# THE LSBB URL: A NEW PLATFORM FOR FUNDAMENTAL & APPLIED LOW BACKGROUND INTER-DISCIPLINARY UNDERGROUND SCIENCE & TECHNOLOGY

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## INTRODUCTION

The LSBB platform is dedicated to fundamental and applied research in a favorable geological environment with low environmental and anthropogenic back-grounds allowing multidisciplinary developments. The exceptional potential of its properties allows interdisciplinary innovations at national, European and international levels. The URL facility enjoys a unique natural environment in the Luberon Regional Natural Park with a low human impact and gives access jointly:

- Within the shallow and deep unsaturated and saturated zones of the Fontaine-de-Vaucluse aquifer, France (Emblanch *et al.*, 1998; Garry *et al*., 2008),
- Within a carbonate platform in Urgonian facies analog to oil fields of the Middle East (Masse, 1968, 1993; Puig, 1987; Jurgawczynski, 2007),
- Within the seismogenic area of Provence (Champion *et al.*, 2002; Baumont & Cushing, 2010).

The LSBB's infrastructure represents in broad strokes, 54 ha in surface area, 4 km long horizontal drifts at a depth ranging from 0 to 518 m, with NS and NNW main orientations. The galleries give notably access to underground vaults and voids, a clean room, and an electro-magnetically shielded space of $\approx 1250\ m^3$ with a residual noise of $2\ fT/\sqrt{Hz}$ above 40 Hz. The underground drifts and surface areas are connected to energy, telephony, optical fiber Internet, and GPS synchronization. This unique environment with specific properties allows the emergence of interdisciplinary research programs involving solid earth, atmosphere, astronomy, astrophysics, geology, rock mechanics, radiative environment, physics, engineering, metrology, electronic, contemporary history (*i.e.* the old war) and life sciences, including:

- Fundamental research (Collar *et al*., 2000a, 2000b, 2000c; Waysand *et al*., 2000; Girard *et al*., 2005a, 2005b, 2011; Girard & Giuliani, 2007, 2011; Bordes *et al*., 2006, 2008; Felizardo *et al*., 2008a, 2008b, 2010a, 2010b, 2011; Lesea *et al.*, 2007, 2008; Yedlin *et al.*, 2009; Shahidi Zandi *et al.*, 2011; Maufroy *et al.*, 2012a, 2012b; Pozzo di Borgo *et al.*, 2012),
- Applied research and demonstrators of industrial compagnies (Lesea *et al*., 2005, 2007, 2008; Cheminet *et al.*, 2011),
- Tests and developments of new instruments and metrological concepts (Schultze *et al.*, 2002; Yedlin *et al.*, 2009; Reich *et al.*, 2008; Ebert *et al.*, 2008; Andrieux *et al.*, 2011; Henry *et al.*, 2008; Cheminet *et al.*, 2011; Febvre & Reich, 2010; Chawah *et al.*, 2012).

As a whole the LSBB URL associates geo-environmental issues, tools for academic and industrial research, and an engineer team providing development and adaptation for the optimal integration of experiments within the facility. These assets push the LSBB a worldwide unique interdisciplinary platform, steered by the Universities of Nice and Avignon, and by the CNRS.

The practice of interdisciplinarity by the LSBB led to sign scientific agreements to strengthen the relationships with the University of British Columbia, Canada, and with the Universities of Aix-Marseille, Chambery and the Côte d'Azur' Observatory, France. In a similar approach, the LSBB URL contributes to the worldwide networking effort among Underground Research Laboratories endorsed by J.S.Y. Wang (LBNL/ESD, Berkeley), J.A. Hudson (Imperial College, London), and Xia-Ting Feng (ISRM President, http://www.isrm2011.com) for international, inter-disciplinary innovations (Gaffet & Wang, 2009; Wang et al., 2010; Salin et al., 2011a, 2011b).

## FUNDAMENTAL & APPLIED RESEARCH, OBSERVATORY

The LSBB is an inter-disciplinary platform that allows the observation, characterization and modeling of the terrestrial, atmospheric and nearby universe with approaches developed in the frame of national and international collaborations with the CFN (Lisbonne, Portugal), UBC (Vancouver, California), Hertford (Oxford, United Kingdom), Dept. EEE (Bath, United Kingdom) that integrate the following active themes in 2012.

*Reservoir & resources:* The addressed issues are related to water resources in the context of global changes integrating the interactions between the environmental and the population evolutions. It mainly concerns the karst groundwater resources and the knowledge of carbonate platforms operation. The countries that border the Mediterranean basin are concerned by these issues. Research addressed several approaches within the LSBB URL that concerns for instance the carbonate platform, the porous fractured reservoirs, the imaging and modeling of the dynamics and heterogeneity of water transfers in the unsaturated zone shallow and deep karst (Yedlin *et al.*, 2009; Gaffet *et al.*, 2010; Sénéchal *et al.*, 2012).

*Fluid vs. rock interactions:* The carbonate reservoir can be accessed through the drifts assimilated to kilometric horizontal wells and through vertical and horizontal wells drilled from the galleries. These capabilities allow

the development of research programs on poro-elastic dynamics in fractured media (petrophysics, THM couplings ...), on geomechanics and induced seismicity, and more generally the handling of fluids and gas in porous and fractured media (Cappa *et al.*, 2005, 2006; Derode *et al.*, 2011).

