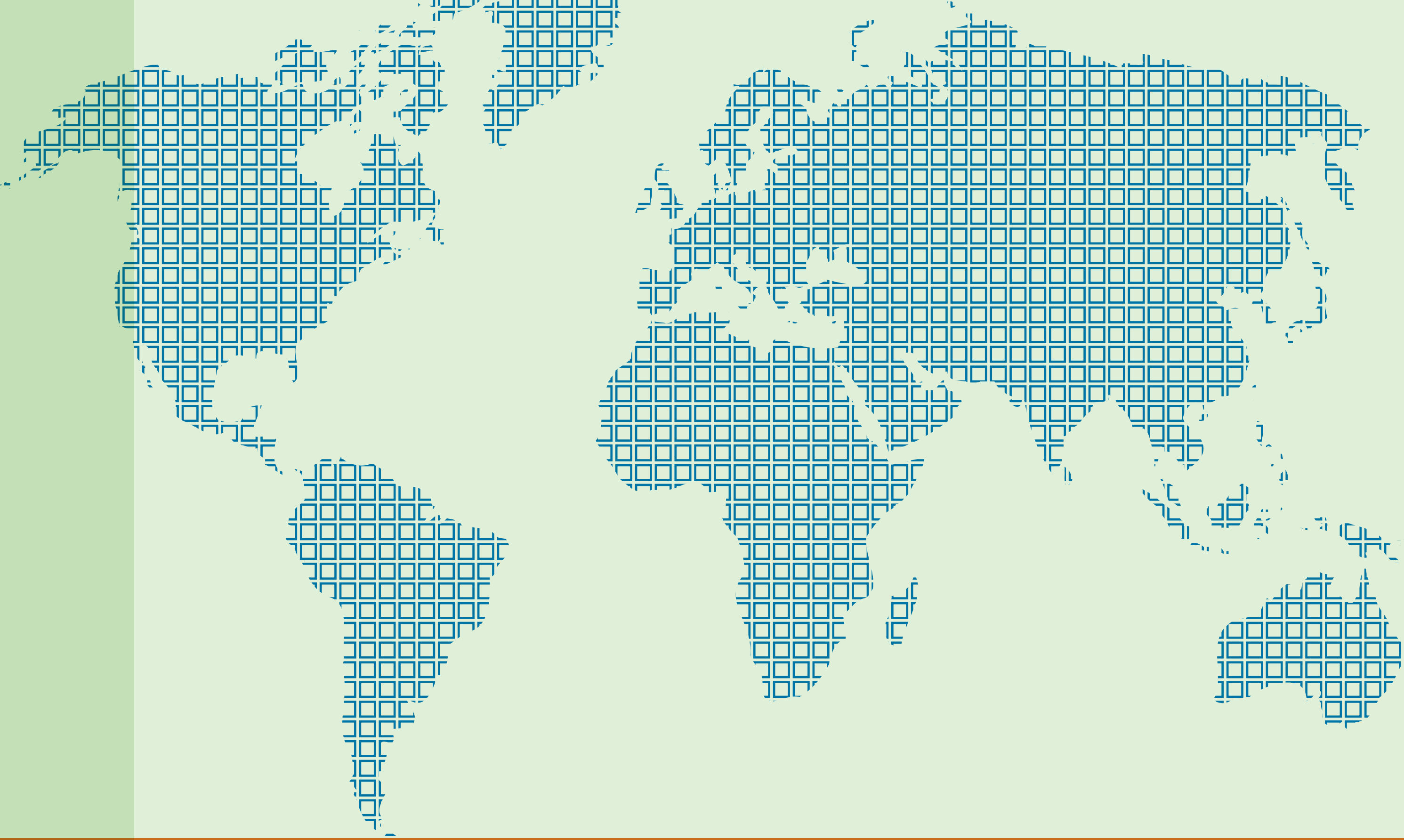

2014 GLOBAL R&D FUNDING FORECAST

DECEMBER 2013

- U.S. R&D investment up one percent to $465 billion
- Historic U.S. commitment to research intensity expected to remain firm
- Economic growth continues to propel Asian R&D spending
- China's R&D spending could surpass U.S. by early 2020's

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CEO MESSAGE

Battelle and *R&D Magazine* are pleased to release our annual forecast of global research and development funding, which is a public service for use by policy makers, corporate research leaders, researchers, educators, and economists.

In 2014, it is important to consider both the levels and locations of funding, and also how R&D is performed and measured. Public and corporate expectations of impact and productivity are high. Fortunately, there is ample historical evidence that research and innovation contribute in the short and long terms to prosperity and competitiveness, as well as to the resolution of society's greatest challenges in areas like health, energy, and security.

At Battelle, we are cautiously optimistic that U.S. R&D funding growth will recover after a flat 2013. This perspective is based on assumptions about the economy, and on indications that our leaders in Washington may be able to find common ground on the value of R&D investment. We are impressed by R&D commitments in Europe and Asia, where increasing research intensity amplifies the investment momentum that strong economic growth provides. In a world where scientific discovery and technology commercialization are truly global, these trends have implications beyond national borders.

I want to thank the many researchers, executives, and academic leaders who contributed to our global survey on which many of this report's findings are based. Your insights enrich our ability to anticipate the outlook for R&D funding.

Jeffrey Wadsworth, Ph.D.
President and CEO
Battelle

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EXECUTIVE SUMMARY

"*Somewhere, something incredible is waiting to be known,*" said astronomer Carl Sagan, who succinctly captured the essence of what it means to be a researcher.

That wide-eyed sense that anything is possible through research and development—that we can help solve some of the most critical challenges by increasing our knowledge and understanding of the world—that's the essence of a researcher's calling.

But innovation is improbable without proper funding, so we project how political developments and economic conditions around the globe will affect R&D support in 2014. This forecast is for policymakers and researchers alike because of the multiplier effect R&D investment can have, both in economic and cultural terms. There is an important relationship between economic growth and research and development, between industry creation and political stability, and between the nurturing of research and sowing the seeds of a middle class in developing nations.

While R&D funding isn't the sole indicator of how a nation, region or industry will perform, it certainly is a fundamental consideration among other factors like science, technology, engineering and mathematics education levels, capital markets, healthcare, infrastructure, property rights and immigration policy.

Each section of this report forecasts research and development levels for 2014, closely examining the expected funding for a region or industry. There are many important projections and key findings for each country and industry under discussion.

Among the most far-reaching projections for 2014 are the following:

U.S. tops the list, but China is closing in:

- The ranking of the top ten countries as measured by R&D spending isn't expected to change in 2014, with the U.S. reprising its role as the dominant force in global research across numerous industries.
- U.S. federal spending on R&D, a large contributor to R&D momentum in the U.S., is in turmoil because of enormous pressures to pare federal spending, especially defense and aerospace budgets.
- The growth in China's R&D budgets will far outpace those of the U.S., which has resumed modest growth that is expected to be relatively stable through 2020.
- At the current rates of growth and investment, China's total funding of R&D is expected to surpass that of the U.S. by about 2022.

Who is spending the big money:

- In 2014, ten countries will spend about 80% of the total $1.6 trillion invested on R&D around the world; the combined investments by the U.S., China and Japan will account for more than half of the total.
- Together, the U.S., China, Japan and Europe account for about 78% of 2014's $1.6 trillion total.

How major U.S. industries will invest:

- For 2014, we project declines in defense and aerospace R&D, increases in energy-related research, increases in life science research and development, strong growth in information technology research investment and growth in R&D budgets for chemicals and advanced materials.

Key research investment trends around the globe:

- Given the current, weak economic environment in Europe, large increases in R&D investments are not expected for the next several years.
- Emphasis by Southeast Asian countries on economic growth through increased R&D investments is likely to continue through the end of the decade.
- Significant R&D investments by western countries in long-range technology platforms like robotics, high-performance computing, social media, software, cost-effective energy sources and nanobiotechnology could stimulate rapid industry-scale economic growth.

The research standouts in the "Rest of the World":

- The "Rest of the World" countries are expected to undergo moderate growth in R&D investment in 2014, with leadership from countries like South Korea, Russia and Taiwan.
- Most Middle East countries will experience strong GDP growth in 2014, but are constrained by weak R&D infrastructure—with exceptions such as Israel and Qatar.
- Africa is expected to see strong GDP growth, but is also limited by under-developed R&D capabilities—with the exception of South Africa.
- Strong GDP growth is expected in South America, but this region also lags in R&D capacity—even Brazil appears to be under-performing expectations.

The United States remains the world's largest R&D investor with projected

$465
Billion

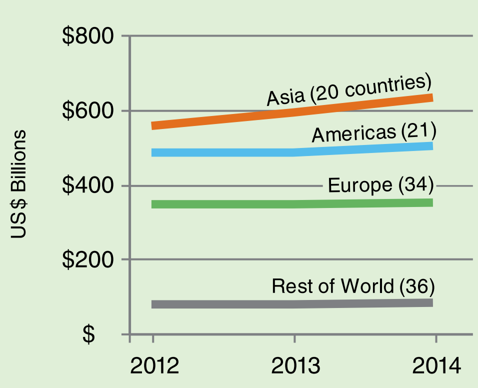
spending in 2014. This is a globally competitive level of research intensity equal to

2.8%
of U.S. GDP

Total investments in R&D (as a percentage of GDP) will stay relatively steady throughout the world in 2014.

	2012	2013	2014
Americas	2.5%	2.4%	2.5%
Asia	1.8%	1.9%	1.9%
Europe	1.9%	1.9%	1.8%
Rest of World	0.9%	0.9%	0.9%

But GDP growth in Asia will continue to drive higher absolute levels of gross expenditures on R&D.



Global Funding of R&D

Research spending to increase in 2014

Summary

Growth in global research and development funding slowed in 2013 from the pace of growth seen in 2011-2012. The 2013 slowdown was due primarily to unsettled European and U.S. economies that, in turn, affected global performance. R&D investments often are closely linked to GDP and economic outlook. Global R&D investments, according to our analysis, are forecast to increase in 2014 and 2015—albeit at a decreasing rate in 2015. Other highlights include:

- Economic and R&D growth in Asian countries have slowed, but R&D investments in this region still outpace the rest of the world.
- U.S. R&D investment is back on track with modest growth that is expected to continue through 2020.
- China continues its unmatched economic growth and double-digit R&D increases.
- R&D rankings have not changed significantly in the past five years, but differences have narrowed in funding levels between countries.

Asia's Role Continues to Increase

While 2013 R&D investment growth was minimal in the U.S. and Europe, growth in most Asian countries—especially China—continued. Asian R&D investment growth rates are expected to return to their pre-2013 levels in 2014 and 2015. The exception to this outlook may be Japan, which is more correlated with trends in the U.S. and Europe than with neighboring Asian countries.

In 2014, China will continue its two-decade trajectory in R&D investment, consistent with the current Five-Year Plan (FYP 2011 to 2015). According to our Forecast, China's research intensity will increase to 1.95% of GDP in 2014. China's FYP is aimed at achieving 2.2% of GDP by 2015. This rate of growth is expected to continue through the end of the decade as China strives to transition from a manufacturing economy to being "innovation-driven" by 2020. At current rates of R&D investment and economic growth, China could surpass the U.S. in total R&D spending by about 2022.

The ranking of the top ten R&D-spending countries has not changed over the past five years, except for China surpassing Japan for the number two position in 2011. These top ten countries spend about 80% of the total $1.62 trillion invested in R&D around the world; the combined investments by the U.S., China and Japan is more than half of the total.

Outlook

The broad patterns of R&D spending are not expected to change significantly in 2014, but regional shifts are occurring. Just five years ago, the U.S., Canada and Mexico were responsible for nearly 40% of global R&D. That share has dropped to about 34%, with the U.S. shrinking from a 34% share in 2009 to 31% now. Europe has experienced a similar decline from 26% in 2009 to less than 22% in 2014. Where the west has retrenched, Asia has advanced. In the same five years, Asia's share of R&D investments has risen from 33% to nearly 40%, with China rising from 10% to nearly 18%. China's high level of research intensity has now been sustained for nearly 20 years, and its total R&D investments are now more than 60% those of the U.S. The economic and political context in each of these regions suggest these trends are not likely to change in the near term and are likely to continue through 2020.

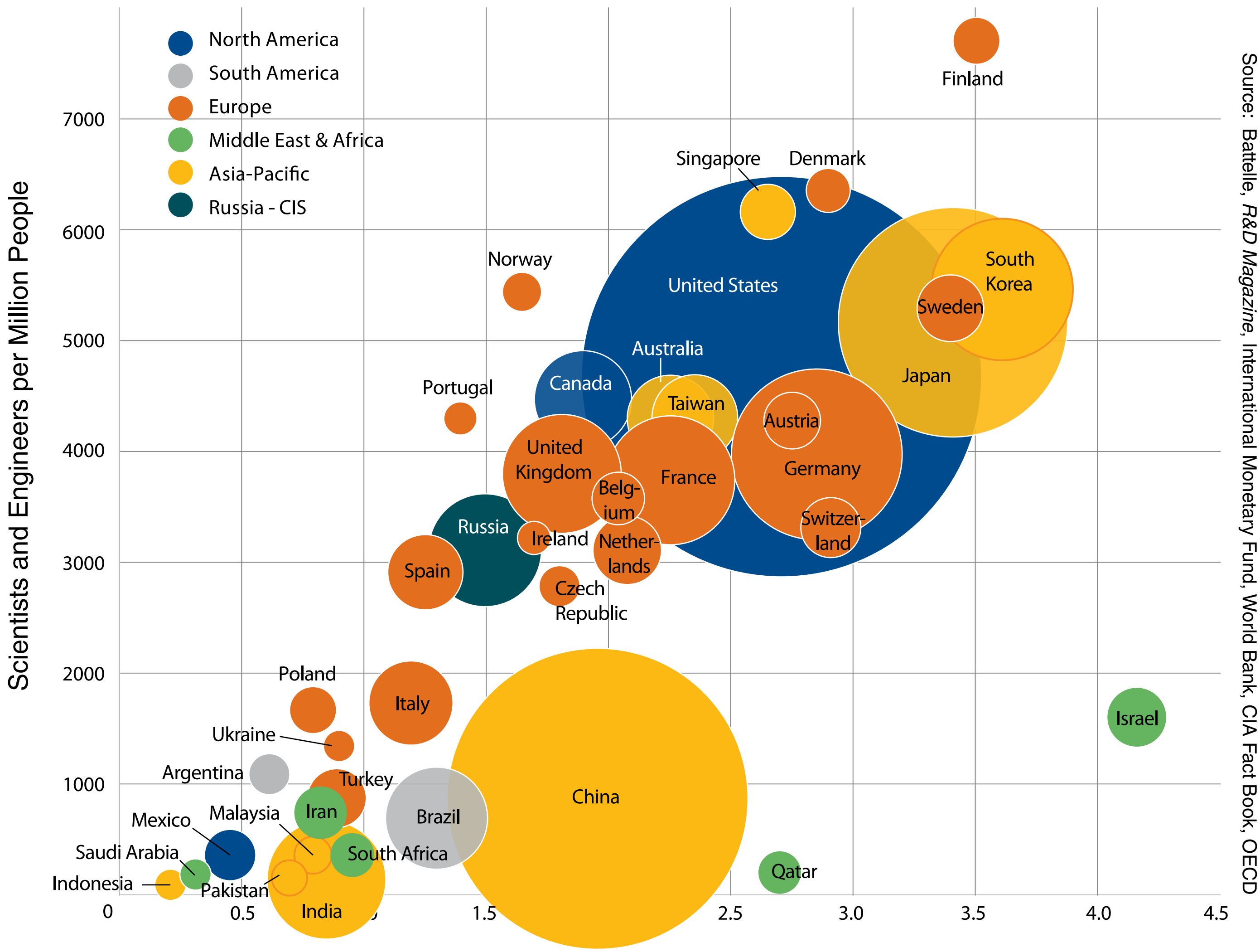
The "Rest of the World" in this Forecast includes countries in Africa, the Middle East and Russia and the Confederation of

Share of Total Global R&D Spending

	2012	2013	2014
Americas (21)	**34.5%**	**34.0%**	**33.9%**
U.S.	32.0%	31.4%	31.1%
Asia (20)	**37.0%**	**38.3%**	**39.1%**
China	15.3%	16.5%	17.5%
Japan	10.5%	10.5%	10.2%
India	2.7%	2.7%	2.7%
Europe (34)	**23.1%**	**22.4%**	**21.7%**
Germany	6.1%	5.9%	5.7%
Rest of World (36)	**5.4%**	**5.3%**	**5.3%**

Source: Battelle, *R&D Magazine*

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



R&D as a percentage of Gross Domestic Product

Independent States. While ROW countries account for about 11% of global GDP ($10 trillion), they only account for about 5% of global R&D. The growth rate for R&D investments in ROW countries is also low—less than 4% expected in 2014. The low rate of investment in these countries implies priorities other than innovation-based growth, and may also relate to under-developed domestic R&D infrastructure and educational capacity.

