

EXPLORATION &
PRODUCTION

RESEARCH & DEVELOPMENT

The keys to performance





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E&P R&D IN FIGURES



300
RESEARCHERS

representing

25 NATIONALITIES

work in networks in multi-site R&D teams.

6



research centers

with different areas of expertise are located in close proximity to the regional competency hubs of the oil and gas industry. These centers work in synergy with the nerve center of R&D for Total's Exploration & Production branch in Pau (France).

Houston (United States); Rio de Janeiro (Brazil); Aberdeen (Great Britain); Stavanger (Norway); Lacq (France); Doha (Qatar)



9,000 M²

of laboratories and test sites

are equipped with cutting-edge technologies and large-scale permanent R&D equipment.

- The E&P research center in Qatar has a tool called LIPS (Laser Induced Pyrolysis System) for the automatic quantification and mapping of organic matter in cores.

2/3

OF THE R&D ACTIVITIES

of the Exploration & Production branch focus on cutting costs in line with Total's objective to deliver oil and gas at the most competitive prices.

6.7 PETAFLUPS

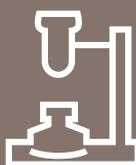
of available computing power (i.e., 6.7 million billion operations per second).



SOME 340 PATENT FAMILIES REPRESENTING 1,700 PATENTS OF ALL NATIONALITIES.

The E&P branch contributes to the Group's ambition to double the number of new patent applications filed per year by 2025.

GROUP-WIDE



912 MILLION DOLLARS

were invested by the **Group** in Research & Development in 2017, including 656 million dollars in innovation and R&D for its oil and gas activities.

OUR SPRINGBOARDS TO PERFORMANCE

The R&D organization is geared up and ready to lend momentum to the Group's ambition: satisfying the energy needs of a growing population by providing safe, clean and affordable energy solutions.

CROSS-FUNCTIONALITY AND SYNERGY

Total made the choice of a centralized R&D organization to optimize the strategy and operational uptake of its research. In addition to the programs run by each branch, other cross-functional R&D programs focus on major themes of key interest to the Group as a whole. We lead many of the research actions under four of these cross-functional programs: CCUS (Carbon Capture, Utilization and Storage), HSE, Numerical (High Performance Computing, Computational Science Engineering, Data Science, Artificial Intelligence) and Prospective Labs (which conduct foresight or exploratory research programs).

BUDGET PRIORITY

Innovation is crucial for addressing the needs of our stakeholders and meeting the challenge of highly competitive technical costs; this will guarantee Total's capacity to operate in a volatile price environment. The 2% increase in research budgets annually between 2015 and 2017, despite a low barrel price, reflects the Group's priority on R&D.

BACK TO BASICS

We have developed the scientific aspect of our R&D considerably. Safety, environment, geology, reservoir and production mechanisms are just a few of the disciplines in which an in-depth understanding of the physical and chemical phenomena at play is absolutely vital. Multiphysics and multi-scale approaches – from nanometer- to basin- or even planetary scale – are required to deliver the conceptual and technological breakthroughs that will push back the boundaries of Exploration & Production.



