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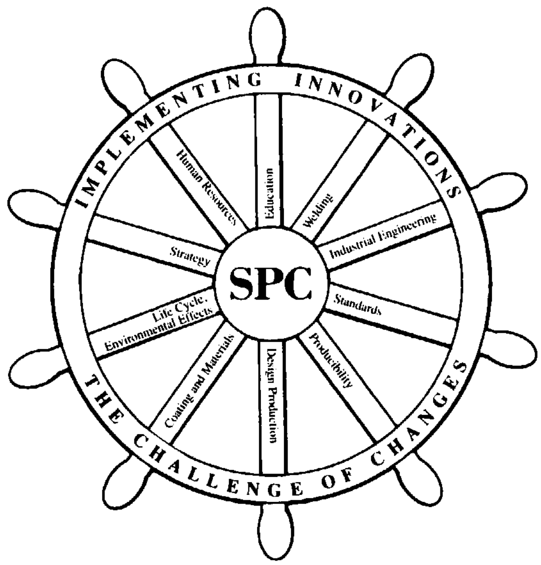

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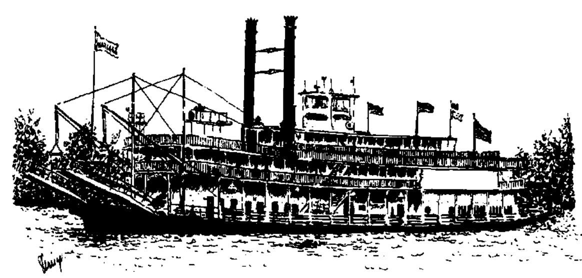

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Design/Production Integration and the Industrial Structure

No. 6B-1

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ABSTRACT

The naval architect or the designer is considered as the integrator of countless subsystems into the system, called the ship. In order to integrate, he must have in the design phase the freedom to communicate with all levels of production. This communication is the prerequisite to a successful design/production integration. The freedom to communicate can be fostered or impeded by the industrial structure.

The structure itself is driven by the economy of scope and scale and by legal requirements expressing views on competition and/or cooperation. The impact of structure and law on communication is sketched in comparative form for the American on foreign ship building industry.

The scope of the paper is restricted to fundamentals.

FOREWORD

Desiring to integrate the design/production process in ship building is not necessarily new. Advantages of such integration for time and cost-scheduling are well recognized. Less recognized is that integration is not only a management function but, rather, a response to existing facts of engineering, economy and law. Engineering concerns the process of the manufacturing operation. The process, in turn, is driven by the existing industrial structure which is a consequence of economic decisions, to be made within the framework of existing laws.

The objective of this paper is to sketch an outline of interaction between the design/production operation within the framework of technical, economic and legal facts.

The scope of the paper is restricted to "concepts only," explained in a rudimentary form, enough to get me point across. The paper deals with the essence of the design/integration problem.

OBSERVATIONS

It was evident from factory (1936) and ship yard (1948) experiences that design engineers and production engineers were a team. Prime contractors and subcontractors worked as another team. The goal of those teams was to deliver the best possible product at a cost acceptable to the customer. The term "price" had a strange connotation for the European engineer and the question about design and production integration would have been meaningless, because design and production has been an inseparable entity. The engineer with a master's degree had to know design AND production and to "design for production" was so self-evident that to mention it would raise astonishment.

The first time separation of design and production was encountered in 1957 when invited to the United States to testify about European ship building before panels of the Maritime Administration (MARAD). It was surprising that one could design and specify a ship in great detail without knowing the yard and its facility where the ship was to be built. In Europe at that time, bidding documents comprised a general arrangement plan plus two-to-five pages of "specifications."

In the early '7Os, in a major claims case for the U.S. Navy, this same separation was the culprit. The problems were complex but the conclusion was simple: Claims and disputes are the consequence of breakdowns in communication between parties involved. The different interpretations of rules, regulations and events are a failure in communication. Complexity is created by uncoordinated and often contrary goals of parties involved in the game, fostered by an insufficient market and empty order books.

