AgroTechnoPôle platform for the development of new technologies and services for the agro-ecological transition

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Abstract

The agro-ecological transition is now a priority stated by public authorities and shared by more and more socio-economic players, in which agricultural equipments have a key role to play in the adoption of new agricultural practices (e.g. reduction in the use of plant protection products, crop diversification, low-carbon energy solutions, etc.), aimed at triple economic, environmental and social performance. The AgroTechnoPôle platform, launched officially in early 2022 and supported by INRAE, is firmly positioned to take up this challenge and help accelerate the development of new technological solutions to meet the challenges of tomorrow's agriculture.

The AGRITECH DAY by AXEMA conference on 5 November 2022 gives the opportunity to the AgroTechnoPôle to present more in details its new infrastructures and also the existing facilities which can be mobilised actually by the external actors. In this way, three Lead Companies will testify their interest and contribution to the AgroTechnoPôle platform.

1. Introduction

The AgroTechnoPole is a platform supported by INRAE at the service of all stakeholders for the development of their technological and digital solutions in line with the requirements of the agro-ecological transition. After a general presentation of the AgroTechnoPole's positioning (point 2) and illustrations of existing equipment and infrastructures that can be mobilized by the AgroTechnoPole's partners (point 3), the article will focus more specifically on the description of the new infrastructures that the platform will acquire by 2024 in order to respond to and accelerate the agroecological transition.

2. General presentation of the AgroTechnoPôle platform

The AgroTechnoPole - as illustrated in Figure 1 - is an open platform at the service of all players (manufacturers, equipment suppliers, technical institutes, technology clusters, research laboratories, etc.) to support them in their development of technological and digital solutions for the Agroecological Transition.

It allows to accelerate in its strong fields of action both incremental innovations (improvements of existing machines) and breakthrough innovations (new machines, processes) to meet the challenges of agriculture.

