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A Critical Role for Design Technology

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A phenomenon very apparent to the American businessman, as well as to any lay observer, is the wave of "restructuring" passing through the country. It is a fact of life for seemingly all large companies, and through ripple effects, it affects all but those companies most finely tuned to the new realities of the marketplace. Less apparent, but of greater portent, is the implicit recognition that new rules are taking form for how the games of business will be played. As the recession abates, and revitalized industries emerge, they will not return to the ways of the past; they will seek a development philosophy for their products and services in tune with the times. Of the factors involved in this product/service philosophy, *design* will be one of the most important, as the growing interest of the business press makes that very clear. There is little question that design will play a major role in the kind of economic world on the horizon. The question is, *What role will that be?*

The Quality Pyramid

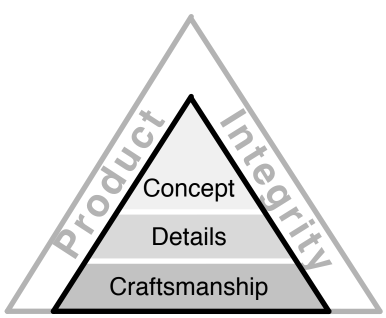


*Figure 1. The Design Core of the **Quality Pyramid** reveals three levels at which design can contribute to the attainment of product quality.*

The issue really involves "quality", and what is now being termed "product integrity". To a great extent, the present opportunity for design is what it is because of the now-general concern for quality. Most customers equate quality with *craftsmanship,* an observable attribute that has been drummed into everyone's consciousness for at least a decade. U.S. companies and others who needed it learned the craftsmanship lesson well in the last ten years, and products worldwide are significantly more competitive insofar as construction, reliability and other aspects of craftsmanship are concerned.

The lesson, however, does not stop with craftsmanship. Quality is a hierarchical concept. There are higher levels of quality than craftsmanship, and quality principles can better be explained in terms of a "Quality Pyramid" (see Figure 1). Craftsmanship is the base of the design core of the pyramid. At the second level, quality is expressed and revealed in *details.* At this level, a better product is recognized by its better performance, easier use, and better fit in its cultural niche. Perceptive companies are working now to incorporate this understanding into their product development processes.

Far less well understood, but probably most important of all, is the third level in the quality pyramid, *concept.* A better concept sweeps the competition; customers are actually *willing to pay more* for a conceptually better product. What distinguishes a better concept is its "rightness"—its thorough response to all the needs of its users. And in this respect, *all* users need to be considered—not just those who operate the product, but those who distribute, sell, store, transport, maintain, repair, adapt and even dispose of it.

Product Integrity

Beyond concept is the all-embracing idea of *product integrity,* the capstone and cladding of the quality pyramid (see Figure 2). Product integrity is a way of characterizing a product's contribution to the perception of overall quality through its own performance, its ability to improve associated services and its ability to transfer approval to the company itself. Products that achieve product integrity do so because users' experiences with them at all levels are uniformly happy ones—over and over again. In time, this appreciation is translated to trust and respect, distributed in equal measure to the product, to all the various services associated with it, and to the company as the entity responsible.

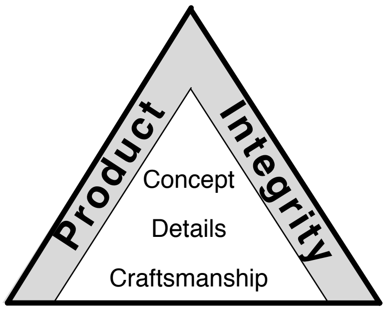


Figure 2. ***Product Integrity*** *is the capstone and cladding of the Quality Pyramid. Products achieving product integrity generate trust and respect not only for product and services, but for the company.*

Design technology exists in varying degrees for working at all levels of the quality pyramid. At the level of craftsmanship, there is considerable knowledge about how to design better products for production. Engineering design, value engineering, design for manufacture—all contribute to managing quality control. At the level of details, computer-aided design, concurrent engineering and computer-aided engineering now significantly contribute to better performance. Human factors design and interface design are increasingly capable of dealing with human cognitive and physiological design factors. And product designers and communication designers have effective means for tailoring function and form to social and cultural needs.

At the third and capstone levels, the task is both more difficult and more important. Design for concept and product integrity is more information-intensive, more complex, and potentially more rewarding. Unfortunately, most companies either don't know that design technology exists for these levels or confuse it with conventional R&D or market research. A common practice, particularly in U.S. companies, is to require assessment of the viability of a market before resources are committed to planning a new product. The effect, inevitably, is to skew new development drastically *away* from substantial innovation and toward incremental change and cautious evolution instead.

Markets Don't Invent; They Buy

Markets respond to what they are offered. They don't invent; they buy. If potential customers can't be shown a new concept, they can only respond to problems they perceive with what they already know. Not surprisingly, there is almost never real innovation under this model—how can the customer be expected to invent the product? Without real innovation to show, the result of a market assessment is often that there is little or no market for innovation. Something for senior executives to think about is the successes of innovative products that were developed anyway. There are always some. Sharp's ***Wizard*** is a recent example; Goodyear's new ***Aquatred*** tire appears to be another. The moral of the story is that the old advanced-planning model is critically flawed. What is missing is a process for conceptualizing innovative products *before* the market studies.

