Who Drives E&P Innovation?

Robert K. Perrons, Queensland University of Technology, and **John Donnelly,** *JPT* Editor

Few would argue that the upstream oil and gas industry has become more technology-intensive over the years. At the same time, the increasing costs and complexity of today's exploration and production (E&P) technologies are making it increasingly difficult for any one company to support an aggressive research and development (R&D) agenda single-handedly. The coming together of these two evolutionary forces gives rise to important questions. How does innovation happen in the E&P industry? Specifically, what ideas and inputs flow from which parts of the industry's value network, and where do these inputs go? And how do firms and organizations from different countries contribute differently to this process? This survey was designed to shed light on these issues.

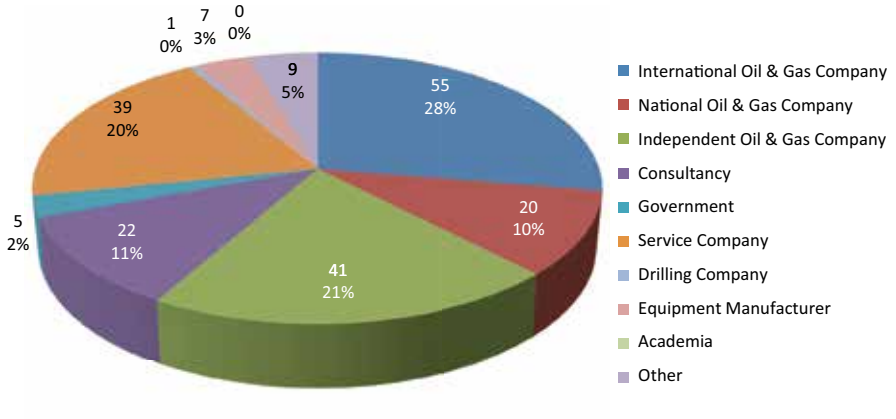

Fig. 1—Respondents by type of organization.

TABLE 1—BREAKDOWN OF RESPONDENTS BY TYPE OF ORGANIZATION

Type of Organization	Number of Respondents	Percentage
IOC	55	27.6
NOC	20	10.1
Independent	41	20.6
Consultancy	22	11.1
Government	5	2.5
Service Company	39	19.6
Drilling Company	1	0.5
Equipment Manufacturer	7	3.5
Academia	0	0.0
Other	9	4.5
Total	199	100.0

About the Survey

This survey was a joint research initiative between *JPT* and the Queensland University of Technology in Brisbane, Australia. A "data firewall" was established for this collaboration so that the participating university researchers did not have access to any of the specific details of the survey participants.

It is not uncommon for large multinationals in the E&P industry to have R&D facilities in several different parts of the world. For example, Shell has E&P research centers in the Netherlands, USA, Qatar, and India. Thus, to capture region-by-region differences, this survey asked questions about how technology- and innovation-related activities are managed at the "business unit" level. Smaller companies and organizations that develop and deploy upstream oil and gas technologies in a consistent way throughout all their operations around the world were instructed to consider their entire organization as a business unit for the purposes of this survey. The survey also included consultancies, universities, and governments; their business unit was the part of their organization that interacts with upstream oil and gas companies in their region.

Of the 469 people invited to participate, a total of 199 people completed the survey, yielding an overall response rate of 42.4%. Invited participants were high-ranking managers who play significant roles with regard to R&D and/or technology deployment in their business units. **Fig. 1** and **Table 1** outline the breakdown of respondents by type of organization and **Fig. 2** shows the worldwide size of the employing organizations. **Table 2** shows the location of the worldwide headquarters for the respondents' employing organizations, and **Table 3** shows the geographic location of respondents' business units.

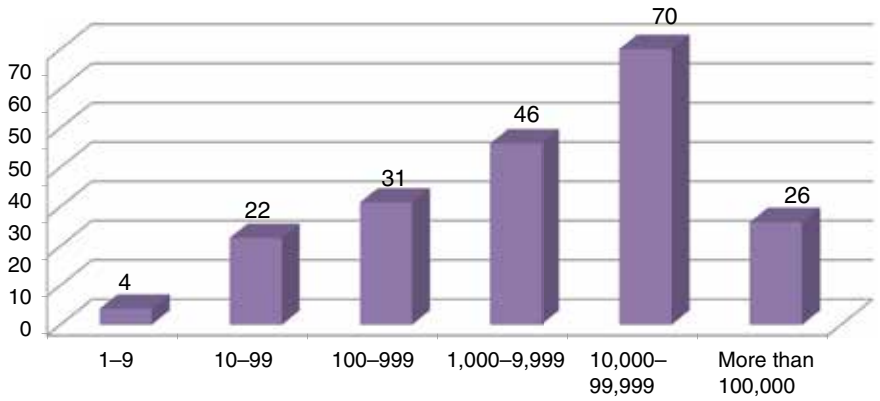

Fig. 2—Worldwide size of respondents' employing organizations.

