

**Sophisticated Concurrent
Engineering Without Computers:
Ecole Nationale Supérieure des
Arts et Métiers, Paris**

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SUMMARY

The Ecole Nationale Supérieure des Arts et Métiers (ENSAM) Laboratory for New Product Concepts is an interesting mix of research, teaching, continuing education, and industrial consulting. Without the aid of fancy computer tools, this group has carefully and pragmatically elaborated a product development strategy that is considerably richer than typical concurrent engineering (CE) methods. Products are described at three levels (architecture, minimal parts list, and full parts list), and roles for each of the actors in a CE process (marketer, fabricator, assembler, purchasing agent, etc.) are spelled out for each level. This is considerably more sophisticated than just forming teams and letting them figure out what to do.

BACKGROUND

ENSAM is an Ecole Supérieure, which means that it is dedicated more toward teaching and less toward research than a university. In this sense it is like a polytechnic in the United Kingdom (U.K.). This article describes the Laboratoire Conception de Produits Nouveaux (New Products Development Laboratory). The director of the laboratory is Professor Robert Duchamp. Because he was absent the day I visited, this article is based on discussions with Ph.D. candidate M. Marc Le Coq. The laboratory itself is a combination of teaching site, research laboratory, and industrial consulting company. All the activities center on design of new products. In some cases this involves creating concepts, while in others laboratory evaluations and prototypes are produced. The customers include private industry and the French government. The laboratory openly advertises its services and has booths at trade and technology fairs. It also holds its own seminars and laboratory open-houses. Most of its glossy literature is in English, German, and French in an effort to attract European customers and students.

APPROACH

The students participate in and do their research as part of the consulting activities. In addition to the students, several full-time engineering staff are involved in mechanical design, software, and construction of apparatus.

Examples of specific products the laboratory has worked on include:

– a pump for Third World countries that runs on solar energy (they discovered that people in such countries don't understand how to maintain this kind of equipment, a factor they had not taken into account when designing it);

– applications of water-jet cutting: composites, chocolates (for composites, abrasives can be added to the water to help it cut but for food you cannot do this, so they added ice crystals—a nice idea). They invited artists to try designing innovative things from the composites; one came up with one-piece folded armchairs (Fig. 1);

– a new kind of large-screen display based on optical fibers (it was not a good concept—very hard to make, and no one is interested);

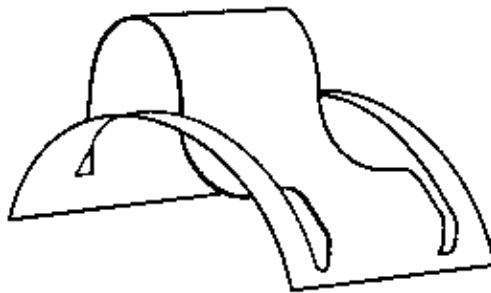


Fig. 1. Chair made from laser-cut composite material

– a coffee maker for small hotel restaurants being developed for a small business that has government funds for the project;

– a computerized training aid for operators of complex offset printing presses (the issue is to get four or five colors to line up and look right, a skill that normally takes several years to acquire; in this case, high-quality color computer graphics, a mouse-menu interface, and an expert system have been combined into a nice training tool).

In the past they worked on robot assembly, but the demand for this from industry has fallen to zero.

DEVELOPMENT OF DESIGN METHODOLOGIES

On top of the consulting and teaching activity is an effort to generalize what they have learned into procedures for carrying out new product development and CE. The procedures they have followed up to now constitute a manual methodology rather than computer tools. The main steps in the process that they describe are the familiar ones of identifying the need, converting need statements into function statements, searching for possible implementations, choosing one, testing and prototyping, etc. In this regard their work sounds like that of Prof. Beitz and others [see "Design Research and an Industrial Application of Systematic Design Methodologies," *ESNIB*, this issue].