At the needs-satisfying levels of today's developed societies, wants and needs almost never strongly stimulate new product development (as they did following World War II when potential customers everywhere *knew* what they were missing). Abraham Maslow's famous hierarchy of personal needs postulates seven levels of need, each of which usually must be satisfied before the next can be addressed: physiological needs, safety and security needs, belongingness and love needs, esteem needs, need for self-actualization, cognitive needs, and aesthetic needs. Stable, developed societies tend to be at the higher levels, and their needs at all but the highest levels are usually well satisfied—at least well enough relative to everything available that there is little innate demand for new products. New products at any but the most active need-levels for consumers in these societies must offer improvements so noticeable that they reopen concerns for how satisfactorily current products serve in comparison.

Under these conditions, needs, wants and desires appear in response to new product offerings, rather than the other way around. The driving forces switch to science, technology and invention, and the most appropriate form of product planning is one that incorporates early conceptualization with strong emphases on advanced planning, design and innovation. Design technology for this kind of planning does exist—Structured Planning, developed at IIT's Institute of Design, is an example.

Design Technology and Advanced Planning

Design is the likely touchstone for industrial success in the coming decades—*but* it will most certainly not be the "styling" traditionally employed at the back end of the development process. The kind of design that will make the difference is design at the front end. It will be conceptual design that employs advanced-planning task-force teams assembled from appropriate functional groups company-wide, computer-supported design/planning methodology, life-cycle design thinking and a commitment to the development and creative use of qualitative as well as quantitative information. If success at the expected level of competition is to be achieved, *conceptually better* products must be developed at a rate of delivery that is both reliable and predictable. This will enable the introduction of dependably superior products before competitors can undercut price and take over markets.

This strategy is called *escalator delivery.* Employing it, a company does not rely on once-in-a-lifetime ideas and long periods of market monopoly with them. Instead, it professionalizes the development of concepts with product integrity and it regularly replaces its own successes with new ones. The company with escalator delivery controls its markets by controlling the introduction of industry-dominating products.

New Products Await Better Design

Surprisingly, considering the reversed roles of technology and need as driving forces, there is actually more technology available now than necessary to meet needs and desires at considerably higher levels. The problem is that the effective use of design trails achievements in both basic and applied science. It used to be that a better product only awaited better technology. Now, it frequently awaits better design.

New generations of information-age products can be virtually whatever they are asked to be. *What should they be?* Global competition suggests better concepts. What those concepts should be is best addressed by design technology. A rapidly widening variety of design technology tools can be brought to bear on the problem. The spectrum of application ranges from the first questions about the goals of a project to problems of product implementation in a naive or even hostile market environment (as sometimes occurs in the public sector). The most crucial applications, however, are in that portion at the earliest stages of development. Improvement in performance here will significantly enhance a company's competitive position in world markets filled with increasingly sophisticated concepts.

An example of design technology developed expressly for this purpose is Structured Planning. It is a comprehensive process with the means to invigorate and extend the development model to meet new challenges. In the following discussion, some of its features are presented to illustrate how design technology can be deployed at the critical advanced-planning stage.

While this is not the forum to discuss Structured Planning in detail, the captioned figures 3 through 13 provide some idea of the forms work takes through key phases in the process. In what follows, there are references to the figures where practicable; for more elaborate treatments, see the Suggested Readings at the end of the article, most particularly, ***Design for Integrity***.

Reforming the Development Model

Conventional planning for product development suffers from problems both of breadth and depth. The breadth problem is that too little attention is paid to the *what* question before considering the *how.* The conventional model for development too often begins with the project statement already well down the road of specificity. On a scale from "What should we do?" to "Follow this specification", it is much more likely to be near the latter than the former. The product probably is already in mind before the development process begins. It may be a response inspired by the competition's new product, an idea that occurred recently to a senior executive, or just some new features for the current model that ought to be "upgraded".

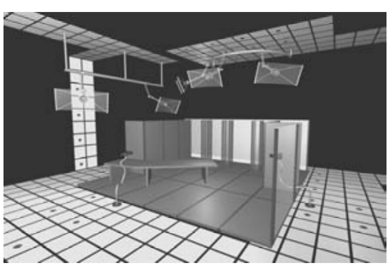
Solution Element | Title: Environmental Image Mapping | 1/ 1

Project	Functions Fulfilled	Related Solution Elements
TV Command	27, 29, 34, 35, 37, 38, 41, 42, 55, 56, 57, 59, 62, 66, 67, 82, 91, 92	2. Infra Net 3. New Senses c. Gesture Glove f. Virtual Viewer 4. Thunder Dome a. Thunder-D Grip 6. Construx b. Surface Pixels c. Shadow Cues
Super-Set Solution Element		
None		
Sub-Set Solution Elements		
None		

Discussion

Until now, studio productions required individualized studio sets. The entire concept of "studio" work was built around the idea that control of the environment could be optimized only on location – in a studio set. Movie and television sets of the past (and today) have ranged from minimal sets, little more than seating with controlled lighting, to mammoth, exceedingly complex and expensive recreations of entire environments.

The revolution in computer processing of the last decade brings the concept of set to a new level of awareness. A variety of inventions, from matting techniques and computer-controlled movements in film making to texture mapping in computer graphics, have made it possible to create realistic three-dimensional images that combine human actors and environments constructed from data bases.



Environmental Image Mapping takes maximum advantage of this capability both to reduce the cost and complexity of the sets, and to increase the flexibility and speed at which sets can be constructed and struck. The elements of ***TV Command***'s studio system are designed to work synergistically with this specialized approach to virtual reality.