Consisting of 23 questions, this survey asked respondents about several aspects of their business unit's R&D and innovation-related activities. Much of the survey focused on the sources of knowledge they rely upon throughout their innovation activities. What sources of information, data, and knowledge are most important as they develop new technologies? This part of the survey was modeled after the Eurostat Community Innovation Survey, which has been used in more than 60 academic articles for measuring the knowledge inputs that go into innovation-related activities (Laursen and Salter (2005) and Cosh and Zhang (2011) are specific examples of research that have used this type of framework for analysis). The framework consists of 16 potential sources of knowledge (**Table 4**). Respondents were asked to identify the degree to which they had used each of the sources throughout the past 3 years, ranging from "not used" to "high use."

The survey also asked for several measures of R&D output from their business unit, including the number of patents arising from technologies principally developed by their business unit in the past 3 years, the number of technologies deployed by their business unit in the past 3 years, and the number of radical innovations among these. All of these output measures were self-reported by the respondents. Respondents were informed before completing the survey, however, that their results would be made anonymous and aggregated with data from other respondents, thereby removing any incentive to distort their responses.

Respondents were asked at the end of the survey if they would object to being asked a few clarifying questions about their responses. Several said yes, and a

TABLE 2—BREAKDOWN OF RESPONDENTS BY COUNTRY WHERE EMPLOYING ORGANIZATION'S GLOBAL HEADQUARTERS IS LOCATED

Country	Number of Respondents	Percentage
Australia	4	2.0
Austria	3	1.5
Canad	23	11.6
China	2	1.0
Denmark	6	3.0
India	6	3.0
Italy	3	1.5
Malaysia	2	1.0
Netherlands	23	11.6
Nigeria	4	2.0
Norway	8	4.0
Oman	4	2.0
Pakistan	3	1.5
Switzerland	3	1.5
UAE	4	2.0
UK	18	9.0
USA	71	35.7
Other	12	6.0
Total	199	100.0

TABLE 3—BREAKDOWN OF RESPONDENTS BY LOCATION OF THEIR BUSINESS UNIT

Country	Number of Respondents	Percentage
Australia	7	3.5
Austria	2	1.0
Brunei	3	1.5
Canada	26	13.1
Denmark	3	1.5
France	2	1.0
India	7	3.5
Indonesia	2	1.0
Malaysia	8	4.0
Netherlands	10	5.0
Nigeria	4	2.0
Norway	6	3.0
Oman	7	3.5
Pakistan	3	1.5
Qatar	2	1.0
UAE	3	1.5
UK	18	9.0
USA	74	37.2
Other	12	6.0
Total	199	100.0

TABLE 4—SOURCES OF INFORMATION AND KNOWLEDGE FOR INNOVATION-RELATED ACTIVITIES ACROSS ALL RESPONDENTS

Type	Knowledge Source	Number of Responses	Percentages			
			Not used	Low Use	Medium Use	High Use
Market	Suppliers of equipment, materials, components, or software	143	6.2	23.1	33.6	37.1
	Clients or customers	141	19.2	16.3	33.3	31.2
	Competitors	142	19.7	45.8	28.2	6.3
	Consultants	144	18.8	45.8	23.6	11.8
	Commercial laboratories/R&D enterprises	141	24.8	37.6	22.7	14.9
Institutional	Universities or other higher education institutes	145	17.2	39.3	26.9	16.6
	Government research organizations	143	37.1	38.5	18.2	6.3
	Other public sector, e.g., business links, government offices	142	40.8	40.1	13.4	5.6
	Private research institutes	141	41.8	36.9	16.3	5.0
Other	Professional conferences, meetings	142	3.5	23.2	43.7	29.6
	Trade associations	142	31.1	38.7	22.5	7.7
	Technical/trade press, computer databases	141	15.6	31.9	36.9	15.6
	Fairs, exhibitions	141	15.6	36.2	38.3	9.9
	Technical standards	142	13.4	31.0	36.6	19.0
Specialized	Health and safety standards and regulations	142	16.1	31.0	26.1	26.8
	Environmental standards and regulations	141	14.8	29.8	28.4	27.0

handful of follow-up discussions were carried out to deepen an understanding of the survey results.