In the chart above, comparisons of R&D spending, growth in the number of researchers and the ratio of R&D spending as a share of GDP reveal a convergence among many countries on stable levels of research intensity echoing that which has been sustained by the United States for the last half-century. The globalization of R&D endeavors is maturing. Differences among regions in R&D economics, as well as major science and technology priorities, are narrowing. Noteworthy exceptions include China and India, which produce large numbers of scientists and engineers, but the general population is growing at a faster rate. As a result, these S/E (scientists and engineers) ratios continue to lag those of the U.S. and European countries.

FORECAST GROSS EXPENDITURES ON R&D

		2012			2013			2014		
		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	15,940	2.8%	447	16,195	2.8%	450	16,616	2.8%	465
2	China	12,610	1.8%	232	13,568	1.9%	258	14,559	2.0%	284
3	Japan	4,704	3.4%	160	4,798	3.4%	163	4,856	3.4%	165
4	Germany	3,250	2.8%	92	3,266	2.8%	92	3,312	2.9%	92
5	South Korea	1,640	3.6%	59	1,686	3.6%	61	1,748	3.6%	63
6	France	2,291	2.3%	52	2,296	2.3%	52	2,319	2.3%	52
7	United Kingdom	2,375	1.8%	43	2,408	1.8%	44	2,454	1.8%	44
8	India	4,761	0.9%	40	4,942	0,85%	42	5,194	0.9%	44
9	Russia	2,555	1.5%	38	2,593	1.5%	38	2,671	1.5%	40
10	Brazil	2,394	1.3%	30	2,454	1.3%	31	2,515	1.3%	33
11	Canada	1,513	1.9%	29	1,537	1.9%	29	1,571	1.9%	30
12	Australia	987	2.3%	22	1,012	2.3%	23	1,040	2.3%	23
13	Taiwan	918	2.3%	21	938	2.3%	22	974	2.4%	23
14	Italy	1,863	1.3%	23	1,829	1.2%	22	1,842	1.2%	22
15	Spain	1,434	1.3%	19	1,415	1.3%	18	1,418	1.3%	18
16	Netherlands	719	2.0%	15	710	2.1%	15	712	2.1%	15
17	Sweden	399	3.4%	14	403	3.4%	14	412	3.4%	14
18	Israel	253	4.3%	11	263	4.2%	11	271	4.2%	11
19	Switzerland	369	2.9%	11	375	2.9%	11	382	2.9%	11
20	Turkey	1,142	0.9%	10	1,185	0.9%	10	1,227	0.9%	11
21	Austria	365	2.8%	10	366	2.8%	10	372	2.8%	10
22	Singapore	332	2.6%	9	344	2.6%	9	355	2.7%	9
23	Belgium	427	2.0%	9	427	2.0%	9	432	2.0%	9
24	Iran	1,016	0.8%	8	1,001	0.8%	8	1,014	0.8%	9
25	Mexico	1,788	0.5%	8	1,809	0.5%	8	1,864	0.5%	8
26	Finland	201	3.8%	8	200	3.6%	7	202	3.5%	7
27	Poland	814	0.8%	6	825	0.8%	6	844	0.8%	7
28	Denmark	214	3.1%	7	214	3.0%	6	217	2.9%	6
29	South Africa	592	1.0%	6	604	1.0%	6	621	1.0%	6
30	Qatar	191	2.8%	5	201	2.8%	6	211	2.7%	6
31	Czech Republic	292	1.8%	5	291	1.8%	5	295	1.8%	5
32	Argentina	755	0.6%	5	781	0.6%	5	803	0.6%	5
33	Norway	282	1.7%	5	287	1.7%	5	293	1.7%	5
34	Malaysia	507	0.8%	4	531	0.8%	4	557	0.8%	5
35	Pakistan	524	0.7%	4	543	0.7%	4	556	0.7%	4
36	Portugal	251	1.5%	4	246	1.5%	4	248	1.4%	4
37	Ireland	195	1.8%	3	196	1.7%	3	200	1.7%	3
38	Saudi Arabia	922	0.3%	2	955	0.3%	3	997	0.3%	3
39	Ukraine	341	0.9%	3	341	0.9%	3	348	0.9%	3
40	Indonesia	1,237	0.1%	2	1,303	0.2%	2	1,374	0.2%	3
Subtotal (Top 40)		**73,362**	**2.0%**	**1,478**	**75,338**	**2.0%**	**1,518**	**77,896**	**2.0%**	**1,576**
Rest of World		**10,071**	**0.4%**	**39**	**10,413**	**0.4%**	**40**	**10,837**	**0.4%**	**42**
Global Spending		**83,434**	**1.8%**	**1,517**	**85,751**	**1.8%**	**1,558**	**88,733**	**1.8%**	**1,618**

*** GERD = Gross Expenditures on Research and Development**
PPP= Purchasing Power Parity (used to normalize)

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

U.S. R&D – Small Increase in 2014

Despite federal spending uncertainty, a case for optimism in research levels

Summary

In the United States, R&D spending is likely to increase in 2014, turning the corner from near-zero growth in 2013. Federal funding is difficult to forecast because of the breakdown of orderly budget processes, but there are indications of bipartisan political support for increases or reallocations that favor R&D. Historic post-recession economic data suggest that private-sector R&D spending will also increase in 2014.

Key findings:

- U.S. R&D investment will increase by 1.0% (after inflation) to $465 billion.
- National research intensity will remain stable at 2.8% of GDP.
- While government R&D funding is forecast to increase, flat or reduced spending are possibilities.
- The private sector continues to account for about three-quarters of U.S. research activity.

Factors that Influence the 2014 Outlook for U.S. R&D

Except for a dip in the 1970s at the point where industry surpassed government as the dominant research sponsor, the U.S. total commitment to R&D has ranged between 2.5% and 3% of GDP for decades, according to historic data from the National Science Foundation. Research intensity has been correlated with macroeconomic growth, and has been the foundation of U.S. technological innovation. This evidence of impact and economic return may account for much of the stability in the portion of U.S. GDP which is devoted to research. In addition, there may be a stabilizing portfolio effect in the complementary roles of public and private research, as well as the diversity of societal objectives and commercial markets they encompass.

The reliable trend in research intensity continued in 2013 (2.8%), although multiple contemporary factors influence the prediction of 2014 activity. Among the most important are political and economic conditions in the U.S., as well as globalization of markets, companies, research capabilities and collaborations.

The 2014 Source-Performer Matrix

Four sources of R&D funding—the federal government, industry, academia and non-profit organizations—also perform R&D. Additional funding flows to academia from state and local governments. R&D is also performed by federally funded research and development centers (FFRDCs), some of which are operated for the government by industrial firms, non-profit research institutes or universities.

US$ Billions (Percent Change from 2013)

Source of Funds	Performer of R&D: Federal Gov't	FFRDC (Gov't)	Industry	Academia	Non-Profit	Total
Federal Government	$35.7 1.0%	16.5 1.1%	27.8 1.1%	37.1 2.5%	6.0 1.1%	123.0 1.5%
Industry		0.3 0.7%	302.5 4.1%	3.3 1.7%	1.4 0.5%	307.5 4.0%
Academia		0.1 0.1%		13.2 2.0%		13.3 1.9%
Other Government		0.0 0.1%		4.0 1.1%		4.0 1.0%
Non-Profit		0.1 0.2%		5.3 2.2%	11.3 4.0%	16.7 3.4%
Total	$35.7 1.0%	17.0 1.0%	330.3 3.8%	62.9 2.2%	18.7 2.7%	464.5 3.2%

Source: Battelle, *R&D Magazine*

Some factors are relatively new and unpredictable. For example, the federal budget sequester is now a fiscal reality, despite originally intended as improbable. Arising from the Budget Control Act of 2011 (BCA), it has obvious direct effects on federal government appropriations, but it also introduces uncertainty into long-term programmatic and institutional research planning. Forecasting the net impact of sequestration in 2014 involves not only analysis of draft budgets, but also interpretation of activity and intentions in congressional committees, agencies and the White House, as well as leaders of research institutions.

Forecasting must also accommodate updates and corrections to historic economic data. For example, this 2014 Forecast incorporates a revision of the NSF's 2011 baseline research expenditures[1]. In addition, preparation of the Forecast begins with analysis of actual 2013 results through the third calendar quarter, which allows refinement of the full-year estimate. We now project that 2013 U.S. R&D spending will reach $450 billion.

Taking such issues into account, the Battelle/*R&D Magazine* team forecasts that U.S. R&D activity will increase to $465 billion in 2014. This represents growth of 3.2% over the revised 2013 projection. Against the Office of Management and Budget's estimate of 2.2% inflation for 2013-2014, the forecast level of R&D would be an increase of 1.0% in real terms.

R&D Funding in the U.S.: A Case for Optimism

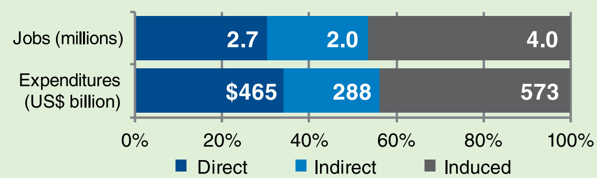
This Forecast assumes a 1.5% improvement in federal government R&D funding during calendar year 2014. However, the outlook involves substantial uncertainty. In one scenario, BCA-mandated continued reductions in non-defense discretionary spending could result in lower R&D funding. Another strong possibility is a series of short-term continuing resolutions, such as the one in effect at the end of 2013 in lieu of an approved budget, resulting in flat R&D spending. The third possibility is that R&D spending could increase either as the result of reallocation of sequestration, or from the passage of a budget.

This 2014 forecast is based on the third scenario. Reasons for making this optimistic assumption despite continuing economic and governance challenges include:

- General acknowledgement that R&D investment has both short- and long-term return to the economy.
- Concern about maintaining U.S. innovation-based competitiveness at a time when other nations are catching up in R&D spending, capability and output.
- Apparent bipartisan support for publicly funded R&D. While policy priorities and objectives vary, expressions of support suggest that R&D may benefit under various budget and sequester-adjustment scenarios.

In the current economy, R&D jobs are multiplied 3.2X

Projected U.S. R&D spending of $465 billion will directly employ over 2.7 million U.S. residents in the private and public sectors. In turn, an additional 6 million U.S. jobs will be supported.[2]



Source: Battelle, *R&D Magazine*

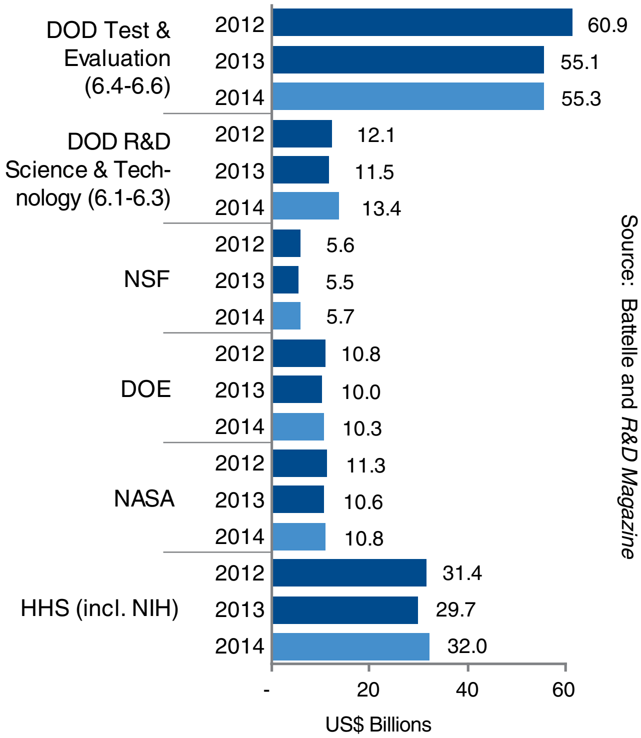
R&D spending is amplified 2.9X

As R&D spending ripples through the U.S. economy, it will generate an additional $860 billion in indirect economic impact.

Long-term economic growth is linked to research intensity

The most important example of long-term R&D impact is U.S. economic growth in the second half of the 20th century. Large research initiatives like the Human Genome Project or the War on Cancer also have high rates of social and economic return over the long term.[3]

Leading Federal Sponsors of R&D



- R&D intensive agencies like NIH, NSF, NIST and DOE's Office of Science could receive some R&D increases via legacy commitments to innovation in the America COMPETES Act.

Moreover, as of this writing in late 2013, the administration, the House of Representatives and the Senate are considering increases to agency R&D budgets; the 1.5% growth figure noted above is the least among proposals under consideration.

Actual research expenditures in 2013 are also an important input to the 2014 Forecast. Though many individual firms and some industries increased their investment, industry investment in R&D as a whole was flat in 2013 due to the slow global economy, continued rationalization of R&D activities in selected industries and the private-sector impact of federal budgets and sequestration. The sequester-associated reductions in 2013 U.S. R&D had a pronounced effect on university research activity, among other areas. Industries that supply and support the federal government, notably aerospace, defense and security, were also subject to funding reductions and increased uncertainty. The impact on revenue led many firms to restrain internal R&D activity in 2013, and these cautious strategies are likely to continue in 2014.

Excluding federal R&D funding that flows through the private sector via grants, internal R&D cost recovery and other mechanisms, industry R&D funding is projected to rebound from 2013, increasing by 4.0% to $307.5 billion in 2014. The information and communications technology (ICT) sector will continue to be a particularly strong contributor.

There is historic evidence, including in recent years, that industrial R&D spending is correlated with the current economy and the stability of its outlook. Any economic destabilization from government shutdowns or defaults, international conflict or other factors could change the trajectory of private-sector R&D spending in 2014.

Where Nearly a Half-Trillion R&D Dollars are Spent

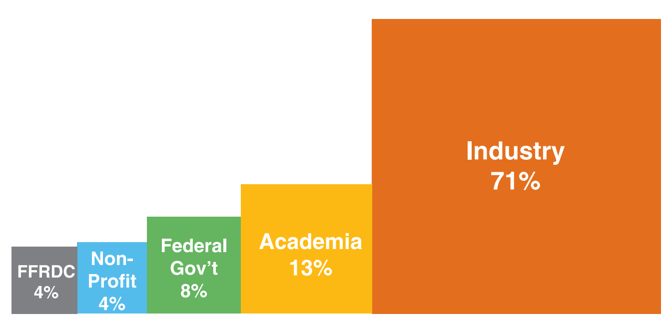
The "performers" of research are identified by the NSF through surveys of R&D expenditures. The "Source-Performer Matrix" on page 8 describes not only who will fund, but also who will consume R&D funding in the U.S. in 2014. The matrix is modeled on the NSF's *National Patterns of R&D Resources*, as well as the most recent data (2011) from the NSF's *Business R&D and Innovation Survey* (BRDIS).

Increased industry investment equates to more R&D activity, which is projected to increase by 3.8% to more than $330 billion, or more than 71% of the U.S. total. While about 8% of industry R&D activity is funded by the government (particularly the Department of Defense), most of the funding originates in the private sector and is correlated with the business cycle and economy rather than government actions.

As a group, the nation's research universities are the second largest performer of U.S. R&D, accounting for 13% of the U.S. total, and more than half of all U.S. basic research. With nearly 60% of their R&D budget coming from the federal government, the recent dynamics of federal R&D funding, from increases via the American Recovery and Reinvestment Act (ARRA) investments in 2009-2011 to budget reductions in 2012 and sequestration in 2013, are causing some institutions to seek diversification of their R&D funding. From all sources, academic R&D performance is forecast to increase by 2.2% to nearly $63 billion in 2014.

Federal intramural research performance is forecast to reach $35.7 billion, or nearly 8% of all U.S. R&D, in 2014. When federally funded R&D centers (FFRDC) are taken into account, R&D worth $52.7 billion will be performed under close programmatic control of the federal government. Among the thirty-nine FFRDC's are the U.S. national laboratories, many of which are operated by contractors. Through basic and applied research, these globally recognized institutions pursue missions in energy, security and other areas of national importance.

