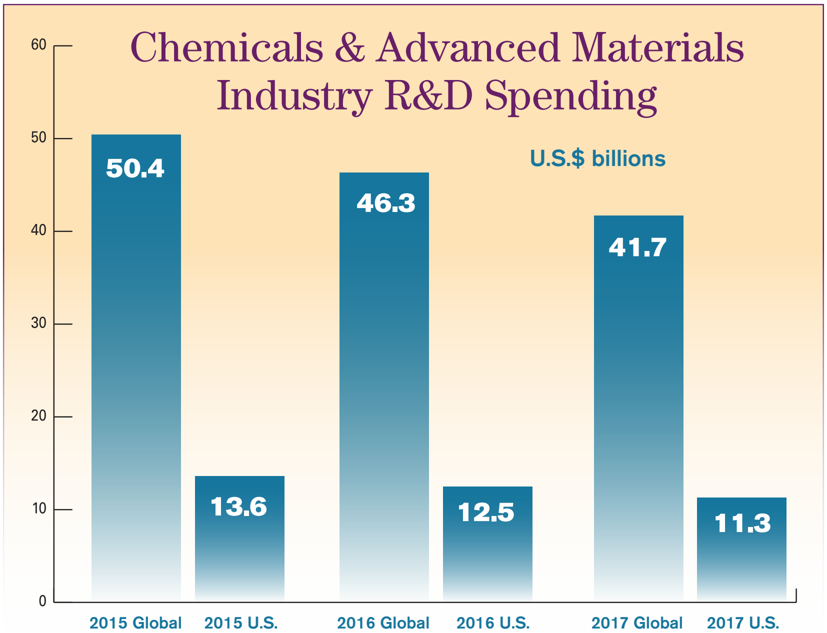
ChemChina, or China National Chemical Corp., is looking to reduce reliance on food imports through the acquisition of Syngenta and its portfolio of top-tier chemicals and patent-protected seeds. Years of intensive farming in China combined with overuse of chemicals has degraded land and poisoned water supplies, leaving China vulnerable to crop shortages. Only about 10% of China's farmland is currently efficient.

The merger of Bayer and Monsanto would create the world's largest supplier of seed and crop-protection products. The combined company would own 37% of the market for corn seed and 30% of the market for soybean seed. It would also own about 70% of the market for cottonseeds. Bayer's expected 2017 R&D spending was $4.88 billion. Monsanto's expected 2017 R&D spending was $1.66 billion.

> The big news for the 2016 to 2017 timeframe was the announcement of three mega-deals…

The DuPont-Dow Chemical (2017 R&D spending equals $1.53 billion and $1.48 billion, respectively) was proposed to take advantage of the size of both companies to reduce expenses on some of their products. The commodity chemicals produced by both companies are low margin products with no distinguishing characteristics for each company's products. Large companies, including DuPont, have already spun off some commodity operations to smaller companies.

The resulting DuPont-Dow company would be split into 1) an agricultural company that combines the seeds and crop protection businesses of both companies resulting in a total global seed share of about 41%; 2) a materials sciences company that combines both companies' industrial and commodity chemical products; and 3) a specialty materials products company including nutrition, electronic materials, films, safety/protection products and advanced bioscience-derived polymers. The cost savings expected from the DuPont-Dow merger are expected to be $3 billion/year from combined operations, worker layoffs and reduced overhead–most of these savings at the "low end" of the business, the commodities. Growth synergies are expected to be worth more than $1 billion.



Rapid and Strong ICT R&D Growth

Information and communication technology (ICT) continues in 2017 as the largest and strongest R&D industry—the future is ICT. With technologies such as artificial intelligence (AI), Big Data, Cloud computing, quantum computing, autonomous operations, machine learning, deep learning, and hardware and software virtualization, there is an abundance of leading-edge concepts that will keep ICT at the forefront of R&D efforts for years to come. ICT has already become an integral part of most new discoveries.

According to a recent *R&D Magazine* survey focusing on ICT, the leading innovation areas for ICT are in science and engineering applications and biomedical applications. ICT's importance in the biomedical arena emphasizes the growth that application has seen and the level of involvement of ICT in that growth.

An analysis of the ICT industry by *R&D Magazine* reveals that global ICT R&D will increase by 5.1% in 2017 to $218.3 billion, while the U.S. component of those R&D investments will increase at a similar 5.1% to $122.2 billion in 2017.

A big part of R&D growth is driven by the mega-giants in the ICT environment:

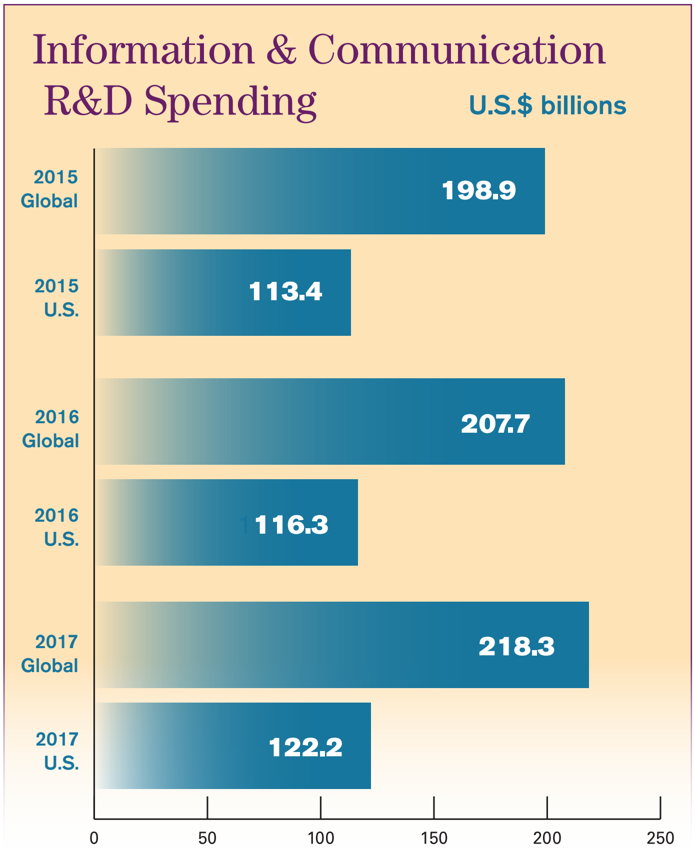
	2017 R&D	*R&D Growth*	*2015 Revenues*
Alphabet/ Google	$15.8 billion	13.0%	$75.0 billion
Microsoft	$13.2 billion	5.8%	$93.6 billion
Intel	$13.5 billion	5.3%	$55.4 billion
Apple	$11.5 billion	15.7%	$233.7 billion
Cisco	$6.8 billion	3.2%	$49.2 billion
IBM	$4.6 billion	-6.3%	$88.5 billion

The average growth from 2016 to 2017 in R&D spending for these ICT companies is 7.7%—far ahead of most other industries, other than those in life science where the average R&D growth is more than 15% to accommodate the long-term nature (up to 12 years) of drug development and the very expensive processes involved (up to $1 billion per approved new drug entity).

The rapid and unique growth of ICT technologies has led to changes in the conventional ways that R&D is performed in some of the industrial ICT organizations. The older, more conventional companies have a structure of research labs scattered throughout the world to support their basic research requirements and support the local communities. IBM, for example, has 12 research labs on six continents. Substantial basic research is performed at these labs and numerous Nobel Prize winners populate them. Microsoft has a similar organizational structure with nine research labs on six continents. In both the IBM and Microsoft research labs, there are specific technologies focused on at the labs.

Apple is also creating a global network of research labs focusing on specific technologies in Japan, China (two labs), France and Indonesia. Intel initially created six research labs, but decided to reorganize its research operations to include all research performed at Intel, including the research work performed outside of Intel. Intel now directly funds research, such as the Intel Science and Technology Center for Visual Computing at Stanford University.

Alphabet/Google also takes a non-traditional approach to its research operations. At Alphabet, most of the fundamental research is performed in various offices of Google's product divisions. This concept supports the collaborative nature of the research throughout the organization. Embedding researchers working on fundamental concepts into the core business makes it possible for the company to encourage creative contributions who are far removed from any kind of formal research and development. Secretive projects within Alphabet are performed in product development shops rather than research labs. This concept mirrors the research programs at Edwards LifeScience, Tesla Motors and Space X, where short-term R&D needs are accommodated while also considering "blue sky" ideas and concepts.



Change is Coming in Automotive R&D

The global automotive industry is in the throes of the largest technological changes in more than 100 years. Vehicles are evolving from fuel-efficient hybrid systems to full electric systems. Simple driver-assist technologies are evolving to fully autonomous driving systems. Digital audio entertainment systems are evolving to fully Internet-compliant systems. And trucks are evolving from mostly steel-alloy structures to lighter weight aluminum and composite structures. All of these changes are occurring simultaneously and will require considerable R&D efforts in 2017 and well into the 2020s.

To accommodate these changes, an analysis by *R&D Magazine* of the automotive industry reveals that global R&D investments will increase by 1.6% in 2017 to $98.2 billion, while the U.S. component of those investments are projected to increase by 3.9% to $42.2 billion in 2017.

Not included in these R&D investments are the infrastructure changes that will need to be implemented to support these changes. There is a modicum of public charging stations created in the U.S. for Tesla vehicles, but many more will need to be installed for the additional electric vehicles being planned for over the next five years. The U.S. is behind other countries in this regard—Japan, for example, now has more electric charge points than gasoline stations.

