THE STAKES OF THE MECHATRONICS IN RESEARCH , TRAINING AND INDUSTRY:

A pratical example of a technical development policy in Haute-Savoie

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The mechatronic remained during ten years, a technology confined on the level of the aeronautic space and army R&D programs. It's then established in a parallel way in the engineering departments and the industrial research laboratories but still remaining in a restricted core of specialists.

During the five last years the mechatronic made its real entry in the industry and the services. The term "mechatronics" was even seen recently as a cover of news magazines. Remarkable examples of products were born: instrumented bearing which allowed the development of ABS in car, electronic balances, wear detection systems for production or DVD recorders are a simple illustration. A study from the French agency for the valorization of research showed that on 100 innovation projects in mechanics, the majority was on the merging point of the electronic and of the mechanic.

The mechatronic is also quoted as one of the key technologies on the 2005 horizon by the federation of the mechanical engineering industries. In the same way the FIEV (Federation of Industries for the equipment for vehicles) led a study concerning the industrial strategies on the development of the mechatronic in vehicules . Which best demonstration of the importance of mechatronic today? But one should not be deluded. Like any innovative technology, the mechatronic must raise true challenges.

- Challenge in design because the CAD tools for mechatronic will have to be able to globalise more and more the mechanical, electronic and data-processing requirements.
- Challenge in production because the integration of mechanical and electronic subsets requires competences but also assembly conditions which are not always available in the workshops.
- Challenge in quality and reliability because the definition of operating conditions in degraded mode for complex systems is far to be obvious. The current indicators for the automotive industry which shows a light fall of the reliability of vehicles due to the massive introduction of electronic, brings back to the fundamentals of quality.
- Cultural challenge finally, because the mechatronic is demanding on the level of competences either in-house or in collaboration system between industies. Mechanics and electronics people need a common language even if their field of competences are different.

Haute-Savoie, a french area located at the foot of the Mount Blanc launched at the beginning of the Nineties a programm for the development of the mecatronic in SME's. No one is astonished here that industrial parks are named Mechatronics1, 2 or 3 or that a mechatronic professional licence exists since many years.

The network Thesame with the University of Savoy and the technical centers meet here all the conditions to help industry, research formation and engineering departments to exchange competences and the develop new products. But any pole of competences has to be build today at least at the european level.

The goal of this article is to show with some pragmatic examples , the opportunities and the difficulties of an industrial and scientific development policy in mechatronics.

INTRODUCTION

The departement of Haute-Savoie is part of the Rhône-Alpes region, the second industrial area in France. Haute-Savoie is well-known across the world for tourism due to the presence of Chamonix and the Mont Blanc on its territory. The département also enjoys a healthy economy. The reasons for this success are a balanced industrial structure, good transport facilities and a geographical location at the heart of Europe. One of the département's goals is to favour endogenous development by utilising and strengthening local know-how, competence and resources. Permanent technological development is necessary in order to maintain and improve the industrial base and to contribute to its evolution with a strategy purposely orientated towards the strengthening of the small- and mid-size business sector. Local industry is based upon

manufacturing activities which are highly labour-intensive, directly or indirectly. The improvement of the technological and managerial environment for small- and mid-size businesses (offering technogical consulting and resources) contributes to keeping decision centres and production units and therefore employment through increased attractiveness. From 1992, local political bodies initiated a "technological base" initiative aimed on the one hand at federating local technological resources and on the other hand at inserting new competences (electronics, sensors, production engineering, etc...).

The initial network consisted of :

- Laboratories of the University of Savoie
- The manufacturing process departement of the "Centre Technique de l'Industrie du Décolletage" (C.T.D.E.C.)
- The Competence Centre for Integrated Circuit (C4i) and Sensor-Measurement-Instrument Design (ACMI)
- The Centre for Production Engineering (CPHS)

Traditional mechanical engineering, which is one the pillars of local industry, today faces far-reaching evolution in the trade. This largely sub-contracting industry has to tackle two main challenges :

- Differentiation : this means moving from parts or standard sets of parts to integrated modules including complex functions (e.g. command functions or measuring).
- Continuous cost-cutting on the whole of the product chain, from R&D to final delivery. This includes the initial pre-design stage (simulation tools, technological resources), the setting-up of R&D management tools (project management, technological watch, licences, etc...)