Industry Continues to Lead U.S. R&D Investment



Source: Battelle and *R&D Magazine*

Academic R&D

Sequestration impacting U.S. universities

Summary

Federal R&D policy and implications of budget sequestration are the largest factors in funding for U.S. academic research, which has dropped from a recent high of 6% annual funding increases in 2011 to a forecast of 2% in 2014. Long recognized as an essential scientific foundation of U.S. innovation, academic research programs have been under pressure as a result.

Highlights of the academic research enterprise include:

- Academia performs about 60% of all U.S. basic research.
- Federal funding for academia will increase 2.5% in 2014.
- U.S. universities continue to lead world rankings.
- ARRA funding for academia has expired.

Funding Trends & Outlook

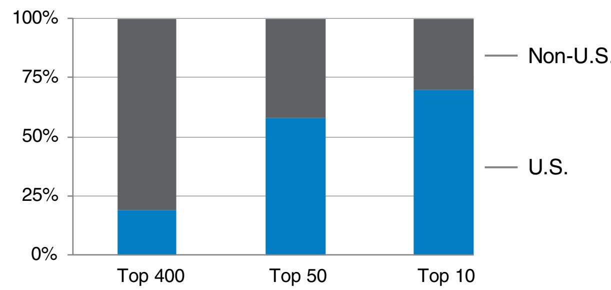
In response to the 2009-2010 recession, the ARRA added about $18 billion of federal investments to baseline funding for academic research. These funds extended from 2010 to 2012, boosting research activity in those years. With the bolus of ARRA funding past, federal investments in academic R&D declined from 2012 to 2013, resulting in flat funding levels when all sources are taken into account.

By a number of measures, U.S. academic R&D remains globally competitive and respected. The scale of university research activity is indicated by 2011 spending, which is the most recent year for which comprehensive data are available. Several institutions exceeded $1 billion in research that year, including Johns Hopkins University (including the Applied Physics Laboratory), the University of Michigan at Ann Arbor, the University of Washington at Seattle, the University of Wisconsin at Madison (including WARF), Duke University, the University of California at San Diego and the Massachusetts Institute of Technology (including Lincoln Laboratory). At the system level, the University of California and the University of Texas topped the list, accounting for $5.4 billion and $2.5 billion in research, respectively. Looking ahead, funding at these institutions will continue to be among the $63 billion expected to be spent on U.S. academic research in 2014—which is more than the whole-country totals for all but the top four non-U.S. nations.

Strong Position Masks Emerging Concerns

The Times Higher Education (THE) World University Rankings reflect continued leadership of U.S. educational institutions, many of which are also the leading performers of publicly funded R&D for the nation. THE rankings are based on teaching, research, knowledge transfer and international outlook.

U.S. Standing Among World's Top Universities



Source: Times Higher Education rankings

Despite this positive track record, the U.S. academic research enterprise faces challenges, many of which were expressed as concerns by researchers responding to the survey on which this forecast is partly based:

- Effect of reduced U.S. federal R&D funding (84%).
- Insufficient R&D budget to accomplish goals (66%).
- Increasing costs (50%).
- Difficulties in finding qualified R&D staff (48%).
- Increasing regulations (44%).

Academic researchers are also confronted by the emergence of global competitors, changing demographics and rapidly evolving technologies. Among the responses to these concerns is a recent report from the National Academy of Sciences entitled "Research Universities and the Future of America," which makes ten recommendations that recognize the association between university research and U.S. prosperity and security.

In Their Own Words

Comment from the Battelle/*R&D Magazine* Global Researcher Survey

Over the coming years, it will be increasingly critical to clarify the role of universities and their relationship to corporations in technology development. An understanding of this relationship will be necessary to drive policy decisions, both in terms of the university teaching mission and the research carried out at universities. If universities are expected to perform as for-profit companies, driven by short-term returns on investment, then the foundations upon which major high-risk scientific discoveries are made will eventually erode. As these research centers are slowly lost, so too will be lost the supply of highly trained researchers who drive innovation and competition.

- Academic Researcher/ U.S.

International Overview

R&D leadership shifting from west to east

Summary

For the past six years, the top ten countries funding R&D have remained mostly the same. There has been dramatic change, however, in the extent of globalization involved in research, as well as shifts in the way funds are spent. Driven in part by China's aggressive programs, Southeast Asia has become the world's largest region for research investments—a trend that is expected to continue through at least the end of the decade. Collaborations with technology firms and research organizations in the U.S. and Europe are also increasing as Asia seeks to leverage global scientific knowledge and capabilities. And major infrastructure investments continue to be made, often with the goal of creating an innovation ecosystem with mechanisms for technology commercialization and industry engagement, leading to amplified economic returns from research investment. Leading examples include Skolkovo in Russia, Biopolis in Singapore and the Qatar Foundation.

Highlights of the international research funding environment include:

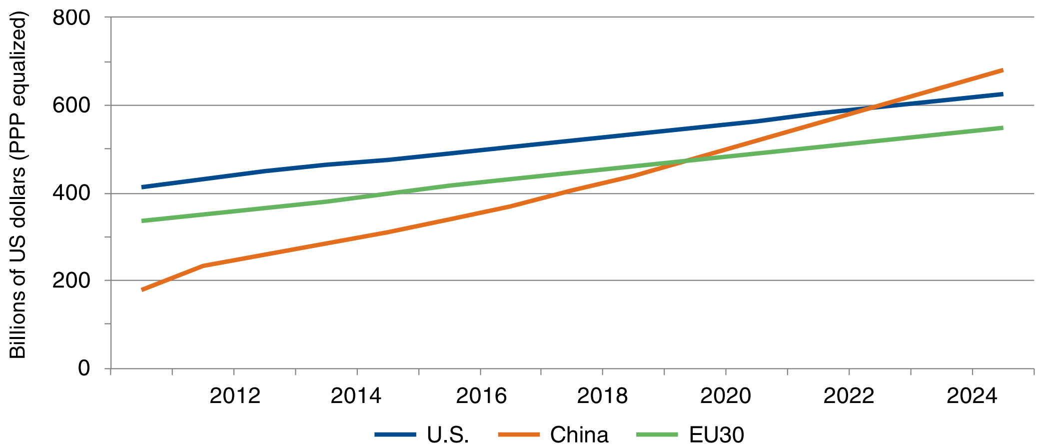
- Asian share of global R&D continues to increase, driven by China, Japan and Korea, while U.S. and European shares decrease.
- U.S. and Europe remain global leaders in high-quality research output, but the balance is shifting.
- African, Middle East and South American R&D remains relatively small, albeit with some noteworthy national initiatives.

Globalization Unleashed

Globalization of R&D has accelerated in the past decade through a combination of R&D funding growth in emerging economies, off-shoring and outsourcing of a portion of western R&D, improved communications and the need for larger-scale, interdisciplinary collaboration on major scientific

	2012		2013		2014	
	GERD *PPP Bil, US$*	R&D *as % GDP*	GERD *PPP Bil, US$*	R&D *as % GDP*	GERD *PPP Bil, US$*	R&D *as % GDP*
Americas (21)	**485**	**2.5%**	**489**	**2.4%**	**504**	**2.5%**
U.S.	447	2.8%	450	2.8%	465	2.8%
Asia (20)	**561**	**1.8%**	**596**	**1.9%**	**633**	**1.9%**
China	232	1.8%	258	1.9%	284	2.0%
Japan	160	3.4%	163	3.4%	165	3.4%
India	41	0.9%	42	0.9%	44	0.9%
Europe (34)	**350**	**1.9%**	**349**	**1.9%**	**351**	**1.8%**
Germany	92	2.8%	92	2.8%	92	2.9%
Rest of World (36)	**81**	**0.9%**	**83**	**0.9%**	**87**	**0.9%**
Global Total	**1,517**	**1.8%**	**1,559**	**1.8%**	**1,618**	**1.8%**

GERD=Gross Expenditures on R&D; PPP=Purchasing Power Parity.
Source: Battelle, *R&D Magazine*



Long-Term Outlook for R&D Expenditures

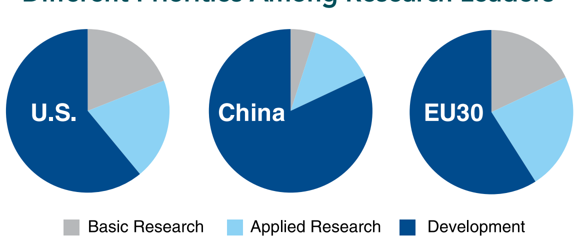
Even if the historic stability of the U.S. and European commitment to research intensity (i.e., spending as a percent of GDP) continues, growth in China's economy is likely to propel it to the top position in absolute R&D spending by the early 2020s.

Source: Battelle and *R&D Magazine*

challenges. In the commercial sector, innovation capabilities tend to follow the wealth created by manufacturing, catalyzed by accelerating product development cycles and sometimes by regulation. China's Huawei, for example, now competes for telecommunication contracts in Europe and the U.S. Its related attempts to acquire U.S. telecom companies have been largely rebuffed by federal regulators, providing incentive to develop indigenous product development capabilities. Moreover, China is designing and building state-of-the-art next-generation nuclear power plants, a space station, high-speed rail systems, military and commercial aircraft and other major projects—many of which draw on global science and technology assets.

R&D capabilities also follow markets for technology-enabled products. Automobiles are a good example, since the major manufacturers have R&D operations around the world. Japan's Toyota is holding its position as the world's largest car maker, with leading market shares for advanced hybrid and electric vehicles (EV). Toyota's research effort in this field, along with that of Ford and others, builds on earlier publicly funded basic research in batteries and power electronics, while government research now turns to areas like grid accommodation of fueling demand for EVs. EVs are a good illustration of a globally distributed, multi-decade R&D effort with domains of coordinated collaboration, complemented by independent efforts that leverage loosely coupled global connectivity through publications, licensing, recruitment of experienced scientists and engineers and other forms of knowledge transfer. Momentum in EVs is shifting from research to development, and the prospects seem good for realization of the original policy goals in energy security and environmental protection that stimulated early public investment.

Different Priorities Among Research Leaders



China places more emphasis on development, less on basic research

Source: Battelle and *R&D Magazine*

Linkage Between R&D and National Priorities

Tepid economic recovery in Europe and the U.S. suggests significant increases in R&D investments are unlikely in the next several years. Emphasis on public deficit and debt reduction will continue, with unpredictable short-term effects on discretionary research investments. While the historic stability of research intensity in the U.S. and Europe suggests dramatic declines in national R&D investments are not likely, these headwinds mean that the west will continue to lag the accelerated level of R&D spending in Asia.

Governments around the world, and particularly in Asia, recognize the importance of investing in the building blocks of innovation-based economies. All countries seek economic growth, often amplified by the need for job creation to match rising populations: energy, food and water demands. Strategies vary. In the U.S., the government tends to seed innovation with investment in basic research and some tax and policy incentives, but the free market decides which technology is deployed at large scale. China, on the other hand, has fixed a macroeconomic goal of spending 2.2% of GDP on research by 2015, toward becoming an innovation-based economy by 2020. Such a command approach can sometimes accelerate the translation from research to development. This is illustrated by the large proportion of development investment in China versus funding for basic and applied research, and is manifested (for example) in the large-scale deployment of clean energy and advanced grid technologies in China. But this approach can also lead to expensive failures, and economists have warned that sustained large investments in innovation must be paired with investments in social and environmental-protection infrastructures.

R&D IN CHINA

Summary

China has increased its R&D investments by 12% to 20% annually for each of the past 20 years; while at the same time, U.S. R&D spending increased at less than half those rates. As a result, China's investment is now about 61% that of the U.S., and continuing to close. At the current rates, China's commitment is expected to surpass that of the U.S. by about 2022, when both countries are likely to reach about $600 billion in R&D. China is investing heavily to create an innovation infrastructure that will allow it to develop, commercialize and market advanced technology-based products, moving beyond its established position as a low-cost location for manufacturing.

Key observations:

- China's middle class will expand from 35% to 75% over the next 10 years—a demographic statistic that reflects economic growth and, to some extent, an innovation-enabled society.
- 12th Five Year Plan (2011-2015) targets R&D spending at 2.2% of GDP by 2015.
- Global researchers surveyed still consider U.S. superior to China in basic and applied R&D.
- U.S. industrial, academic and government R&D are also viewed more favorably than Chinese counterparts.
- China's goal of an innovation-driven economy by 2020 requires solving resources and environmental challenges.

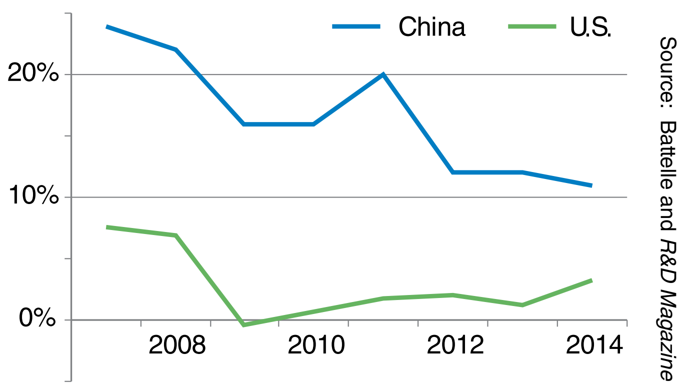
Economic Impact

In 2013, China is positioned as a location for cost-effective manufacturing, including for high-technology products. But efficient manufacturing alone is not adequate to maintain economic growth. Recognizing this, China intends to evolve from a manufacturing-centric model in 2013 to an innovation-based economy by 2020. Mirroring the approach taken by the U.S., Europe and Japan since World War II, China is making steady progress at building a research infrastructure and educating the scientists to operate it. Results are impressive so far, with leading indicators of innovation rapidly approaching parity with the west.

China's R&D investment is linked to national goals for industrial growth, stable domestic evolution to an advanced economy, power projection and international prestige. These goals are manifested in large R&D-enabled projects like a Chinese space station and energy generation infrastructure spanning from renewable to nuclear power. In the latter, China draws on companies as well as public-sector research assets in the U.S. and Europe. This creates opportunities at a time when new unconventional fossil reserves have decreased emphasis on large-scale deployment of renewable energy technology in the U.S. Moreover, cost and public perceptions have weakened the outlook for nuclear energy in the U.S., Europe and Japan—all three of which, nevertheless, still have vast experience in nuclear engineering and operations. China's program sustains these capabilities and accelerates its ability to address growing power requirements.

However, China has a number of significant challenges that

Comparison of annual change in national R&D investment



While China's rate of annual growth is dropping from unsustainably high levels, it still exceeds the U.S. and is catalyzed by GDP growth.

must be overcome to reach the 2020 innovation-economy target. China has demonstrated that the ability to sponsor and perform R&D is not an impediment, and in fact is part of the solution to resource-based growth restraints like energy capacity and independence, water supply, agricultural productivity and environmental protection.

China's continued strong economic growth—more than three times that of the U.S.—provides the resources to support its strong R&D investments and expansion of basic infrastructure as well. The ambitious program and globally enabled economic growth means that China has become an exporter of jobs into Asia to meet its own needs. Ten years ago, most foreign direct investment was being made in China. Today, China has grown to a point that it is now a foreign direct investor throughout Asia, and by 2017 it is expected to be a net outbound investor in the region.

China Has Arrived

For the past forty years, the global R&D enterprise was dominated by Europe, the U.S. and Japan. In 2011, China surpassed Japan's overall spending. By 2018, it is expected to surpass the combined R&D spending of Europe's 34 countries. And by sometime around 2022, it will likely also exceed the R&D investments of the U.S. in absolute terms.

In addition to recognizing the strong linkage between R&D and economic growth, it is likely that the professional perspectives of China's leadership are influential in science and innovation policy: eight of the nine members of China's Standing Committee of the Political Bureau have engineering degrees.

As part of the aggressive funding program these leaders support, China is expanding its science and technology infrastructure through investments in its academic research institutions, the Chinese Academy of Sciences and its industrial research firms.

While taking its place among global R&D leaders, China recognizes the leverage available through international collaboration. Many of China's R&D programs involve collaborations with European and/or U.S. research organizations. According to the Battelle/*R&D Magazine* Global Researcher Survey, about a third of China's advanced R&D is pursued in collaboration with U.S. research organizations, and about a quarter in collaboration with European research organizations.