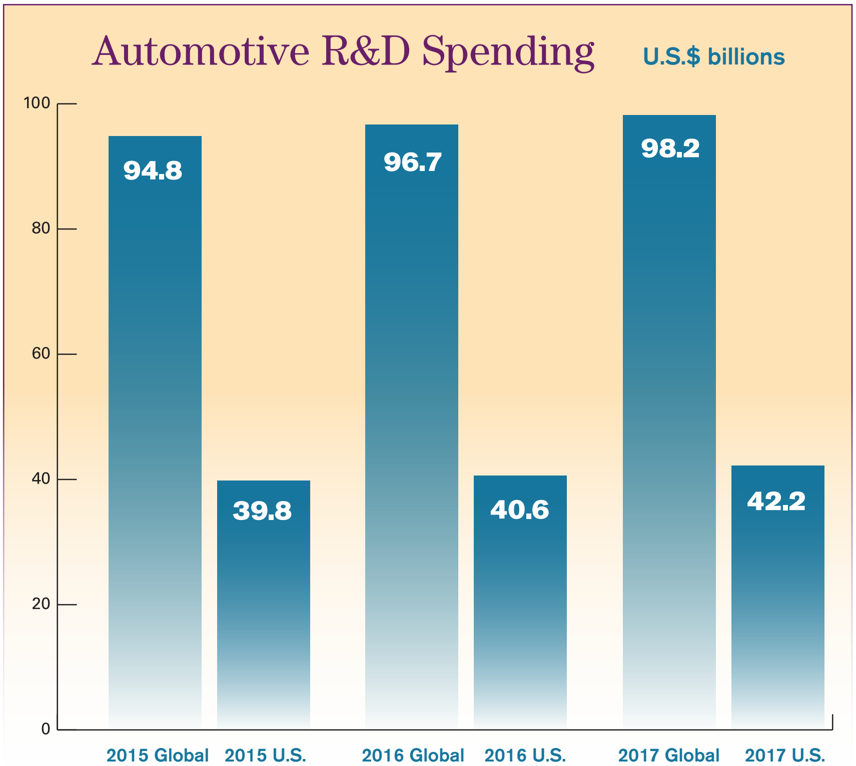
Standardizing the plug configurations for these charge points may also be needed—European charge points can accommodate up to 12 different configurations. A more reliable communications infrastructure may also need to be developed/installed in current "blackout" areas to ensure the safety of autonomous vehicles currently being planned to be on the road within the next four years. A full parts/service infrastructure and training program/system will also need to be developed for electric vehicles in addition to those within the dealer networks.

Other R&D programs that will need to be developed and implemented include electric vehicle diagnostics; similar diagnostic systems for autonomous vehicles; charging station monitoring/communication systems; user-friendly web-based systems for accessing local charging stations and their status (some public sites already exist for charging site locations, but lack real-time details); and an adequate real-time infrastructure for parts and installation details.

One of the concerns that automobile manufacturers are just becoming aware of is that in the future they will have to simultaneously supply a new mix of vehicles—traditional, autonomous, gas driven and electric driven—and provide the R&D and production resources to keep all of them relatively current. But the manufacturers cannot afford to dramatically increase their R&D spending, so they will have to prioritize and judiciously manage their design efforts.

The development of these dramatically changed vehicle formats is a long-term exercise. It has been estimated that even if electric vehicles were fully available by 2030, it would take more than 30 years to fully integrate them into the global fleet based on consumer purchasing patterns and the vast number of vehicles currently in use.

Most global manufacturers are in various stages of creating the technologies needed for autonomously driven vehicles with many performing extensive field testing. These companies have established collaborations with smaller firms with the expertise they need to create smart, Internet-connected vehicles with intelligent sensing systems. Ford and Volvo, for example, have already committed to fielding autonomous vehicles by 2021. Some of these autonomous vehicles could be dedicated to urban transport systems, such as those operated by the uber and lyft systems currently in place in most cities.



Costs Drive New Energy Systems

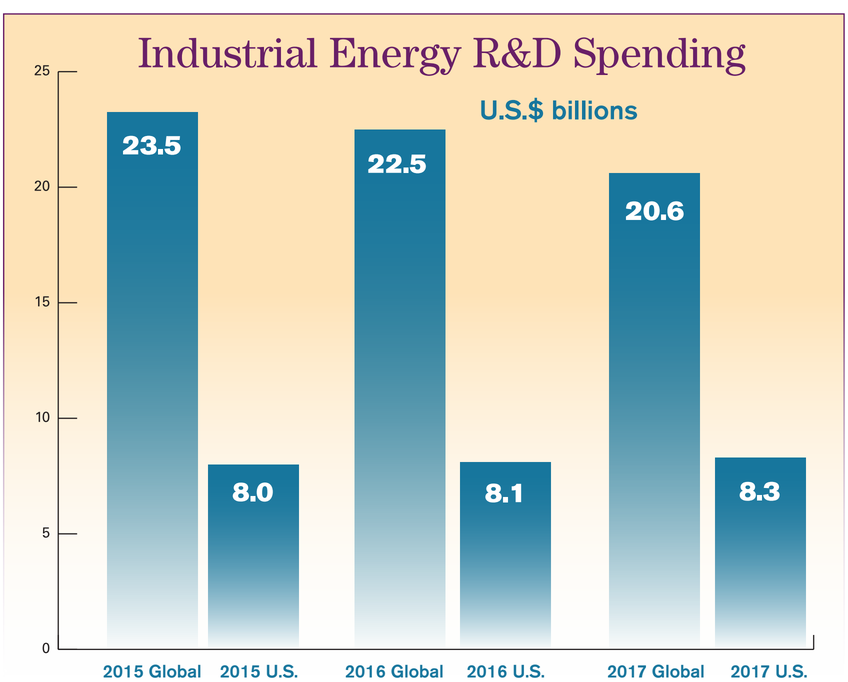
Global industrial energy R&D is forecast to decline -8.4% to $20.6 billion in 2017, while the U.S. component of that energy R&D is expected to increase 2.5% to $8.3 billion in 2017. The U.S. Dept. of Energy was expected to get a 4.2% increase in its R&D budget to $15.0 billion for FY2017, some of which R&D may be similar to that performed in the industrial sector. Industrial energy R&D includes research for development of fossil fuels (oil, natural gas and coal), solar (photovoltaic or PV) and solar boilers, wind turbine power systems, batteries and other storage devices/systems.

Research on fracking-based oil/gas recovery systems has pushed the U.S. into a net exporter of natural gas by the end of 2016 and into the foreseeable future. There continues to be a substantial amount of research on the fracking fluids used in these processes and their long-term effects on ground water contamination and the overall environment.

Overall costs of oil and natural gas have been the big drivers for these advances. The drop below $40/barrel of oil reflected a global oversupply situation and a weak global economy. Limiting the supply and an improving global economy will work to drive these prices back up and provide more funds for increased R&D. In 2015 and much of 2016, industrial oil producers reduced their overall expenses due to the low cost of oil. At the end of 2016, OPEC and Russia had agreed to reduce production to limit supplies and increase revenues. This has been tried several times in the past without success and how long this agreement will last will depend on the staying power of the principals. But the current situation is why the R&D forecast noted above was reduced by more than 8%, while the U.S.'s new trade situation allowed an increase in R&D investments.

R&D in solar cell devices continues to improve in efficiencies every year…

As noted in previous reports, R&D in solar cell devices continues to improve in efficiencies every year, while the overall installed cost continues to decline, which is the obvious goal of solar-based R&D efforts. The installed base of solar panels also continues to grow, with numerous organizations now touting their solar-panel-based effects on reducing their operating costs. What was once considered a novelty with isolated cases has become an established design condition for new or renovated facilities. Elon Musk's SolarCity also announced in 2016 the creation of solar panel tiles that can cost-effectively replace standard roofing tiles, while providing PV energy for use or storage. A lot of R&D still needs to be performed on these and equivalent suppliers' versions of solar roofing tiles, before they can suitably replace existing roofing tiles. The initial versions shown also targeted high-end roofing replacements, not the traditional lower cost materials used in more than 80% of the installations.



A number of energy-saving devices and systems have been developed over the past ten years, including those for lighting, appliances and industrial equipment. These savings directly reduce the operating costs of homes, offices and factories. Due to the increased activities and number of devices in use, the overall energy use has increased but energy use per devices has decreased. A number of structures are now being designed and implemented that are net-zero-energy sites–and it is expected that many more of these will be created over the next five years.

Government and industrial research on improving the efficiencies of high-end PV cells for advanced applications such as solar panels on spacecraft and satellites, while not particularly cost-effective, have raised the technological base for development of commercial grade PV devices through the discovery of new basic concepts and possible new advanced materials.

Globalization Changed Everything

Over the past ten years, the U.S. has increased its R&D investments by about 43% to more than $525 billion, yet its share of the global R&D pie over that same time declined from 32% to 25%. That's because global R&D investments have doubled during this same period from about $1 trillion to more than $2 trillion. While until 2007, the Americas dominated total R&D spending, now it is the Asian countries that dominate those investments with a combined 43% share, compared to a 30% share total invested by both North and South America.

Much of those changes are attributable to the continuing massive increases being made by China which, during the early 2000s was increasing its total R&D investments by more than 10% annually. While, even for China, this level of increases could not continue indefinitely, in 2017 the country still increases its annual R&D spending at more than twice the rate of annual increases made by the U.S.

R&D spending is indeed global, along with the quantity and quality of the R&D being performed. Global R&D spending follows a modified Pareto Rule, where just 12 countries account for more than 80% of the total R&D invested in the world by the 116 countries we measure. Actually, 20% of the countries measured account for more than 90% of the total R&D invested. Global R&D spending is (and traditionally has been) dominated by the top few countries. The bottom 20% of the countries measured account for less than 0.2% ($3.2 billion) of the total R&D invested.

As noted in the industrial R&D section of this report (pages 14 to 20), the R&D globalization aspect has carried over into all industries from life science to ICT. U.S. researchers, as noted in the Table, however, dominate the field in terms of specific technology leadership as revealed in a survey by *R&D Magazine*. The only leadership position of the 12 areas listed that is dominated by another country is automotive technologies, which is led by Japan with the U.S. in the runner-up spot.

> The recovery from the recession has been one of the longest and slowest recoveries on record.

The global recession in 2008 to 2010 slowed overall global R&D investments, and the recovery from the recession has been one of the longest and slowest recoveries on record. Other than China, all economies have slowed to growth levels that are only marginally better than the regional inflation rates. Even China's economic growth has slowed, but still remains strong due to its positive balance of trade data and government-supported economic policies.

The weak global economies have been incentives for some countries to invest in their R&D infrastructures to boost their technology base and create a knowledge economy for improving their export trade. These countries also work to attract the creation of foreign research centers in their countries and the researchers and technological expertise they bring with them.

Which country has technology leadership?