*Wave propagation & radiative environment:* This theme focuses on the coupled processes discussed notably from the perspectives of the seismology, of the Earth magnetism, of the electro-magnetic perturbations, of the radiation of particles (gammas, neutrons, muons), and of the search for particle dark matter candidates (weakly interacting massive particle, WIMP). The related issues concern the seismic hazard (*e.g.* site effect), the electronic hazard (*e.g.* SEU), the monitoring of water and of the rheological properties of rocks, the internal damaging of rock massifs, the seismo-hydro-magnetic couplings, or the space weather (Girard *et al.*, 2011; Fullekrug *et al.*, 2011, 2012; Cheminet *et al.*, 2011; Maufroy *et al.*, 2012a, 2012b; Pozzo di Borgo *et al.*, 2012).

*Metrology, instrumentation and measure:* The low noise environment of LSBB is made possible on the one hand by the low human impact preserved by the Regional Natural Park of Luberon (*i.e.* absence of highways and railways, no heavy industry or power lines 10 km around) and on the other hand by the initial hardened design of the military infrastructure. It allows applied research programs to develop new highly sensitive sensors (*e.g.* optical strainmeters, tiltmeters and seismometers, muon telescopes for rock densitometry, cold atom gravimeter, ...) whose performances can be tested and cross-compared in a multi-disciplinary environment.

*Solid Earth, atmosphere & nearby universe observatory:* Deployed within the LSBB platform, observation networks record continuous data which allow to follow the temporal evolution of physical processes that may impact the environment of the experiments processed at LSBB. These measurements are made available through http://www.lsbb.eu with notably *(i)* a seismic 3D antenna consisting of 6 Streckeisen STS2 velocimetric sensors (Gaffet *et al.*, 2003, 2009) broadcasted nationally and internationally towards ORFEUS and IRIS-DMC data centers, *(ii)* a superconducting quantum interfero-metric device magnetometer located within a shielded vault qualified for ionosphere detection (Henry *et al.*, 2008; Marfaing *et al.*, 2009, 2011; Waysand *et al.*, 2009, 2011a, 2011b), *(iii)* a continuous hydrogeological monitoring (Garry *et al.*, 2008; Blondel *et al.*, 2010), and *(iv)* a continuous monitoring of gamma and neutron radiations in surface and within the galleries (Cheminet *et al.*, 2011)

## INDUSTRIAL AND SOCIETAL ISSUES

In parallel to the developments of the potential for applied and fundamental research, the industrials and local authorities have developed strong interests for LSBB in two main areas *(i)* The first one is related to the natural environment of LSBB, *(ii)* the second considers the infrastructure and its properties as a means of testing, a facility for demonstration and for implementation of innovative technology (Lesea *et al*., 2005, 2007, 2008; Cheminet *et al.*, 2011) in relation with the industrial clusters. These fields of interests allow establishing collaborations with a high added value held by the LSBB platform for the industrial partnership.

The two example fields described below benefit from LSBB and have a strong impact for sustainable development and human society; they are related to energy and water resources. These areas confirm the interest of industrials to access open test facilities, allowing them to test and compare ideas in a multi-partnership academic environment prior developing any phase of applied research or prototype development.

*Energy:* In the oil industry, 60 % of the world resources are stored in carbonate reservoirs (Bush, 2010). They represent 40 % of the reserves of the future (Pabian, 2010). Their exploitation interferes with the water circulation which remains constitutive of the reservoirs. It is thus necessary to understand the dynamics of water transfers in carbonate reservoirs to optimize the exploitation of oil resources. The oil industry needs methodologies to be developed on easily accessible geological analogs in order characterizing the operation of carbonate reservoirs and their multi-scale heterogeneity to optimize the productivity of oil fields in exploitation. A major issue for the resolution of this problem lies in the identification of the physical processes involved during fluid transfers that requires the use of multi-physic experiments and modeling that associate for instance measurement and excitation of mechanical waves, electric and electro-magnetic sounding, or particle characterizations (gamma, neutrons, muons ...). Facing this problematic, the LSBB provides a strong potential since it allows access to surface and to underground within the Bedoulian to Barremian levels with Urgonian facies, and the ability to drill wells reaching the saturated area of the aquifer.

*Peri-mediterranean underground water resources:* The karst systems contain important groundwater resources for the global supply of fresh water (Ford & Williams, 2007). Karst formations cover 35 % of the European territory and 10 % of the Earth's land area. They provide to countries from 5 to 50 % of the fresh water needs and sometimes all the groundwater collected for this purpose (Bakalowicz & Dörfliger, 2005; Bakalowicz, 1998). Unfortunately, this water is extremely vulnerable, limited and unevenly distributed, it is vital for the adaptation of societies and territories in terms of global environmental change. The watershed of Fontaine-de-Vaucluse, the broader karstic aquifer in Europe with chronicles of more than 140 years, includes the LSBB along its southern border. This

karstic system contributes to the federation of scientific initiatives in the frame of national and international hydrogeological networks systems for the long term observation and experimentation for research in environment (*i.e.* SOERE "*National watershed*" and "*H+*" networks) labelled by the alliance ALLENVI (http:// www.allenvi.fr) and by the French Research Ministry.

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