Solution Element | Title: Environmental Image Mapping | 1/ 2

Discussion (continued)

After a set is designed in virtual reality using the **Thunderdome,** it is prepared by assembling basic **Construx** building elements in an arrangement that approximates the intended environment. The physical **Construx** elements are for the actors' convenience only. Actors move around tables, sit in chairs, walk through doors, etc. as they would in a conventional set.

What the actors see is the skeletal **Construx** set with cues on surfaces wherever they need them – on the floor, walls, desks – any flat surface. The cues, produced with **Shadow Cues** and produced with **Surface Pixels,** are invisible to the television audience.

What the audience sees is quite another picture. From the studio's data bases, detailed images are mapped into a three-dimensional model of the set maintained in the computer. This model of the desired environment (for example the living room of a contemporary home) is integrated with the studio cameras' images of the actors on the live set. The result is an image for transmission that looks as if the actors are on location.

Essential Features

- Speeds the construction of sets and programs.
- Eliminates the high cost of authentic sets through the use of skeletal "for actors only" structures.
- Extends possibilities for program settings to the entire range of environments capturable as images in visual data bases.
- Exploits virtual reality processes to enable the same image data to be used for design and finished productions.

Figure 3. The end product of Structured Planning is a **Plan***, with a number of* **Solution Elements***, each descibing ideas and specifying their essential features. The Plan is the "Problem Statement" for the detail design work next in the development process. This example of a Solution Element (and other examples to follow) is from a demonstration of how Sony Corporation might implement Structured Planning. The project considers television production systems for the turn of the century.*

Saddling the development team with this kind of start is like setting a record-attempting mountaineering team on a trek up the wrong mountain. The team may do a splendid job of finding the best way to the top, but that will soon be forgotten when a higher peak comes into view. Real effort must be spent on developing a good concept—just as it must be spent on turning a good concept into a good product. The first task of reforming the development model is to provide a focus for concept development.

The depth problem concerns finding the potential users of a product and determining their needs. We hear much today about listening to the "customer", but Unfortunately, what is meant by "customer" is usually far too shallow a characterization. These customers are most likely just the purchasers and operators of the product. Good design requires a much deeper look than that. Users properly include everyone who lays a hand on the product, or in any other way has something to do with it that might be affected by its design.

TV Command
Design a television and information system that incorporates studio and field operations capable of addressing advancements in technology and changes in society.

Figure 4. A **Project Statement** *begins the project with a simple description of the project's primary goal stated in operational rather than noun-name terms.*

Defining Statement | Issue Topic: Storage and Retrieval | 1

Originator
Eduardo Sciammarella

Project
TV Command

Constraint, Objective or Directive
Constraint

Question at Issue
What provision should be made for the storage of equipment and its expedient retrieval?

Position
Storage and retrieval elements must prevent damage to equipment and optimize access, both in the field and in the studio.

Background and Arguments
There are several situations in which proper storage and fast retrieval of equipment are critical to operations. Field operations are a good example. Operations in the field, by definition, imply changing environments that place priority on the protection of equipment -- and, thus, storage and retrieval. Design for retrieval becomes important when time constraints are considered. It is absolutely necessary, for the continuous flow of information, to have the right equipment in place, on time.

Transport is another mode of operation that places equipment in potentially damaging situations. In the field, the need for care in transport and fast return to action is obvious. In the studio, relative permanence of location is deceptive. Equipment is moved to the studio, between studios, within a studio as changing setups demand, and in and out of use as equipment is changed or replaced.

The nature of the technologies used in for the production and transmission of information dictates the use of thoughtful strategies to protect fragile systems. Sound collecting systems can be easily broken; light collecting systems require clean optics -- unscratched and unfouled by destructive environments; electronic systems must be protected from heat, cold and shock. Field use requires special attention to storage and retrieval. Studio use is less traumatic, but equipment will be moved, and thought must be given to its protection.

Alternative Positions
• Equipment must be designed to be self-protecting so that it does not require separate storage elements.
• Individualized storage and retrieval elements must be designed to meet special equipment needs in the field and in the studio.

Figure 5. **Defining Statements** *extend the project statement and help to bound the problem. This Constraint sets goals for finding good fit for "storage and retrieval".*

Breadth

Structured Planning deals with the breadth problem directly by separating the concept and detail phases of the development process. In doing so, it forces serious consideration of what the product should be; allows extensive creative thinking at an early, formative level; and encourages broad participation from a range of centers of expertise. The result of a Structured Planning study is a "Plan" made up of a number of "Solution Elements", each with a description and discussion of features (see Figure 3). The Solution Elements may be physical, procedural or organizational. That is to say, they may be hardware (mechanisms, system components, form treatments, human-factored configurations), software (computer programs, communications, operation manuals, interfaces), or "linkware" (organization structures, event schedules, service plans, policy descriptions). Where appropriate, they are given visual form with fast prototyping software, such as the **Alias** software used in the Sony project figured here.

In concert, the elements of a plan make up a comprehensive description of a concept that can be criticized and modified *before* time and resources have been committed to engineering or producing anything. Issues of purpose, benefits, desired qualities, operational characteristics, appropriate technologies and a host of other important topics can be explored at a level sufficiently above the detail design level that thinking can easily change as ideas evolve. Castles in the air are easier to demolish and rebuild than castles on the ground.