	Survey Respondents								
	U.S.	China	France	Germany	Japan	Russia	S. Korea	U.K.	Other
Advanced materials	63%	12%	0%	13%	7%	1%	2%	1%	1%
Agriculture/food	77%	7%	1%	3%	40%	0%	6%	1%	7%
Automotive	28%	4%	1%	21%	38%	0%	6%	1%	1%
Commercial aerospace	76%	4%	8%	2%	1%	5%	0%	1%	3%
Computing/IT	60%	22%	1%	1%	5%	2%	2%	1%	6%
Energy	55%	10%	6%	16%	4%	2%	0%	1%	6%
Environmental/sustainability	42%	2%	7%	26%	6%	0%	1%	3%	13%
Information/communications tech	62%	13%	2%	3%	8%	1%	3%	2%	6%
Instrumentation/electronics	45%	15%	1%	11%	20%	1%	4%	0%	3%
Healthcare	43%	1%	7%	16%	6%	1%	1%	11%	14%
Military/space/defense	78%	9%	0%	1%	1%	7%	1%	1%	2%
Pharmaceutical/biotech	70%	4%	6%	9%	2%	0%	1%	1%	7%
Average	**58%**	**7%**	**3%**	**10%**	**12%**	**2%**	**2%**	**2%**	**6%**

Leader **Runner-up**

INTERNATIONAL R&D:

China Continues Strong R&D Growth

China is expected to increase its total R&D spending by 7.1% in 2017 to $429.5 billion (in PPP dollars). While this is down slightly from the 7.6% R&D growth seen from 2015 to 2016 due to the country's slowing economy, the 2017 growth is basically twice the percentage change and twice the dollar amount of change as the growth forecast for the U.S.'s 2017 R&D spending. China's R&D is mostly funded by the government with its economic might to support their continuing R&D investments. For more than 20 years now, there has been no let-up in China's desire to build its R&D infrastructure and science and engineering (S/E) capabilities, with a goal to surpass the U.S. and other Western countries in all aspects of S/E.

Indeed, at its current rate of growth for R&D, China's total R&D is expected to surpass that of the U.S. by 2026. China's R&D has already surpassed that of all 34 countries of Europe combined in 2016. Europe is struggling with a weak economy and various political and Brexit turmoil issues. Europe's forecast R&D spending for 2026 is not expected to meet the current (2016) R&D investments by the U.S.

China's research spending and research performance eclipses that of all other countries, except that of the U.S. (currently). Much of China's R&D is managed and directed by the Chinese Academy of Sciences (CAS). Formed in 1928, the CAS has 124 direct-report institutions consisting of 104 research institutes, five universities and supporting organizations and 12 management organizations. There also are 25 legal affiliations and 22 CAS-invested holding enterprises. It has a staff of more than 60,000 and claims to be the largest research organization in the world. Its R&D covers a wide range of activities and programs, which are included in China's five-year plans (currently the Thirteenth, which runs from 2016 to 2020).

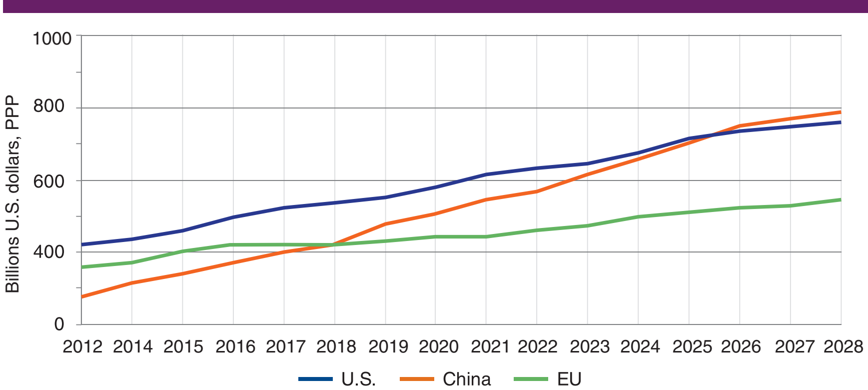
The CAS consistently publishes about 3,000 scientific articles per year in the 68 journals that comprise the Nature Index. This output is more than all other global research organizations. It also has a WFC (weighted fractional count) of articles that is higher than many scientifically advanced countries including Spain, Switzerland and South Korea.

China has many scientific accomplishments:

- **Space:** Their large modular manned space stations based on Soviet-era Mir vehicles started with the Tiangong 1, which was launched in 2011 and is scheduled to reenter the atmosphere in 2017. Tiangong 2 was launched in September 2016 and Tiangong 3 is scheduled to be launched in the 2020s with a planned lifetime of 10 years. These three-man vehicles have many of the same functions as those on the Mir and ISS (International Space Station). In 2002, China became the third country following Russia and the U.S. to launch humans into space orbit. China has also landed spacecraft on the moon and collected and transmitted data back to earth.
- **Astronomy:** The CAS completed the Five-hundred meter Aperture Spherical Telescope (FAST) in July 2016, which is now the largest operating single aperture radio telescope in the world–the similar Arecibo telescope operated by the U.S. National Science Foundation in Puerto Rico is 300-meters in diameter and has been operating since 1963.
- **Ocean Engineering:** China has two arctic-class (ice breaker) research vessels and two more under design. The latest vessel was launched in 2016.
- **Physics:** Prominent physicists, including Stephen Hawking, have suggested that China build the next generation large hadron collider (LHC), to build upon the knowledge gained from CERN's LHC device. Chinese physicists are taking these suggestions seriously and are considering appropriate sites near Shanghai.
- **Research:** China has built four research stations on Antarctica and currently is surveying where they might build a fifth research station.

China aims to build itself into an innovative country by 2020, when scientific progress and accomplishments

China/U.S./Euro R&D



are supposed to contribute to nearly 60% of the country's economic growth, according to China'' national outline for scientific and technological development.

On the industrial side

China has a number of world leading organizations in the energy industries. Three of the top four largest organizations in the world, for example, according to the 2016 Fortune Global 500, are Chinese. Number two on the list (following number one U.S.-based Wal-Mart) is State Grid (the largest electric utility in the world with $330 billion in 2015 revenues). China National Petroleum Corp. (CNPC, the largest integrated energy company in China with $299 billion in 2015 revenues) follows, and Sinopec Group (an oil and gas exploration company with $294 billion in 2015 revenues) is number four on the list. All three companies have the Chinese government as their parent.

State Grid has ownership/operating partnerships with electric suppliers in Australia, the Philippines and Malaysia. China's smart-electric grid differs from that in the U.S. in that they primarily use ultra-high voltage (800 to 1,000 kV) lines, while U.S. smart-electric grid suppliers employ lower voltage (1 to 35 kV) lines. CNPC has 2016 R&D investments of $1.7 billion and 1.6 million employees. It has long-term operating partnerships with Iraq, Iran, Syria, Kazakhstan, Uzbekistan, Afghanistan, South Sudan, Russia and New Zealand. Sinopec has 2016 R&D investments of $751 million and 360,000 employees. It has long-term oil exploration and production relationships throughout Africa–Gabon, Sudan, Ethiopia, Cameroon, Nigeria and Angola. It also has acquired stakes in the Alberta, Canada, oil sand fields and Saudi Aramco/Exxon oil refinery operations.

From an electric energy supply standpoint, China surpassed the U.S. in generating capacity in 2012 and continues to add more capacity, even though it is currently in an overcapacity position. China has been and is the country with the largest installed power capacity and has increased this by 14% since 2012. Most of China's generating plants (73%) are powered by coal. China is both the largest producer and the largest consumer of coal. According to some reports, their use of coal for electric generating plants peaked in 2014 and has declined slightly (1.5%) since then. However, China is continuing to build coal-fired electric plants due to the low cost of coal (half of what they were in 2011) and the creation of jobs. China is expected to add 200 GW to its capacity between 2015 and 2017 with these new coal-fired plants.

China is also a significant producer of nuclear-powered electricity with 35 reactors in operation, 20 under construction and more in the planning stages. China wants to double its nuclear power capacity to 58 GW by 2021 and then up to 150 GW by 2030 and much more by 2050. The incentive for this capacity increase is increasingly due to the air pollution in China from the coal-fired plants. With the help of significant foreign expertise, China has become largely self-sufficient in nuclear reactor design, construction and operation, as well as other aspects of the fuel cycle, all the while adapting and improving the technologies. An associated goal is to get to the point where it can export nuclear power technologies including all of the heavy power plant components that go along with it.

China also is a significant producer and technology developer of photovoltaic (PV, or solar cell) devices for internal use and export. With this base, they continue to install PV capacity within China and now have more than 65 GW of that type of capacity (double its capacity in 2014) with more planned. During the first half of 2016, for example, China installed an additional 20 GW of PV capacity.

As noted, there are significant issues with the pollution created by China's coal-fired electric generating plants, along with the pollution from its other industrial activities. According to Chinese surveys of its citizens, air pollution is China's biggest concern. In Beijing, more than 200 days a year are classified as unhealthy due to the air pollution. An Asian brown cloud is created from this pollution that has been imaged from space from multiple satellites, including those from NASA. It engulfs the northern Indian Ocean, India, Pakistan and southern China. This event is particularly evident between January and March when airborne particles and pollutants are created from combustion (wood fires, cars, and factories), biomass burning, and industrial processes with incomplete burning.

The brown cloud is associated with the winter monsoon during which there is no rain to scrub pollutants from the air. A major effect of the brown cloud events is on health, with research studies indicating that nearly two million people die each year, in India alone, from conditions related to the brown cloud. The brown cloud has also been shown to increase global warming effects, especially in the Himalayas with retreating snow packs and glaciers. Other effects, from research conducted by Australia's CSIRO, include the shifting of weather patterns over the western Pacific and a decline in crop harvests due to elevated concentrations of surface ozone.

Twenty years ago, China became the target for low-cost manufacturing with their low labor costs and large manufacturing force and capabilities. In 2016, this picture has changed with escalating labor costs and an increasing environment of competitive countries to choose from. In response to these events, China is evolving into an automation-driven factory environment. While purchasing existing robotic systems from places like Germany, China is also starting to build its own robotics industry. China's robots are increasingly being used in electronic assemblies, where workers age 15 to 59 are increasingly harder to find, due to China's one-child policy (now eliminated, but the long-term effects continue). Chinese worker labor costs have also doubled over the past several years and are now approaching that of U.S. workers.