Slowly and after many pleasant and unpleasant experiences, it became clear, first that NO ORGANIZATION CAN BE BETTER THAN ITS INTERNAL AND EXTERNAL COMMUNICATION. This holds true for an organization as small as a family, for a factory, apolitical organization or whatever. Second, THE FORMAL STRUCTURE OF AN ORGANIZATION CAN BE AN IMPEDIMENT OR A HELP FOR THE NEEDED COMMUNICATION. Of course, the formal structure and the purpose of an organization should be harmonized and driven by the specific need for communication in a particular organization.

Military combat units are a perfect example of a perfect blend between formal structure and communication need. In most other organizations, communication is the undernourished stepchild and rather a hang-on to the formal structures designed to satisfy other criteria; i.e., value-added subdivision, ownership preferences, financial aspects and other determinants. And, here the problem starts.

VALUE-ADDED HISTORY

Every product, be it an end product or an intermediate product in a production chain, has two major cost components. First is the material (M) a particular enterprise buys from the outside and, second, is the value-added (V) representing the enterprises contribution in capital (C) and labor (L). The M/V-ratio is the first and highest indicator for the organizational structure of an enterprise, and the sum of M plus V represents the cost of the product. (Price, a different matter, is not addressed.)

Shipyard specific: In the time of the reciprocating steam engine and the scotch boiler, most shipyards were almost self-sufficient or, in modem terminology, fully integrated. They bought only plates, profiles, bars and wires from the outside and everything else, from hull to engine and boiler, were made at the yards. Hence, the M/V-ratio was often 10 percent for M and 90 percent for V.

Beginning about World War II, the picture changed as a consequence of what may be called a technological revolution: Electronic devices arrived, new propulsion systems were developed, new weapon systems invented, and so forth. The (economy of) scope of all new subsystems needed specialists in design and production far beyond a shipyard capability, far beyond the economy of scale to be built by each individual shipyard, and new subcontractor industries developed delivering new specialties to many shipyards. The yards lost self-sufficiencies and became more or less assemblers, buyers and coordinators of products of the "supply industry." As a result, modem shipyards (building U.S. Navy ships) may produce only IO percent value-added, and, 90 percent of the ship cost is material, either in subcontracted material or government furnished material. Briefly, technology reversed the make-or-buy decision from 90/10 percent to 10/90 percent.

Table I illustrates this development.

PRODUCT LEVELS

A work breakdown structure (WBS) can be developed for anything and everything, what is called a system. In turn, every WBS can be defined with six levels, (used in many DOD studies). Each of the six levels is associated with a key activity, shown in Table II.

By inspecting examples in the table, note a non-homogeneity at Level I. Obviously, a ship and an aircraft or a tank are, if considered "systems," completely different entities. Now, go to Level II. The generic term of engine or air condition could apply to ships, aircraft and tanks. This points toward the need to split the WBS, beginning with Level II into types of subsystems like:

(1) structural

(2) mechanical

(3) electrical

(4) electronic

(5) chemical.

Within each subsystem level the first indication of homogeneity may appear and exactly this is it, what leads to the existence of, for example, mechanical industries, electronic industries, and so forth. Continuing through the next levels, components and elements are again "dedicated" to types of subsystems and only at the material and raw-material levels

Table I. VALUE ADDED HISTORY

TABLE A:

Line #	Item	Ship Type ①	②	③	④	⑤	⑥	⑦	⑧	⑨
		Lead	Follow	Lead	Follow	—	—	—	Follow	—
		TAO		TAK X		CVN	CV	SSN	FFG	CG
①	Value Added	26	22	41	39	22	37	23	10	25
②	Money Flow	67	72	49	51	21	20	21	13	13
③	Business Volume	93	94	90	90	43	57	44	23	38
④	GFM	7	6	10	10	57	43	56	77	62
⑤	End Cost	100	100	100	100	100	100	100	100	100

TABLE B:

Line #	Item	①	②	③	④	⑤	⑥	⑦	⑧	⑨
①	Business Volume by Definition 100%	100	100	100	100	100	100	100	100	100
②	Value Added as Percentage of ①	28	23	46	43	51	65	52	43	66
③	Money Flow as Percentage of ①	72	77	54	57	49	35	48	57	34

Notes: Line 3 of Table A is normalized to 100% in Table B.