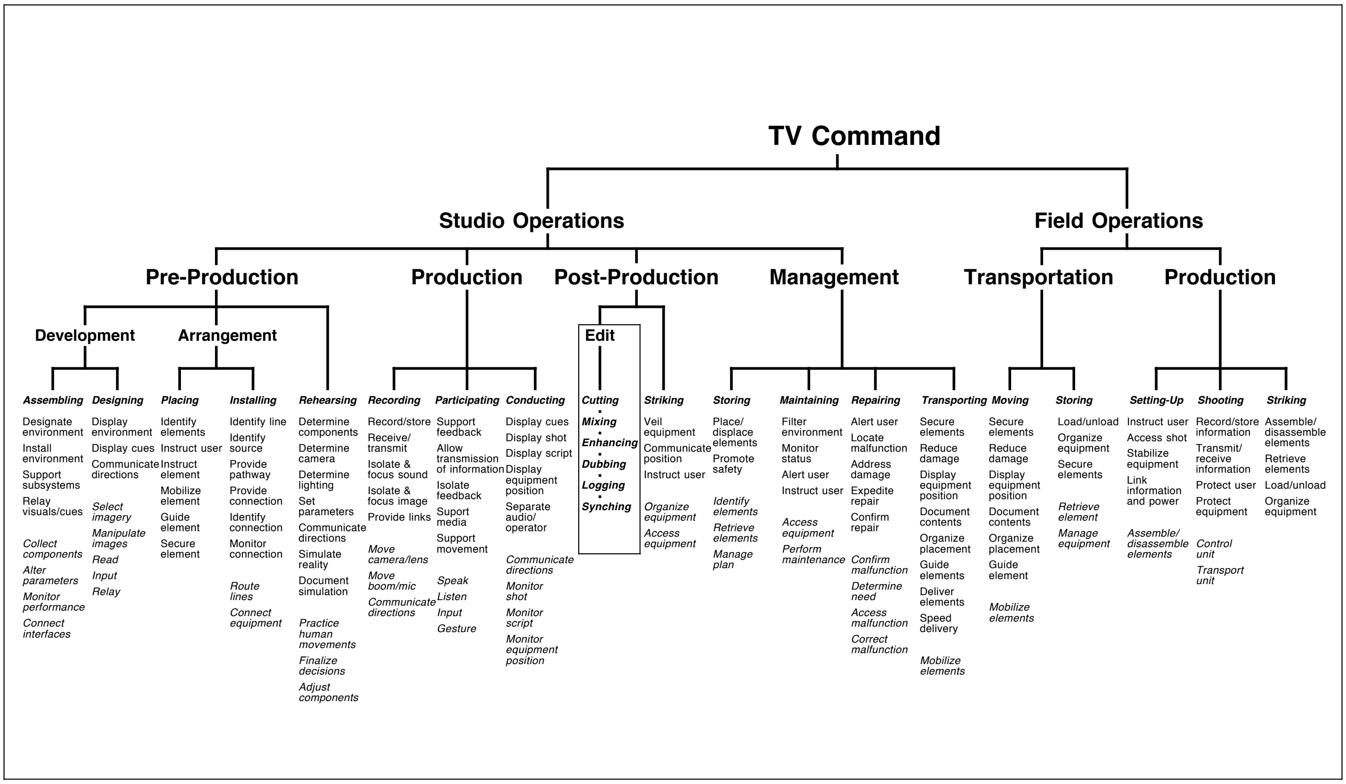


Figure 6. ***Action Analysis*** *produces a* **Function Structure** *from a top-down analysis of a project's* **Modes** *of behavior and the* **Activities** *within them. In this example, Modes are in bold, Activities are in bold italic (at the base of the tree), and system and user* **Functions** *are in columns under the Activities. The Edit* **Submode** *(outlined) was not considered further in this project.*

Depth The depth problem is addressed by a phase of Structured Planning called Action Analysis. Its purpose is to establish what the product, system, service or other entity being planned must do (actions labeled **Functions**); to gain insight about what happens as Functions are performed (observations recorded in documents called **Design Factors**); and to collect on-the-spot ideas (**Speculations** for how to use the insights inventively).

In the normal development process, the search for information usually reaches only the primary users of the product—those who own it and operate it for its intended use. Those it misses are the very users who could reveal many of the needs that should be considered in the product's design. They are the many secondary and auxiliary users of the product—those who make it, distribute it, store it, transport it, sell it, maintain it, repair it, remodel it, recycle it or retire it. Through the eyes of each of these "users", a product looks radically different. Each sees it in terms of the Functions he or she has to perform with it, and each viewpoint can contribute insights to the development of a better concept. Action Analysis directs information collecting through the top-down creation of a Function Structure (see Figure 6). This tree-building process assures that a full range of users will be considered and deep coverage will be given to their needs.

A Function Structure is a three-level hierarchy topped with the project label and successively layered below with **Modes** of operation, **Activities** and, finally, **Functions.** Modes of operation are the major kinds of behavior alluded to above—maintenance, repair, retirement, etc.—along with "use", the only mode frequently considered. Activities are the sets of actions users engage in to accomplish the tasks required by the Modes. The actions performed by users and system during an Activity are recorded as Functions.