Asia Shows Strong R&D Growth

The countries in Asia have the greatest R&D growth in the world by a substantial margin. Their strong economies, dedicated work ethic and technological expertise have positioned them at this point in time to take control. Take away China in the evaluation and the 23 countries we follow for Asian R&D have a combined R&D investment ($457 billion) that is greater than China and everyone else, except for the U.S. The average Asian country R&D increase expected for 2017 is 2.93%. R&D spending for the countries in the attached Table are based on forecast GDP growth (by the IMF's World Economic Outlook, October 2016), the countries' historical R&D as a percent of GDP, and the countries' actual GDP.

As noted in the attached Table, U.S. R&D is rated stronger overall than Asian R&D by a substantial margin in all categories, according to the respondents in recent surveys by R&D Magazine. These results are similar to the same question asked in last year's Global R&D Funding Forecast report.

JAPAN's 2017 R&D is expected to be about 8.4% of the global R&D total and 38% of the non-China Asian total. Industry provides the bulk of the R&D funds (77%) and similarly performs most of the work (78%). However, Japan's standing in the global science and technology (S&T) community, while strong, is declining. Their scientific research papers are dropping in international rank, and their S&T activity is falling behind the world leaders (U.S. and China). Japan's output of papers in the Nature Index has decreased by 12% over the past four years. And over the past 10 years, while China's R&D spending has increased by 180% and the U.S.'s R&D has increased by 45%, Japan's has only increased its R&D by 30%.

Japan's economic growth over the past 10 years explains their R&D results–China has increased its GDP by 150%, the U.S. by 60% and Japan by only 25% (China's figures are exaggerated since they were starting from a smaller base, but normalized results reveal similar results.) The outlook for a reversal of Japan's S&T fortunes are poor. Japan currently has the world's oldest population, a declining birthrate and a large number of young adults who state they don't want to have children. Japan is facing substantial future expenses for healthcare and their workforce is struggling to find an adequate number of researchers. On the positive side, efforts to globalize their universities (with their Research University Network) and encourage international partnerships is working–these type of collaborations have increased over the past year. Similarly, it is increasing the number of industrial collaborations with the U.S., Germany and China. Japan also continues to spend a higher proportion of GDP on R&D than its primary competitors–Germany, U.S., France, China and the UK.

Japan is also a strong supporter of international science endeavors. The Japan Aerospace Exploration Agency (JAXA) has supported the International Space Station (ISS) and its attached Kibo experiment module with six regular supply flights by its unmanned H-IIB rocket over the past seven years. Japan is also well known for its high-quality auto and truck industry with Toyota, Nissan, Mazda, Mitsubishi, Suzuki, Subaru, and Honda brands being manufactured in Japan and in multiple global locations as well. Toyota recently announced that it was investing $1 billion over the next five years for development of artificial intelligence (AI), robotics and autonomous systems. The new company, called Toyota Research Institute, will have offices in Silicon Valley, Calif., and Cambridge, Mass.

SOUTH KOREA's 2017 R&D spending is expected to be $83.9 billion and about 4.1% of the global R&D total. Korea is committed to R&D as a key to its economic development. It has the world's largest R&D as a share of its GDP (4.29%), a highly educated workforce, large knowledge-intensive and internationally competitive firms and a strong ICT (information and communications technology) infrastructure. The government has stated that it plans to increase its R&D/GDP ratio to 5% within the next two years. They also stated that they plan to increase their basic research spending by 36% by 2018. Some critics question whether the country can continue this level of R&D investments. About 75% of their R&D investments are funded by industrial companies (22% is funded by the government). Industrial researchers then perform about 78% of the total R&D, with academia performing 10% and

How does the U.S. and Asian R&D compare?

	Survey Respondents				
	U.S. Far Superior	U.S. Superior	Same	Asia Superior	Asia Far Superior
R&D Investments	18%	28%	28%	24%	4%
R&D Quality/Value	19%	29%	40%	10%	2%
R&D Productivity	17%	24%	36%	19%	4%
R&D Basic Research	20%	31%	40%	8%	1%
R&D Applied Research	14%	33%	37%	13%	3%
R&D Development	16%	35%	37%	11%	1%
R&D Trends	16%	28%	41%	15%	0%

the remainder is performed by government researchers.

Korea is also the world leader in patent applications per capita, outpacing Japan, Germany, the U.S. and even China, due primarily to industrial leaders Samsung and LG. China is the global leader in the absolute number of patent applications (2.9 million applications filed in 2015), but China (1.36 billion) has more than 27 times the population of Korea (50.2 million). In 2016, the government also committed to investing about $1 billion in artificial intelligence (AI) research by 2020, with encouragement to the Korean industrial sector to invest another $2.5 billion.

In 2007, Korea launched their Institutes for Basic Science (IBS) as a response to Germany's long-standing Max Planck research institutes. The plan was for 50 IBS centers to be constructed. As of 2016, 26 of the IBS centers have opened with the remainder scheduled to be open by 2021.

INDIA's 2017 R&D spending is expected to be $77.5 billion resulting in a global R&D total share of about 3.7%. India's economy (GDP) is expected to grow 7.6% in 2017 according to the IMF, however its R&D is only expected to increase by 6.3%, a lower rate than its neighbor China. Only about a third of India's R&D budget is contributed by industry, a much lower rate (about half) than its non-socialist contemporaries, Japan and the U.S.

India has one of the largest public research systems in the world. Funding for R&D in these higher education sectors is larger than in France and nearly equals that of Japan. However, these universities are not considered world-class and have a weaker scientific and engineering publication record than other emerging economies such as Brazil, China and South Africa. As a result of its political structure, the academic institutions have no consolidated public research budget and no central research funding body, like the NSF or NIH in the U.S. The budgets for India's public research institutes (PRIs) recently declined in real terms.

India has been very successful at attracting foreign R&D investments in a number of categories, including electronics and information technologies. Research studies found that India attracted about a third of nearly 200 engineering R&D (ER&D) centers created in 2015. The enterprises setting up these ER&D centers included the likes of Rolls-Royce, Ericsson, BASF, Bosch, Michelin, Foxconn and LeEco. India now has more than 1,000 ER&D centers.

AUSTRALIA's 2017 R&D spending is expected to be $36.2 billion resulting in a global R&D total share of 1.8%. About half of Australia's R&D is funded by industry, while the government funds nearly 40% of the total. In terms of performance, Australian industry does about 55% of the R&D, about 15% is performed by government labs/researchers and the remaining 30% of the R&D is performed by Australian academia. Government funding of Australian funding is declining and is now about 2.3% of the government's budget, which is down from a high of 2.8% about 20 years ago. Industrial support is continuing. Following the 2008 to 2010 Great Recession, Australian industries increased their productivities faster than many other countries. Australian researchers perform well in life science research, placing third in this category in the Nature journal Asia-Pacific Index. Australian universities ranked fourth in overall publishing output.

SINGAPORE's 2017 R&D is expected to increase by 2.2% to $12.8 billion. Nearly two-thirds of Singapore's R&D comes from industries with a third coming from the government. Industry also performs about two-thirds of the R&D, with academia doing 23% and government labs/researchers performing about 10%. With a population of less than 6 million, the island state boasts one of the world's highest number of scientist and engineering researchers per capita. More than 30 global biopharmaceutical companies have a presence in Singapore, and their combined spend is about $0.5 billion on R&D in Singapore. Novartis has several production plants in Singapore, as well as the company's Asia-Pacific headquarters—the Novartis Institute for Tropical Diseases. Part of Singapore's reputation has come from the partnerships it has created with international research organizations such as the French National Research Agency, Nestle and Agilent Technologies.

2017 Asian R&D

	billions US$, ppp	change from 2016
Japan	$173.4	0.60%
South Korea	$83.9	3.73%
India	$77.5	6.33%
Australia	$36.2	2.70%
Taiwan	$27.7	3.83%
Singapore	$12.8	2.16%
Malaysia	$11.1	4.61%
Indonesia	$9.4	5.37%
Pakistan	$6.1	4.96%
Bangladesh	$4.6	6.94%
Thailand	$4.1	3.50%
Hong Kong	$3.0	2.04%
New Zealand	$2.3	4.09%
Vietnam	$2.0	5.85%
Philippines	$1.3	6.78%
Myanmar	$1.0	7.61%
Sri Lanka	$0.4	5.41%
Nepal	$0.2	4.76%
North Korea	$0.2	0.00%
Cambodia	$0.1	7.69%
Afghanistan	$0.1	0.00%
Macau	$<0.1	0.00%
Lao P.D.R.	$<0.1	0.00%

European R&D

As noted earlier, Europe is the third largest global region for R&D with about 20.8% of the global R&D total. The European share has been declining over the past decade (as has the U.S.'s R&D share) due to the higher R&D growth rates in the Asia region, and in particular China. Europe is the second largest (next to the U.S.) source of science, technology and innovation (STI) information in the world. According to Nature, the 34 countries that make up northern and western Europe had 15,785 WFC (weighted fractional count) articles in the latest Nature Index–North America had 19,245 and East and Southeast Asia, which includes China and South Korea, had 11,464. Europe was first overall in the creation of physical science articles, second in life science and earth and environmental sciences, and third in chemistry.

From an economic standpoint, Europe has 30 out of the top 100 industrial organizations in Fortune's latest Global 500 listing, compared to the U.S.'s 38 and Asia's 28. The top European industrial companies are Royal Dutch Shell (#5 in *Fortune*'s list), Volkswagen (#7) and BP (#10). These companies are expected to invest $11.3 billion (VW), $0.9 billion (Shell) and $0.3 billion (BP) in R&D in 2017 (Shell and BP have depressed values due to declining energy prices in 2015 and 2016).

While Europe's overall R&D is expected to increase by 1.46% in 2017, its combined GDP is expected to increase by 1.76% in 2017 to $23.1 trillion, according to the IMF's latest World Economic Outlook. The combination of the Brexit vote, Trump's election and his protectionist views and continued strong economic growth in the Asia-Pacific region have complicated the overall economic situation and forecast for Europe which will likely not be resolved until mid-2017. The best estimate is that most economic relationships will continue throughout 2017 and any changes in the overall economic situation and the resulting R&D investments won't likely be made until late-2017 and into 2018.