Innovation-Related Activities Across All Respondents

- Among the highlights: The largest sources of the industry's knowledge and inputs for innovation-related activities were suppliers and clients. Professional conferences, health and safety standards, and environmental standards were also considered to be very important.
- Overall, the industry places less emphasis on government research organizations, universities, and public sector organizations where R&D inputs and knowledge are concerned.

Of the 16 potential knowledge sources identified in Table 4, five were selected for more in-depth analysis because more than 25% of the total respondents had indicated they relied on these particular knowledge sources as "high use" inputs. **Table 5** and **Fig. 3** point out how different types of organizations rely differently on these top-five knowledge sources.

- International oil companies (IOCs) rely on their suppliers more than any other knowledge source, but service companies rely little on this source.
- The tables are turned on "clients or customers," however: IOCs do not consider this to be as big a knowledge source, but service companies believe it to be important. This suggests that IOCs' innovation-related activities are more guided by what their suppliers are doing than by what their clients are doing.
- This figure also shows that the industry's consultants seem to rely heavily on professional conferences and meetings as knowledge sources.
- National oil companies' (NOCs') and government respondents' innovation activities seem to put noticeably more emphasis on health and safety standards and environmental standards than other types of organizations do.

The numbers of patents and deployed technologies reported by the respondents were then examined. A "deployed technology" was defined as an innovation that has successfully gone through field trials, and that is ready to be used in revenue-generating activities. **Table 6** and **Fig. 4** show the number of patents awarded in the past 3 years by type of organization.

- Service companies generated about 80% of the patents reported in the survey. Less than

TABLE 5—PERCENTAGE OF RESPONDENTS INDICATING "HIGH USE" FOR VARIOUS KNOWLEDGE SOURCES THROUGHOUT INNOVATION-RELATED ACTIVITIES

Type of Organization	Total Responses to this Question	Suppliers of Equipment, Materials, Components, or Software (%)	Clients or Customers (%)	Professional Conferences or Meetings (%)	Health and Safety Standards and Regulations (%)	Environmental Standards and Regulations (%)
IOC	31	51.6	25.8	25.8	29.0	29.0
NOC	14	42.9	21.4	28.6	42.9	42.9
Independent	32	43.8	9.4	15.6	21.9	21.9
Consultancy	15	40.0	40.0	53.3	20.0	13.3
Government	5	20.0	60.0	40.0	60.0	60.0
Service Company	30	20.0	43.3	30.0	30.0	33.3
Equipment Manufacturer	7	28.6	42.9	14.3	0.0	0.0

20% of the respondents worked for service companies, so this is an impressive statistic.

- Adjusted for the differing numbers of respondents, NOCs reported far fewer patents than IOCs. IOCs have recently become more vocal about being innovative and putting more value on R&D (e.g., Parshall 2011).

Patents were not the sole indicator as a measure of innovation-related outputs. Respondents were also asked about the number of deployed technologies from the past 3 years for which their business unit played a leading role. Summarized in **Table 7** and **Fig. 5,** the responses here reinforce what was seen with the patent statistics.

One of the things that did jump out by comparing Tables 6 and 7, however, is the relative number of patents filed for each of the deployed technologies. **Table 8** and **Fig. 6** accordingly ask an obvious question: Do different types of organizations put different amounts of emphasis on the number of patents that they file for the innovations that they create? The answer is a clear "yes."