Under analysis (see Figure 7), an Activity comes to life as a "scene" in a play. Users are the players, system elements are the props, and environmental elements make up the set. As an analyst plays out a scene, the

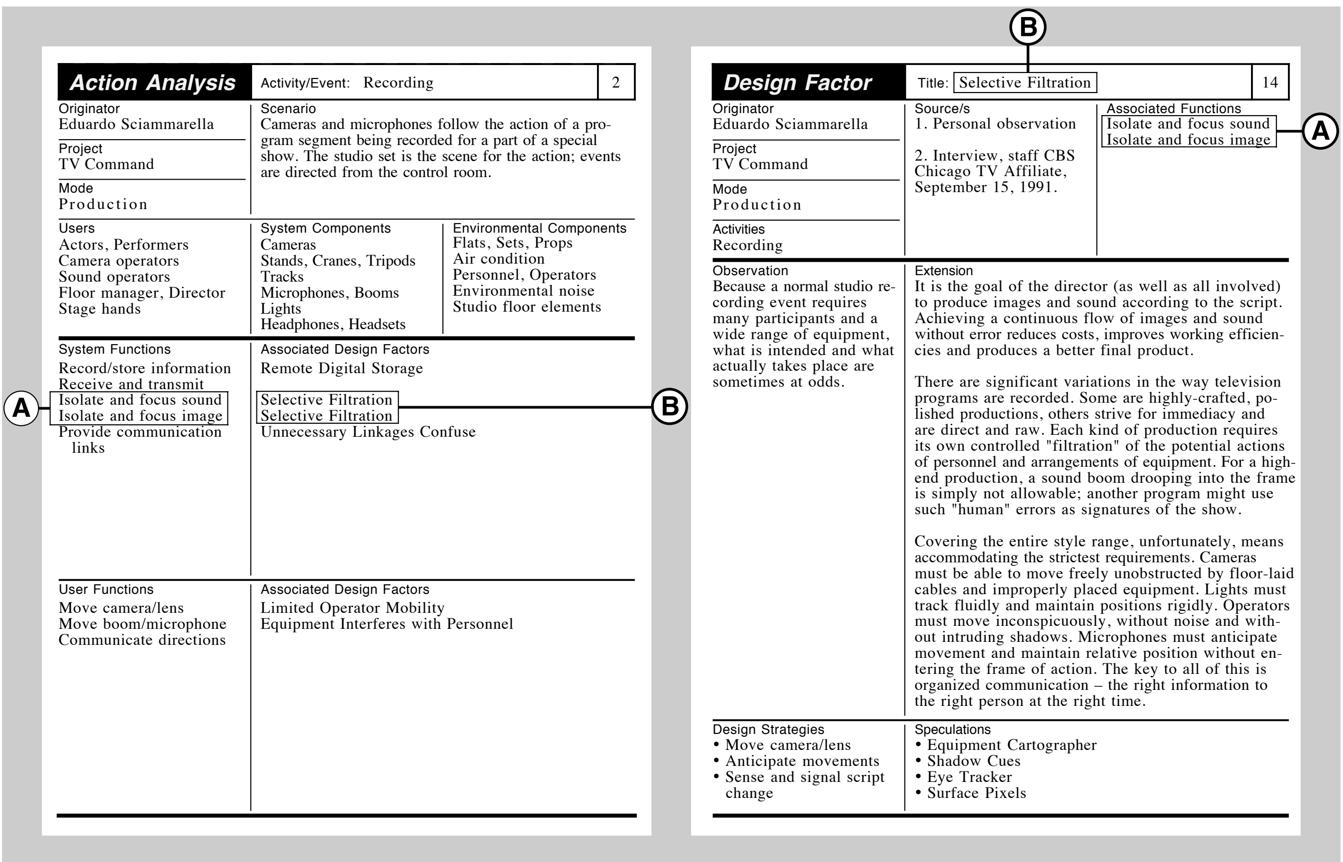


Figure 7. The **Action Analysis** *form is used to identify* ***Functions*** *and* ***Design Factors*** *associated with an Activity. It helps an analyst to cover an Activity thoroughly. A* **Design Factor** *records insights and information about* **Functions** *(**Observation** and **Extension**) along with ideas for how to use that knowledge (**Design Strategies** and **Speculations**). A and B keys show how documents are associated.*

actions of users and system can be pinpointed and recorded, either actually, where the Activity is observable, or intentionally, where the Activity will be created by the project. The result is hundreds of Functions, all of concern to the advanced-planning team. Successfully fulfilling them will ensure a high probability of success for the project.

Considerable additional depth is provided by "insights" about how the Functions are performed. These are recorded in Design Factor documents, probing, discussing and highlighting what can go wrong (or right) when a Function is performed. Written at the time an Activity is under scrutiny, these documents seek out the precious insights that trigger inventive product and system features. Because ideas follow insights almost hand-in-hand, the Design Factor format also demands ideas for how to use the insight and includes them in the record as "Speculations". These ideas may or may not be used ultimately, but they *will exist* in the information base, captured when they were formed.

Cross-referenced to the Functions they illuminate, Design Factors provide a "project memory" that is intentionally *qualitative* rather than quantitative. The format is narrative, but discussions can be supported with quantitative data as well as visual illustrations. This sets a style for unconstrained observation and explanation able to supply the rich detail frequently important to nuance and thorough understanding. As an archive for a project, Design Factors and their associated Functions constitute a project memory; by extension, these project memories become a corporate memory that remembers *why* things were done—and does not quit or retire.

Building the Function Structure creates the information base. The structure itself, however, is fundamentally flawed for the tasks of using the information. For optimal use of the hundreds of Functions and Design Factors, a more suitable structure must be constructed from the bottom up.