R&D relationships within the European Union and its strong collaboratory policies are also in a state of flux due to the Brexit vote in April 2016 that disconnected the UK from the EU. These relationships and their effects on overall R&D spending are not expected to be resolved until mid-2017 or later.

The comparisons of U.S. and European R&D in the attached Table are similar to the comparisons of U.S. to Asian R&D (in this report's previous section), with the exceptions being that U.S. basic research R&D is stronger than that in Asia and only slightly better than that in Europe. Productivity values are also substantially stronger in Asia than they are in Europe, although both Asian and European R&D productivities are less than they are in the U.S.

GERMANY is the driver of economic growth and STI investments in Europe with $112.5 billion in R&D forecast for 2017 or a global R&D share of 5.4% and a 26% share of Europe's overall R&D spending. Germany accounted for the largest share (25.5%) of the WFC STI published articles in Europe with leadership positions in chemistry and physical science topics. Germany also has a strong R&D as a percent of GDP ratio (2.84% for 2017) that is a full percentage point ahead of the overall average for Europe–Switzerland (2.98%), Denmark (3.04%), Sweden (3.30%) and Finland (3.50%) all have higher R&D/GDP ratios than Germany. The Max Planck Society and the Helmholtz Association of German Research Centres are the second and third largest national research organizations in Europe, behind the French National Centre for Scientific Research (CNRS), according to the Nature Index listings. Globally the Planck and Helmholtz organizations are ranked fourth and fifth, respectively.

Germany's position as the driver for Europe's economy is established with a 2017 GDP forecast for $3.96 trillion, which is about 17.2% of the European total. The UK and France follow with substantially smaller 11.9% and 11.8% shares of the total European economy, respectively.

From an industrial standpoint, Germany's Volkswagen is the global leader in terms of both overall automotive production and in overall R&D investments (by any industry). VW has annual revenues of $236.6 billion (2015) and R&D spending of $11.3 billion (2017 forecast) for an R&D/sales ratio of 4.8%. VW's R&D/sales ratio is slightly less than that for Honda (5.3%), Ford (5%) and GM (4.9%), but ahead of Toyota (3.9%) and Germany's Daimler (3.1%), but obviously ahead in terms of overall spending. VW manufactures about 10.18 million vehicles/year (2016) compared to its closest competitor Toyota's 10.16 million vehicles–#3 GM is expected to

How does the U.S. and European R&D compare?

	Survey Respondents				
	U.S. Far Superior	U.S. Superior	Same	Europe Superior	Europe Far Superior
R&D Investments	18%	29%	37%	15%	1%
R&D Quality/Value	9%	30%	50%	9%	2%
R&D Productivity	13%	33%	48%	5%	1%
R&D Basic Research	21%	17%	40%	21%	1%
R&D Applied Research	13%	37%	34%	12%	4%
R&D Development	13%	34%	40%	11%	2%
R&D Trends	8%	30%	52%	6%	4%

manufacture 9.6 million vehicles in 2016. VW's largest market is China, where it has a 14% market share of a very diverse field.

FRANCE's expected 2017 R&D spending is the second largest in Europe with $60.8 billion, or a 2.9% share of the global total R&D investments and a 14.2% share of the expected 2017 European total. France is third in Europe in terms of the number of WFC articles with 2,222 article in the Nature Index, following Germany and the UK. The country's GDP and R&D are both expected to grow in 2017 by 1.3%.

The CNRS is Europe's top research organization as ranked by the Nature Index. CNRS has an R&D budget of $3.8 billion, a research staff of more than 30,000 and 18 regional divisions throughout France. Established in 1939, the organization performs fundamental research in chemistry, physics, biology, computer sciences, mathematical sciences, engineering and astronomy, among others.

France has eight companies in the top 100 of *Fortune*'s Global 500. The largest of these, Total, #24 on *Fortune*'s list, is the fourth largest energy producer and provider in the world and the second-rank photovoltaic (PV) solar energy operator. It also is involved in bioenergies, polymers, specialty chemicals and various other petrochemicals. The company operates in more than 130 countries on all five continents. It operates the California Valley Solar Ranch and recently was awarded three blocks in the first deep water oil bidding in offshore Mexico. Total has R&D spending of $0.8 billion in 2016.

The **UNITED KINGDOM** is expected to spend $48.2 billion on R&D in 2017 or a 2.3% share of the global total R&D investments and a 11.2% share of the expected 2017 European total. The UK is the fourth largest creator of WFC documents for the Nature Index and with Germany account for nearly half (46%) of all of Europe's output. Much of this output is created in academia, and the UK has some of the world's oldest, best-known and most productive research universities. The Times Higher Education (THE) World University Rankings 2016-2017, for example, ranks the Univ. of Oxford as #1, the University of Cambridge as #4, Imperial College London as #8 and University College London as #15. The UK has 12 universities in the top 100 THE rankings and 32 universities in the top 200 THE rankings. THE rankings are well established and based on 13 calibrated indicators to provide comprehensive and balanced comparisons among the top 980 universities in the world.

2017 European R&D

	billions US$, ppp	change from 2016
Germany	$112.5	0.00%
France	$60.8	1.30%
United Kingdom	$48.2	1.09%
Italy	$28.0	0.90%
Spain	$21.6	2.17%
Netherlands	$18.1	1.63%
Sweden	$16.6	3.23%
Turkey	$15.6	2.98%
Switzerland	$14.7	2.01%
Austria	$12.4	1.22%
Belgium	$11.9	1.44%
Poland	$9.6	4.56%
Denmark	$8.0	2.03%
Finland	$8.0	1.13%
Czech Republic	$6.5	5.71%
Norway	$6.4	4.26%
Ireland	$4.9	5.17%
Portugal	$4.3	4.63%
Hungary	$3.8	2.44%
Ukraine	$2.8	2.54%
Romania	$2.7	3.83%
Greece	$1.8	5.81%
Slovenia	$1.7	1.78%
Slovak Republic	$1.3	3.20%
Belarus	$1.2	-0.82%
Serbia	$0.9	2.20%
Bulgaria	$0.9	3.53%
Luxembourg	$0.8	6.41%
Lithiuania	$0.8	2.63%
Croatia	$0.7	1.43%
Estonia	$0.6	3.28%
Iceland	$0.4	2.44%
Latvia	$0.3	3.33%
Bosnia	$<0.1	0.00%
Total	**$429.2**	**1.46%**
Global share	**20.8%**	

The UK's R&D is funded by industry (48%), government (21%), offshore accounts (18%), academia (9%) and non-profit organizations (4%). The R&D is performed by industry (65%), academia (26%), government and research councils (7%) and non-profit organizations (2%). The UK's R&D/GDP ratio has been fairly stable at about 1.7% for the past 20 years. R&D expenditures for defense purposes accounts for about 6% of the total R&D spending. This includes research for the development of aircraft, ships and associated systems and equipment.

The UK government recently announced that it will cut annual student visas from the current 300,000 to 170,000 amid a sharp reduction in students coming to the country from outside of Europe, including India. The number of citizens from southern Asia coming to study has been halved over the past several years. These policies are being established to have more control of immigration and getting net immigration numbers to sustainable levels that are even smaller.

In terms of industrial research, the largest UK company on the 2016 *Fortune*'s Global 500 is BP, the oil and gas energy firm which is ranked #10 on the *Fortune* list. BP is expected to spend $0.4 billion on R&D in 2016, according to Schonfeld & Associates' 2016 R&D Ratios & Budgets. BP's R&D spending has been nearly halved over the past several years due to the supply glut-induced decline in gas/oil prices. Despite their overall R&D reductions, BP continues to invest in digital components. For example, BP has the largest supercomputer in the world for commercial research and has developed a Well Advisor tool that helps monitor what is happening in the wells being drilled and being prepared for production subsurface and subsea.

Rest of the World R&D

The 57 countries reviewed in this section of the *R&D Global Funding Forecast* represent roughly half of the 116 countries that we analyze for their R&D forecasts and trends. Most of these Rest of World (ROW) countries are emerging nations that represent entire continents (Africa and South America). Only five of these countries have R&D/GDP ratios greater than 1%: Canada, Brazil, Russia, Israel and Qatar. And 43 will spend less than $2 billion in 2017 on R&D. Combined, however, they're expected to increase their R&D spending by 2.1% in 2017 and represent more than a tenth of the global R&D.

CANADA is expected to increase its R&D spending in 2017 to $30.3 billion or 1.5% of the 2017 global R&D total and 5.3% of the North American total R&D investments. This represents a 2% increase over what Canada spent on R&D in 2016. Approximately 46% of Canada's R&D funds come from its industrial base, while 34% come from the Canadian government and 9% come from outside of Canada. Industry performs about half of the Canadian R&D, with 10% being performed by government labs/researchers and 39% performed by Canada's academia.

> There has been a drive to broaden South Africa's WFC focus, especially into the life science arena.

On the industrial side, Canada is strongly involved in energy R&D areas, especially the oil sands in Alberta. Canada's Magna International is a large automotive component supplier with 312 manufacturing operations and 98 product development, engineering and sales centers in 29 countries. Magna has more than 150,000 employees and spends $1 billion on R&D. Magna is involved in the development of components and operating systems for future autonomous cars as well. Canada is also home to Blackberry, the former cell phone maker that is transitioning itself into a software and Internet of Things system provider. Commercial aircraft maker Bombardier is the top R&D spending company in Canada, investing more than $2.3 billion in the development of large commuter jets for commercial airlines.

MEXICO is the other large North American R&D investor with $11.6 billion expected to be spent in 2017, a 2.3% increase over what it spent in 2016.

BRAZIL expects to invest $37.2 billion in R&D in 2017 or 1.8% of the 2017 global R&D total and 74% of the South American total. Brazil's R&D as a percent of GDP is 1.2% which has remained fairly stable for the past six years. The funding of Brazil's R&D is split equally between industry and government.