Two respondents with extensive backgrounds in service companies said

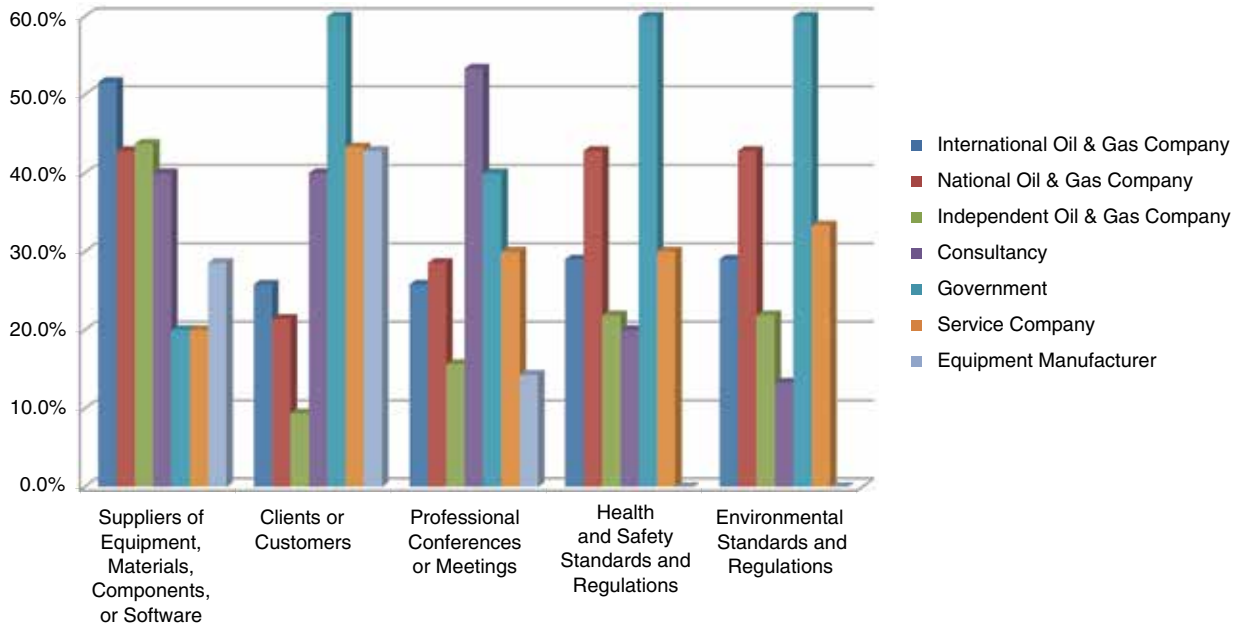

Fig. 3—Percentage of respondents indicating "high use" for various knowledge sources throughout innovation-related activities.

TABLE 6—NUMBER OF PATENTS AWARDED IN PAST 3 YEARS BY TYPE OF ORGANIZATION

Type of Organization	Number of Patents Awarded in Past 3 Years for Which Respondent's Business Unit Played a Leading Role	Percentage of Total Reported Patents	Percentage of Total Respondents
IOC	1008	13.0	27.6
NOC	179	2.3	10.1
Independent	61	0.8	20.6
Consultancy	21	0.3	11.1
Government	6	0.1	2.5
Service Company	6221	80.0	19.6
Drilling Company	8	0.1	0.5
Equipment Manufacturer	63	0.8	3.5
Other	207	2.7	4.5
Total	7774	100.0	100.0

they were not surprised by the result (direct quotes offered here):

- "Intellectual property is typically used to defend a space in the market place for future business or to defend products and service evolution in the businesses we are in. If you start to plot out 'competitive threat vectors,' the service side (especially the integrated service side) has the most degrees of competition (from direct competition, niche service players, tech start-ups, academia, and customers)."
- "As such we typically have intellectual property strategies that build protective layers around core ideas to make it more difficult for competitors to 'design around.'"
- "Patent portfolios are often pivotal areas in the assignment of value to an enterprise valuation (especially if the company is still in the investment phase)."
- "IOCs can't easily commercialize what they develop. Take Shell: They have lots of ideas for widgets but have no mechanism to make a business out of them. Their structure/cost base is geared around development of oil/gas fields worth billions, not a widget working in the few millions. This is true for Chevron and ExxonMobil too… . Good tech development in the past but little success in marketing and commercialization."