In Their Own Words

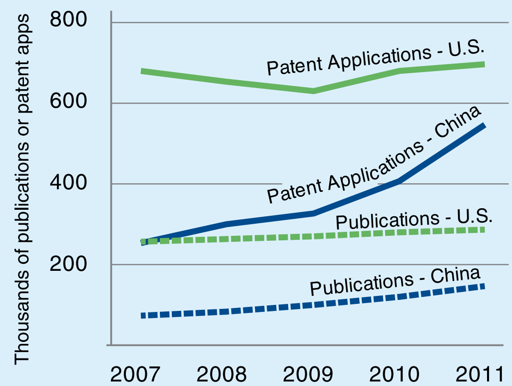
Comment from the Battelle/*R&D Magazine* Global Researcher Survey

The investment that China is making in scientific research and the top quality training their scientists have received around the world is evident from the large improvements in quality that publications from that country have shown in recent years. They now appear regularly in top journals and may come to dominate important medical fields.

- Academic Researcher/U.S.

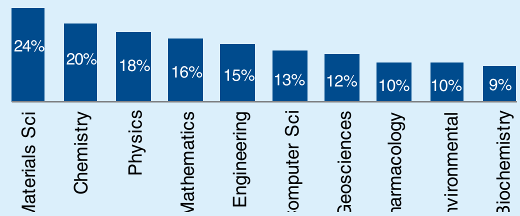
Leading indicators of innovation

China is rapidly gaining in patent applications and scientific publications



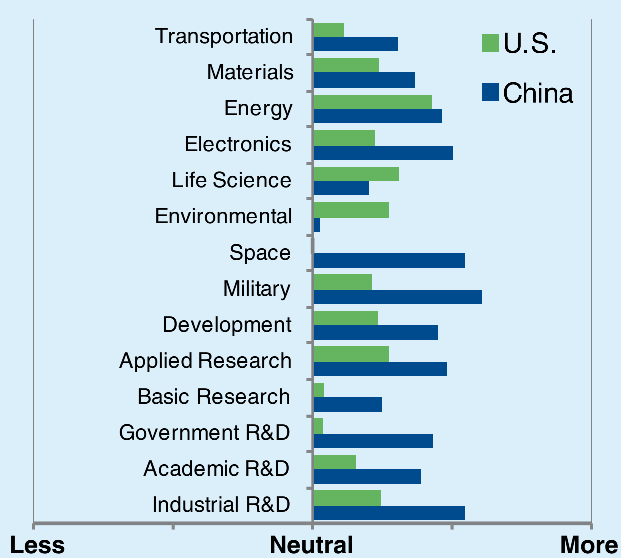
Source: WIPO; Nature Publishing Index

And China originates an increasing percentage of global scientific literature.



Source: Thomson Reuters

Chinese researchers expect more change in nearly all research domains than their U.S. counterparts (1-5 scale).



Source: Battelle and *R&D Magazine*

R&D IN EUROPE

Summary

With the large number of European Union member states, Europe's research community is diverse in its economic composition and national interests, while central funding and administrative mechanisms allow coordinated operation of public research at a scale that is comparable to that of the United States. There also are parallels in research priorities (like the level of commitment to basic research), demographics and research productivity.

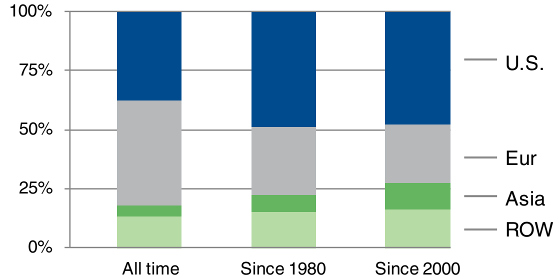
Economic conditions heavily influence R&D funding; so struggling EU member states Greece, Spain and Italy influence this 2014 R&D forecast, offset by recovery in Germany, France and the U.K. The EU is the only global region that had negative growth in 2013, and it is projected to grow at only about 1% per year through 2017. R&D funding is expected to follow a similar track.

Highlights of the European research enterprise and its economic context include:

- The amount of R&D performed in Europe is essentially flat for 2012, 2013 and 2014.
- The R&D-focused Eighth Framework Programme is projected to increase nearly 60% to $110 billion over FP7.
- Performance of U.S. academic research institutions rank just above those in Europe, although European universities are well-regarded in global standings.
- Survey results indicate that U.S. applied research is viewed more favorably than Europe, but that basic research efforts are close to parity.

Nobel Prizes in Science & Medicine

European and U.S. shares accommodating emerging regions



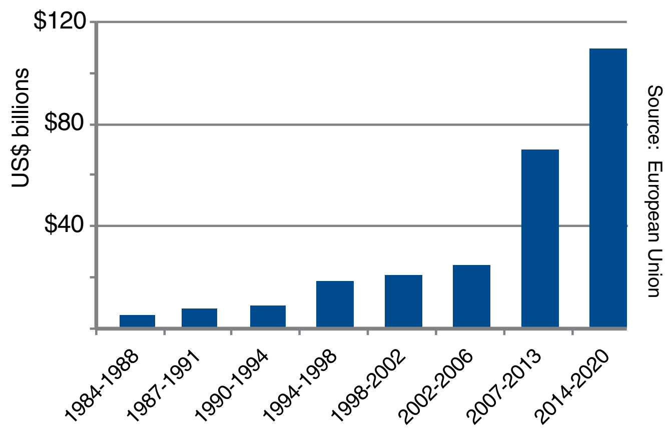
Outlook

In the second quarter of 2013, the EU emerged from six consecutive quarters of economic contraction, ending the longest economic contraction on record for the EU The rebound was driven by the EU's largest economy, Germany, where output grew by 0.7% for the quarter. Most European countries are forecast to experience economic growth of about 1% through 2014, although Eastern European countries could see GDP (and related R&D) growth rates in the 1% to 2% range. Germany is expected to see 1.4% GDP growth in 2014 and commensurate R&D growth over 2013. France and the United Kingdom are also gaining economic momentum, according to the most recent report by the Organization for Economic Cooperation and Development (OECD).

The EU's Framework Programme for Research and Technological Development (FP8) is scheduled to be renewed for the

Europe's Commitment to Public Research

Supported by the European Framework Programme



eighth time in 2014 since the popular program began in 1984. FP8 (also called Horizon 2020) is anticipated to run from 2014 through 2020, and will be funded to $110 billion (i.e., $15.7 billion/yr). This represents a 58% increase over FP7, which ran from 2007 to 2013 and was funded to $70 billion. FP8 funding will provide $42 billion for research on climate change, renewable energy, food safety and aging. $23 billion will be dedicated to industrial leadership in innovation, including increased access to capital and support for small-to-medium enterprises.

A dedicated budget of $34 billion will focus on top-level research supported by the European Research Council, the EU's equivalent to the U.S.'s National Research Council. While representing less than 5% of the EU's total forecast R&D investment in 2014 of $351 billion, the high-profile research is dedicated to creating new growth and jobs in Europe. It also emphasizes the translation from scientific research to commercialization to economic impact by helping innovative enterprises develop technological assets into viable products with large commercial potential. This market-driven approach includes creating partnerships with the private sector and member states.

In their responses to the Battelle/*R&D Magazine* survey, global researchers anticipate positive changes in European research priorities over the next 10 years, including (in priority order) focus on energy, environmental and life science R&D applications. Areas that may become less emphasized include military and space-based research.

In the aggregate, R&D expenditures in Europe are expected to increase 0.7% in 2014. Europe's share of global R&D spending will drop to 21.7%, while Asia's rises to 39% in 2014 from 38% in 2013.

Academia's Important Role

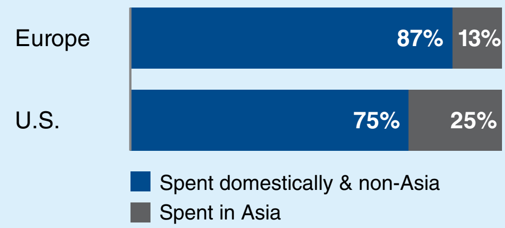
As in the U.S., an important portion of research activity will be conducted by academia. European universities place second only to U.S. universities in the latest Times Higher Education World Rankings, with about 71 European universities ranked in the Top 400, compared to 77 U.S. universities. THE rankings are based on 13 performance indicators in areas involving teaching, research, knowledge transfer and global outlook. The U.K. had the largest number of European universities in the top 400 list with 29.

In Their Own Words

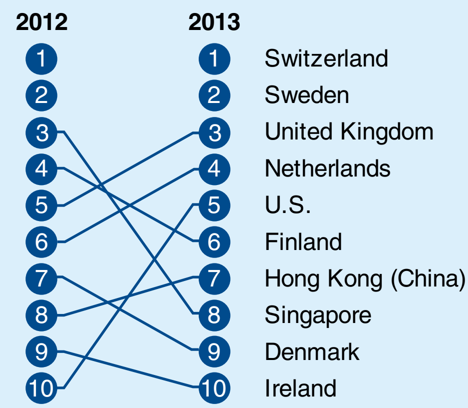
Comment from the Battelle/*R&D Magazine* Global Researcher Survey

> *The most important challenge facing the global research community is ensuring that populations regard its contributions as positive, responsible and legitimate. R&D policy is not just about throwing money at scientists and engineers - it is also about ensuring that their innovations can be brought into use, which is a quite different challenge.*
>
> *- Domestic Corporation/U.K.*

Like the United States, Europe deploys a portion of R&D investment to Asia.

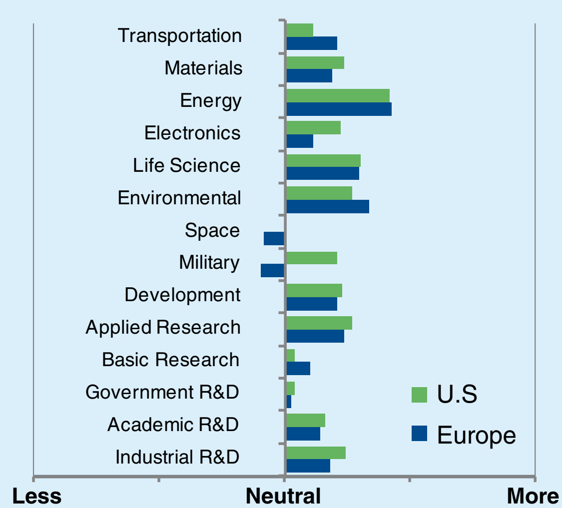


Europe and the U.S. continue to dominate the top positions in WIPO's Global Innovation Index.



Source: World Intellectual Property Org.

Expectations for change are similar in nearly all research domains for U.S. and European researchers (1-5 scale).



Source: Battelle and *R&D Magazine*

R&D IN THE REST OF THE WORLD

Summary

As a group, the "Rest of the World" (ROW) countries—those other than the U.S., those in Europe and China—are expected to see moderate growth in their R&D investments in 2014, with leadership from countries like South Korea, Russia and Taiwan. Most Asian countries are projected to experience significant economic growth in 2014. When GDP momentum is paired with national commitments to increase research intensity, robust R&D funding growth typically results (as is the case in China). However, some countries elect to deploy resources against other priorities, and in other cases, the lack of well-developed research infrastructure inhibits the impact of R&D spending that does take place.

Highlights of R&D funding prospects in ROW countries include:

- Russia's economy is expected to grow 3%, with R&D growth exceeding that rate. Russia's strong infrastructure for scientific research positions it better than other CIS affiliates, which should also see positive GDP growth, but will likely not advance R&D funding to the same degree.
- Most Middle East countries will experience strong GDP growth in 2014, but they are constrained by weak R&D infrastructure. The exceptions include Israel and Qatar, which invest in R&D at globally competitive levels.
- Africa is expected to see strong GDP growth, but is also limited by under-developed R&D capabilities—the exception is South Africa.
- Strong GDP growth is expected in South America, but this region also lags in R&D capacity—even Brazil appears to be under-performing expectations.

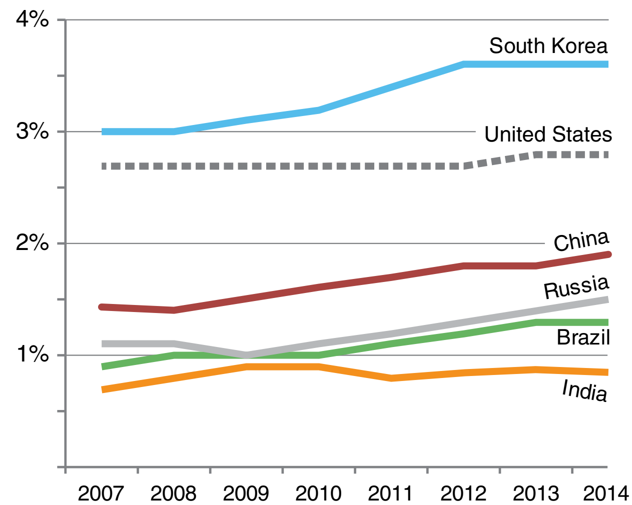
Economic Context

The U.S., China, Japan and Europe (34 countries) account for about 78% of the $1.62 trillion which we forecast to be invested in R&D around the world in 2014. ROW countries (74 of which are included in this forecast) account for the remaining 22%, or $350 billion. Among this group are innovation-driven economies like South Korea (where $63 billion will be invested in R&D in 2014), to significant nations with relatively low emphasis on R&D (e.g., India), to entire continents where R&D funding is traditionally weak and can be forecast in the aggregate (e.g., Africa).

China, South Korea, Japan and Taiwan, in addition to their regional proximity, all have strong R&D programs that support development of science and technology (S&T) in the public and private sectors. Like China, Korea has established aggressive five-year plans for S&T. The objectives involve national competitiveness in innovation-intensive industries in which each country also has a strong manufacturing stake. Contribution to scientific discovery is also valued, with publications being among the measures of success. As the global R&D funding rankings indicate, each of these countries is expected to see substantial R&D growth in 2014.

Countries like Mexico offer a stark contrast. Despite shar-

Research Intensity Trends in BRIC and Other Key Nations



BRIC countries—except India—are increasing research intensity; South Korea is second only to Israel in level of commitment proportional to GDP.

ing a border with the U.S. and an economy that is expected to experience reasonable growth in 2014, Mexican research intensity (R&D as a share of GDP) has languished below 1% range for some time. The country's S&T and academic infrastructures are not well suited to support a higher level of growth. As a result, based on its current resources, priorities and national aspirations, Mexico's prospects for long-term growth based on innovation are limited. It ranks in the top 40 R&D-sponsoring nations only because its large GDP, which is driven by agricultural, materials and lower-technology consumer products. Mexico is typical of the R&D infrastructure and policy context in a number of emerging countries, and contrasts with countries like Finland and Denmark, which spend about the same absolute amount as Mexico on R&D while having economies about one tenth the size.

In ROW, Means & Policy Disproportionately Affect R&D

The sustained high rates of R&D growth in China are unusual. Apart from the historic R&D leaders like the U.S., Japan and Europe, no countries are positioned to match China's level of commitment. Even South Korea, with its exceptional level of research intensity, cannot achieve the same scale or rate of growth.

Emerging countries with similar aspirations for innovation-based growth require a diversity of talent, capabilities and markets—and the will to invest. With the world's fourth-largest GDP, India is a good example. It has significant academic infrastructure, large population and global connectivity, but social and political priorities draw investment away from R&D. India's projected rate of R&D funding growth in 2014 is only one-fifth that of its anticipated economic growth.

Although difficult to quantify, a lack of willingness or capacity to invest in R&D could restrain such economies from reaching larger potential in the long term. And it may become more difficult. According to McKinsey Global Institute analysis, as global economic growth slows in the future (as it is projected to do), the supply of capital will fall short of demand by 2030. This is especially important for those among the 74 ROW economies with limited R&D infrastructures: They could become even more restricted in building a foundation for R&D in the future than they are now.

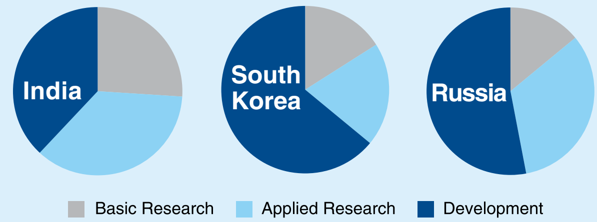
In Their Own Words

Comment from the Battelle/*R&D Magazine* Global Researcher Survey

The globalization of research, finance, production, etc. will balance world economies in ways not seen ever before to the advancement of some and the stalling or loss of income of others. Water and climate extremes will likely be key sources of world tension that will need addressing through all means possible including research and technology.

- Researcher at Multinational Corporation/U.S.

Commitment to basic research is not limited to the U.S. and Europe.



Source: Battelle / *R&D Magazine*

Although areas of focus and expertise vary by country.