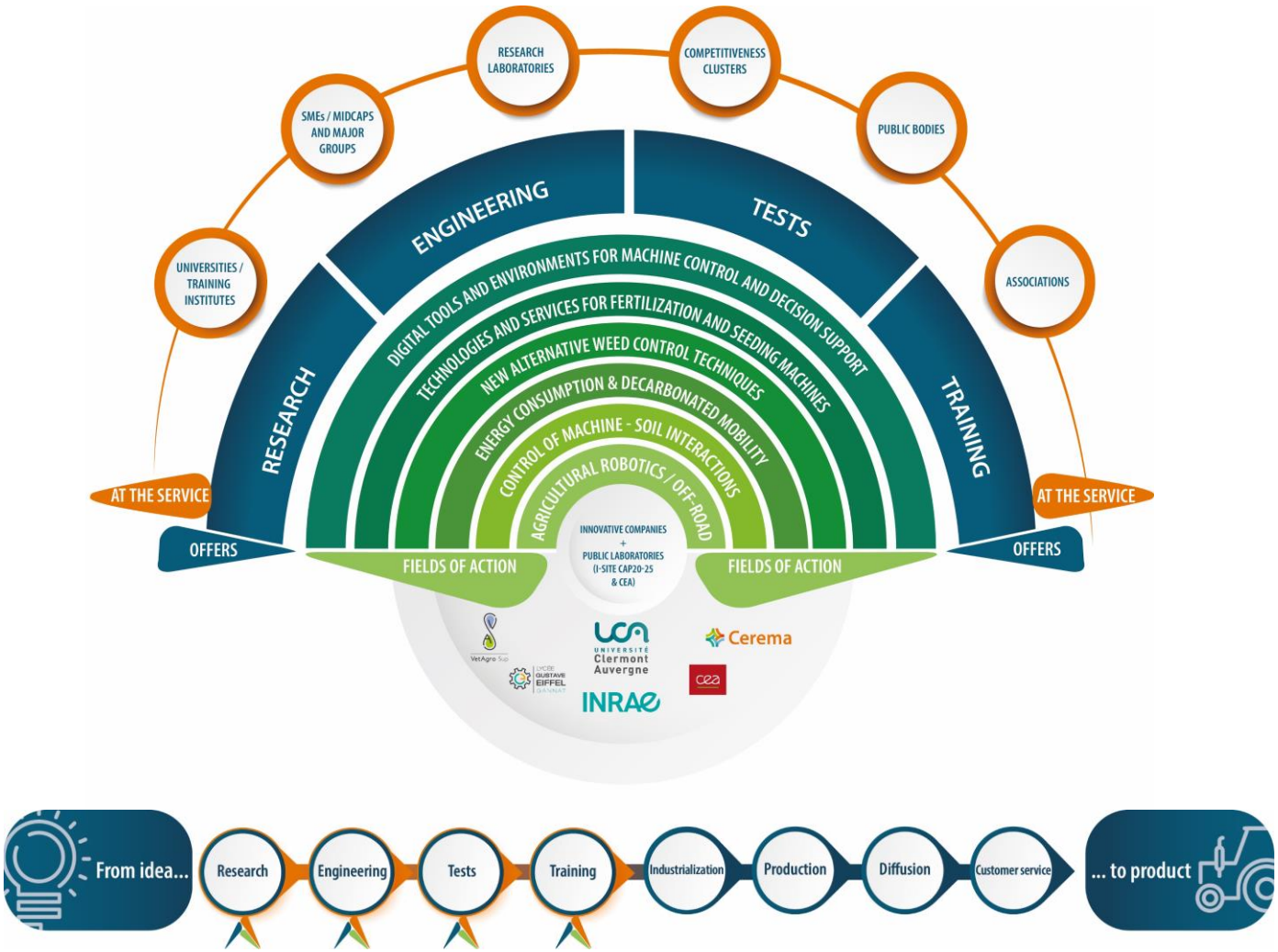

Figure 1: Positioning of the AgroTechnoPôle platform

The AgroTechnoPole is particularly involved in the development of new tools / machines / services for agriculture that are more efficient in terms of execution of localized tasks, respect of the environment (reduction of Greenhouse Gases, soil protection ...).

The targeted fields of application mainly concern technologies for crop production, including machines (robotized or not) for tillage, sowing, fertilization, alternative weeding techniques, and harvesting, as well as those involving new practices.

The platform - in which the TSCF Research Unit of the INRAE-Clermont-Auvergne-Rhône-Alpes Centre plays a central role - is based on its ability to mobilise multiple skills from its Academic Partners (CEA, CEREMA, Clermont-Auvergne-UCA University, VetAgro-Sup, LP Gustave Eiffel, INRAE) and/or its specialised Innovative Company Partners (Mechatronics/Robotics, Terramécanique, AI, IoT, Modelling/Simulation, etc.) to conduct different types of projects in terms of RESEARCH, ENGINEERING, TESTING and TRAINING.

The platform can rely on the various networks of its Members representing Professional Collectives (composed at the beginning of 2022 of AXEMA, RobAgri, the CIMES & VEGEPOLYS VALLEY Competitiveness Clusters) or its membership in the Carnot Institute Plant2Pro and the CAP20-25 I-Site in Clermont-Ferrand to disseminate its offer, its expertise and its know-how to the actors of different value chains (technological, agricultural productions).

3. Means already existing within the AgroTechnoPôle platform

The AgroTechnoPole already has many existing facilities and infrastructures that it can quickly mobilize with its partners according to the problem addressed.
As examples, we cite some of the equipment and infrastructures already available:

- With AgroTechnoPôle partners :

- Reverberation chamber with mode mixing of the Institut-Pascal - UCA for EMC tests (Photo 1).
- Rain and fog platform of the CEREMA for the ARPA 2 robotic safety tests under the test operator status for AgroTechnoPôle (Photo 2).
- 100 kW fuel cell test bench of CEA (Photo 3).
- Augmented reality platform of the LAPSCO - UCA.