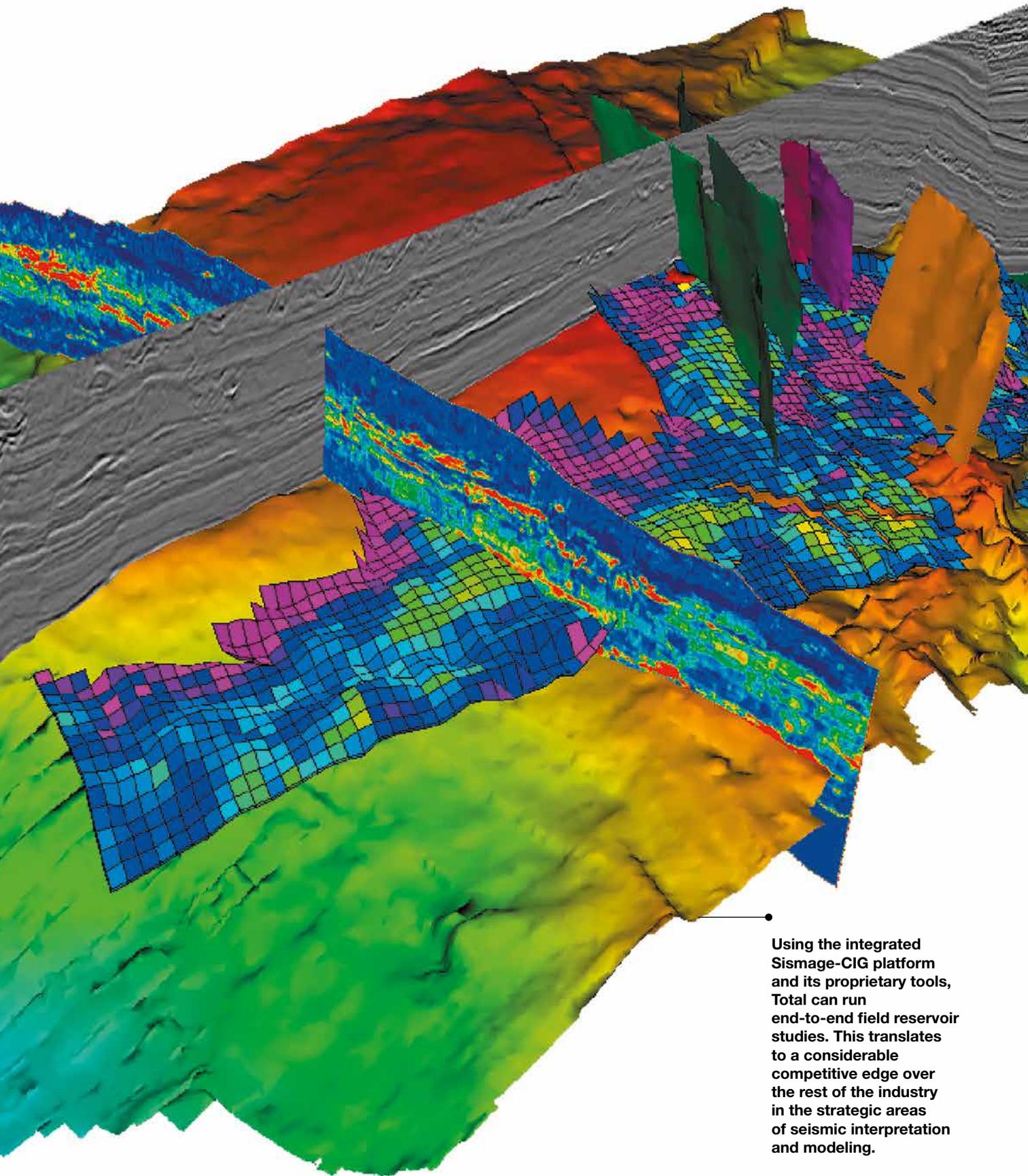
OPENNESS

A proactive scientific and technical watch means that we have our finger on the pulse when it comes to the most promising discoveries made outside the Group, so we can adapt them to our own operations. Our openness is also reflected in our strategic alliances with international academic or industrial leaders, in the form of exclusive joint research ventures on a large scale, over an extended period and with high added value.

GOING DIGITAL

Our supercomputer – one of the industry's most powerful HPC – enables us to achieve high-resolution seismic images and numerical models of the most complex subsurface zones. It's also the kingpin of an R&D organization that is spearheading the digital transformation and already inventing 4.0 asset management solutions that draw increasingly on Big Data and Artificial Intelligence technologies.

In partnership with Alseamar, Total has designed and constructed autonomous subsea gliders, equipped with specific sensors able to detect natural hydrocarbon seeps in the water column. The gliders were deployed in the deep offshore in a world first in 2017. This innovation improves our exploration performance while reducing costs and HSE risks.



Using the integrated Sismage-CIG platform and its proprietary tools, Total can run end-to-end field reservoir studies. This translates to a considerable competitive edge over the rest of the industry in the strategic areas of seismic interpretation and modeling.

FOR OPTIMUM EFFICIENCY

Structuring our R&D initiatives according to Technology Readiness Levels (TRL) guarantees our efficiency in exploring new ideas and assessing their potential, so we can invest in the development of the most promising ones and take them forward to the operations phase.

Drilling in a foothills environment in Bolivia.

AROUND 10 DISRUPTIVE TECHNOLOGIES

are pilot-tested in the field every year to move them up through the Technology Readiness Levels (TRL) and on to industrialization.

RESEARCH

DEVELOPMENT

DEPLOYMENT

TRL

TRL: TECHNOLOGY READINESS LEVEL

PROSPECTIVE LABS

STREAMLINED, AGILE AND RESPONSIVE

The Prospective Labs carry out exploratory research activities on potentially disruptive technologies that are a breakaway from our conventional disciplines. The challenge is to make sure that we take on board any scientific or technological breakthroughs having the potential to bring significant benefits for the Group, as far upstream as possible.

Devoted to targeted themes and staffed by small, flexible and responsive teams, the Prospective Labs are built on partnerships with scientific teams. They have a limited lifetime, which is conducive to quickly transferring their outcomes forward. This ensures a fast-paced renewal of our Prospective Labs portfolio.