It is in this framework that the Thésame project was developed. The aim is to capitalise upon results produced by regional poles and the initial technology bases at département level and to establish around Thésame transverse competences centred around mechatronics, industrial management technology and innovation management.

The originality of the project resided in the fact it didn't only consider technology (mechatronics in this case) but its entire environment from production to sales.

The selected themes for the technological network involve competences which are very targeted and in tune with evolutions deemed necessary by the manufacturers themselves :

- To ensure lasting economic development, the mechanical engineering industry must maintain or restore margins on its products, from single parts to complex mechanical-electronic subsets (inserting electronic components into mechanical subsets : mechatronics).
- The constant improvement in industrial productivity implies a continued evolution of industrial information systems (industrial engineering)
- Small- and mid-size businesses need greater mastery of R&D techniques in order to work with the big outsourcers as real partners or to expand into new market segments (innovation).

ANTICIPATING THE NEEDS

In its generally accepted form, mechatronics is the blending of three basic techniques : mechanics, electronics and information technology. Its is a marriage of convenience which enables more compact, higher performance products, for a cheaper cost.

Without getting into and academic debate on the limits of mechatronics, we consider it to be a technology requiring competences in multiple disciplines : electronics, automation, mechanical engineering, micro-IT. It calls upon complementary know-hows such as electrotechnics, power electronics, microelectronics, microsystems, sensors, design- and simulation techniques. It may be difficult to sum up in a few words the complexity of the required technological evolution, but one can state that the technological leap to be accomplished consists of mastering the reception of information and its transfer to a mechanical base.

For a decade, mechatronics was confined to large programmes in the aeronautics, space- and arms industries. It then developed in parallel in industrial design workshops and research laboratories, often remaining in a restricted specialists' nutshell. The democratization of mechatronics in the last five years brings about a noticeable entry into industry (products and processes). In terms of product design however, it is still limited to large companies or highly specialised activities. For Paul Rivier (INSA President and former director of the SEB group), mechatronics is an opportunity for mechanical engineering firms, under the proviso that they accept risk-tasking : "by bringing new functions to a product, mechatronics can counter the relocation of business. There are two possible strategies : being a centre of competence or a cost centre. Focalising on future needs is a way to remain a major player in the evolution." Knowing how to anticipate is also the message of Philippe Sebillote (General Delegate of UIMM) to illustrate the creation of the TETRAS-IUT professional

bachelor's degree in Annecy : "As early as 1995 we made a choice to train highly skilled technicians with a left brain which thinks mechanics and a right brain which thinks electronics! Eight years ago it was a risky bet but demand is here today and should continue to grow." For his part, Fernand Peilloud (Département Local Authority) recalled the essential role of public administrations : " the Haute-Savoie Département, supported since by the group of Annecy communes, the Rhône-Alpes region and the Ministry of Research, launched in the early nineties a voluntarist approach for the development of mechatronics. No-one here is surprised by the fact that industrial areas were christenend mechatronics 1, 2 or 3 or that a professional bachelors degree in mechatronics has existed for many years, currently extended by the training of engineers. It is a real choice of technological development for the area. The Thésame network with all its partners, including ESIA and the University of Savoie, the CTDEC et the C4i, includes all the conditions for industry, research, tranining and designers to exchange competences and develop new products.

THE TRAINING CHALLENGE : "can you really teach mechatronics?"

One of the basic problems with mechatronics can be summed up by the following question : "can you really teach mechatronics?".

During the "European mechatronics days" (March 2003), it was demonstrated that approaches could be very different with real innovations to the image of mechatronics! Alain Bidaut (TETRAS-IUT of Annecy) explained the importance of a real synergy between business and teaching, which lead to the creation of the first professional bachelor's degree in mechatronics. "The experience of combining lectures and company work, added to the bachelor's degree, enables easy placing of young people into small- and mid- size businesses". For Eric Descouvrières (INSA Strasbourg), the mechatronics engineer is more of a supply architect, a generalist more than a specialist. According to the school, the relative weight of modules such as project management, automation and IT varies greatly and often depends on the main specialty. The history of the industrial activity or the training programmes is often reflected : for example the region of Besançon (Franche-Comté), namely the ENSMM (Alain Bourjault is one of the founders of mechatronics in France) differentiates itself through the importance of microtechniques coming from the watchmaking industry, electronic schools such as ESIEE will place greater emphasis on simulation, real time, etc... Serge Samper (ESIA) is positionned less on technologies than on the system approach : "what is required of a mechatronics engineer is the ability to operate a synthesis between various experts. He may himself be a specialist in one technique but his first mission is to think of the system as a whole".