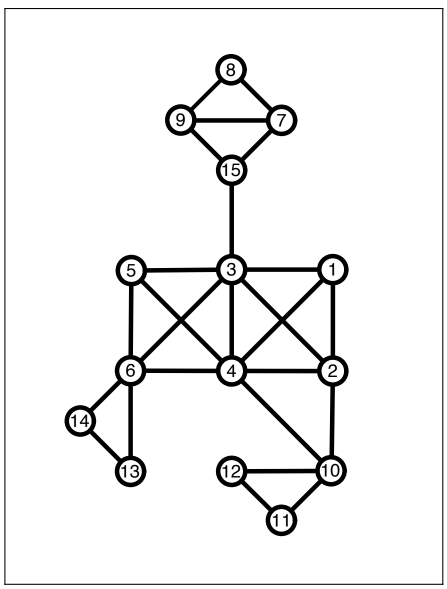


Figure 8. Demonstrating a **Function Network***, this small sample shows* **Functions** *(vertices) as they might be linked by the RELATN program. Linked Functions have a number of solutions potentially of common interest.*

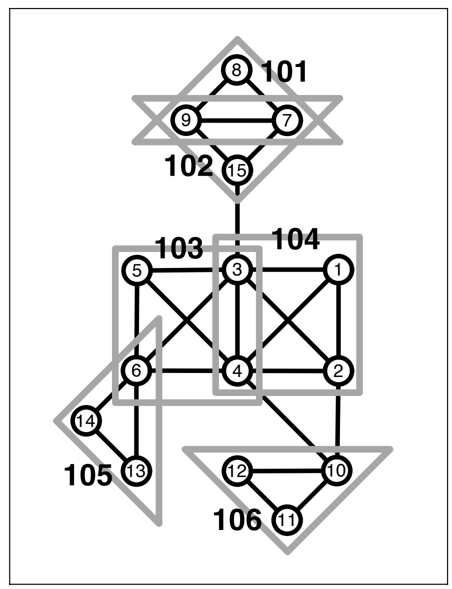


Figure 9. The **VTCON** *program finds clusters of* **Functions** *that are strongly interlinked. Because the clusters will themselves be clustered, notation denotes both level and cluster number (***103** *is level* **1***, cluster* **3***).*

Structured Information

Having insightful information in breadth and depth is necessary, but not sufficient. It must also be in the right place at the right time. The problem with information is that the more there is of it, the more difficult it is to organize. Given the ambitious goals of holistic, creative concepts, it is particularly important that information be juxtaposed in such a way that maximum synergy is generated among the ideas that come up for consideration. In other words, concept building would be best served if the components of the proposed concept elegantly solved multiple problems, performed multiple functions, and did all with an economy of means. The elegant solution not only does things with style, it does them with a simplicity that belies the effort that went into its design. To bring these kinds of concepts into being, the advanced-planning team needs to have the right information when they need it, *whether or not they know that they need it.*

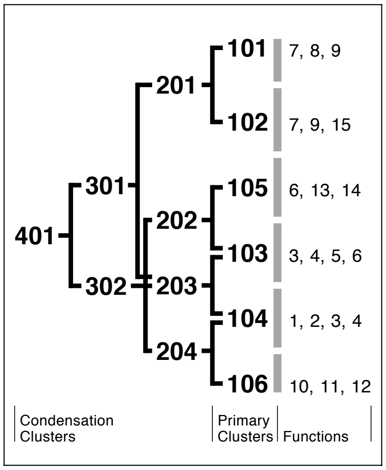


Figure 10. The primary (lowest level) clusters identified in the Function Network are condensed hierarchically by the **VTCON** *program to produce an* ***Information Structure.***

In the structuring phase of Structured Planning, two computer programs, RELATN and VTCON, organize the information produced by Action Analysis. The RELATN program (see Figure 8) uses a special "measure of interaction" to establish links between Functions in the information base. It does so *not by membership in a common category,* the usual means for establishing association in a database, *but by the likelihood of Functions being fulfilled by the same component or components of a design solution* (the Speculations produced during the development of the Design Factors).

Conventional top-down data structures (including the Function Structure used in generating the Functions and Design Factors for Structured Planning) associate data items by their common membership in predetermined, higher level categories (for example, all Functions to do with repair in a "repair" category; all Functions concerned with transport in the "transportation" category). The RELATN program associates them, instead, by their potential for being fulfilled by the same design ideas—whatever their previous categorization might have been.