***Source: NavSea Shipbuilding Statistic,* 1980**

a confluence may occur, independent of the subsystem type.

Now to the naval architect: According to the classical definition, an architect is planner of the total. The architect must understand requirements and interactions of all subsystems. To what level of detail can the architect go before being overwhelmed? This point will be addressed later.

LINKAGE MECHANISMS

The six product levels are interacting and, by necessity, interconnected. The structure of the interconnectedness is called linkage mechanisms (plural). Three distinct forms of such mechanisms exist:

- first, ONE functional (or value-added) linkage mechanism
- second, EIGHT organizational linkage mechanisms can be identified and
- third, 32 ownership linkage mechanisms.

The Functional Linkage Mechanism

The "concept" of the functional linkage mechanism is ubiquitous: It is valid for any system and any type of subsystem and, furthermore, is identical to the value-added flow of the processes through the product.

The rudimentary form of the linkage mechanism is shown in Figure 1.

Figure 1 shows the functional linkage system from top-down, similar to a WBS. On the left side,

Table II. LEVELS OF PRODUCTS

PRODUCT LEVEL	NAME OF PRODUCT AND PRODUCT DEFINITION	PRODUCT EXAMPLES	KEY ACTIVITY AT EACH LEVEL
I	SYSTEM The end product	ship, aircraft, tank, missile	Assembling system
II	SUBSYSTEM A subassembly of the end product: a major subdivision of the end product	engine, bilge, air conditioning unit, gun, avionics	Assembling subsystem
III	COMPONENT A fundamental constituent of a subsystem or an end product ; a number of elements joined together to perform a specific function and capable of disassembly	carburetor, pump, heat exchanger, audio- frequency amplifier	Assembling component
IV	ELEMENTAL A fundamental constituent of a component or a subsystem: one piece, or a number of pieces joined together which are not normally subject to disassembly without destruction	screw, gear rotor, frontwheel bearing, frame	Making element
V	MATERIAL The basic ingredient (material) from which an element is produced	fuel oil, plate, wire, casting	Refining material
VI	RAW MATERIAL The mined (or untransformed) material	ore mineral, oil extracted	Extracting raw material

Source: "Financing Defense Systems Programs", Dr. Franz A.P. Frisch and David D. Acker, *Concepts*, Autumn 1981

there is **the product** (P). This might be the ship, delivered by the shipyard at the systems Level I. The shipyard bought material M1, originated at the subsystem Level II and applied labor (L_1) and capital (Cl), or its value added to the material. Thereafter, dissolution is continued of M_1 into Level II, and so forth, until arrival at raw-material Level VI.

Turning the flow from Figure 1 around, starting with raw material (RM) as first input, and adding value-added at the mine, the mined ore as product P6 is received. Thereafter, P_6 enters Level V as material (Ms), and so forth, through the system until arrival of/at the end product (EP), the ship. This flow is shown in Figure 2.

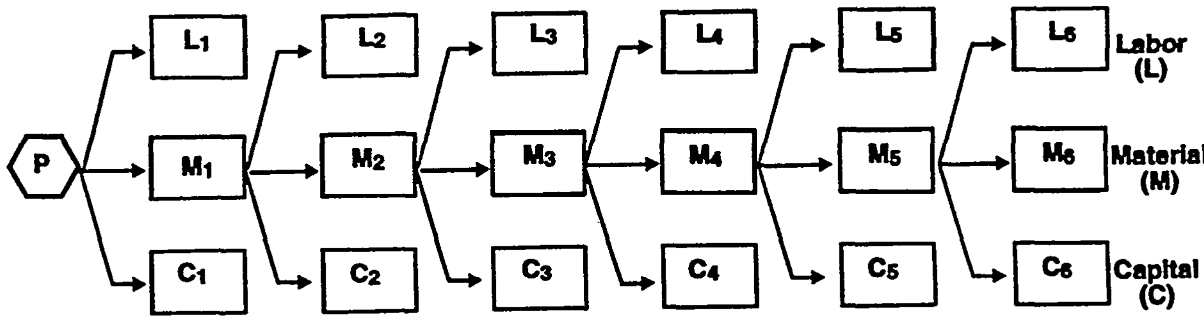
The most important point in Figure 2 indicates multiple suppliers at Levels VI through Level II. This indicates the possibility of competition at each level but does not mean competition must exist.