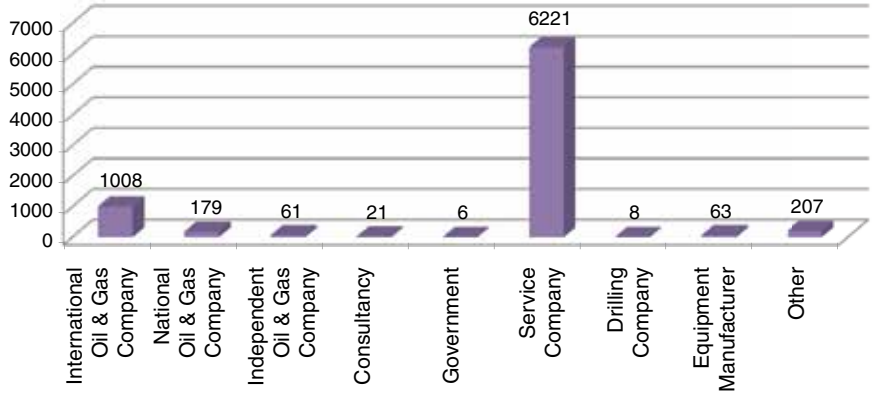

Fig. 4—Number of patents awarded in past 3 years for which respondent's business unit played a leading role.

Why does this particular finding matter? Many studies done over the years have talked about patent filings as a direct proxy for innovation within the E&P sector. In those studies, numbers of patents were portrayed in such a way that they became a bellwether for how much R&D and innovation each company was doing. Our finding here challenges this logic because it shows that service companies typically file many more patents per innovation than other types of E&P companies. It is true that service companies do much of the heavy lifting with regard to innovation in the industry, but focusing just on patent statistics will skew this perception to the high side.

Table 8 also shows that IOCs typically file more patents per deployed technology than NOCs, and much more than independents. This again probably can be attributed to the growing business case for IOCs to put forward novel, hard-to-replicate technologies. These results from the survey suggest that intellectual property and patents are somewhat less of a priority for NOCs and independents.

Another important question arising from the survey data was whether or not

TABLE 7—NUMBER OF DEPLOYED TECHNOLOGIES IN PAST 3 YEARS BY TYPE OF ORGANIZATION			
Type of Organization	Number of Deployed Technologies in Past 3 Years for Which Respondent's Business Unit Played a Leading Role	Percentage of Total Deployed Technologies	Percentage of Total Respondents
IOC	227	18.3	27.6
NOC	65	5.2	10.1
Independent	58	4.7	20.6
Consultancy	19	1.5	11.1
Government	2	0.2	2.5
Service Company	782	63.1	19.6
Drilling Company	2	0.2	0.5
Equipment Manufacturer	34	2.7	3.5
Other	51	4.1	4.5
Total	1240	100.0	100.0

the size of the company affected R&D output. Are big companies better positioned to create new innovations in the E&P industry than small ones? **Table 9** shows the data that address this question.

The lion's share of deployed technologies (74.8%) and patents (79.2%) from the past 3 years reported by respondents came from firms with between 10,000 and 99,999 employees. Most service companies probably fit this profile so one could argue that this outcome is not at all surprising.

But what kinds of innovation do these huge organizations create? Might smaller firms play a unique role in the industry by offering innovations that are more radical in character? Toward answering this question, respondents were asked to report the number of radical innovations that they had deployed throughout the past 3 years. Using the widely used definition put forward by Leifer et al. (2000), a "radical innovation" was defined in the survey as a new technology that fulfilled at least one of these criteria:

1) It delivered an entirely new set of performance features to the marketplace that simply were not available before.

2) It brought about an improvement in existing performance features of five times or greater.

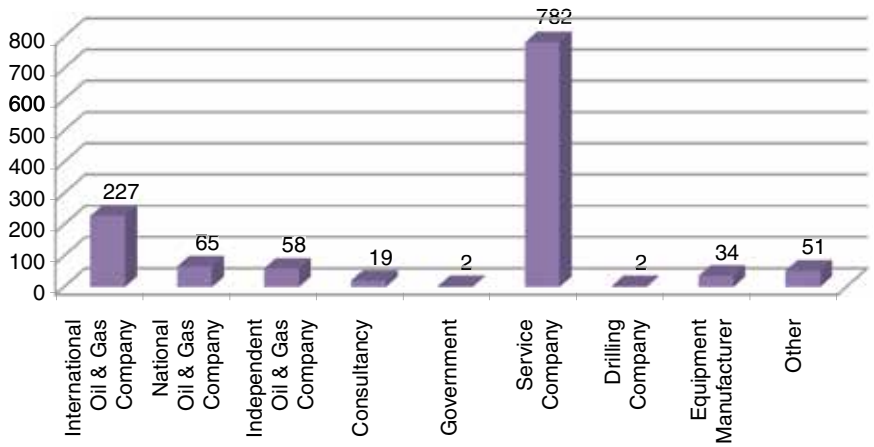

Fig. 5—Number of deployed technologies in past 3 years for which respondent's business unit played a leading role.