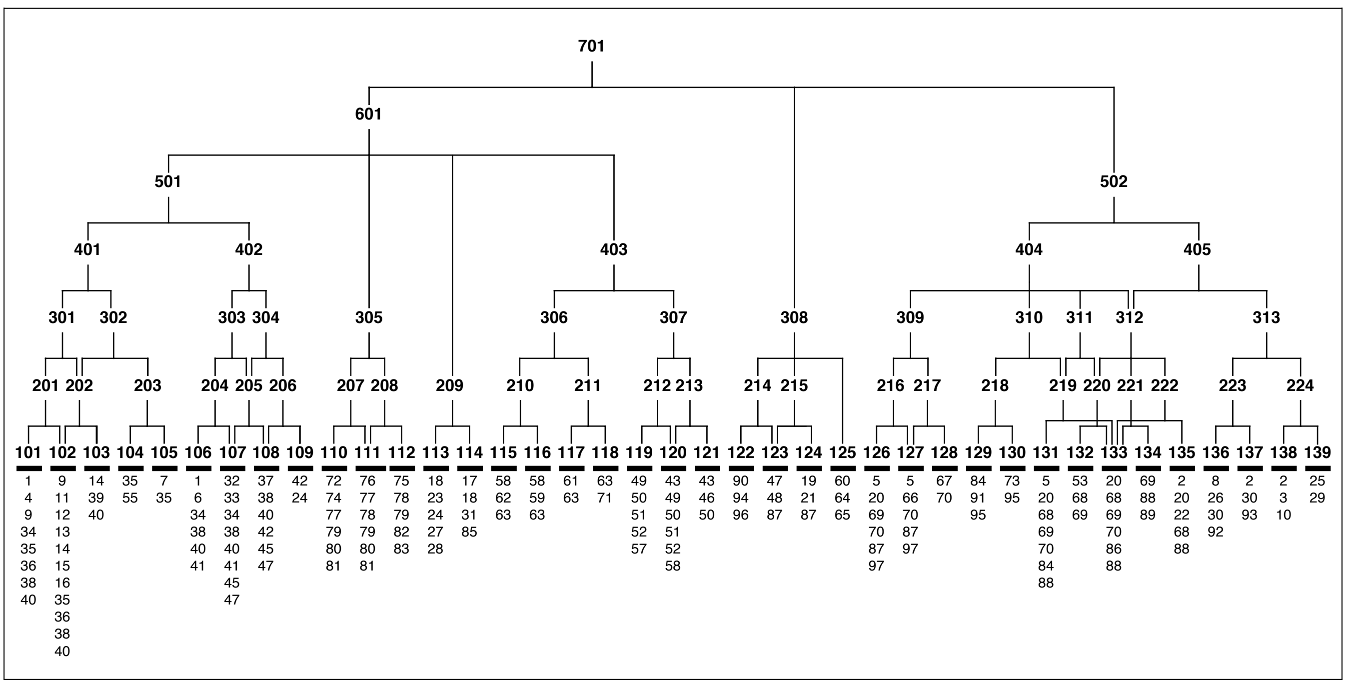


Figure 11. The actual Information Structure produced by **VTCON** *for the* ***TV Command*** *project. This new structure, organized from the bottom up, is optimized for the advanced-planning team seeking to consider the "right Functions together at the right time".*

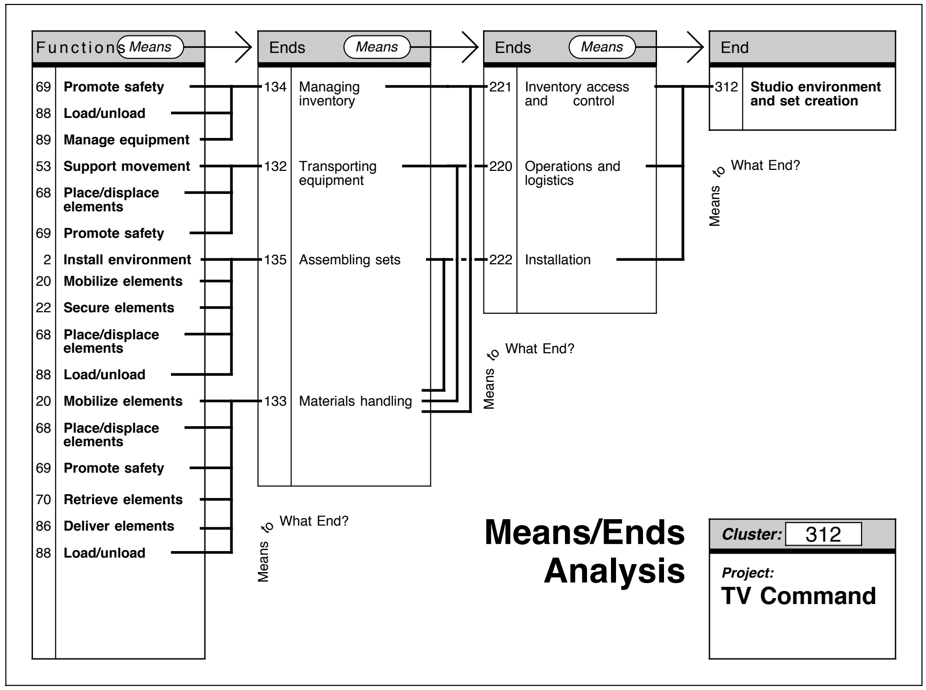


Figure 12. A cluster from the Information Structure (312) is subjected to Means/Ends Analysis to establish meaning for the structure revealed by the **VTCON** *program. Beginning with the Functions at the left, clusters are given labels to express the structure's functionality as insightfully as possible.*