Functional linkage is the skeleton of the industrial anatomy, independent of selected organization or ownership of and at various levels, and is discussed below.

The Organizational Linkage Mechanism

While the functional linkage has been a MUST-concept, the organizational linkage is an OPTIONAL concept, to choose from eight possible forms as shown in Figure 3.

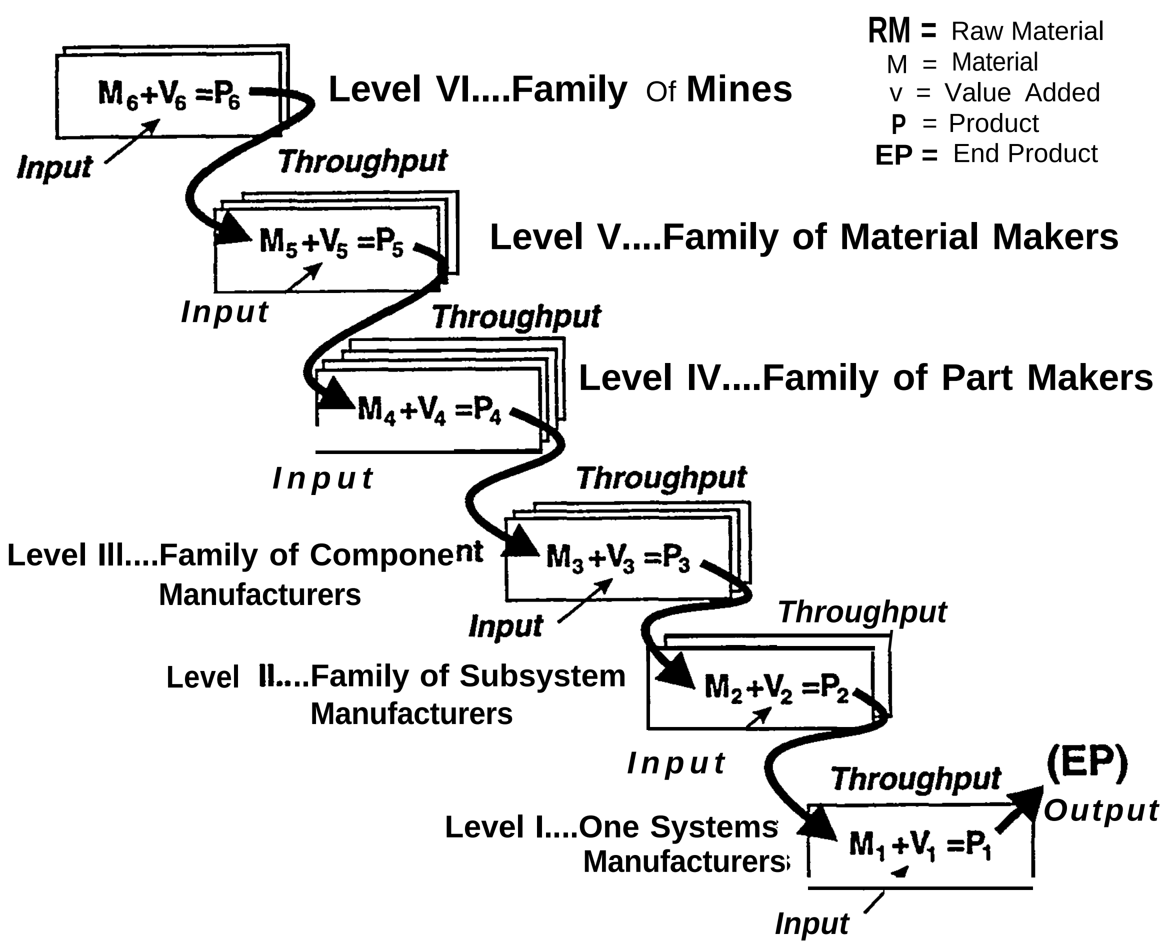
In Figure 3, only linkage between Level VI, the raw material, forward to Level V, the steel mill, may be called a natural linkage, but other linkages are free



Notes:
1. P represents the end product
2. Subcripts 1 through 6 represent labor, material, and capital at the six product levels within the supply breakdown structure.