However, Prof. Beitz takes a heavily engineering-oriented approach whereas the ENSAM people work at a more conceptual level and are not as technically focused. Interesting aspects of their methods include making a semantic characteristics list to describe a product, making diagrams that show how each part or assembly satisfies each requirement, and looking at a product at different levels called "minimal parts," "architecture," and "individual parts."

Figure 2 is an example "semantic shape" diagram. One attempts to describe the product at the concept stage on a scale from -3 to 3 according to each of the characteristics (ergonomic vs hard to use, functional vs stylish, attractive vs repulsive, intuitive vs rational, etc.). Market-sensitive people apparently fill out this diagram first. Later, when concepts or prototypes are ready, they are graded against the original diagram. The contrasts are immediately visible in the different shapes of the profiles.

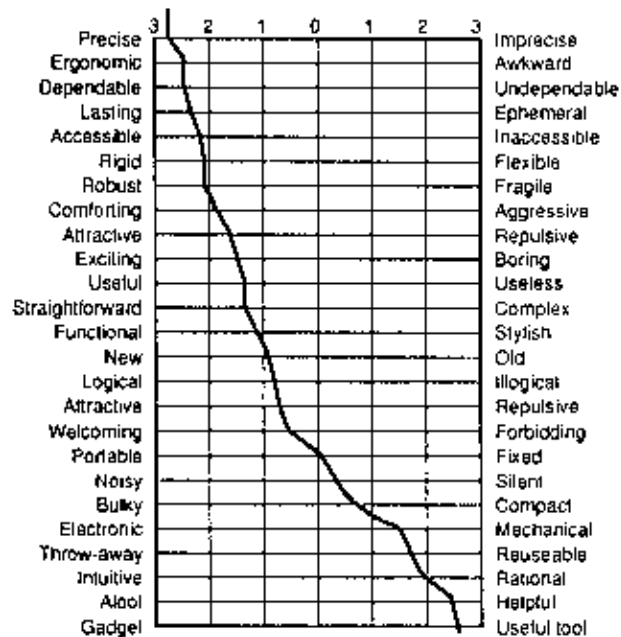


Fig. 2. "Semantic shape"

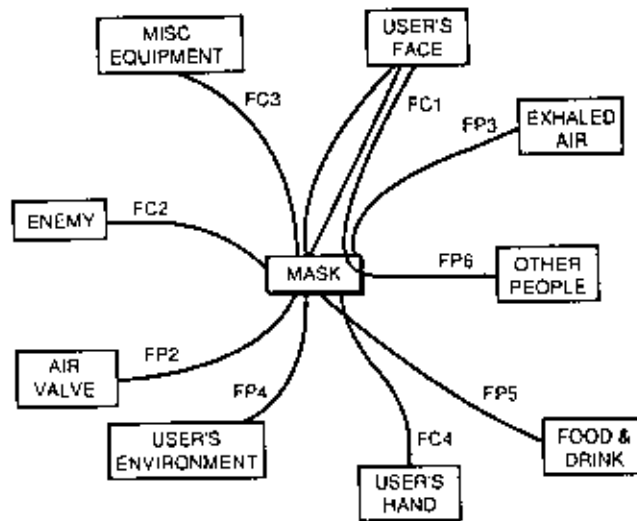


Fig. 3. Functional schedule of conditions (FP, relates mask to user; FC relates mask to its own environment)

Figure 3 is an example of a "functional schedule of conditions," a diagram relating parts to functions. The product in this case is a gas mask designed for the French Ministry of Defense. A key issue here was utilization of totally new materials, one for the opaque body and the other for the transparent visor that could be injection-molded at the same time. The Materials Laboratory at ENSAM developed the materials first, and the New Products Development Laboratory got the follow-on contract to design the mask itself. The items listed are:

- FP1: protect user's face from the outside
- FP2: permit user to breathe
- FP3: vent exhaled air to the outside
- FP4: permit user to see environment
- FP5: permit user to feed himself
- FP6: permit user to communicate
- FC1: adapt itself to user's face
- FC2: resist attack
- FC3: be compatible with use of miscellaneous equipment
- FC4: be adaptable to user's hand.