3) It delivered a significant (30% or greater) reduction in cost.

Table 10 outlines the results. As predicted, smaller firms with fewer employees contribute relatively more to the creation of the E&P industry's radical innovations than to more incremental ones. Nearly 15% of the reported radical technologies from the past 3 years came from companies with less than 1,000 employees, but these firms were responsible for less than 8% of the total number of deployed technologies during that same period.

The same large firms—that is, those with 10,000 to 99,999 employees—that create most of the E&P industry's new technologies also seem to be responsible for nearly two-thirds of the radical innovations. In other words, large companies are contributing most of the industry's radical innovations.

Does the type of the organization play a role in how radical its innovations are? **Table 11** offers evidence of this.

There is no shortage of qualitative evidence in the literature (e.g., Daneshy and Donnelly, 2004) suggesting that service companies tend to steer their portfolios toward more incremental technologies that are essentially an iterative improvement on an existing technology. The data presented here do not contradict this widely held belief. Service companies considered a much

TABLE 8—"PATENT INTENSITY" OF INNOVATION: AVERAGE NUMBER OF PATENTS RECEIVED PER DEPLOYED TECHNOLOGY BY ORGANIZATION

Type of Organization	Number of Deployed Technologies in Past 3 Years for Which Respondent's Business Unit Played a Leading Role	Number of Patents Awarded in Past 3 Years for Which Respondent's Business Unit Played a Leading Role	Patents / Deployed Technology
IOC	227	1008	4.4
NOC	65	179	2.8
Independent	58	61	1.1
Consultancy	19	21	1.1
Government	2	6	3.0
Service Company	782	6221	8.0
Drilling Company	2	8	4.0
Equipment Manufacturer	34	63	1.9
Other	51	207	4.1
Total	1240	7774	6.3

smaller fraction of their deployed technologies to be radical than other types of organizations.

NOCs and independents do not generate high numbers of technologies overall, but they consider what they do create to be fairly radical in character.

Another interesting question arising in the survey was whether business units that were geographically closer to their world headquarters generated more new technologies than more remote business units. In other words, do worldwide organizations tend to conduct most of their R&D and innovation in their own backyard, or in the interest of placating host governments, do they do much of their R&D abroad? **Table 12** examines this question. The major findings:

- Although the difference is not huge, the survey evidence suggests that respondents working in business units that are in the same country as the organization's worldwide headquarters are proportionally responsible for a larger fraction of the industry's deployed technologies than their more remote colleagues. Over two-thirds of the respondents were working in business units away from their organization's world headquarters, but this group was responsible for only half of the total number of deployed technologies during the last 3 years. By contrast, less than one-third of the respondents were working in the same country as their world headquarters, but this group was responsible for the other half of the deployed technologies.

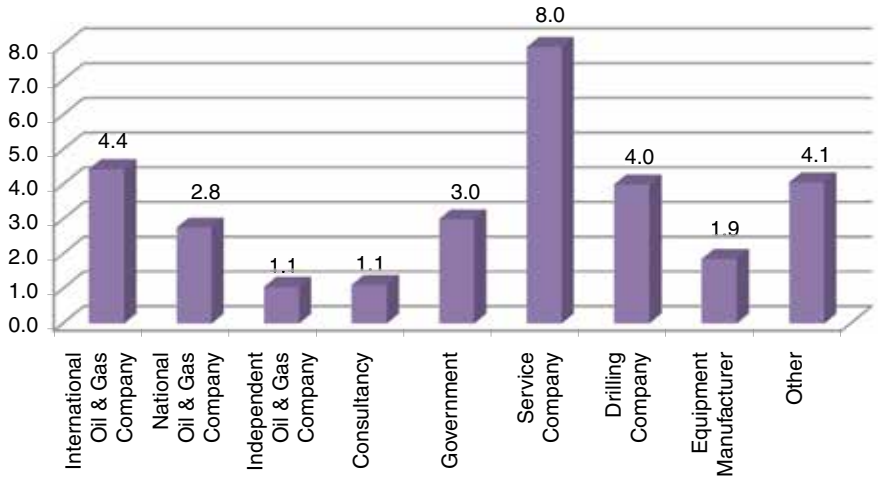

Fig. 6—"Patent intensity" of innovation: number of patents received per deployed technology by organization type.