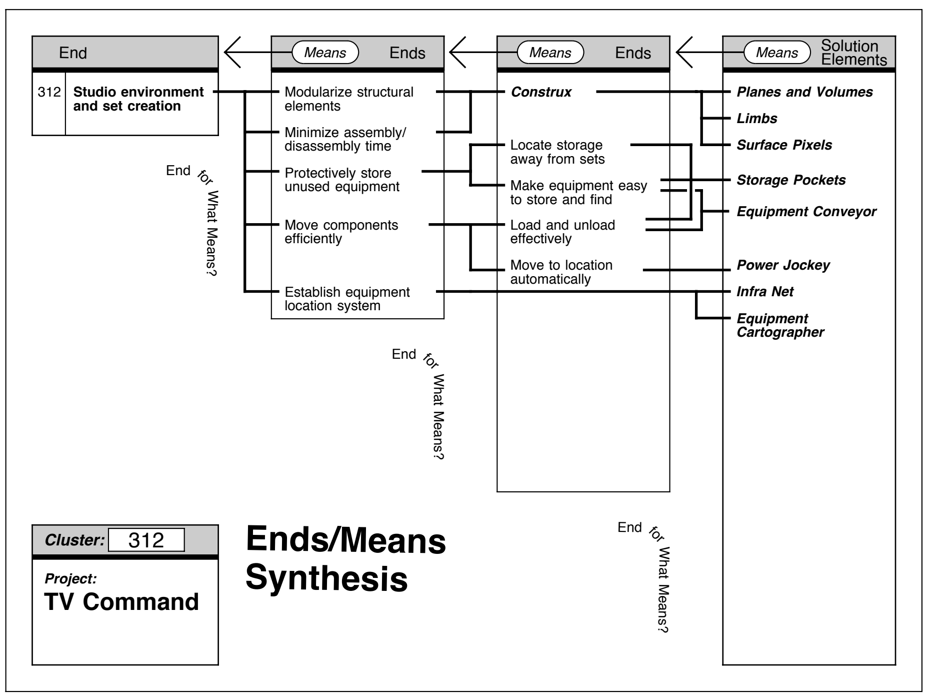


Figure 13. Using Ends/Means Synthesis, a description of system need taken from the results of the Means/Ends Analysis is subjected to idea generation at successively more refined layers. The process ends when specific **Solution Elements** *for all needs have been invented or selected, refined and modified from* **Speculations**. *These are then evaluated against the Functions from the original Means/Ends Analysis and written up as elements of the Plan.*

The VTCON program (see Figure 9) operates on the network of linked Functions produced by the RELATN program. It first finds clusters of highly interlinked Functions and then, looking at links crossing cluster boundaries and Functions common to more than one cluster, "condenses" the clusters to larger, inclusive clusters at higher levels until a final level is reached at which all Functions are represented (see Figure 10). This hierarchical **Information Structure** (see Figure 11), created from the bottom up, is the optimal organization to support the synthesis activities of the advanced-planning team.

Conclusions and Recommendations

Design technology has many roles—all important—to play in the evolving new product development process. Most critical, however, is its role at the beginning because it can be so influential and effective there. Toward implementation in this role, the following recommendations are guidelines:

• As policy, strengthen the use of design technology at *all* levels of the Quality Pyramid. Quality will be measured by more than just craftsmanship in the competition ahead.

• Embrace product integrity as an umbrella goal for product, system and service attainment. As an overarching idea, it directs all aspects of producer/consumer/observer relations and places lesser goals in proper perspective.

• Separate conceptual levels of designing from detail levels of designing—in the same way that strategy is separated from tactics. Freed by the separation, the concept development process can be reframed as a "task-force" activity.

• Prepare an initially small number of design-trained staff as leaders for advanced-planning teams. Training in the skills necessary for creative team work and the design technology for information-intensive planning will enable this nucleus group to transfer the technology in the process of using it.

• Periodically commission compact, interdisciplinary, advanced-planning teams of selectees, on loan from appropriate functional groups, with a nucleus designer as leader to conceptualize "products after next". When their projects are completed, these team members will be the ideal champions in their specialty areas for the detail development to follow.

• Treat selection for an advanced-planning team as an award for creative, team-supportive service, and extend it progressively to the widest range of employees possible. Through participation on advanced-planning teams, a cadre of knowledgeable personnel experienced in creative planning will be built up to institute the concepts throughout the corporate culture.

• When enough projects have beeb completed to justify it, establish an information base to make the accumulated knowledge available to future teams. As the level of training extends through the company, entries to the information base should be sought across the spectrum of corporate associations with products, services and users. Information generated at these points of contact is the means for instituting life-cycle design practices that can influence new product development as well as old product revision and upgrade.

Design technology is no longer the plaything of academicians; it is a fact of business. Industry is now entering an era in which those who understand

and use it effectively will win; those who do not will lose. Product-integrity quality must be the standard. The goal should be *planning* that can achieve it—reliably and predictably—*on an escalator delivery schedule.*

Suggested Readings

Owen, Charles. *Methodology of Project Phoenix: Structured Planning* (in Japanese, translated by Akira Harada). **Industrial Design** [Japan], Special Feature 3: Research Papers, No. 155 (October 1991): pp. 38-46.

Owen, Charles. *Product Integrity by Design.* In **Colloque "Design, Matériaux et Environnement".** Proceedings of the Recontres Internationales du Design et de l'Industrie, pp. 135-140. Toulon, France: Promo Design, 1991. Published also in: **Design Processes Newsletter** Vol. 4, No. 1 (1991): pp. 7-9, 11; and **Design Recherche** [France] No. 3 (February 1993): pp. 5-10.

Owen, Charles. *Context for Creativity.* **Design Studies.** [England] Vol. 13, No. 3 (July 1992): pp. 216-228. Published also in **Design Processes Newsletter** Vol. 4, No. 4 (1992): pp. 1-6.

Owen, Charles, editor. **House of the Future.** Chicago, IL: Institute of Design Communications Center, Illinois Institute of Technology, 1984.

Owen, Charles, editor. **Project Phoenix: Macro-Design Proposals for Confronting Global Warming.** Chicago, IL: Institute of Design Communications Center, Illinois Institute of Technology, 1990.

Owen, Charles, editor. **Design for Integrity.** Chicago, IL: Institute of Design Communications Center, Illinois Institute of Technology, 1993.