Brazil	Russia	India	South Korea
Physics	Physics	Psychology	Mat'ls Science
Mathematics	Immunology	Engineering	Space Science
Engineering	Clinical Med	Physics	Ag Science
Computer Sci	Ag Science	Computer Sci	Chemistry
Geoscience	Pharmacology	Mat'ls Science	Physics

Source: Thomson Reuters

Asian research output and quality is not limited to China: Japan remains internationally strong, and South Korea's rate of R&D investment shows in publication volume and quality.

Source: Nature Publishing. Figures are papers in Nature-affiliated journals

Maximizing the Economic Value of R&D: The Role of Ecosystems

R&D funding is only one ingredient for innovation-based economic success

Research and development is a long-term investment in the future, serving as the cornerstone for innovation-driven growth. While there is a significant immediate economic impact from R&D activities (estimated to reach a total impact of 8.7 million jobs from the full effects of R&D spending across the U.S. economy in 2014), the big pay-off from investments in R&D are longer-term sustained economic gains through strengthened global competitiveness and even creation of entire new industries.

R&D investments are the foundation for generating new knowledge through basic research and ultimately for generating products and services through applied research and commercialization. For this pay-off to happen and innovation-driven growth to flourish requires a successful R&D ecosystem.

What it Takes to Build a Successful R&D Ecosystem

In successful economies, innovations are fostered and prepared for market within robust, supportive environments—ecosystems—that enable risk-taking and catalyze enterprise formation. Well-known examples include the dedicated Research Triangle in North Carolina and the more loosely evolved Silicon Valley. More recently, purposeful development of geographically integrated ecosystems has resulted in Russia's Skolkovo, Singapore's Biopolis and the innovation assets of the Qatar Foundation.

One fundamental aspect of these ecosystems is that they are "sticky" environments in which talent and capital are retained and recycled into successive phases of innovation and commercial development.

Key features of any successful ecosystem regardless of location include:

- LARGE INVESTMENTS IN HUMAN CAPITAL: Close attention is paid to encouraging and advancing a talent pipeline in science, technology, engineering and math (STEM) skills, along with broader base of product design, management, sales, finance and entrepreneurs to ensure commercial success.
- SCIENCE IS PARTNERED WITH COMMERCIAL VISION AND ENTREPRENEURIAL EFFORTS: Basic research is an essential starting point, and scientific discovery per se can be an explicit objective for a portion of publicly sponsored research. However, when seeking maximum economic impact, innovations are viewed from the outset in terms of their future commercial applications, and close collaborations with entrepreneurs are in place to advance their commercialization.
- CAPITAL AVAILABLE FOR ALL STAGES OF R&D: All levels of funding are encouraged, from small-scale grants for early stage proof-of-concept research to large-scale commercially focused equity investment.
- GOVERNMENT SUPPORT IS ESTABLISHED & RESPONSIVE: Policies, regulations, incentives and taxes are in place to support the formation and growth of R&D ecosystems. Industry is offered opportunities to give input on the changing needs of ecosystems.

Absence of one or more of the key components substantially hinders an ecosystem's ability to provide returns on investment and to successfully commercialize innovations.

These components are determining factors in the ongoing stability and growth of established ecosystems during recessionary periods and market contractions. They also are essential measures for the viability and growth of ecosystems in emerging economies.

The Challenge of Translating R&D into Commercial Success Persists as the Rate of Innovation Increases

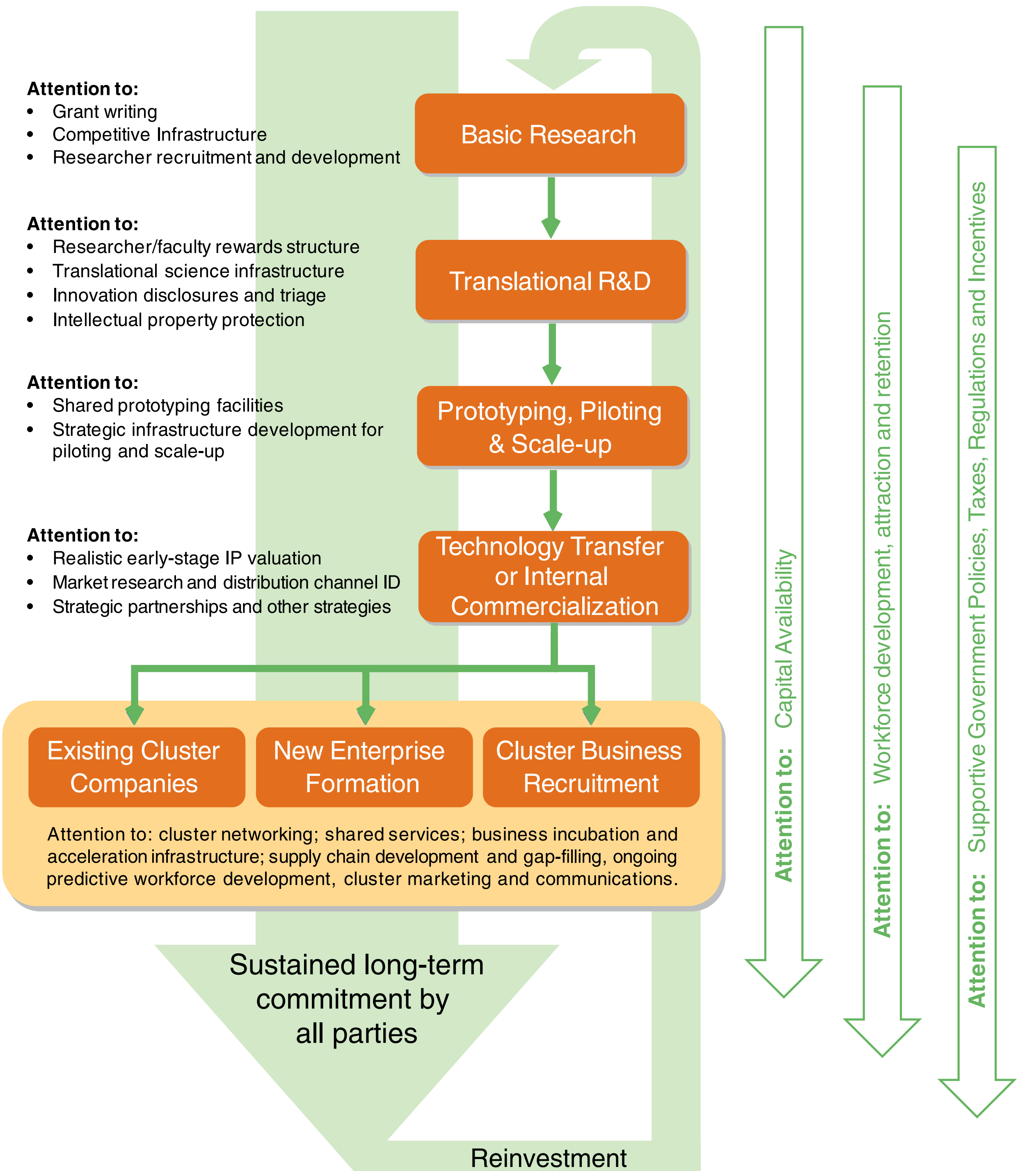
An important measure of research and development is how it improves or generates new products. The 2014 Battelle/*R&D Magazine* survey finds that the translation of R&D into products that reach the market remains an uneven endeavor throughout industry. Nearly half of industry executives report having only some success, with remaining industry responses split between rarely having success to regularly having success in the translation of R&D into new or improved products.

Yet the need for industry R&D to keep pace with advancing technology mounts. In the past year, 22% of industry executives reported significant technology growth and another 56% slight-to-moderate technology growth affecting their industry. So while industry perceives that innovation consistency could be improved, the demands to keep pace are unrelenting.

In a more positive direction, the 2014 survey reflected a sense of improving productivity, efficiency and return on investment in R&D. Seven out of ten of the industry executives report productivity gains in the last two years, with 20% noting significant improvements. The results from industry executives who track return on investment is one of a generally improving bottom-line impact of research and development activities, with 18% noting substantial returns, while an additional 35% reported slight improvements in ROI.

These positive signs point to the fact that industry is hard at work to make its research and development efforts more effective despite an uneven track record in the past. The ability of U.S. industry to continue raising the bar on the rate and efficiency of innovation will be a critical driver of future growth and competitiveness.

Elements and Interrelationships in a Comprehensive R&D Ecosystem



INDUSTRY BREAKOUT — LIFE SCIENCES

Summary

As represented in this Forecast, the life science industry includes biopharmaceuticals, medical instruments and devices, animal/agricultural bioscience and commercial research and testing. However, the industry's R&D spending is driven primarily by the mass and research intensity of the biopharmaceutical sector, which accounts for nearly 85% of all expenditures.

The life science industry's research activities in the United States continue to lead the world, but it is an area that also remains in significant transition. Not only is life science—led by the biopharmaceutical sector—the leading U.S. industry in terms of volume of research, U.S. life science R&D accounts for 46% of the global total—one of the highest shares in any industry.

Still, pressures persist to improve on productivity, product pipelines and ROI in consideration of expiring patents, cost pressures and the rising complexity of innovation in drug development. While primarily affecting the biopharmaceutical sector, the medical device sector is not immune to some of these trends. A new factor complicating the R&D environment for the life science industry is the set of changes in the U.S. healthcare landscape mandated by the Affordable Care Act. While it is hard to predict exactly how this new law will affect life science R&D, these transitions and uncertainties suggest that while the U.S. remains a global leader life science R&D, it is vulnerable, especially as European competitors and new, emerging Asian competitors target life science research for growth.

For the U.S. life science industry, we project a small rebound over 2013 levels (up 2.2%) to R&D spending of about $93 billion in 2014, with the growth coming primarily from smaller biopharmaceutical innovators and medical device manufacturers.

The global expansion of the life science industry has slowed over the last few years, but the industry is forecast to have a stronger recovery (up 3.1%) to more than $201 billion in 2014.

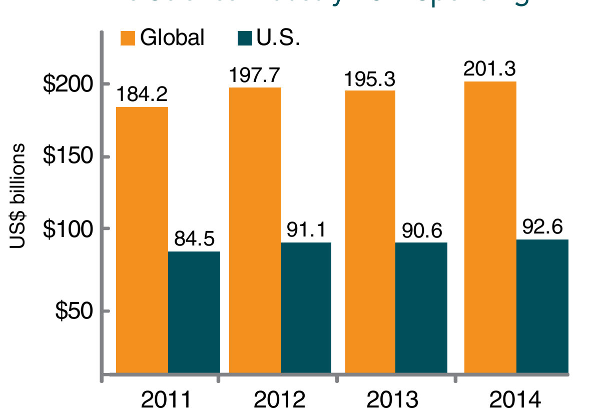
Regulatory Context Influences U.S. R&D Outlook

The U.S. life science industry emerged from the combined challenges of the recession and patent expirations with fresh strategies for R&D. Traditional pharmaceutical companies, while still massive and investing significant resources in R&D, continue to struggle with reduced product pipelines and productivity from discovery through development. As these firms rationalize drug development activities, R&D spending often declines and programs are sometimes reduced and refocused. Smaller biotech companies find opportunity in these circumstances, and innovation through acquisition continues to be an important strategy by larger firms. Medical device and instrumentation firms continue on a steady R&D growth trajectory, but also seek greater efficiency. Universities have become increasingly important sources of innovation and collaboration in life science research in applied areas like drug discovery, as well as more fundamental research in systems biology, nanobiotechnology and other areas.

The future operating environment for this industry is complex. As noted, the Affordable Care Act creates uncertainties in areas like the introduction of new medical products. On one hand, expanding the number of Americans who have health insurance coverage may increase the market for medicines and treatments, and certain regulatory requirements like "meaningful use" of electronic data will accelerate new markets and healthcare efficiency, as well as research in health outcomes.

There also are a number of provisions that will regulate the pricing of prescription medicines and medical treatments, such as mandatory prescription drug rebates and discounts under

Life Science Industry R&D Spending



Source: Battelle/*R&D Magazine* estimates

Medicaid and the Independent Payment Advisory Board for Medicare—empowered to set reimbursement rates that would require Congressional action to offer alternative cost savings. At the same time, new regulations that affect product approvals, pricing and reimbursement could increase costs for industry, although this could also stimulate additional innovation.

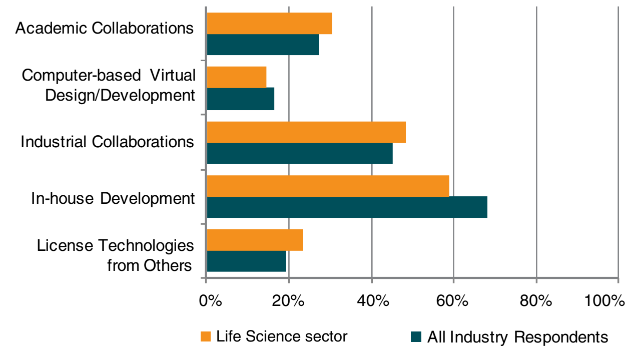
Another significant influence on life science research is the modernization of regulatory approaches used by the Food & Drug Administration. There is an ongoing effort in the U.S.—as well as a separate initiative in the European Union—to ensure that the FDA has the advanced scientific tools, standards and pathways to evaluate medical products under development and use advanced sciences to create efficient processes that also improve product safety, quality and manufacturing. Though steps have been taken within FDA to improve the turnaround time for new approvals and within NIH to assist in the translational research process, the time to market for individual compounds continues to lengthen as drug development becomes more specialized.

What Researchers Think

In our 2014 survey, we asked U.S. industry representatives to provide context on key factors in their R&D investment plans. Their answers were mixed regarding future R&D investment: 45% were more pessimistic about the sufficiency of their R&D budgets, while just 33% were more optimistic. With R&D budgets under pressure, life science industry respondents believe their R&D budgets insufficient to accomplish their corporate research goals, especially as the cost of doing business continues to increase.

As life science companies re-engineer R&D, the well-documented trend toward external partnerships within the U.S. continues. International collaboration still is less common: nearly 60% have no plans for specific foreign engagement. 20% are planning new R&D facilities outside the U.S., and an additional 7% expect to expand existing foreign operations over the next year.

Sources of Innovation



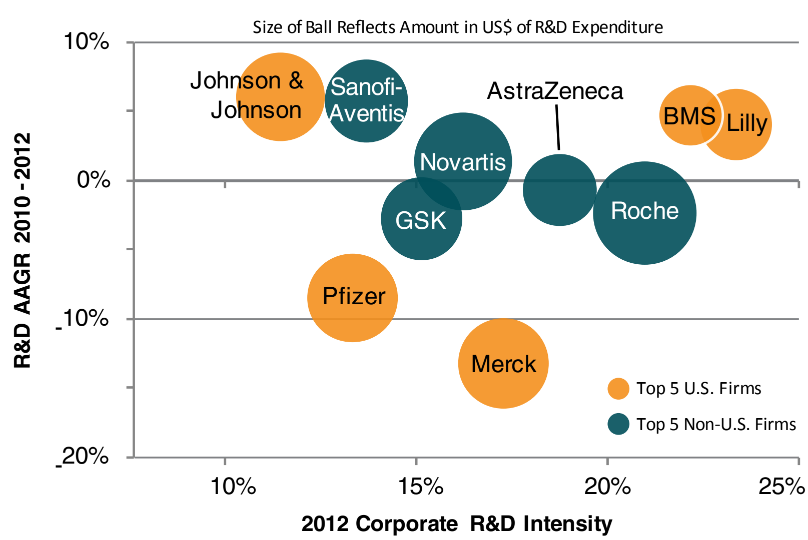
Source: Battelle/*R&D Magazine* survey

Survey results also made clear that expectations are high for accountability and ROI. 64% of life science firms now calculate ROI against research investments—a higher level than industry at large, where only 48% attempt these complicated calculations.

Origins & Priorities for Innovation

The survey also explored the link between R&D investment and technology development. One conclusion is that open innovation plays a more integrated and pervasive role in life science than in other industries. Considering the degree of reliance on research collaborations, acquisitions and in-licensing, internal development capabilities appears to have a slightly smaller role relative to other industries. This suggests that the innovation ecosystem for life science is more complex and inter-related.

The diverse nature of this industry was also reflected in responses about key areas for technology development. The largest was biomaterials, with 68% of the life science respondents seeing future development in this area. Other leading areas of interest included personal genomics (59%) and stem cell applications (54%). In medical devices, increased development emphasis is expected for biomedical monitoring devices (43%) and surgical implants (34%).