Source: "Financing Defense Systems Programs Dr. Franz A.P. Frisch and David D. Acker, Concepts, Autumn 1981

Figure 1. Supply Breakdown Structure



Source: Dr. Franz A. P. Frisch, DSMC Paper

Figure 2. Value Added Flow

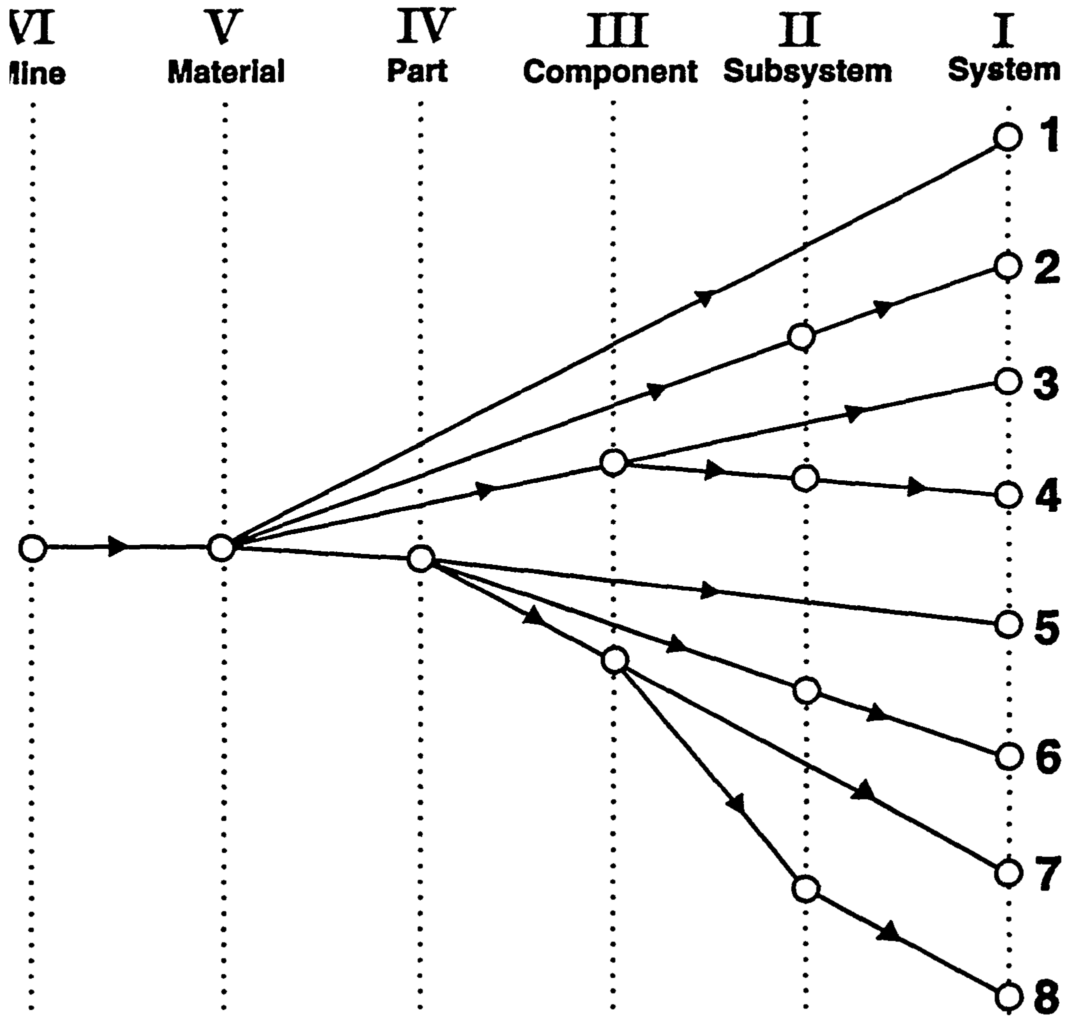


Figure 3. Organizational linkage

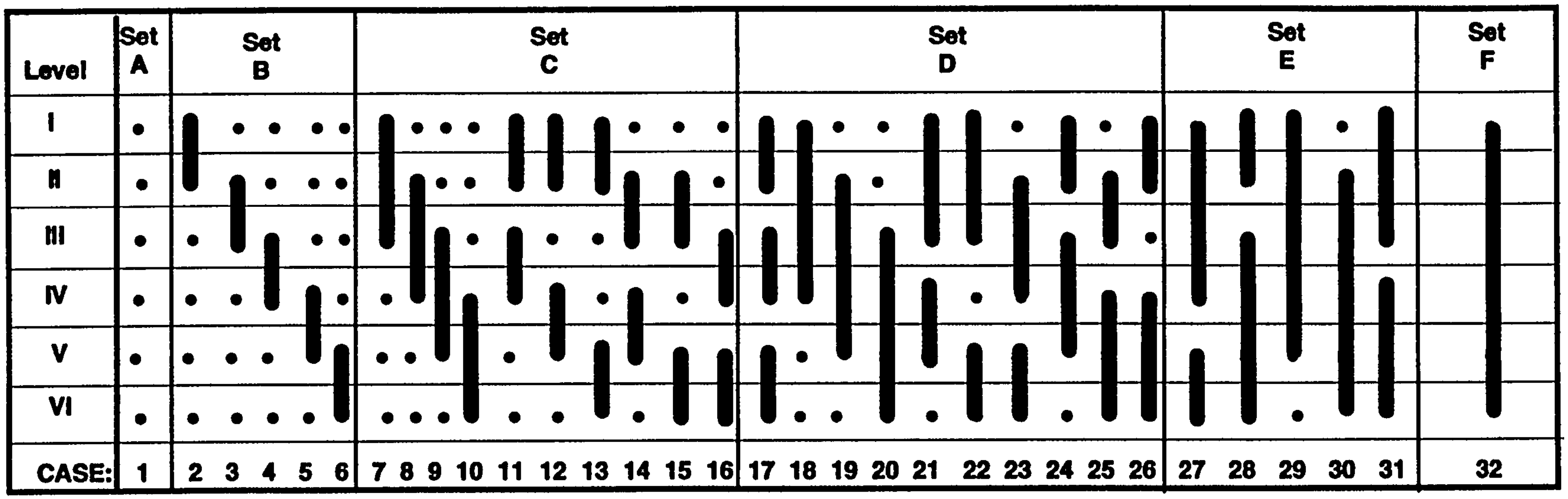
to choose. For example, in Path 1, the steel mill can deliver material directly to Level I (ship yard), or in Path 2 to Level II, manufacturer of the subsystem...and so forth.

Each of the selected eight branches will he driven by the economy of scale as expressed by uncountable make-or-buy decisions along each path. Each buy-decision can be "economically" superior to any make-decision. Even economic superiority has its trade-off. With every buy-decision, there is a shift from internal communication (within the family of one manufacturer) to external communication (across families of manufacturers). This point will be addressed later.

The Ownership Linkage Mechanism

The Dominant Ownership Structures shown in Figure 4 represent a part of the linkage mechanism. Dominant shall mean that only collocated levels may be under co-ownership. Non-dominant would mean lack of co-location like, for example, a common ownership for the shipyard (Level I) and the steel mill (Level V). The uncountable non-dominant ownership is not considered.

Cases #1 and #32 in Figure 4 represent the extremes. In Case #1, all levels have independent ownerships. In Case #32, all functional activities of the six levels have a common ownership. Forms of ownership are not only an economical problem, but are subjugated to legal constraints; i.e., embedded in cartel laws, rules for competition and others.



SET A....six ownerships
SET B....five ownerships
SET C....four ownerships
SET D....three ownerships
SET E....two ownerships
SET F....one ownership

Source: Dr. Franz A. P. Frisch, DSMC Paper

Figure 4. Dominant Ownership Structures

From a communication point of view, in Case #1 there may be almost perfect internal communication at the six functional levels, but tremendous difficulties with external communication across the levels. In Case #32, there may be imperfect internal communication because of organization size, but there are no problems with external communication because nodes for such do not exist. This points toward a trade-off between quality of internal communication as a function of organizational size and difficulties in external communication because of separation. More follows.