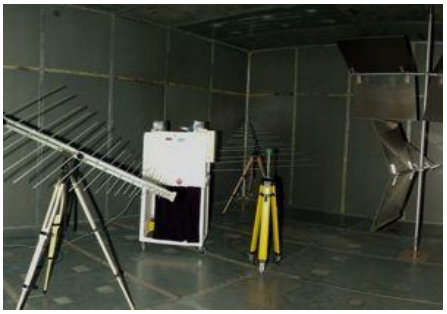

Photo 1: Mode mixing reverberation chamber (IP)

Photo 2: Rain and fog platform

Photo 3: Test bench for 100 kW fuel cells - CEA

- **On the privileged site of the AgroTechnoPôle - INRAE -TSCF located in Montoldre (03) :**

- Laser tracker (Photo 4), a high precision field reference tool for dynamic positioning of machines.
- Robotic mobile platforms (Photo 5) to support the development of new perception/control/command algorithms in terms of gripping, high-speed mobility, ...

- Monoroue (Photo 6) for the characterization of the efficiency of tires.

Photo 4: Reference positioning tool (XYZ precision 1/100 mm)

Photo 5 : Robotic mobile platforms

Photo 6 : Monoroue

Existing infrastructures such as the "cross track (Photo 7)", "inclined profiles", and «seted up plots (Photos 8 and 9) already make it possible to conduct qualification tests relating to the qualification of the performances of agricultural robots.

Photo 7: Cross track - ARPA1 tests with Sitia robot

Photo 8: Field-tests - ARPA3 - Agreenculture robot

Photo 9: Plot with SONY ROMI robot during the METRICS - ACRE challenge

These experimental supports have supported the TSCF research unit in conducting the ARPA (Agricultural Robots Performances Assessment) project for the development of new test protocols for the safety of agricultural robots, carried out within the framework of the European DIH (Digital Innovation Hub) AgROBOfood with the involvement of industrial partners AgreenCulture, VITIBOT and SITIA.

The results obtained are now contributing to the construction of the second version of the ISO 18 497 standard and the OECD test code for the safety of agricultural robots. They will be presented on October 28, 2022 at the TEC (Test Engineers Conference), which brings together engineers from the test stations of OECD member countries.

The test services for the qualification of robot performances (safety and beyond) are already available under the leadership and responsibility of the Partner SHERPA- Engineering under the status of test operator of the AgroTechnoPôle.

To date, other research projects are already conducted in AgroTechnoPole mode and many others are being set up.

4. New infrastructures of the AgroTechnoPôle

The AgroTechnoPole claims a differentiating positioning with the development of solutions and the qualification of performances "from the Bench to the Field" under controlled and therefore reproducible conditions thanks to the skills gathered and its unique means (infrastructures and equipments).

The new infrastructures - presented below - are, since the official launch of the platform in 2022, technically and financially supported by BUREL PRODUCTION, KUHN, MICHELIN and SHERPA-Engineering as the first Leading Company Members of the AgroTechnoPole.

The following six sections give a perspective and overview of the composition of the future facilities being defined and built on the privileged site of the AgroTechnoPôle based in Montoldre in the Allier (03).

4.1 Section 1 : Tracks and development areas for agricultural / off-road vehicles

As agricultural / off-road machines and equipment are becoming increasingly efficient thanks to their new functions (based in particular on the increased development of on-board artificial intelligence), it is essential to qualify them in an advanced and reproducible manner.

To this end, the AgroTechnoPôle platform will be equipped with new tracks and development areas (Figure 2) and associated field reference equipment (measurement and data collection tools), thus offering a range of perfectly defined and calibrated experimental conditions.

Different obstacles (negative or positive, reproduction of different crop rows, etc.) can be placed throughout Section 1 according to the specific needs of each project.