We are in charge of five labs under the cross-functional Prospective Labs program for 2018: Sensors, Nanotechnologies, Robotics, Environmental Microbiology, Computer Vision & Artificial Intelligence.



PROGRAMS

THE POWER OF R&D

The R&D Programs focus on core areas for the future of Exploration & Production, where excellence is the prerequisite to keeping Total among the front-runners. In each critical area, our aim is to deliver game-changing innovations a step ahead of our rivals.

The Programs are a central link in the R&D chain; they are entrusted to multi-site teams – often divided among several of our international research centers – to better take advantage of the competencies available in our regional excellence hubs.

Overflowing with ideas and driven to succeed, the teams federate a community of top-level researchers, experts and PhD students with complementary backgrounds and areas of expertise, all working together to achieve shared objectives while adhering to carefully orchestrated timelines.

PLATFORMS FOR INNOVATIVE TECHNOLOGIES (PIT)

BRIDGES BETWEEN R&D AND OPERATIONS

The PIT are the final link in the R&D chain and serve a dual purpose:

- To carry innovations from the Programs or Prospective Labs through to industrial upscaling, promoting their use in the studies, projects and operations of the Exploration & Production branch; and
- To advance the development of know-how in the Exploration & Production branch.

Supervised by the Technical Divisions, the PIT carry out the work program defined as part of the R&D budget. For 2018, fourteen PIT cover all the technical areas and product lines of the Exploration & Production branch and catalyze the operational uptake of innovations.

OUR STRATEGIC PROGRAMS

A “one-step-at-a-time” approach to R&D is no longer sufficient to overcome the increasing difficulty of discovering and producing new resources. Today’s challenges demand disruptive solutions – an imperative reflected in the ambitious objectives of our R&D programs.

Tufa towers in Mono Lake (California). The Frontier Exploration R&D teams work to identify basins likely to contain carbonate systems with high reservoir potential, combined with prolific petroleum generating systems.

8 themes

FRONTIER EXPLORATION

Inventing geological concepts to redefine the map of possibilities for oil and gas exploration: both demanding and stimulating, this major objective for the Earth's energy future requires us to look again at the potential of proven basins and try to pinpoint new ones.

EARTH IMAGING

Remote sensing; an airborne multiphysics acquisition system for the real-time imaging of foothills and new-generation algorithms: these examples show how we are innovating at every step along the geophysical chain, from data acquisition to processing. We want to eliminate obstacles to exploration and get value-adding 3D ultrasound scans of the subsurface to our geoscientists and drillers as quickly and cost-effectively as possible.

FIELD RESERVOIR

Large volumes of resources lie dormant underground failing economic solutions to produce them. To bridge this gap, we are directing our efforts at: understanding the physical-chemical phenomena at play in reservoirs from molecular to field scale; optimizing the data management workflow; developing a new generation of reservoir modeling tools; and designing low-cost enhanced recovery techniques.

GAS SOLUTIONS & SUSTAINABLE DEVELOPMENT

Natural gas emits half as much CO₂ as coal in power generation applications. Increasing the share of natural gas in Total's portfolio and ensuring rapid deployment of CCUS solutions are therefore crucial to curbing climate change. Our investment in these topics goes hand in hand with developing innovations that lead to projects with the lowest possible environmental impact and controlled costs, consistent with regulatory changes and the evolving expectations of both our stakeholders and civil society.



WELLS

Real-time access to bottomhole (while drilling) and well production data is one of the main thrusts of our work. Our twofold objective is to maximize the safety and operational efficiency of wells from drilling to plugging and abandonment, and to enhance their cost-effectiveness.

DEEP OFFSHORE AND NEXT-GENERATION FACILITIES

Cost reduction is the main driver for work under this Program. The aims here are to cut technical costs by 50% by 2025 through "full subsea" solutions, develop disruptive technologies for achieving profitable exploration and development of assets in over 3,000 m of water; and invent game-changing operating strategies for tomorrow's conventional assets to boost cost-effectiveness without the slightest compromise on safety.

UNCONVENTIONAL

Fundamental research (multi-scale characterization of source rocks, hydrocarbon genesis and expulsion), advanced scientific calculations to simulate hydraulic fracturing, and technical innovations to optimize recovery – all these lines of research converge to guide Exploration to the most promising plays and provide the technological keys to cost-effective, responsible production.

Nanofiltration pilot to eliminate sulfates from injection water. The Platform for Experimental Research in Lacq (PERL) is investigating innovative injection and produced water treatment techniques, in particular membrane filtration.