Corporate leaders in life science R&D investment

The dominant role of biopharmaceutical firms in global life science R&D is apparent as all 10 leading R&D firms are biopharmaceutical manufacturers. Roche, the largest R&D spending firm in 2012, declined by more than 2%, on average, in each of the past two years. The R&D intensity of the biopharmaceutical sector is also shown with R&D exceeding 10% of sales for all 10 firms, with Lilly exceeding 23%. The recent restructuring of R&D operations by the two largest U.S. biopharmaceutical firms is reflected with both Pfizer and Merck declining by double-digit levels each of the past two years.

Source: Battelle/*R&D Magazine*, Schonfeld & Associates, European Commission-JRC/EIRI

INDUSTRY BREAKOUT — INFORMATION & COMMUNICATION TECHNOLOGIES

Summary

The information and communications technologies (ICT) industry, and the significant level of R&D that supports it, is driven by constant change in consumer preferences, market demand and technological evolution.

The ICT industry is the largest private-sector R&D investor in the U.S., performing nearly one-third of the total. Two firms, Intel and Microsoft, each invested more than $10 billion in R&D in 2012, and both expect to exceed $10 billion in 2013. The U.S. ICT industry is forecast to grow by 5.4% to $146 billion in 2014. U.S. ICT firms are also dominant globally and will account for more than half (57%) of the industry's worldwide R&D expenditures of $257 billion in 2014.

Though ICT involves numerous areas of focus, cloud computing and technologies built on it will remain a major R&D thrust for the foreseeable future.

Trends and Forecast

The ICT industry provides hardware, software and services that make up the modern information age, spanning semiconductors, telecommunications, productivity or security software, computers, tablets and gaming. Across all these applications the integration of smaller, faster, mobile, and more powerful electronics with the increasingly pervasive Internet continues to drive innovation in networking and information technologies across all industries.

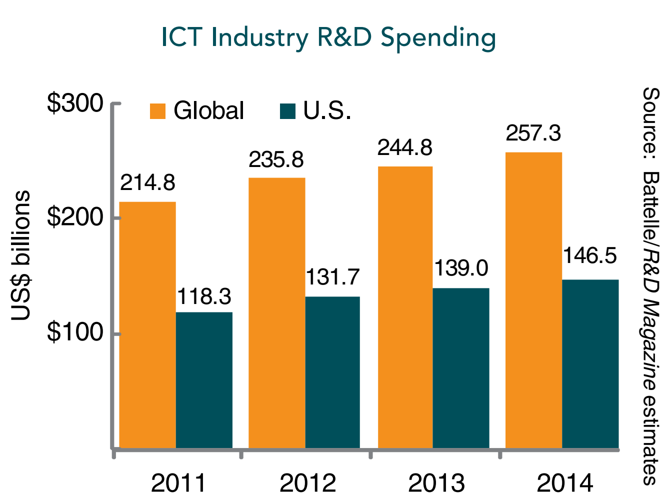
To keep pace with the demand for increased device performance, chip makers continue to invest in technology and manufacturing capabilities that improve functionality, size and power consumption. Other device and software manufacturers are addressing the functional size of their applications as devices get smaller, lighter, thinner, and memory to hold operating systems becomes faster and cheaper. The concept of "wireless" is no longer a feature, but a requirement in the "Internet of Things" for both distinct ICT devices and their embedded counterparts in diverse areas such as automobiles, logistics, smart grids/utilities and homes.

The U.S. continues to be the dominant R&D force in the ICT industry and will account for 57% of the global industry's R&D in 2014. It should be noted, however, that this share reflects firms that are squarely in the ICT domain. Some firms with a strong ICT context, including many global technology giants such as Samsung (which operates a semiconductor R&D operation in the U.S.), are currently classified in other areas such as consumer electronics or appliances. As Internet functionality continues to evolve these domains, a redefinition of ICT may be needed. Such a change could alter the perception of U.S. strength.

We forecast the U.S. ICT industry to grow again this year by 5.4%, reaching $146.5 billion in 2014. The global growth of the ICT industry will reach 5.1%, tempered only slightly by projected slower growth in some of the leading European communications technology companies.

Factors Driving R&D Investment

While it might be said that Moore's Law is driving the relentless investment in semiconductor R&D, it is consumer demand for functionality driving R&D investments in other sectors of the ICT industry. Both of these drivers



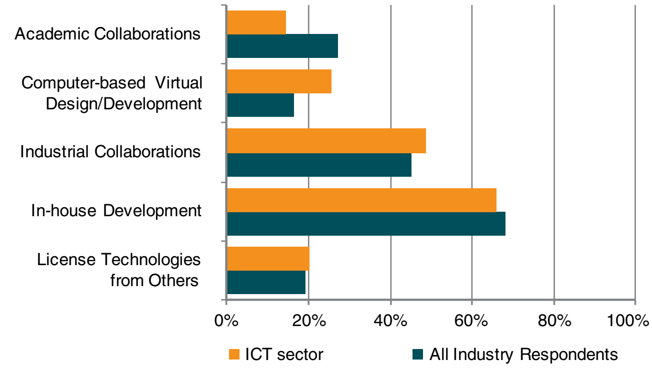
are inherent and recognized as integral to the modern ICT industry, with 65% of the ICT survey respondents citing conventional technology evolution as the biggest change in their technologies over the past year. Increased competition, at 39%, was the second most cited factor in industry technology change.

The constant evolution of ICT technologies is recognized as both a market driver and as a driver for R&D, as the ICT industry's R&D operations are built to support these demand requirements. Nearly three in four industry respondents felt technology change was a decisive factor, with 31% reporting significant technological changes just in the past year. To keep up with the constant change in the industry, 62% of the respondents cited faster time to market as a key organizational factor of their R&D operations, more than 20% higher than the other industries' respondents.

ICT industry respondents, reflecting steady growth even in weaker economies, are optimistic regarding their 2014 R&D budget. While 47% of respondents were more optimistic about their 2014 budgets, when asked for specifics about their budget forecasts, fully 93% stated their R&D budgets will be staying the same or increasing for 2014. Part of this discrepancy in optimism versus actual budgets may reflect that 43% of the respondents also stated that their R&D budgets are not large enough to accomplish their goals. So, while budgets are not declining, they may not be growing at the rate the firms' researchers desire.

The global nature of the ICT industry is apparent as half of the U.S. respondents currently have some level of foreign R&D operation, with 23% planning new R&D facilities outside of the U.S. These global operations are dynamic and not without some challenges, as 33% of those with foreign operations are planning expansions while another 27% are planning reductions.

Sources of Innovation



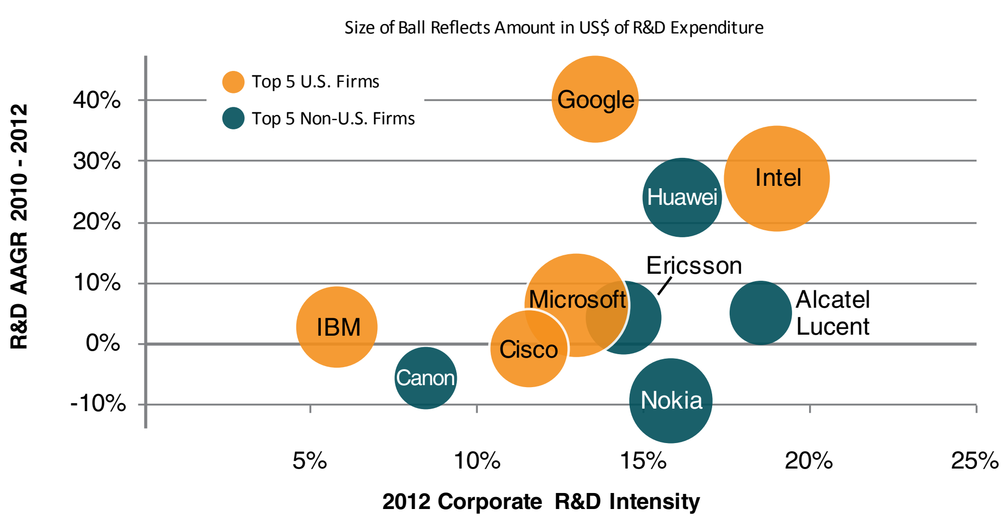
Source: Battelle/*R&D Magazine* survey

Changing Technology Landscape

Technology development within the ICT industry is primarily oriented toward a combination of in-house development and industrial collaboration. The industry's use of academic collaborations, at 14%, is the lowest among the five industries examined in detail, while its use of virtual design, at 26%, is significantly higher than the others.

Two-thirds of ICT respondents cite cloud computing as the key technology development area for 2014-2016, reflecting the ever-changing ICT technology landscape. Contrast this with results from our 2012 forecast where cloud computing was just emerging and not seen as a key development area by 2014.

Core technologies, however, are part of the constant development process of the ICT industry. Continued development of wireless technologies was cited by nearly half (49%) of the respondents, cybersecurity capabilities (46%), and embedded technologies (37%) all at levels nearly identical to the 2012 forecast.



Source: Battelle/*R&D Magazine*, Schonfeld & Associates, European Commission-JRC/EIRI

Corporate leaders in ICT R&D investment

The U.S. leadership in ICT R&D remains strong, with both Intel and Microsoft exceeding US$10 billion in 2012 R&D investment, and Google's and Intel's R&D investments growing by 40% and 27%, respectively, in each of the last two years. The innovation- and R&D-intensive nature of the global ICT industry is evident with all of the U.S. and global leaders firms exceeding 5% and Intel reaching 19%.

INDUSTRY BREAKOUT — AEROSPACE, DEFENSE & SECURITY

Summary

R&D among aerospace, defense and security firms is primarily driven by two sectors: the U.S. Department of Defense (DOD) and the global airline industry. The major aerospace and defense contractors plan R&D in close coordination with DOD to meet the needs of national defense and global security, while capacity, economics and efficiency are drivers for civil aviation requirements. Recent declines in U.S. R&D have been the result of reductions in defense R&D and procurement spending and reductions in commercial aviation R&D, driven largely by Boeing's R&D returning to a more typical level following the Dreamliner launch.

Internal R&D and technological integration in materials, electronics and communication and surveillance technologies, within both civilian and defense aerospace, is partially offsetting reduced government funding by creating more efficient, cost-effective capabilities.

The economic and policy climate indicates a small decline in 2014, and we project (-1.2%) retrenchment for aerospace/defense/security industry R&D, reaching $12.6 billion. Beyond the U.S., global industry R&D spending remains stable due to growth among major non-U.S. aerospace firms in Asia, Russia and Europe, reaching $26.4 billion in 2014.

Trends and Forecast

The aerospace, defense and security (ADS) industry comprises the major aerospace firms—almost all serving both military and commercial aerospace markets. It also includes navigation, instrumentation and communication suppliers, and other firms engaged in defense and homeland security-related activities. Firms in this industry typically maintain close R&D ties with the U.S. DOD, through collaboration and contract research.

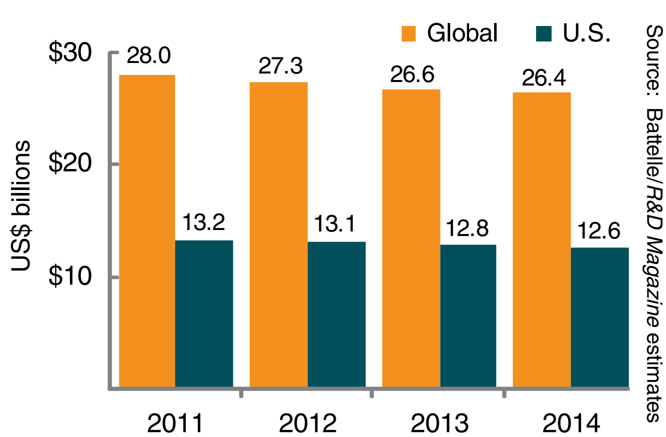
The DOD funds a wide variety of contract research activities that fall outside the scope of this specific industry forecast.[4] Our estimates and forecast for the U.S. and global ADS industry R&D are based on company-funded efforts only and do not include the value of defense-related contract research. However, ADS firms' internal R&D investments are often strongly aligned with the direction and substance of these contract R&D efforts.

Overall defense spending, and hence R&D spending, has been declining over the last few years in a somewhat consistent and expected manner. The impacts of sequestration, however, caused additional across-the-board reductions in both contract research and procurement, leading to declines in revenue at ADS contractors. Together, these reductions caused ADS firms to more directly reduce their own R&D budgets now and into the future. 69% of our ADS industry respondents believe their 2014 R&D budget is likely to be affected by reduced U.S. federal R&D investments.

While the impact of federal spending on the ADS industry is noteworthy, it is important to recognize the significant role U.S. commercial aerospace has on ADS innovation and R&D trends, especially among some of the largest firms in the industry. For example, Boeing typically spends more than 60% of its annual R&D on commercial airplanes, with more funds and a larger share of investment during major jet liner development.

With the combination of reductions in defense spending, and a commercial market that is essentially flat in R&D expenditures, we forecast a small decline of 1.2% in U.S. ADS R&D to $12.6 billion in 2014. Outside the U.S., the ADS industry's

Aerospace/Defense/Security Industry R&D Spending



R&D will be generally flat, leading to a total global industry decline of -0.9% to $26.4 billion in 2014.

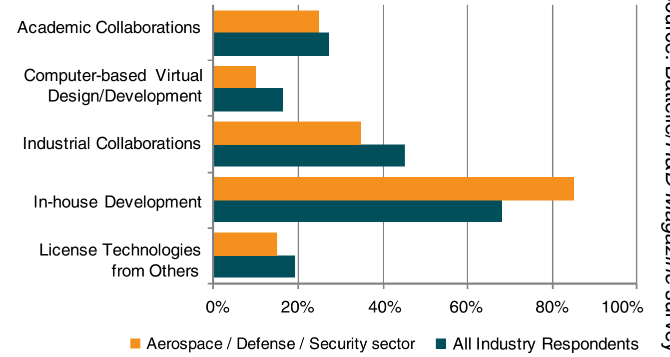
Factors Driving R&D Investment

Unlike other industries examined in this forecast, concern over federal budgets and spending is a significant factor in U.S. ADS company R&D investment. Reflecting these concerns, 56% of ADS respondents are more pessimistic about their 2014 budgets. Cost cutting and budget reductions in recent years appear to be taking a toll on R&D investment and functions in the industry. Approximately 40% of the respondents believe their R&D staff budgets are not large enough to accomplish their goals. R&D costs are becoming a significant issue for 46% of the ADS industry, and 44% of the respondents are concerned their aging R&D infrastructure is affecting their work, again to a greater degree than any other industry.

Even with reductions in defense-related aircraft R&D budgets, growth in commercial aviation and non-traditional defense and homeland security technologies, such as UAVs, will continue to provide momentum in ADS R&D investment. R&D related to improving the fuel efficiency, operating costs and production of commercial aircraft will continue to benefit from the growing demand for global air travel. Growth in the deployment of UAVs, primarily (but not exclusively) from increasing military demands, is driving R&D related to structures, materials, electronics and communication and surveillance technologies. As border security and civilian uses of similar autonomous vehicles emerge over the next few years, R&D efforts will evolve to develop payload and sensor platform technologies for a wide array of new applications.

As external funding declines and costs continue to increase, industry leaders are looking for ways to increase R&D efficiency and spread the financial and development risks. Nearly half (47%) of the ADS respondents believe increased collaboration would be beneficial to their R&D operations. Such collaborations are becoming more important to the ADS industry. One illustration is the recently announced government-industry partnership between NASA and six aerospace prime contractors to advance composite materials research, development and certification.

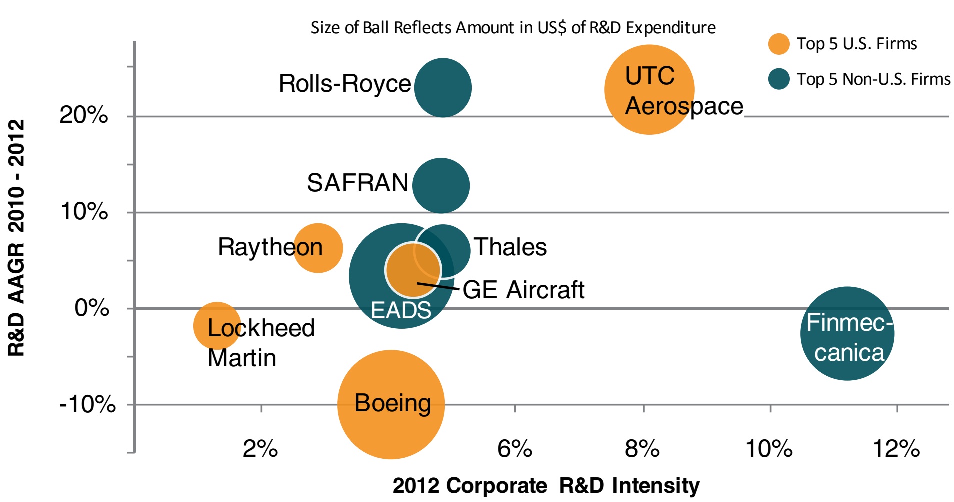
Sources of Innovation



Changing Technology Landscape

Given the competitive nature and security requirements of the U.S. and global ADS industry, it is not surprising that in-house development (identified by 85% of the respondents) is by far the most important mechanism for technology development. No other approach reaches the all-industry average.