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Figure 2: Representation of the future tracks and development areas of the Montoldre site

Among the different zones, we should mention "Zone A", which is perfectly flat and made up of different types of hardness of ground (different types of surface). This track will also include a section equipped with standardised exciter blocks that will allow the dynamics of the vehicle/tools combinations to be accentuated. A tangential zone ("Zone Abis") of agricultural land will increase the range of test configurations.

Zone B (with a surface area of more than 1.5 ha) will allow for long-term tests (e.g. robot

endurance tests) in complete safety thanks to its monitoring tools and safety devices (including impassable deep ditches around the periphery).
The zones ("C and C-bis") with different slope profiles (15, 20, 25 and 30%) as well as the "crossing" Zone D (slopes 40 and 60%) will allow the performance of vehicles to be qualified under more difficult working conditions.

4.2 Section 2: huge bins soil with different clay levels

The passage of agricultural machinery on agricultural plots leads to soil compaction with an impact and modification of soil structures.

Figure 3: Modelling of future bins soil at the Montoldre site

In order to characterise the impact of vehicles/machines/implements in detail and to encourage the development of new technological solutions and practices that respect the soil, the AgroTechnoPôle will be equipped with four large soil bins (Figure 3) (120m x 30 m). These bins will be composed of four different clay rates (7%, 10%, 25% and 70%) with a thickness of 0.4 m. They will be complemented by 4 deep pits with the same clay content over a 1.5m horizon. All of these installations will have associated measurement means (pressure probes, humidity, etc.) and irrigation possibilities to modify the characteristics according to the soil.

The originality of this Section 2 is to offer 4 different homogeneous soil types on the same site, allowing the objective and quantified evaluation of technologies under repeatable and controlled conditions. These supports will be used for all kinds of purposes and investigations as well as for the characterisation of traction efficiency in a tyre/soil linkage scheme, work on motricity and associated energy output, trajectory tracking or the adaptability of robots to changing soil textures. They could also be used to characterise sub-assemblies with regard to agricultural machinery/soil interactions, such as the seeding elements of seeding machines. These resources will be used to feed the numerical models that accompany any new development.

4.3 Section 3: Digital twins (modelling, simulation) for agricultural robotics

Digital environments and in particular digital twins (example Figure 4) are now indispensable tools for accelerating new technological and digital developments.

The AgroTechnoPôle platform has chosen to develop and propose these virtual tools in its offer of RESEARCH / ENGINEERING / TESTING / TRAINING activities for its interested external partners.

The Digital Twins workshop proposed for agricultural robotics initially integrates different sub-assemblies. The first sub-assembly allows the robot itself to be modelled (dimensional characteristics, transmission stages, steering actuators, etc.) with varying degrees of representativeness to be agreed. A second sub-assembly models the various sensors (proprioceptive or exteroceptive) used, including interaction models with the environment, but also disturbance models of varying degrees of sophistication. User-friendly interface tools allow the implementation of scenarios reproducing the machine's use situations. This last subset includes a digital model of the robot's evolution space which, in our case, will correspond to and reproduce exactly the privileged experimental site of the AgroTechnoPôle of Montoldre (03) with its plots of land, its operating roads, its new external infrastructures in the process of being built, and its existing and new buildings (see Figure 4 below).

Figure 4: Digital model of the Montoldre site

The strength of the AgrotechnoPôle's offer will lie in the layout and faithful juxtaposition of this 3D digital model with the real physical environment of the entire Montoldre experimental site. Once the results have been validated upstream in the virtual world, the partner will find exactly the same evolutionary environment in the downstream development phases of its solution. Interactions between the virtual world and the real world will of course also be possible within the framework of HIL "Hardware In the Loop" approaches.