NUMERICAL

Computational Science Engineering and Data Science are the two pillars of our numerical research aimed at developing more effective, more economical methods and technologies across the entire Exploration & Production chain. Specific targets include achieving multi-scale, multiphysics numerical simulations of complex phenomena, and developing tools to support data analytics and decision-making through machine learning and artificial intelligence.

DISRUPTIVE INNOVATIONS

Driven by the boldness of a Group with numerous world firsts to its name, our teams deliver results to match our ambitions. Here is a brief overview of some recent innovations that will help redefine our exploration and production methods.

June 2016

Start-up of the industry's first all-electric subsea well (K5F, The Netherlands, North Sea)

It paves the way for all-electric subsea production systems that are more cost-effective and efficient than their hydraulic counterparts. Our wellhead design is currently the reference case for the development of an international standard for the industry. Several IOC and NOC have joined us to work in two JIP kicked off with TechnipFMC, OneSubsea and Aker Solutions to develop the next generation of all-electric Christmas trees. Total owes its vanguard position in this technology to its foresight: the Group has already spent over a decade investigating deep offshore architectures designed to cut the cost of subsea tiebacks, which will need to stretch over increasingly long distances in the future.



March 2018

Kick-off of the industrial pilot for the first autonomous surface robot

The first autonomous surface robot tailored to the oil and gas industry will be operating on our installations by 2020. Able to work in potentially explosive environments (ATEX) and conduct routine inspections in normal or downgraded conditions, it will be one component of our future non-permanently manned operated architectures. This is a perfect illustration of how effective R&D's open innovation strategy can be at diversifying and optimizing our academic and industrial partnership networks. The robot won the ARGOS Challenge (2014-2017) – an international contest that enabled us to build an R&D prototype of the solution in under three years.



January 2019

Kick-off of the BIOMEM pilot for produced water biotreatment in Gabon

BIOMEM is a solution for the biotreatment of produced waters and one of the rare technologies compliant with new regulations concerning the absence of significant toxicity in aqueous effluents near sites. It combines cutting-edge technology and cost-effectiveness: four times less expensive than a process for extracting dissolved solids using solvents, 50 to 100 times more compact than standard biological processes, it significantly speeds up the water purification process while reducing overall toxicity levels by approximately 85%. The ultimate deliverable is a process suited to offshore installations, where the available surface area is limited.



December 2017

METIS® demonstration pilot in Papua New Guinea

Remote sensing, airborne technologies, drones, disruptive wireless sensor technology and artificial intelligence: METIS® (Multiphysics Exploration Technology Integrated System) was designed to change the way exploration is done in complex landlocked zones such as foothills, even with dense vegetation. By reducing the costs and environmental impacts of data acquisition surveys, METIS® paves the way for real-time imaging, which will be used to readjust acquisition parameters when necessary, thereby mitigating the risks of exploration in complex areas.



October 2018

Large-scale controlled gas-emission detection tests on TADI

TADI (Transverse Anomaly Detection Infrastructure), the only test facility of its kind in the world, is used to develop a digital approach to preventing major accidents caused by gas leaks. This open-air site occupies 2,000 m² at the Platform for Experimental Research in Lacq. It can be used to reproduce real-world scenarios with controlled gas emissions and to pilot-test remotely-controlled technologies for gas detection, localization and quantification. This new approach is based on detecting anomalies well upstream by using low-cost sensors and a real-time mass data acquisition/processing/analytics system. The benefit? Diagnostics and recommendations, optimized by artificial intelligence, that give operators the advantage of decision support without exposing them to risks in the field.



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Total is a major energy player committed to supplying affordable energy to a growing population, addressing climate change and meeting new customer expectations.

Those commitments guide what we do. With operations in more than 130 countries, we are a global integrated energy producer and provider, a leading international oil and gas company, and a major player in low-carbon energies. We explore for, produce, transform, market and distribute energy in a variety of forms, to serve the end customer.

Our 98,000 employees are committed to better energy that is safer, cleaner, more efficient, more innovative and accessible to as many people as possible. As a responsible corporate citizen, we focus on ensuring that our operations worldwide consistently deliver economic, social and environmental benefits.

Our ambition is to become the responsible energy major.



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Share capital: €6,207,262,032.50
Registered in Nanterre: RCS 542 051 180

Exploration & Production (Paris)
Tel.: +33 (0)1 47 44 45 46
2, place Jean Millier – La Défense 6
92078 Paris La Défense Cedex – France

Exploration & Production (Pau)
Tel.: +33 (0)5 59 83 40 00
Avenue Larribau
64018 Pau Cedex – France
www.total.com