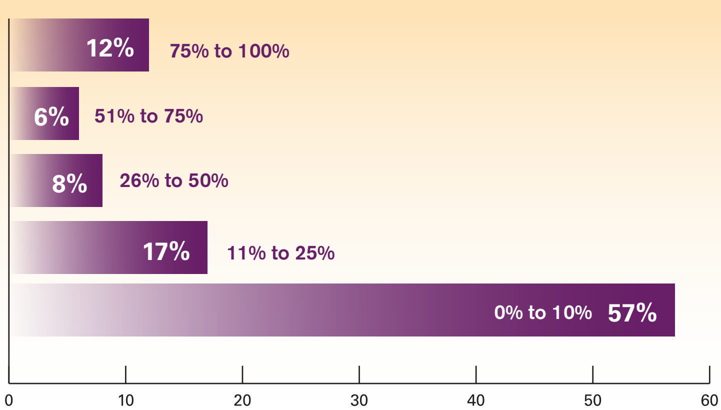
Brazil's technological infrastructure is comparatively weak with shortages of technical personnel in industry and academia limiting their overall capabilities. There are currently only 1.48 researchers per 1,000 total employment (per the OECD) and only about 10% of Brazil's university graduates have degrees in science or engineering.

These weaknesses have led to the creation of external collaborations to build the country's overall infrastructure. Japan's Sumitomo Chemical, for example, has opened an R&D center, the Latin America Research Centre (LARC) for R&D and analysis of Sumitomo's Agrosolution products, including crop protection. LARC contains experimental fields, lab buildings and green houses. LARC enables Sumitomo to conduct field crop trials for other Latin American countries and support its other chemical businesses. The Brazilian crop protection market is the largest in the world, even surpassing that of the U.S.

Brazil is also sponsoring the development of R&D projects relating to energy storage integration. About 90 companies are involved in financing and implementing the projects which are aimed at providing solutions for intermittent and unpredictable renewable energy systems in remote sections of the country. In another collaboration, Nigeria's Petroleum Technology Development Fund (PTDF) is funding full scholarships for Nigerian students to attend the University of Sao Paulo, one of Brazil's leading institutions. Still another collaboration involves the creation of an R&D center in Porto Digital or Brazil's "silicon valley" by Fiat Chrysler that will be focused on automotive engine and transmission control software—the first such facility in Latin America.

RUSSIA is expected to invest $55.9 billion in

What percent of your 2016 R&D was spent outside the U.S.?



R&D in 2017 or 2.7% of the 2017 global R&D total and about 95% of the Russia/CIS (Commonwealth of Independent States) region. Industry provides about 29% of the funds for Russia's R&D, while the government provides about 63% of the funds and the remaining 8% is financed by organizations outside of the country. Russian government researchers/labs perform about 27% of the country's R&D, while 67% is performed by Russian industry researchers and the remainder (5%) is performed in Russia's academia. These relationships have been relatively stable over the past 15 years.

According to Nature Index 2016, Russia has increased its WFC (weighted fractional count) technical paper output in the life sciences category by more than 60% over the past four years, the highest percentage increase of the top 10 countries in this field. Russia's WFC increased from 964 AC (actual count) in 2012 to 1,390 AC in 2015. Since 2013, the Russian Academy of Sciences (RAS) has been undergoing a radical, Kremlin-driven overhaul that could result in the ultimate closure of a large number of the RAS institutes. Control of its research priorities and budgets has already been transferred to a separate government agency. In this process, however, its share of the overall Nature Index contribution has slipped by 2%. Initiatives to raise the quality of university research is showing signs of success, as witnessed by Nature's selection of Russia as a rising Star. One of the most ambitious RAS projects is to raise Russia's universities into the top global rankings by 2020. While life science research was noted earlier, research in the physical sciences continues to dominate the overall Russian academic landscape.

The overall economic situation caused by the falling price of oil, however, continues to depress the funding levels of R&D. The total expenditure decreased by 10% in 2016 as a result, according to a Russian science policy analyst.

ISRAEL is expected to increase its R&D to $12.2 billion in 2017 or 0.6% of the 2017 global R&D total and about 24% of the Middle East's total R&D investments. About 65% of Israel's R&D is funded by Israeli industries, while 25% is funded by the government and 5% comes from outside the country (insourcing). About 76% of Israel's R&D is performed by industrial researchers, with 5% being performed by the government and 14% by Israel's academic institutions.

Israel has the largest R&D/GDP ratio (4.10%) in its region and is only exceeded by South Korea's 4.29% ratio. Israel accounts for about two-thirds of the regions WFC scientific papers. However, this WFC level has not changed over the past four years and the country could be losing some leverage with rising universities in the region. Saudi Arabia's King Abdulaziz University of Science and Technology (KAUST, the 2011 R&D Magazine Lab of the Year winner) is likely to become a strong competitor in the future. Saudi Arabia is well known for getting high-quality science returns for its R&D investments.

2017 Rest of World R&D

	R&D – billions U.S.$, ppp	Change from 2016
Non-U.S. N.America	$44.4	2.21%
- Canada	$30.3	1.88%
South America	$50.2	0.30%
- Brazil	$37.2	0.49%
Russia	$55.9	1.10%
CIS	$2.5	2.44%
Middle East	$51.2	5.05%
- Israel	$12.2	3.03%
Africa	$18.4	2.67%
- South Africa	$6.2	0.65%
Total ROW	**$222.6**	**2.14%**
Global Share	**10.8 %**	

SOUTH AFRICA is expected to increase its R&D to $6.2 billion in 2017 or 0.3% share of the 2017 global R&D total and about 34% of the total African R&D investments. The country's overall WFC scientific paper output has increased by 40% over the past four years. This growth has been driven by a significant rise in its physical science WFC, which rose from 23.70 in 2012 to 39.31 in 2015. This result reflects the country's growing strength in astronomy. About 40% of South Africa's R&D is funded by the country's industrial sector, while 37% comes from the government. The remaining 20% of R&D funds come from sources outside of the country (insourcing). Industry performs about 58% of South Africa's R&D, while the government and academia equally share the remainder of the workload (40% for each sector).

While Africa has 15% of the world's population, the continent only contributed 0.25% of the Nature Index. South Africa accounted for 64% of Africa's total. More than 80 South African research universities contribute to the WFC scientific paper growth noted above. These include the University of Cape Town, the University of Johannesburg and the University of KwaZulu-Natal. The country's focus on astronomy reflects its infrastructure with the southern hemisphere's largest optical telescope and a significant proportion of the Square Kilometer Array radio telescope which is under construction. A significant R&D capability in South Africa is the government-supported Council for Scientific and Industrial Research (CSIR), which attempts to implement astronomy-based innovations into other areas, such as manufacturing and communications.

There has been a drive to broaden South Africa's WFC focus, especially into the life science arena for such areas as research into the Ebola epidemic, which has taken more than 10,000 lives in Africa. Part of this will likely come from collaboratory efforts with other African universities. Already African scientists collaborate more than any other region in the world with most South African universities already involved in 60% to 80% collaborations.

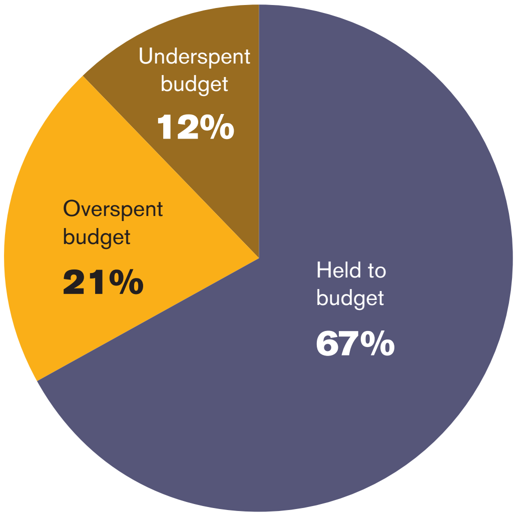
The Global Researcher 2017: Creating the R&D Budget

One of the goals of *R&D Magazine*'s annual *Global R&D Funding Forecast* is to assist global researchers and research managers in preparing their upcoming R&D budget. We've created our annual R&D funding forecasts every year since the very first issue of *R&D Magazine* (then called Industrial Research) in January 1959 and have traversed the R&D economic pipeline through recessions, recoveries, technology bubbles, disastrous inflationary cycles, globalization, outsourcing, in-sourcing and numerous political reversals. The information presented in the previous sections of the 2017 report summarizes the current R&D environment and hopefully provides an accurate forecast of the events and trends that researchers should be aware of for the next 12 months.

The R&D market

One of the first steps in preparing an R&D budget is to understand the market that you're involved in. Researchers should understand all aspects of their specific product area and technologies. They should know where they're going. But to do that they need to look back at what happened over the past several years. As part of the *Global R&D Funding Forecast*, we surveyed our readers regarding their past R&D efforts, their current situation and their plans for the future. When asked how well they performed in R&D last year (calendar year 2015), two-thirds of the survey respondents indicated that they held to their original budgets, while a fifth (21%) said they overspent their R&D budgets and the remainder (12%) said they underspent their 2015 R&D budgets.

How did your organization perform in 2015 relative to your R&D budget?



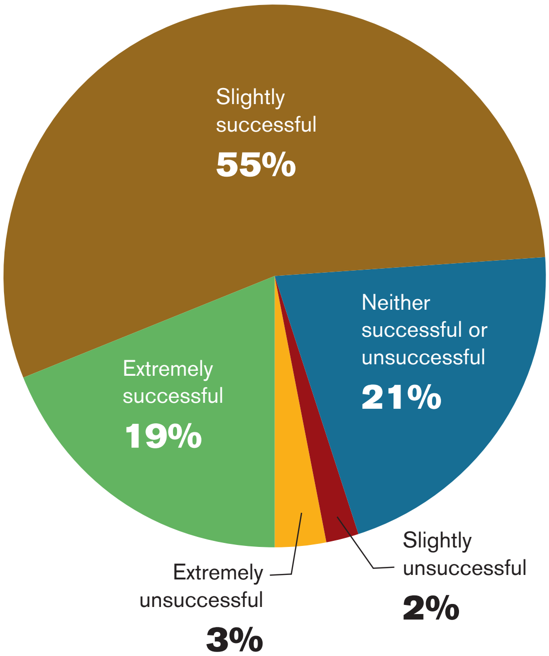
While most of the survey respondents held to their budgets, a third did not. To more accurately create a workable R&D budget, researchers may want to do more research than they currently do, including the monitoring of daily news events and publications, attendance at more technical trade shows, talking with industry analysts, clients and customers, review government economic studies and perform or purchase market studies. Often, researchers need to know what their customers need and what they are looking for in the future. All of this research provides the "big picture" in what is happening to their core or basic technologies and the marketplace, and what new technologies are impacting specific markets. Of course, all of these preliminary studies need to be done in the context of the international market where the researchers' organization plans to operate.