The developments of this digital twins workshop, which has now been defined and will soon enter its implementation phase with the involvement of specialised players in the field, will constitute a powerful virtual tool for the implementation of, for example

- the design of new agricultural robot architectures and the evaluation of their dynamic

behaviour even before the first physical prototype is produced, thus providing significant advantages in terms of saving time and money

- qualification of the performance in terms of mobility, energy motorisation, safety functions, etc. of agricultural robots and vehicles prior to full-scale physical testing campaigns.
- development and evaluation of high-level supervision tasks (cooperation of homogeneous and heterogeneous robots, communication links, etc.) or any other characterisation concerning the development of AI-based modules, deep learning facilitation, database creation, preventive maintenance, training, etc.

The Digital Twins workshop in an exploitation mode will guarantee the industrial partner all the confidentiality in the conduct of developments and exploitation of results.

4.4 Section 4: Energy bench & decarbonated mobility

In a current production system that is still mainly very energy-intensive and polluting, it is essential to be able to characterise the parameters and impact of the motorisation/drive sources of current machines, but also to accelerate the implementation of more virtuous energy sources in terms of sobriety and decarbonated mobility, such as electric power for example.

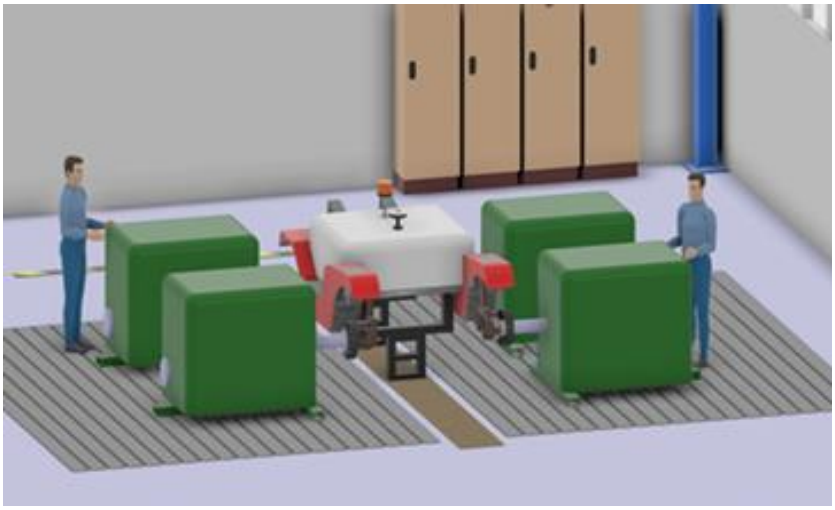

Figure 5: Schematic representation of the future Research and Test Bench on Decarbonated Mobility

In this respect, the AgroTechnoPôle platform has been working for several months on the definition and acquisition of a test bench (Figure 5) dedicated solely to small and medium-power vehicles/robots. This research and test bench will make it possible to reproduce consumption cycles by applying brake/motor torques to the drive shafts as well as the load under controlled conditions of various types of auxiliary plugs (mechanical, electrical, etc.) in order to qualify energy yields and autonomy according to different action/use strategies of agricultural machines and robots defined in the form of scenarios. If the owner of the data authorises it, it can also be used to feed more massive databases used, for example, by Life Cycle Assessment (LCA) methods or predictive models based on artificial intelligence.

4.5 Section 5: Characterisation bench for new alternative weed control solutions

Agro-ecological imperatives require the implementation of new practices in the field of weed control for the elimination of weeds in the inter-row and increasingly within the intra-row itself.

Figure 6: Simplified diagram of the future research and test bed on alternative weed control systems

The AgroTechnoPôle platform wishes to actively contribute to these objectives by setting up a research and test bench (Figure 6) to characterise new alternative solutions for weed control in open fields.

The aim will be to provide manufacturers of weeding machines (robotised or not) or weeding system equipment manufacturers with a first level of qualification of the performance of their Perception, Decision and Action system in terms of precision and speed of execution in a totally controlled environment.