Initial experiments of note were ESNI Limoges (Robert Couderc), which favoured the pooling of resources by secondary schools, IUT and engineers' colleges to build a mechatronics base, or that of Haute-Alsace University, which took the best out of French, German and Swiss teachings into a tri-national training programme.

THE CULTURAL CHALLENGE : "how to think mechatronics?"

If the impact of mechatronics is well understood in certain large-size groups today, there is still a real cultural barrier between "mechanical" tradition and the world of electronics. Thésame acts as a federating co-ordinator on selected specialists' projects across several disciplines in a simultaneous engineering approach.

But on the ground, mechatronics reality is often more complex. Mechatronics may be in full growth, but the culture shock between mechanical engineers and electronics engineers is real. René Nantua has spoken of the "necessary genetical mutation" of a mechanical engineering company. SNR is setting up the "Cap Mécatronique" internal project with the aim to give the company a coherent approach of the mechatronics theme. "SNR gained in credibility at international level by managing to impose a world standard for instrumented ball-bearings. Tommorrow, the explosion in the number of sensors in cars enables the definition of a clear strategy based on ever greater integration of mechatronics".

Andreas Wild (director of MOTOROLA – EMEA Semiconductor) adds light from a large electronics firm : "technological evolution is highly impacted by costs and mechatronics is no exception. It is one of the big challenges for the microprocessor industry, which has to develop partnerships with mechanical engineering firms in order to offer hybrid technologies". The car is an ideal communication support : the development of intelligent connectors and the networking of sensors should enable an improvement in the reliability of systems, which are becoming more and more self-sufficient. It is the challenge of "distributed intelligence" for a safer vehicle.

Further upstream, MEMS microsystems perfectly integrate this mechatronical revolution : "from today nanotechnologies enable to envisage

navigation systems based on micro gyroscopes on silicium". The MEMS market should grow 70% from now to 2005 (Sukhan LEE – SAMSUNG Electronic).

THE DESIGN CHALLENGE

The unfolding of a product's lifecycle in consecutive phases, broken down into independently researched subsystems, no longer enables an adequate answer to the quality/cost/time challenges imposed by the marketplace. As a remedy, two new complementary approaches were born : simultaneous engineering (or concurrent engineering) and the mechatronics approach (or "system"). It is then crucial to take into account the "complexity management" brought about by these new practices by paying particular attention to transverse components :

- Diversity of applications and skills
- Multitasking across disciplines
- Diversity of modelling levels
- Continuity with other levels of abstraction

Specialists in mechatronics design agree on a depiction of the development cycle as a "V-shape cycle", which positions the different phases (from specifications to product validation) according to the corresponding abstraction level : functional level, system or network level, component or geometrical level.

In this complex diagram, modelling and simulation play a central role for their capacity for fine analysis as much as for their benefits in terms of capitalising and transferring know-how, not forgetting reducing development time.

One of the keys to success lies in the ability of the designer to find and master the right level of abstraction for the problem at hand and to link with the other levels. Design tools are progressively adapting to these constraints and tend to patch up continuity breaks in the design chain. New tools bring new answers in dealing with the network level, a key element for mechatronics.

Modelling at the geometrical level also benefits from important advances in terms of multiphysical coupling (the ability to simultaneously deal with several physical dimensions in a single or dual environment : mechanical, thermal, electrical, magnetic, fluid,...) and coupling with other levels. The development of microsystems (MEMS or micromechatronic systems) was first to use these new possibilities, which are progressively evolving into "macrosystems" in all industrial sectors.

THE RELIABILITY CHALLENGE

In the area of mechatronics, the notion of reliability is often felt by manufacturers to be one of the issues least mastered and for some it is a critical point for the spreading and the future or mechatronic technology.

The concept of a mechatronic product or approach is principally characterised by the notion of coupling between different technologies, different disciplines or physical areas. The basis for mechatronics is to utilise this coupling to the maximum in order to offer ever greater technical and economical performance, which creates added value. The increase in the levels of coupling ineluctably brings about a boom in the complexity of systems, of their control and their design and manufacturing processes. This complexity also spreads into related processes such as purchasing and marketing (how to buy or sell mechatronics?).