R&D capabilities

When our survey respondents were queried about how successful their 2015 R&D efforts were, about three-quarters stated that they were successful, while only 5% of the survey respondents indicated that they were unsuccessful in their 2015 R&D efforts. This brings up another aspect of creating a successful, workable R&D budget and that is in knowing your capabilities. Creating an R&D budget that is successful and accurate as revealed by meeting the budget and completing successful R&D projects implies that most of the researchers and lab managers surveyed understand their organization's abilities and resources. While underestimating an organization's abilities can be an inefficient use of resources, overestimating those abilities can often be catastrophic to the successful execution and completion of R&D programs.

An organization's capabilities include a number of both obvious and subtle characteristics. They can include technical personnel, support staff, equipment, facilities, instrumentation, labs, manufacturing equipment, vivariums, IT infrastructure, classified or safety certifications, financial resources and more. Of course, budget managers must take into consideration their organization's limitations as well. These can include contractual agreements, financial restrictions, pending litigation, new or inexperienced staff in key positions, deteriorating infrastructure and others. Some organizations perform structured yearly audits of their R&D capabilities to assist in the understanding of the budgeting process. The audit information can also be used in performance reviews, capital plans, lab upgrades, maintenance plans and restructurings or reorganizations.

How Successful Was Your R&D in 2015?



Strategic goals

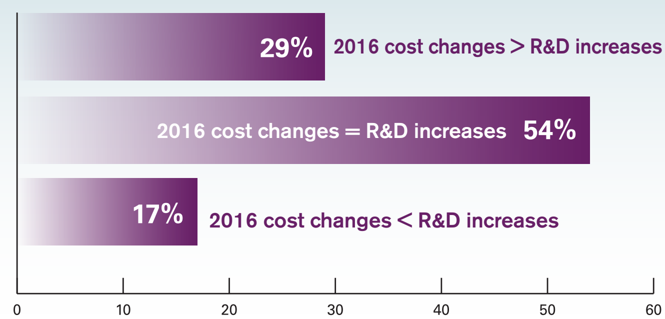
As part of the research for defining an R&D market, R&D managers can also define specific strategic goals for the R&D department of their organization. Putting into words what the R&D manager wants to accomplish informs other parts of the organization where they are, where the R&D department wants to go, and how it intends to get there. Sometimes this can be as simple as a mission statement. Other times, it can set the stage for a "strategic five-year plan" to substantially improve the organization's capabilities from where they are now.

Contingencies

One of the criteria most managers are judged by is how closely they adhere to their budget plans, especially without exceeding them. But, as noted earlier more than 20% of the research managers we surveyed actually exceeded their 2015 R&D budgets. The concern and challenge here when determining a new R&D budget is how conservative budget submitters have been with regard to the accomplishment of their overall goals. To satisfy this situation, many organizations submit "realistic" budgets with a built-in contingency fund. This occurs more often in industrial organizations rather than government organizations. Government budgets are more often more controllable. Contingency funds are generally based on historic norms and can be as much as 20% of the overall R&D budget.

Contingency funds ensure that the organization stays within their finalized budget agreement, assuming the contingency was adequate. Inflation could also be considered in the contingency category, although inflation rates have been relatively small. When our survey respondents were queried about how 2016 cost changes (inflation, etc.) compared to the increases they received in their new 2016 R&D budgets, slightly more than half of the respondents stated they matched well. Nearly a third stated that the R&D cost changes they experienced were larger than the increases they saw in their 2016 R&D budgets relative to their 2015 R&D budgets. The remainder of the survey respondents said that cost increases were less than the increases in their 2016 R&D budget increases.

How do 2016 R&D costs compare to current economic changes?



Actual specifics

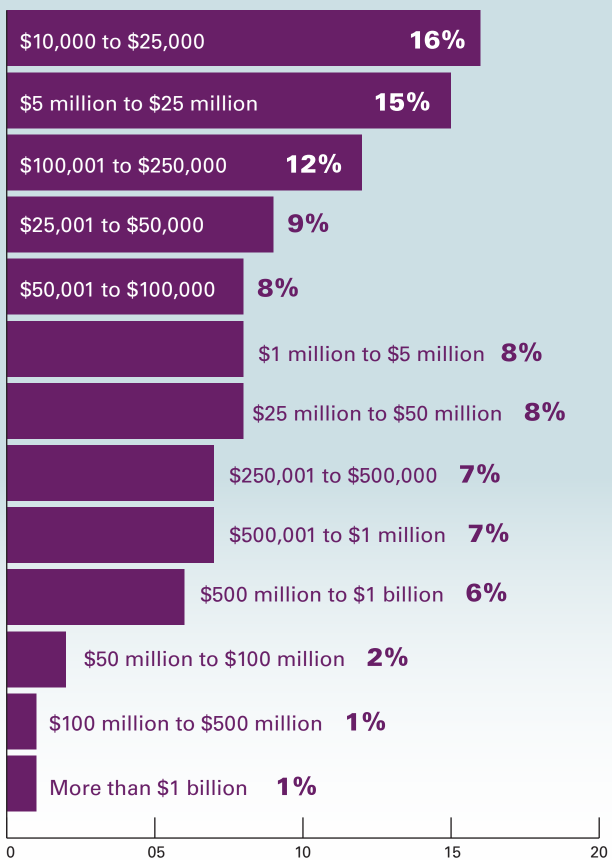
Each R&D budget is specific to a particular application and organization. General budgeting models don't work well for these complicated R&D situations. To simplify these sophisticated documents, some organizations break their R&D budgets into staffing, facilities and equipment, and operational improvement categories. Other organizations separate their R&D budgets into fixed people costs, project costs and variable costs. Some organizations develop their own R&D specific budgeting models based upon historic outcomes. These R&D organizations develop visualization models for R&D growth, income and capability evaluations.

Other R&D organizations use mathematical models for R&D cash flow and investment evaluations. These in-house developed models have inherent strengths and weaknesses. The reliability of a one-year forecast is high using normal extrapolations of current data. The reliability of a five-year forecast of most technologies, even in stable economic periods, however, is generally low. Some industries, like the semiconductor industry, find that even though their technology forecasts continue to be reliable, their historic economic patterns have changed and they have to change their modeling criteria, mostly due to globalization.

It may be useful when establishing a model to consider several variations, such as normal extrapolations, cyclical patterns, contingency models based on unforeseen events, or even a model based on the outcome of an R&D strategic plan.

The specific values of R&D budgets for research organizations cover a wide range of levels as noted in the Chart. The average annual 2016 R&D budget for these organizations in this survey is slightly more than $75 million with about 8% of the organizations surveyed having annual R&D budgets that exceed $100 million.

What is your organization's 2016 R&D budget?

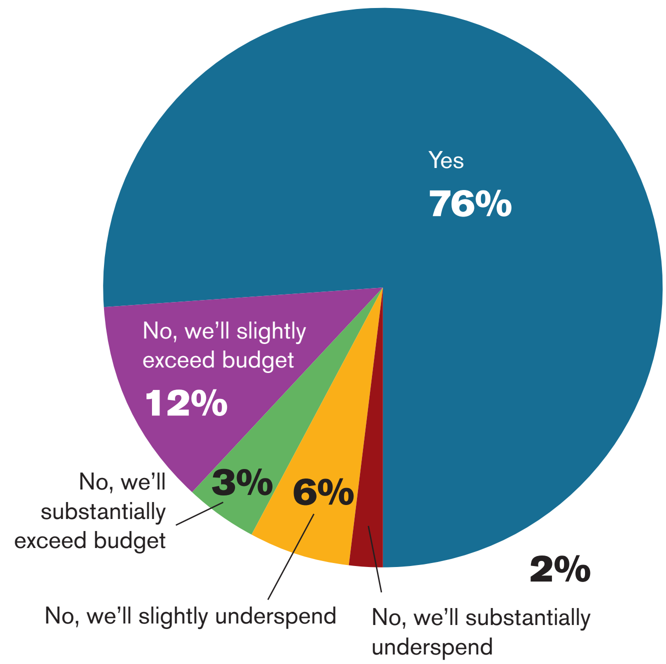


Most of the researchers we surveyed expect to stay close to their established 2016 R&D budgets through the end of 2016 (researchers were queried in early Fall 2016). About 16% of the survey respondents expect to exceed their 2016 R&D budgets—similar to their spending experiences on their 2015 R&D budgets—while 8% expect to underspend their 2016 R&D budgets.

Changing technologies

Advanced technologies continue to change in a basically self-perpetuating rate. And technology change is what R&D is all about. But in some situations, the changes can adversely impact the development of a new R&D budget by changing in unpredictable ways. Globalization has been a major factor in these accelerated developments. The U.S. traditionally was the leader in developing new technologies, but has lost a significant share to foreign competitors in a number of areas. The Table reveals our survey respondents views on the areas where the U.S. has lost and gained

Do you expect to be on budget through the end of 2016?



competitive advantages in various technologies. As shown, U.S. researchers lost a significant advantage in healthcare technologies, with 48% of the survey respondents indicating the U.S. lost advantage, while only 22% stated that the U.S.

How have U.S. technologies changed over the past year?

	Survey Respondents		
	U.S. Gained Advantage	U.S. Lost Advantage	No Change
Advanced materials	48%	21%	31%
Agriculture/food	35%	23%	42%
Automotive	31%	35%	34%
Commercial aerospace	43%	26%	31%
Computing/IT	43%	26%	31%
Energy	44%	29%	27%
Environmental/ sustainability	35%	28%	37%
Information/ communications tech	50%	20%	30%
Instrumentation/ electronics	37%	23%	40%
Healthcare	22%	48%	30%
Military/space/defense	42%	28%	30%
Pharmaceutical/biotech	40%	22%	38%

gained a technology advantage over the past year. Environmental and sustainability technologies are also close, with the U.S. having only a slim advantage in gaining an advantage over foreign competitors.