Another question that the survey data allow us to explore is the geographic origin of the industry's innovations. Where, geographically, do the E&P industry's new technologies come from? **Table 13** breaks down the deployed technologies reported from the past 3 years according to the country where the creating organization's headquarters is located. The major findings:

- Although only 35.7% of the respondents were from the US, more than 60% of the reported deployed technologies came from companies based in that country. This leaves little doubt that the US is still largely the epicenter of innovation and new technologies in the E&P sector.

TABLE 10—OUTPUT OF RADICAL INNOVATIONS VS. WORLDWIDE SIZE OF RESPONDENTS' ORGANIZATIONS

Number of Employees Within Organization	Number of Radical Innovations Deployed in Past 3 Years for Which Respondent's Business Unit Played a Leading Role	Percentage of Total Radical Technologies in 3 Years
1–9	1	0.3
10–99	29	7.9
100–999	25	6.8
1,000–9,999	39	10.6
10,000–99,999	241	65.7
More than 100,000	32	8.7
Total	367	100.0

The US dominance is supported further by the data in **Table 14,** which offers a breakdown of the deployed technologies according to the geographic location of the respondent's business unit.

- Almost certainly owing to Shell's presence, the Netherlands also plays an important role in the industry's R&D activities.
- An equal number of respondents came from Canadian and Netherlands-based companies, but the Canadian respondents reported far fewer deployed technologies than their Dutch counterparts.

TABLE 11—RADICALNESS OF INNOVATIONS BY ORGANIZATION TYPE

Type of Organization	Number of Deployed Technologies in Past 3 Years for Which Respondent's Business Unit Played a Leading Role	Number of Radical Innovations in Past 3 Years for Which Respondent's Business Unit Played a Leading Role	Percentage of Deployed Technologies Considered to be "Radical"
IOC	227	83	36.6
NOC	65	54	83.1
Independent	58	30	51.7
Consultancy	19	12	63.2
Government	2	1	50.0
Service Company	782	155	19.8
Drilling Company	2	2	100.0
Equipment Manufacturer	34	11	32.4
Other	51	19	37.3
Total	1240	367	29.6

TABLE 12—IS INNOVATIVE OUTPUT BETTER IN ORGANIZATION'S HOME COUNTRY?

Is Respondent's Business Unit in Same Country as Organization's World Headquarters?	Number of Respondents	Percentage of Respondents	Number of Deployed Technologies in Past 3 Years	Percentage of Total Deployed Technologies in Past 3 Years
Yes	65	32.7	615	49.6
No	134	67.3	625	50.4
Total	199	100.0	1240	100.0

- Despite the UK's significant footprint in the overall E&P market, respondents from UK-based organizations reported relatively few deployed innovations. A total of 9% of the survey respondents were employed by UK-domiciled companies, but only 3.9% of the deployed innovations came from those firms.
- Although Switzerland is not usually synonymous with E&P innovation, respondents from Switzerland-based organizations reported a surprisingly large number of deployed technologies.

The survey also asked respondents whether the majority of their business unit's technologies were mostly product based, mostly process based, or an almost even mix of the two. The results are shown in **Table 15** and **Fig. 7.** Highlights include:

- Most segments of the E&P market reported that their business units were almost evenly focused on product/component-based innovations and process-based innovations
- Unsurprisingly, service companies had the highest fraction of respondents (40%) who believed that their business units were more focused on product/component types of innovation.

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TABLE 13—GEOGRAPHIC LOCATION OF HEADQUARTERS FOR INNOVATING ORGANIZATIONS

Country	Number of Respondents Whose Organization's World Headquarters is in That Country	Percentage of Total Respondents From This Country	Number of Deployed Technologies in Past 3 Years from Organizations Whose Worldwide Headquarters is in That Country	Percentage of Deployed Technologies That Came From Organizations Whose Headquarters are in This Country
Australia	4	2.0	6	0.5
Austria	3	1.5	7	0.6
Canada	23	11.6	37	3.0
China	2	1.0	0	0.0
Denmark	6	3.0	8	0.6
India	6	3.0	4	0.3
Italy	3	1.5	45	3.6
Malaysia	2	1.0	25	2.0
Netherlands	23	11.6	125	10.1
Nigeria	4	2.0	1	0.1
Norway	8	4.0	25	2.0
Oman	4	2.0	3	0.2
Pakistan	3	1.5	5	0.4
Switzerland	3	1.5	80	6.5
UAE	4	2.0	8	0.6
UK	18	9.0	48	3.9
USA	71	35.7	748	60.3
Other	12	6.0	65	5.2
Total	199	100.0	1240	100.0