The development of autonomous vehicles and related technologies has increased in importance over the last two years as 70% of our ADS industry respondents now cite it as a key area of development over the next three years, compared to 57% in our 2012 forecast. Among the ADS respondents, development of cybersecurity technologies also has taken on increasing importance. 45% of the respondents in our current survey cite it as a key development area, compared to 31% two years ago. Both robotic/drone systems and composite materials are cited by half of the respondents in both years' surveys, indicating a continued platform level of development is expected in these areas. Finally, within a new response category, half of the respondents cited more development in commercial space technologies as important over the next two years.



Source: Battelle/*R&D Magazine*, Schonfeld & Associates, European Commission-JRC/EIRI

Corporate leaders in aerospace & defense R&D

The two largest global aerospace/defense/security R&D firms, Boeing and EADS, both exceeded US$ 3.0 billion in R&D in 2012, though EADS reached this level by averaging 3.5% growth in each the last two years, where Boeing declined by 10% on average in each of the last two years. Italy's Finmeccanica, the third largest R&D performer, also decreased R&D over the last two years, but still maintains the highest R&D intensity among the U.S. & global leaders.

INDUSTRY BREAKOUT — ENERGY

Summary

The energy industry includes a broad array of companies, ranging from multinational oil and gas firms to large and small technology firms. Reducing costs of production is a large driver of R&D in the energy space, and materials development and advanced materials integration are increasingly important in shaping the industry's R&D investment.

National and state governments have a significant influence on the energy industry and long-range research programs. Tax policies and incentives, renewable energy policies, climate change actions and strategic considerations shape economic prospects and, in turn, research directions for industry. Government laboratories (especially the U.S. Department of Energy's national laboratories) are key components of an intensive energy R&D ecosystem.

Although biofuels still face challenges in reaching an economically competitive production level, this technology is still seen as the most significant development area by our industry survey respondents.

For 2014, we forecast the level of the energy industry's R&D will exceed $7 billion in the U.S. (up 1.7%) and reach nearly $22 billion globally (up 4.8%).

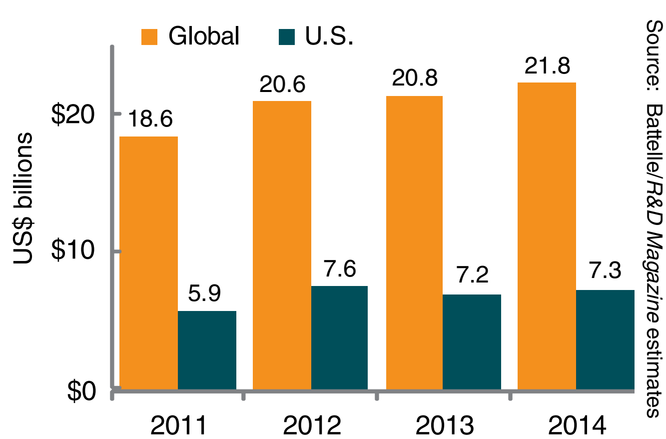
Trends and Forecast

In this Global R&D Funding Forecast, the energy industry includes full scope of companies engaged in developing technologies to generate, transport, store and efficiently consume electricity and fuels. Production can come from traditional oil and gas fields, wind turbines or solar panels, and increasingly from biofuels, new oil recovery techniques and shale gas deposits. The firms in this industry may be standalone energy technology manufacturers or multinational energy producers with significant R&D operations.

Costs of production, materials and R&D all play a role in the direction and growth of the energy industry. Production costs, including both field production of oil and gas as well as the manufacturing costs of various energy technologies, are a significant factor in long-term planning and energy technology development. Many energy technologies rely on advancements in materials to allow for increased functionality and/or energy generation capacity. For example, developments in carbon fiber and composite material technologies enabled the substantial increase in wind turbine size, allowing for enhanced wind farm electricity production, and hence viable economics. Solar is another area where on-going materials developments for photovoltaic applications (e.g., crystalline silicon versus thin-film versus organic) will enable economically sustainable deployments in the future. And in the most extreme case, nearly all approaches to the development of fusion energy will require extreme performance from constituent materials.

Energy R&D expenditures are often as volatile as the energy markets themselves. With some current stability in terms of global oil and gas prices, and with the rationalization of some advanced energy technology companies, we forecast a 1.7% increase in U.S. energy industry R&D to $7.3 billion for 2014. Globally, we forecast a growth rate of 4.8%, due primarily to increasing R&D among Asian oil and gas firms, to reach $21.8 billion in 2014.

Energy Industry R&D Spending



Factors Driving R&D Investment

R&D activities into new production technologies have led to the ability to access previously unobtainable oil and natural gas reserves and have increased the size, scale and energy output of a host of renewable energy technologies.

Within the energy industry, governments can play a significant role in modulating market demand, and therefore, whether energy-related R&D and technologies have a chance to be successful at large scale. Though this involvement is often necessary to reduce technology and market risks, it also creates financial and timing uncertainty for energy-related development.

The federal government, through grants, tax incentives and R&D at DOE national laboratories and extramural academic institutions, plays an integral and often technology-leading role in the research directions of the U.S. energy industry, sometimes extending to piloting, scale-up and translation-stage finance. Over the 2009-2012 period, alternative and renewable energy applications saw substantial increases in federal technology development support (e.g., through ARRA, ARPA-E and other DOE programs). Other government initiatives have been designed to build market demand and make larger-scale adoption of new technologies viable. That said, the substantial increase in natural gas production from shale resources has, at least temporarily, removed some of the energy price and national energy security pressure behind in development of alternative and renewable energy technologies. In the U.S., government-supported research in these areas continues, but private early-stage investment has waned. Elsewhere, governments are more active in deployment of alternative energy technology (e.g., China and countries in the Arabian peninsula).

State and local governments continue to be actively involved in providing resources to build regional "energy clusters" for economic development purposes and in the licensing and siting of major energy projects. State governments have also enacted incentives and energy portfolio standards and requirements that often determine the potential success of energy production projects.

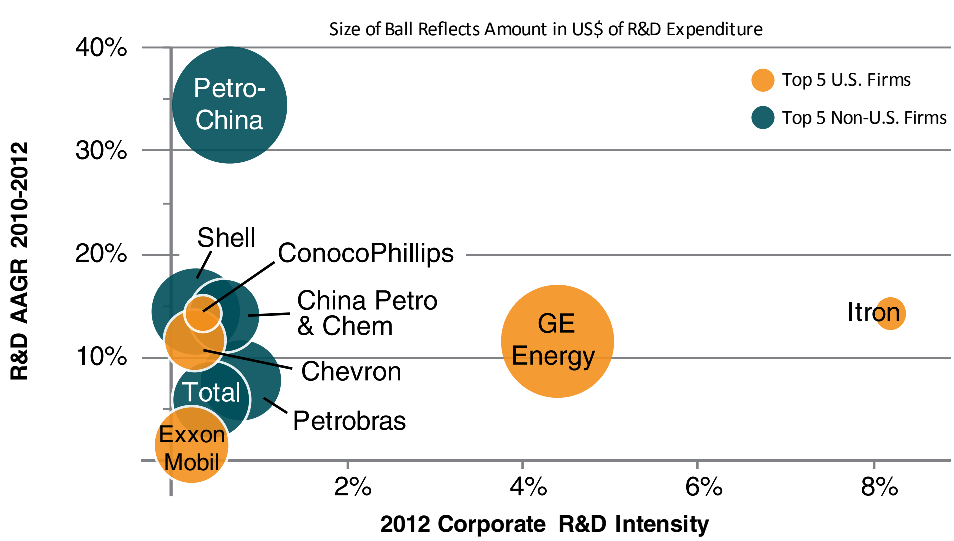
Researcher Perspectives

The energy industry relies on a combination of in-house development (75% of respondents) and industrial collaborations (65%), making this level of industrial collaboration the highest among the five technology industries examined. This may reflect the role that EPRI and the DOE national laboratories play in convening industry members to address significant energy-related research.

From a future technology perspective, biofuels, despite all the technological and feedstock challenges, are seen by 55% of the industry respondents as a key area for energy technology development over the next three years. In contrast, only 28% of the industry respondents in our previous survey felt biofuels were a key area. Composite materials were also viewed by 55% of the respondents, up slightly from two years ago, as a key technology area for energy-related technology development in the near future.

Energy conversion technologies (e.g., heat to electricity; Stirling engines) appear for the first time in this year's survey, with half of the respondents identifying this as a key development area. Four other areas, hybrid systems (50%), fuel cells (45%), photovoltaics (35%) and wind turbines (25%), were identified by this year's respondents as important.

The environmental impact of energy production is an area of increasing R&D emphasis. These (often multidisciplinary) technology development efforts include technologies to manage and filter hydraulic fracturing fluids, technologies for reducing emissions and manging carbon, nuclear waste disposition and wildlife and micro-climate studies regarding the impact of wind farms and utility scale solar operations.



Source: Battelle/R&D Magazine, Schonfeld & Associates, European Commission-JRC/EIRI

Corporate leaders in energy R&D

Dominated by global oil and gas companies, including three U.S. firms, the R&D intensity for most energy leaders is less than 1%. The substantial growth in PetroChina's R&D investment has elevated this firm into the leadership position reaching US$ 2.3 billion in 2012 with all of the other U.S. and global leaders' R&D levels also increasing over the 2010-2012 period. The two U.S. leaders with much larger R&D intensities are both developers of various energy technologies.

INDUSTRY BREAKOUT — CHEMISTRY AND ADVANCED MATERIALS

Summary

The chemicals and advanced materials industry consists of large multinational companies serving nearly every other market, key single market material and application development firms and an array of smaller, niche chemical and material companies.

Research plays a unique role within this industry, driven by production costs (and ultimately the cost of the material to the market) perhaps more than any other industry examined. R&D operations are managed as a cost component like other operations within the firms, but provide the intellectual property enabling new, higher value, and hence higher margin materials and products.

The forecast for R&D growth in the chemical and advanced materials industry reflects the improving global economy and the key markets the industry serves. U.S. R&D spending in chemicals and advanced materials is forecast to grow by 3.6% to reach $12 billion in 2014. Overall global R&D is forecast to grow at a slightly higher 4.7% rate to $45 billion in 2014.

Trends and Forecast

The chemicals and advanced materials industry includes traditional chemical/polymer firms, all of which continue to push the envelope in feedstock and material development, as well as to niche material companies both large and small that focus research activities on unique material properties and the development of applications to exploit these properties. R&D in this industry also works to improve process efficiency and reduce the costs of the large scale production facilities.

The increasingly global nature of materials supply and research continues to drive the rapid growth of new materials capabilities and processing methodologies, driving down costs while greatly enhancing chemical and physical properties and production. This is driving the integration of both chemical and biologically based materials into new medical, industrial and ecological applications. For U.S. advanced materials firms, the global nature of the industry is a double-edged sword. More than a third (35%) of our industry respondents expect to increase their level of foreign collaboration over the next year, yet nearly half (45%) feel that the U.S. is at a moderate to significant risk of losing its leadership position in key material areas.

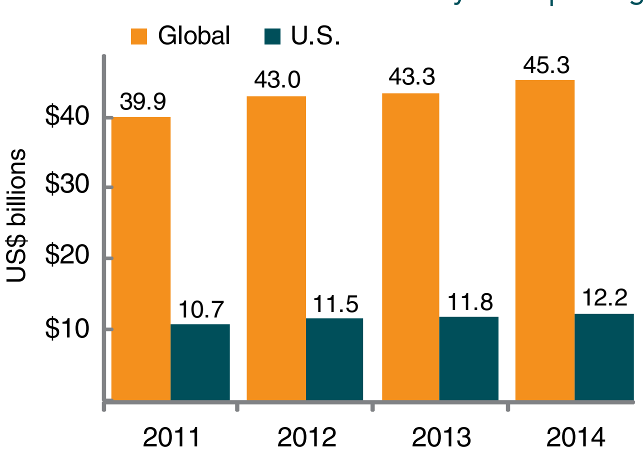
U.S. industry has taken advantage of reduced feedstock costs due to significant increases in the domestic production of natural gas via shale gas deposits. These deposits stabilize the cost of key feedstocks, so U.S. chemical and material companies are feeling more confident and are seeking to bring new, higher value added advanced materials and formulations to market.

The forecast for R&D activities within the chemical and advanced materials industry reflects improvements in the U.S. and global economy, and the role this industry plays in support of other demand-driven industries. We forecast U.S. chemical and advanced materials R&D to increase by 3.6% in 2014, reaching $12.2 billion. Worldwide R&D is expected to increase by 4.7% to $45.3 billion.

Factors Driving R&D Investment

Like most industries, resources to fund R&D activities are strongly connected to industry bottom lines. As the markets for chemical and advanced materials products have rebound-

Chemicals & Advanced Mat'ls Industry R&D Spending



ed post-recession, investments in industry R&D also have increased. These investments are directly tied to developing new, market-leading chemicals and materials for which higher margins can be achieved.

The factors driving R&D are distinctly different across different types of firms. Large, multinational firms such as DuPont, Dow, BASF and Bayer hold industry-leading positions, both within key materials and in product applications across industries and markets. These firms' R&D agendas are driven primarily internally, with emphasis on developing materials to meet future applications. There also are key material-product dedicated firms such as Goodyear's rubber/tire research where the material application defines both the R&D and the market. The industry also has a large number of smaller, material specific firms whose R&D is driven by extensions of their proprietary materials, and by key customer demand.

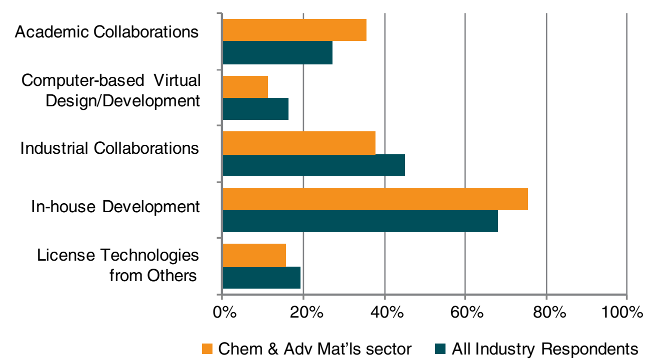
Lower-cost raw materials have dampened, but definitely not eliminated, continued R&D into the use of biomass feedstocks and the production of bioplastics. Research has increasingly focused on materials and applications where the "green" context adds value to support the potentially higher cost of biomass-based material.

Throughout much of the chemical and advanced materials industry "cost" is an overarching driver, as both material substitution and global competition, in what are often commodity products, requires firms to drive production costs to the lowest level possible. R&D costs are also included in these budget equations, and 46% of industry survey respondents believe increasing R&D costs are becoming a significant issue and budget strains are making it difficult to accomplish R&D goals.

Changing Technology Landscape

New technology development within the chemicals and advanced materials industry is largely approached through in-house development activities (76%), supplemented to a lesser extent by both industrial and academic collaborations.

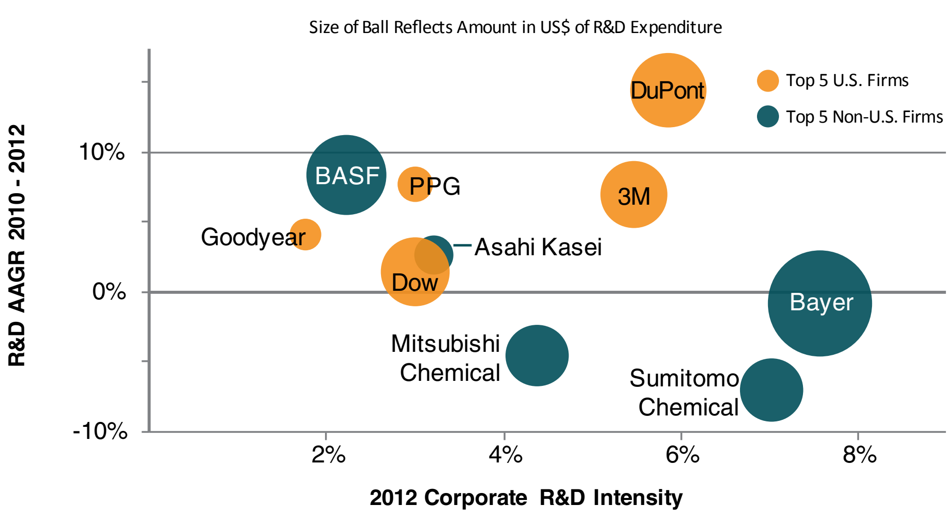
Sources of Innovation



Source: Battelle/*R&D Magazine* survey

Nanomaterials, a key focus of chemical and advanced materials R&D, are expected to be even more important over the next three years, with 80% of survey respondents citing nanomaterials as a key area of technology development (a substantial increase from 67% of the respondents in our previous survey). Similarly, biomaterials will continue to grow in importance as a focus of R&D, with 56% of this year's industry respondents believing biomaterials research will be a key development area, compared to just 38% two years ago.