Those researchers and research managers would be wise in understanding where the U.S. is continuing to hold a significant technological advantage, where it is not, and how significant are the differences between U.S. dominance and foreign technological dominance.

Of course, accelerating advanced technologies aren't the only changes in the R&D environment that might have an effect on the creation of a new R&D budget. According to our recent survey, the costs involved in operating an R&D lab have seen the largest changes over the past year, more than any other area. Costs traditionally are the largest concerns and the biggest challenges in the development of new R&D technologies, materials and processes. On the other side of the coin, just like R&D costs play a large role in creating a new R&D budget, so does revenue growth generated by the R&D operations.

Spending on specific R&D projects is rarely completed or assigned to one fiscal year. R&D is generally spent over several years (or as much as 12 years for drug development by pharmaceutical companies) before a new product is manufactured. By breaking down the R&D budget into product-related investment streams, the link between the revenue growth rate and the R&D budget can be modeled. These models can be used as planning tools to quantify the results of various R&D budgeting alternatives or decisions.

Experts and expertise

All R&D budgets go through several iterations. At some point in these discussions, it may be appropriate to bring in the actual researchers who are going to be working on the projects to get finer details about each project. This information can then be used to create a detailed database of what the R&D organization can support. Creating the database to store all the budget information, capabilities, resources, models, personnel and experts gives the R&D managers the ability to continually fine-tune the budget as it goes through subsequent iterations.

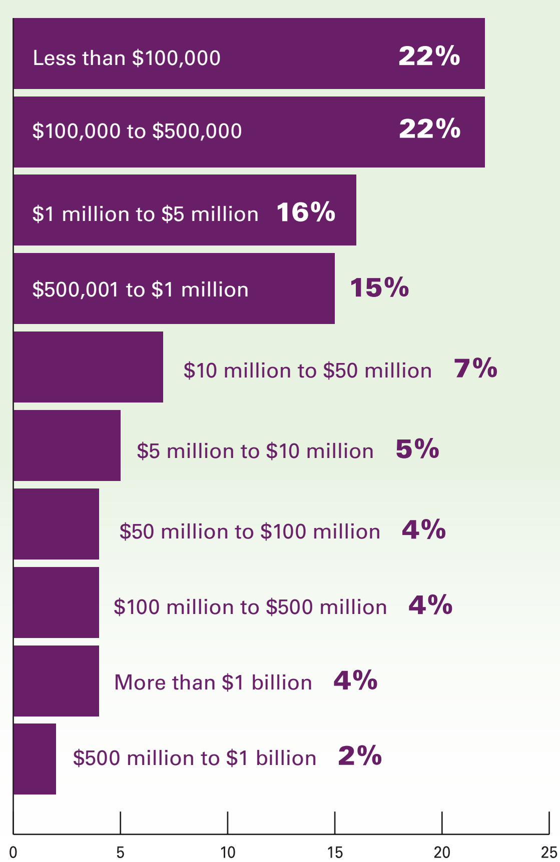
Funding sources

One of the final aspects of creating an R&D budget is establishing who provides the actual funds. This often changes over several years as organizations go through restructurings, mergers, acquisitions or change the strategic planning process. Most of the time, these changes are gradual but nevertheless, as the strategic direction of the organization changes, so may the way the structure of the R&D budgeting process is performed. Sometimes the R&D budgeting goals may be to create or take advantage of new technologies. At other times, it may be to support the parent organization's individual business units with next-generation products to help them win an increased market share.

What has changed in R&D from 2015 to 2016?

	Survey Respondents		
	Increase	No Change	Decrease
M&A acquistions of technologies	15%	42%	6%
Collaborations	17%	56%	9%
Competition	38%	43%	6%
Costs	54%	34%	7%
Grants for academia	13%	35%	14%
Outsourcing	27%	42%	7%
Patents	19%	50%	8%
Staffing requirements	33%	48%	14%
Time-to-market demands	33%	40%	7%

What is your expected 2017 R&D budget?



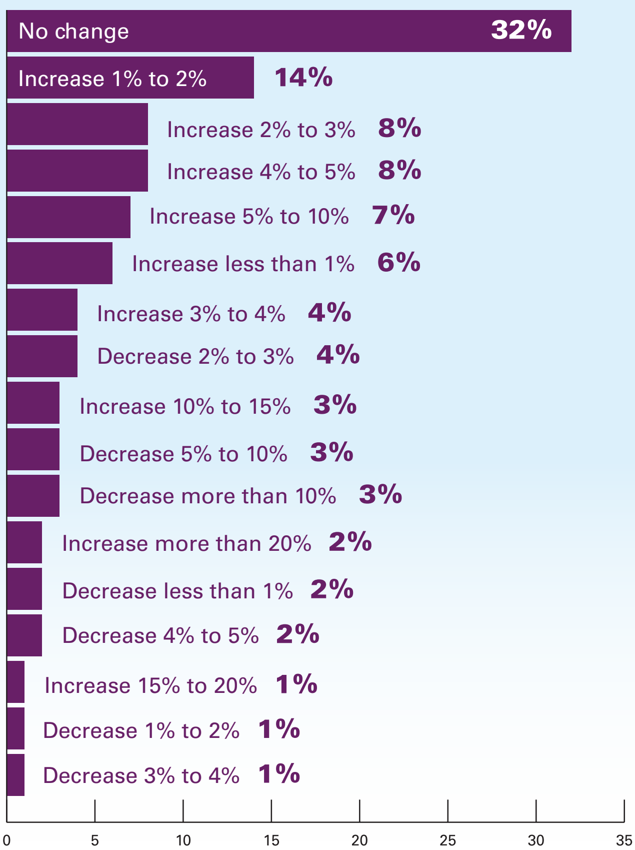
Rarely, through such changes, do the strategic goals remain the same.

The survey respondents were queried on what their 2017 R&D budget was expected to be. The results are shown in the Chart with an overall average of $113,144,000. The overall average increase in the respondents' R&D budget was about 3.5%

The future

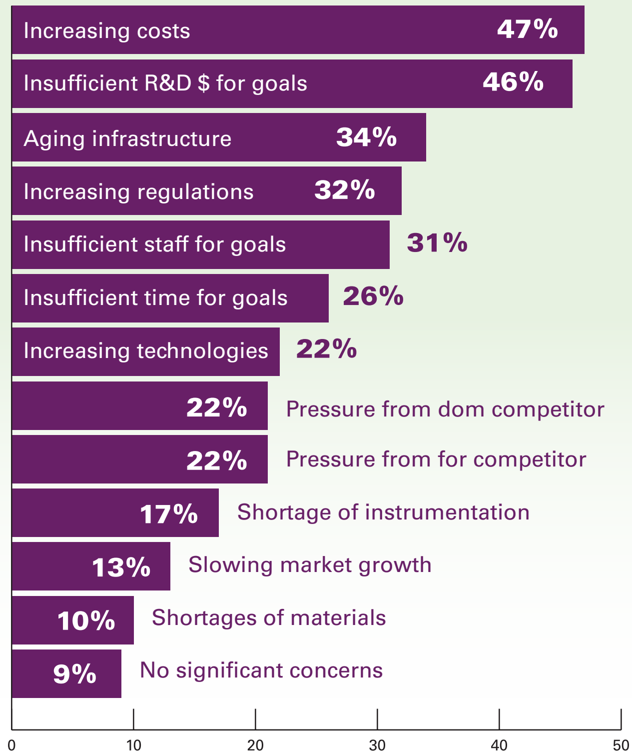
While the expected R&D budget for 2017 was significantly larger than that created for 2016 by about 30%, the absolute values reveal significant growth and confidence in future R&D development.

What is the change in 2017 R&D from 2016?



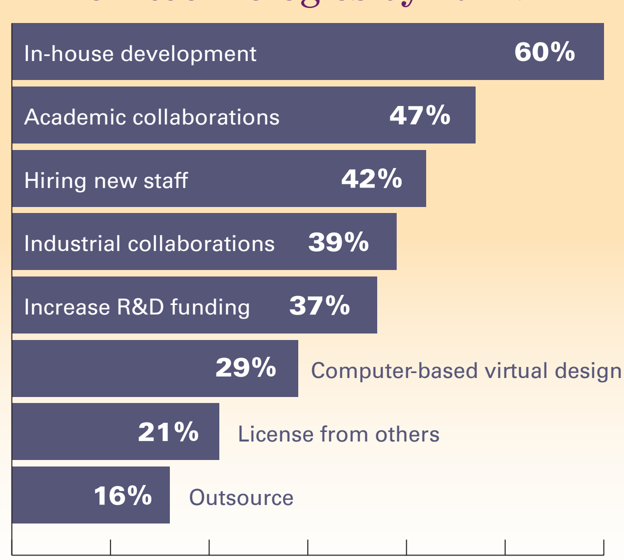
There are, however, issues even with this large a budget (and possible increase). The biggest issue, as chosen by the survey respondents, was a concern over insufficient R&D funding for meeting the organization's R&D goals—this item being selected by nearly half of all the survey respondents. Increasing R&D costs, as identified above, was also selected by nearly half of the survey respondents. It is obvious that the financial aspects of an R&D operation are clearly the largest concern by the lab occupants.

What issues do you have with your 2017 R&D budget?



Another aspect involved in operating the lab of the future was asked in our survey in how do researchers expect to develop new technologies over the next five years. Overwhelmingly, the researchers queried stated that they would do well by developing these new technologies in house.

How do you expect to develop new technologies by 2021?



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.

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

Australasian Industrial Research Group
www.airg.org.au

Booz Allen Hamilton
www.boozallen.com

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

Chinese Academy of Sciences
http://english.cas.cn/

Clarivate Analytics
tipscience.thomsonreuters.com

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

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

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

Industrial Research Institute (IRI)
www.iriweb.org

International Monetary Fund (IMF)
www.imf.org

Japan 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

Strategy & (Global Innovation 1000)
www.strategyand.pwc.com

The World Bank
www.worldbank.org

U.S. National Science Foundation (NSF)
www.nsf.gov

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