TABLE 14—GEOGRAPHIC LOCATION OF BUSINESS UNITS WHERE INNOVATIONS WERE DEPLOYED

Country	Number of Respondents	Percentage of Respondents From This Country	Number of Deployed Technologies in Past 3 Years From Respondents Whose Business Units Are in That Country	Percentage of Deployed Technologies That Came From Respondents Whose Business Units are in This Country
Australia	7	3.5	8	0.6
Austria	2	1.0	5	0.4
Brunei	3	1.5	0	0.0
Canada	26	13.1	39	3.1
Denmark	3	1.5	2	0.2
France	2	1.0	50	4.0
India	7	3.5	4	0.3
Indonesia	2	1.0	1	0.1
Malaysia	8	4.0	33	2.7
Netherlands	10	5.0	93	7.5
Nigeria	4	2.0	5	0.4
Norway	6	3.0	25	2.0
Oman	7	3.5	14	1.1
Pakistan	3	1.5	5	0.4
Qatar	2	1.0	6	0.5
UAE	3	1.5	5	0.4
UK	18	9.0	60	4.8
USA	74	37.2	527	42.5
Other	12	6.0	358	28.9
Total	199	100.0	1240	100.0

TABLE 15—RELATIVE FRACTION OF RESPONDENTS FOCUSING ON PROCESS- AND PRODUCT-BASED INNOVATIONS

Type of Organization	Number of Respondents to This Question	Fraction of Respondents Indicating Majority of Technologies was Product/ Component Innovation	Fraction of Respondents Indicating Majority of Technologies was Process Innovation	Fraction of Respondents Indicating an Almost Even Mix of Product/Process Technologies	N/A or Didn't Create Any Innovations
IOC	34	6	8	15	5
NOC	14	2	3	5	4
Independent	32	7	3	13	9
Consultancy	18	1	6	7	4
Government	5	0	2	0	3
Service Company	30	12	3	14	1
Drilling Company	1	0	0	1	0
Equipment Manufacturer	6	4	1	1	0
Other	9	3	0	4	2
Total	149				

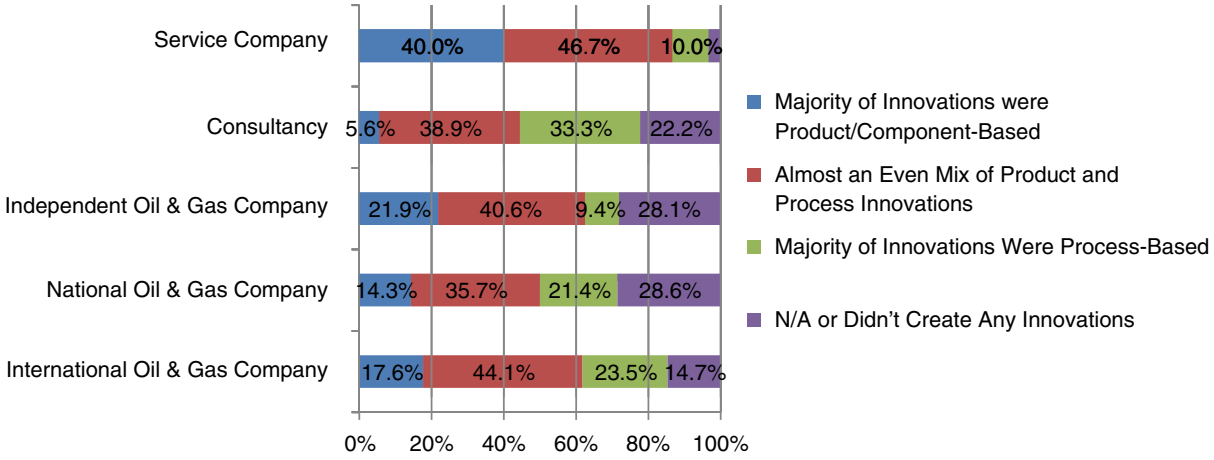

Fig. 7—Relative fraction of respondents focusing on process- and product-based innovations.

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