The items in the boxes are, for example: user's face, expired air, consume liquids, and the central box is labeled Mask (figure is from Ref. 1).

The Ph.D. work of M. Le Coq attempts to tie all of this together by laying out the elements of a systematic product design method. The paper² he (Le Coq) gave me is in French, but I am able to understand most of it. Every product development project has four components:

1. The product concept itself: this is a clear statement of the first idea of how the needs might be met, stated in such a way that all the people who must participate in the design process can understand it.

2. The procedure: this is a statement of the actions that the design team must carry out in order to design the product.

3. The structure: this tells the designers how they must interact with each other in carrying out the procedure. Two different types of structure are identified: the multidisciplinary team method and the series of experts method.

4. The tools: these comprise engineering, computers, etc., plus their software and methods.

The procedure operates at three conceptual levels: the minimal set of parts or elements that can satisfy the requirements, an architecture (spatial arrangement and physical connections) that links those parts, and all the individual parts in a complete design. These are pursued in that order. The main job of the designer is to think up architectures and their minimal parts, while the engineer must determine the flows of energy, fluids, heat, stress, etc., between these minimal parts. In the best of situations, the work is carried out by a designer-engineer who can work at all levels.

The most interesting part of this is a chart (Fig. 4), which shows how each of the players in a multidisciplinary design team might see the minimal parts, the architecture, and the individual parts. For example, the assembly person would look at the minimal parts from the point of view of trying to standardize them and their required assembly processes. This person would look at the architecture from the point of view of assembly sequences and process optimization. Finally he would look at individual parts to see how to speed up their assembly and lower the cost of doing so on an individual part basis.

CONCLUSIONS

Work at the Ecole Nationale Supérieure des Arts et Métiers, Paris, is not at the technical level usually found at universities. However, it has the merit of being derived from actual experience in designing products for industrial customers, plus trying to teach the method to the customers for their own use. Thus it reflects a lot of careful thinking without being encumbered by attempts to do great things on a computer. Considerable structure and detail has been provided on what a good design process should consist of beyond goodwords like "break the design up into functional elements" and so on.

	Indispensable Parts	Architecture	Parts
Marketing, sales	Image, impact of technology, sale price	Market niche or level, diversity, differentiation, cost	Finish, cost, market niche or level
Design, styling	Concept choice, technology	Market niche, image, uses	Appearance, shape, visual and tactile aspects
Ergonomics	Scenarios for use	Scenarios for use, macro actions	Micro actions, visual and tactile aspects
Design office	Technology, choice and realization of actions and flows of energy and information	Respect for constraints on the flows based on the concept requirements	Optimization of flows, shapes, fastenings, and connections
Fabrication	Technology and standardization of processes	Process choice, complexity of parts	Process optimization
Assembly	Technology and standardization of processes	Choice and optimization of processes, trajectories, tools...	Optimization and realizability of cycle times, automation
Testing	Technology and standardization of tests	Testing scenarios and strategies, creation of functional subassemblies	Interfaces, system connections, repairs
Maintenance	Strategy, cost and exchange of parts, warranties	Accessibility for diagnosis and repair, changes to the system	Ease of removal and replacement, special tools
Purchasing	Policy, constraints on suppliers, make-buy decisions		
Recycling	Standards and constraints (toxicity...)	Homogeneity of materials, access to dangerous elements	Material choice, removability, disposability

Fig. 4. Views of the major roles in product conception by each of the members of a multidisciplinary design team

The intellectual problem is whether even this level of decomposition has enough substance to be applicable to a wide variety of products. The hope is that more detail will result in an explicit process that can be followed in many cases. The downside is that as one looks in more detail at the products themselves, one finds that the process must be significantly altered,

even rebuilt, in order to meet the technical content inherent in the product. Thus the effort to describe the generic design process in more detail may not be rewarded because the generic details it comprises will not be relevant to the products. We need to generate and compare more of these candidate design processes and use them on more products before we can see if a pattern emerges. This is one of the more important generic research issues in design today.

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