Composite materials development provides a good example of the unique market position of the chemical and advanced materials industry. Among chemical and advanced materials respondents composites were viewed as the third most important future technology development area, cited by 47% of the industry respondents. Among aerospace and defense respondents, composite materials were cited by 50% of respondents as a key area for development.



Source: Battelle/*R&D Magazine*, Schonfeld & Associates, European Commission-JRC/EIRI

Corporate leaders in chemical & materials R&D

The diverse nature of the global chemicals and advanced materials R&D is reflected in the chart. The largest U.S. firm, DuPont, though currently smaller than both Bayer and BASF, has been growing at an annual average rate nearing 15% over the past two years. Beyond DuPont, the remaining Top 5 U.S. firms all have experienced growth over the last two years. At around 8% of sales, Bayer has the highest R&D intensity among large chemical companies.

Researcher Perspectives

Results from the Battelle/*R&D Magazine* Global Researcher Survey

The Battelle/*R&D Magazine* survey of the global research community delivers original insights that indicate the temperament of R&D activities around the world, and adds context to the quantitative analysis involved in this 2014 Forecast. This year's survey yielded 915 respondents from 71 countries ranging from Australia to Vietnam. U.S.-based researchers comprised the largest geographic cohort at 43% of all respondents.

Global Researcher Profile

As in past years, there continues to be surprising consistency among the global researcher responses, though important distinctions are seen among specific subgroups correlated to organization type and country of origin. The respondent profile reflects the diversity of the global researcher community as well as the random nature of the survey approach, with the majority coming from academic institutions, but with applied research, including clinical and translational biomedical research, accounting for the largest share by research type.

From a technical, industry, or market area perspective the distribution is similar to the last two years. The broad life science/biomedical field accounted for the largest share of respondents at 35%, with chemicals and advanced materials second at a 17% share. Respondents in environmental and sustainability technologies, ICT and agriculture/food account for 10%, 8% and 5% shares, respectively. The diverse nature of research was captured by this survey as 14% of the respondents are primarily involved in basic research in areas falling outside of the ten categories provided. This includes research in mathematics, physics and Earth sciences.

Anticipation of Future R&D Funding

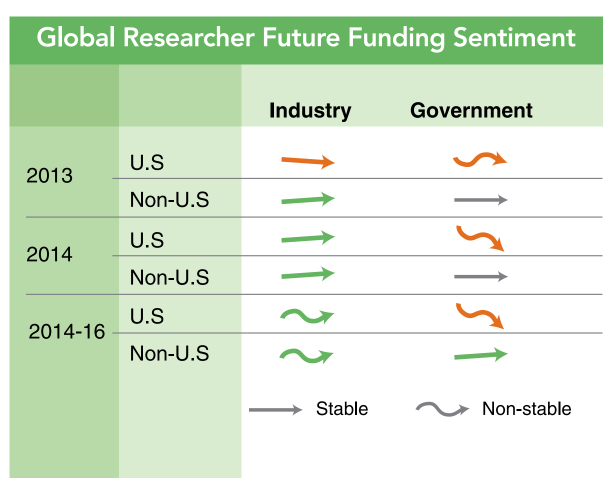
The survey revealed a distinction between expectations for stability and direction of U.S. government R&D funding versus all other types. As noted earlier, the U.S. commitment to R&D funding as a percentage of GDP has been reliable over many years, and there is some evidence that support for public R&D investment crosses political boundaries. Even so, the survey results may indicate eroding confidence in the longer-term future.

> *The ongoing financial problems in Europe, Japan and the US are influencing the sentiment of governments and industry. This is likely to curb spending on R&D, resulting in a loss of research diversity with a focus on payback - this may be a useful short-term solution but could be sacrificing long-term benefits.*
>
> *- Academic researcher in Japan*

Global Researcher Survey Demographics

	Basic Research	Applied Research	Development	Consulting & Other	Total
Academia/University	29%	25%	1%	1%	56%
Research Institute	9%	8%	1%	1%	19%
Government	1%	3%	0%	0%	4%
Domestic Corp.	0%	2%	2%	2%	5%
Multinational Corp.	1%	7%	3%	1%	12%
Other Organizations	1%	2%	0%	1%	3%
Total	40%	47%	7%	6%	100%

Source: Battelle, *R&D Magazine*



Source: Battelle, *R&D Magazine*

Measuring R&D Success

This year's survey asked respondents how they measure the success and impact of their R&D activities. There was little difference in the perspectives of U.S. and non-U.S. researchers, but interesting differences are linked to the type of research organization. Publishing technical papers was cited as a key measure of success across all organizations, although the proportions were different: 95% of academics ranked publication as their #1 measure, while only 55% of corporate researchers did the same. Patents are a key measure of success among all organization types, with 40% of all respondents having at least one patent related to their research. Follow-on research grants are a key success measure for approximately half of the academic and research institute respondents. New product introductions, the most cited measure of success among multinational corporations, was not as highly ranked by respondents from other kinds of research organizations.

Rankings of Research Impact Metrics

	Follow-on grants	Competitiveness	Product quality	Productivity	Profitability	New products	Patents	Cost reduction	Publications
Academia	2			4			3		1
Domestic Corp.			3	4			2		1
Multinational Corp.					3	1	2		4
Research Institute	2	4					3		1
Government			2				4	3	1
All Respondents	2		4				3		1

Source: Battelle, *R&D Magazine*

Global Issues Driving R&D

The survey also asked about the issues that are important in determining, influencing or directing researchers' future R&D efforts. The top ten answers were strikingly consistent regardless of institution or geography, although ordering within the top ten does vary by type of research organization. For example, while governments' understanding of science and technology issues is cited by more than half of the government respondents, the highest response to this issue (57%) comes from domestic corporations, while academics cited this factor at a lower rate (35%)—ratios that are somewhat surprising considering the typical recipiemts of government R&D funds.

Beyond the top ten, drivers diverge based on organization type. Government researchers cite concern over natural disasters and nuclear proliferation at a much higher rate that other researchers. Corporate respondents cite demand for renewable/sustainable energy as a key issue, closely followed by government S&T understanding, fossil fuel availability and the threat of another global recession.

Broad Factors Influencing Research

% of total respondents

Factor	%
Governments' understanding of science & technology issues	38%
Sustainable development	32%
Demand for renewable / sustainable energy	31%
Climate change / global warming	30%
Healthcare for the aging	27%
Citizens' understanding of science & technology Issues	24%
Constrained national budgets	21%
Environmental clean-up / remediation	21%
Global population growth	18%
Global food supply	16%

Source: Battelle, *R&D Magazine*

Common Challenges

The commonality among the challenges faced by the global research community is striking, especially with respect to funding, budgets, and time, with a somewhat higher share of U.S. researchers reporting these challenges. Budget concerns are reflected in travel restrictions, which are a challenge for 21% of U.S. researchers and 16% of non-U.S. researchers.

Twenty percent of non-U.S. researchers find it a challenge to assemble a strong research team, an issue faced by a smaller share of U.S. researchers, likely due to difficulty in finding new collaborators. A unique challenge faced by 16% of non-U.S. researchers is the shortage of skilled R&D workers. Finally, there is some commonality in the challenge of translating research into products, with 10% of U.S. researchers citing this issue and 15% of the non-U.S. researchers.

Challenges Identified by Researchers

	U.S.	Non-US
Limited External Funding	36%	29%
Limited Internal Budget	26%	25%
Lack of Time to be Creative / Innovative	26%	24%
Lack of Long-Term Budget / Perspective	25%	24%
Travel Restrictions / Lack of Funding	21%	16%
Prioritizing Research Efforts	15%	
Assembling a Strong Research Team	14%	20%
Competition	14%	
Translating Research into Products	10%	15%
Finding New Collaborators		17%
Skilled Worker Shortages		16%

Source: Battelle, *R&D Magazine*

Collaboration

Collaboration with academic researchers is the most common kind of research partnership around the world.

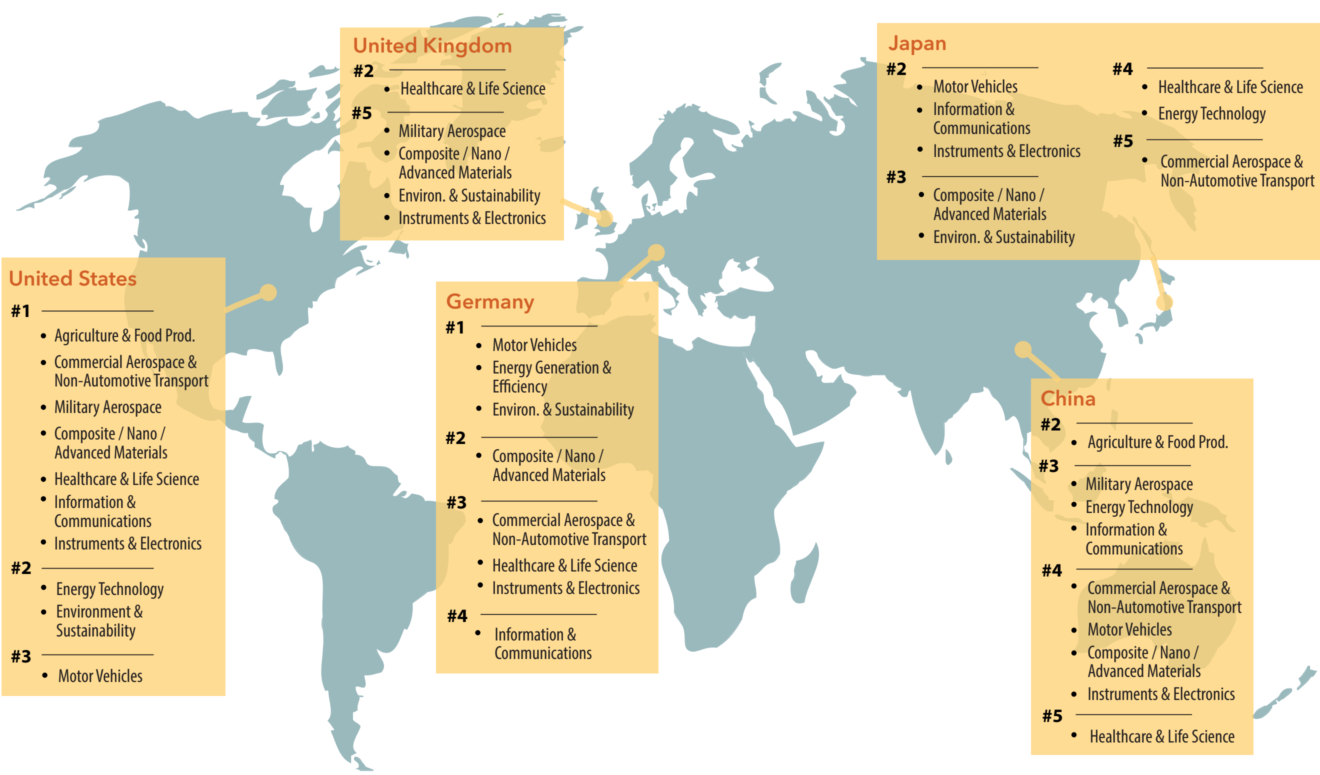
In the U.S., both academics and multinational corporations cite government researchers as collaborative partners at a much higher share than non-U.S. researchers. For non-U.S. domestic corporations, there is generally stronger affinity for collaboration across all the partner types. The prevalence of standalone research institutes and their strength as research partners is shown within the countries of our non-U.S. respondents. More than half of the multinational corporations in both the U.S. and abroad collaborate with other multinational corporations, but 10% or more do not collaborate with any outside research partners.

Collaboration Patterns Among Companies and Institutions

		Collaboration Partner					
		Academia	Research Institute	Govern-ment	Domestic Corporation	Multinat-tional Corp.	None
U.S.	Academia	91%	40%	42%	23%	25%	4%
	Domestic Corp.	56%	28%	32%	44%	36%	8%
	Multinational Corp.	71%	31%	33%	35%	56%	13%
	Government	87%	53%	67%	53%	33%	0%
	Research Institute	96%	61%	48%	30%	26%	0%
	U.S. Total	**86%**	**39%**	**41%**	**28%**	**30%**	**5%**
Non-U.S.	Academia	87%	55%	21%	32%	30%	3%
	Domestic Corp.	67%	48%	38%	52%	38%	0%
	Multinational Corp.	73%	47%	19%	29%	56%	10%
	Government	77%	55%	55%	32%	14%	9%
	Research Institute	74%	60%	25%	32%	30%	6%
	Non-U.S. total	**80%**	**55%**	**25%**	**32%**	**33%**	**5%**
All Respondents total		**82%**	**48%**	**32%**	**30%**	**32%**	**5%**

Source: Battelle, *R&D Magazine*

Researcher-Ranked Global R&D Leaders by Technology Area



Source: Battelle, *R&D Magazine*

REFERENCES AND METHODOLOGY ENDNOTES

1 During 2013 the release of new data from NSF modified the historical data for industry and federal government R&D funding and performance through 2011 resetting the baseline upon which the Battelle/*R&D Magazine* Forecast is built. Additionally, as 2012 came to a completion Q4 performance is included to revise the 2013 forecast estimate. Finally, the impact of sequestration, estimated by various observers to be between $6 and $10 billion in federal R&D funding cuts, was factored into the final post-sequestration 2013 estimate.

2 To measure the economic impact of the forecast U.S. R&D expenditures, we used the scientific R&D sector as a surrogate for all R&D activities. Typically, this economic sector consists solely of standalone R&D operations, ranging from small startups to firms such as Battelle. For simplicity, this approach also models all R&D expenditures the same—spending on pharmaceutical R&D is treated the same as automotive R&D, and likewise the same as university and government R&D. While there are differences in the research being undertaken, there are strong similarities in the economic structure and purchases among these different performers—often more so than R&D has with the other activities of a firm or industry. For example, from a purchasing perspective automotive R&D has more in common with pharmaceutical R&D than automotive R&D has with automotive industry production activities— automotive R&D does not buy billions of dollars of steel and glass, but rather computers, laboratory instrumentation, scientists, and engineers.

This conservative analysis is based on the application of certain economic impact multipliers to the 2014 forecast total R&D spending figure of $464.5 billion. These multipliers are developed using average multipliers derived from the 2009-2011 U.S. IMPLAN economic impact models (with 2011 being the most current available), to help mitigate any severe recession swings from impacting the values). In terms of total (including multiplier effects) employment or output impacts in the economy, the values associated with scientific R&D are smaller than many "high-tech" industries. This indicates that using the scientific R&D sector as a surrogate for all R&D will likely provide a more conservative and more appropriate measurement than applying R&D expenditure

3 For an example of research on the relationship between national research intensity, see "Sources of U.S. Economic Growth in a World of Ideas" (Jones 2002). ITIF and AAAS have also done important work on this topic. An example of the long-term economic returns and functional impact from a major public-private research initiative, see "Economic Impact of the Human Genome Project" (Battelle 2011).

4 These DOD research activities are captured in the U.S. R&D Forecast and are included in the Federal R&D Funding-to-Industry R&D Performance cell of the Source-Performer Matrix.

RESOURCES

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

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

Battelle Memorial Institute
www.battelle.org

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

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

Chinese Academy of Sciences
english.cas.cn

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

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

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

International Monetary Fund
www.imf.org

Information Technology & Innovation Foundation (ITIF)
www.itif.org

IMPLAN Group LLC
IMPLAN Models
www.implan.com

McKinsey & Company
www.mckinsey.com

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

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

Schonfeld & Associates
www.saibooks.com

Thomson Reuters
www.thomsonreuters.com

The World Bank
www.worldbank.org

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

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

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