The bench is designed to be adapted to all Perception/Decision systems (using AI module or not) and all types of localised actions (mechanical, localised chemical, laser, ...)

This approach will allow to qualify the performances in artificial conditions and thus totally controlled and reproducible. The research and test bench will facilitate the development and ensure the optimal functioning of the tested system before its implementation in the field in a real situation. For this last stage, the AgroTechnoPôle - UR TSCF is already in a position to provide methods and know-how, based on its work carried out as part of the organisation of the national ROSE Challenge (2018-2021) [https://www.challenge-rose.fr/], and then the METRICS-ACRE Challenge [https://metricsproject.eu/agri-food/acre-competition/] conducted on a European scale (2020-2023).

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4.6 Section 6: Research and test bench for the characterisation of sowing materials

Among the operations that make up the technical itinerary of the crop production cycle, it is certainly the sowing operation that is already reflected in the field by a spectacular evolution of practices in full participation and support of the agroecological transition. Associated crop sowing (e.g. several varieties of wheat sown together, companion plant sowing, multi-species sowing) planted at different densities, depths, spatial distributions, etc. are now offered by many sowing machine manufacturers.

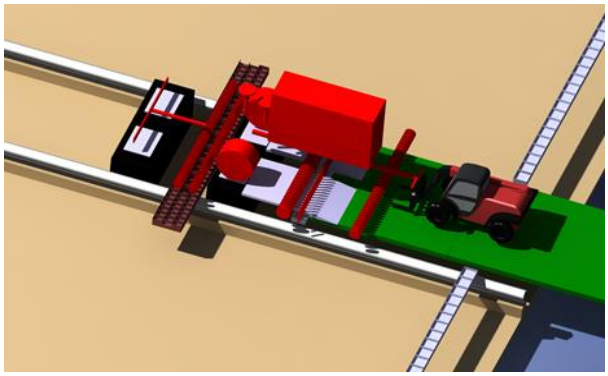

Figure 7: Schematic representation of the future seed material characterisation bench

In order to accompany and reinforce the development of seeding equipment in the fields of spatio-temporal seed placement precision in the soil, the AgroTechnoPôle platform, questioned and encouraged for a long time by certain manufacturers (cf. names of two authors of this article), has decided to develop a first research and test bench (Figure 7) intended to characterise the Transversal and Longitudinal distributions of the seeds at the exit of the seeding units of seeding machines. A second bench will then aim to characterise the Distribution of Seeding Depth even if it constitutes a challenge in itself.

More generally, the means to be developed will have to allow in-situ measurements of the flow characteristics, both of air (speeds, pressures in particular) and of seeds (speeds, directions, sizes) at different points of the transport circuits (by pneumatic or gravity ways) of the seeders from the seed selection device to the planting device.

This bench will help to understand the phenomena at play at the various stages of the seed drills and thus facilitate the development of future seeding machines that can carry out multi-species seeding at different depths in a single pass with great precision and combined with localised fertiliser applications with the characterisation of the longitudinal placement with a view to an agronomic optimum according to each species.

The bench for characterising transverse and longitudinal distributions could eventually be included and serve as a potential support for standardisation.

5. Conclusion

The influence of the AgroTechnoPôle platform is resolutely in an European and international scope. The AgroTechnoPôle is at the disposal of all private and public actors to accompany them in their respective development of new solutions for the agro ecological transition.

In August 2022, the AgroTechnoPôle platform became a partner in the European project AgriFoodTEF, which was submitted last April under the national coordination of the LNE and the general coordination of the Bruno Kessler Foundation (FBK - Italy). This project aims to deploy a European test network for industrialists to validate their AI-based developments. All the infrastructures (existing and new) of the AgroTechnoPole presented in the previous point will serve as supports for the offer of this European network over the period 2023-2027, contributing in an additional way to reinforcing and bringing closer the collaborations between the Private and Public Partners.