This complexity inflation at all levels (which is not solely complication) increases, if one isn't careful, risks of malfunction, unpredictable behaviour and, if taken to extremes, chaotic behaviour.

The methods and tools to master reliability at designers' disposal are very diverse and often too specific for systematic use in mechatronic design. One can find namely non-dynamic models (based only on time) and dynamic models (which include the notion of time and state of the system), trial techniques, statistical analysis, estimation methods, behaviour simulators, evaluation software, simulation tools (Monte-Carlo), optimisation tools (generic algorythms / non linear simplex), risk control tools (malfunction analysis, error trees, markov analysis)...

This area is characterised by the absence of a method and generic tool which could be easily integrated into the design flow from the origin. The notion of reliability must indeed be included very much upstream in the process, in particular in the choice of architecture and components. Mechatronic design is doubtless not an isolated case, but all generic problems are amplified and multiplied by the intrinsic couplings. It is without doubt in this area that the need for evolution in concepts and tools is most acutely felt.

Reliability is a relatively new area driven by technology and the needs of the market. There is much work to be done both on theoretical concepts and tools. Manufacturers and researchers must work together closely to meet the challenge of reliability in mechatronics.

THE COMING AND GOING BETWEEN MARKET, COMPANY AND LAB

Finding the right mechatronic solution for the client's needs cannot be improvised. Jean-Michel Pallas from Valeo Switches Systems calls upon the "cultural melting pot" and doesn't hesitate to colm areas far removed from the car industry. Moreover, that is the general message from manufacturers : a good mechatronics engineer has an investigative, open mind and knows how to work in a team. At Somfy, Pierre Gérinière even talks of identifying people with "mechatronics potential".

If theses examples demonstrate a certain degree of manufacturer's maturity in mechatronics, the typical small- or mid-size firm is far from making an easy transition. The importance of connecting structures such as technical centres is then paramount. In the THESAME network, the mechatronics team of CTDEC works on the real constraints which subcontracting firms may encounter : "integrating a new technology starts with setting-up a design office or by working with a network of other specialised small- or mid-size companies. Our role is to bring "turn key" solutions to crucial problems such as for example product traceability or detection of tool breakages". Christine Brégou from C4i insists on the need to help a company in chosing technologies where they have no in-house know-how. "It is a real training job which prevents strategic errors".

CONCLUSION :

The introduction of new technologies in industry is subject to long cycles. Mechatronics is no exception to the rule, namely in terms of the complete control of the design cycle, and particularly for the question of reliability.

However, there are more difficult aspects to mechatronics since it requires knowledge of very different skills which are not simultaneously present in the company.

We have tried to show some of the areas where the Thésame network is getting involved to rise to the industrial challenge :

- Initial training, which must instigate a versatile or rather a multicultural spirit in the future designers.
- Continued training in order to seek convergence in language and methods between the different skills centres within the company.
- Research in order to improve modelling and quality control tools.
- Designing within a "project-base", cross-sharing engineering logic.
- Manufacturing with integration in mind, when components on the production lines have by nature different constraints.
- Marketing in a spirit aimed at rethinking clients' needs in terms of functions. Integrating electronics into a mechanical component leads to a total rethink of the complementary services (traceability, maintenance history...). It is a real information revolution which may be enabled by mechatronics.

Finally there is the future as can be seen from research laboratories. The arrival on the market of the intelligent computer mouse or DNA chip readers mustn't obscure the fact that the development cycle from the most upstream research exceeds ten years. For example, EPFL (Lausanne) is working on an important "man-machine" interaction project in which a doll obeys the voice and gestures of the researcher thanks to the combination of all mechatronics technologies. Openings towards other disciplines such as biology are just as possible. Indeed the latest innovations such as "humanoïd robots" developed in Japan could have real implications in the creation of intelligent medical protheses.

It is easy to see that mechatronics opens up particularly large possibilities of development. Its transverse characteristics require a review of many work processes in many areas. Our challenge is to attain harmonious development both for research and for industry.
Let the last words to Michel KOSTAFTIS, who propose an impressive theory of mechatronics : the task will be for all of us "to make soft transition from specialists to globalists".