INTERLUDE AND CRITIQUE

So far, so good; the industrial structure was addressed in rough sketches and the naval architect was mentioned once. Let's call him the designer and his product the design. Nowhere, in any chart, did the designer or product appear. Is the design we are to "integrate" hiding? Has this paper, so far, missed the point? Is somebody forgotten? Where is the customer in the industrial picture?

Two answers are possible. First, the customer AND the designer are completely separated from the industrial sphere if the design is used as the basis for competitive bidding and the estimator at the shipyard is floating in uncertainties, as long as the ship yard has not received the competitive bids from all their subcontractors. Integration can start only after the lengthy bidding process is finished. Second, the customer works WITH the designer at or for a preselected ship yard, and the designer selects during the design and estimating process (in continuous communication with the customers) all subcontractors. In this way, integration of design and production starts at the beginning. No time is lost but advantages of competitive bidding have evaporated.

The two answers describe extremes; but, the first can be called the American way, the second the European way. In the first case, the designer is the "owners representative" but he and his design are NOT A PART of the industrial process. In the second case, the customer and the designer and his design ARE A PART of the industrial process.

Both concepts, competitive and the cooperative, have specific advantages and disadvantages and neither is optimal, but both are carrying illusions. The first is the illusion of integration and the second is the illusion of competition. The preferred illusions are embedded in value judgment, reflecting culture and philosophy.

COMMUNICATION CONTROL

Communication control shall be defined as anything and everything that fosters or impedes communication between design and production, at all levels and across all levels.

Looking at any industrial product and process but, in particular at ships and ship yards, there is differentiation among three control types. First is functional control, second is organization and ownership control, and third is the external control mechanism.

Structural Control

The need for structural control is dictated by the complexity of the product and of the processes. The designer and the ship yard, jointly as the "systems integrator," must conduct two activities. First, the subsystems (Level II) MUST be coordinated. Second, the production of the subsystems SHOULD be supervised to guarantee performance and quality. The counter-force to "must" and "should" is CAN. How much can we do? What is possible? To illustrate, look at Table III.

Table III is simple and a masterpiece of naivety (often called a sample for demonstrative purposes only); nevertheless, results are frightening. We assume 10 subsystems (Level II) only; we assume each subsystem is constituted only of 10 components (Level III); hence, the existence of 100 components only and, in turn, we assume existence of 1,000 parts. It must be a primitive system. Here is the result. If we can hire 1,110 independent supervisors, we can SUPERVISE 10 subsystems, 100 components and 1,000 parts. But what shall be done with the COORDINATION of (in round figures) 505,050 interactions? If most 1.110 supervised nodes interact, as assumed, there is a need for ONE coordinator able to understand more than a half-million interactions. Such genius does not exist on earth. So, what is to be done?

We invent the appropriate management system where the lower-level informs the higher-level only about some parameters of each product. For example, producers of subsystems will inform the systems integrator only about requirements for space, weight and power for each subsystem. This means that each

Table III LEVELS, ELEMENTS AND INTERACTIONS

LEVEL	ELEMENTS PER ???	POSSIBLE INTERACTIONS
I - System	10	
II - Subsystem	100	50
III - Components	1,000	5,000
IV - Parts	1,110	500,000
Total		505,050

Source: Dr. Franz A. P. Frisch, DSMC Paper

subsystem proper is for the systems integrator only, a black box with form and function, with input and output. Ultimately, subsystems are cargo colocated in the hull.

There is only one way to handle the problem. Product complexity and constant human limitations killed design/production integration on the drawing board as previously possible in primitive times. Today, the integration process is unpredictable if new subsystems, non-existent before, are involved. Today, the integration process reaches deep into the production phase as documented (for NAVY ships) in thousands of change orders. But change orders are nothing more than elements of a learning process about unpredictable coordination aspects. The solution: Learn to accept the management system of "muddling through" and do not ask for the impossible.

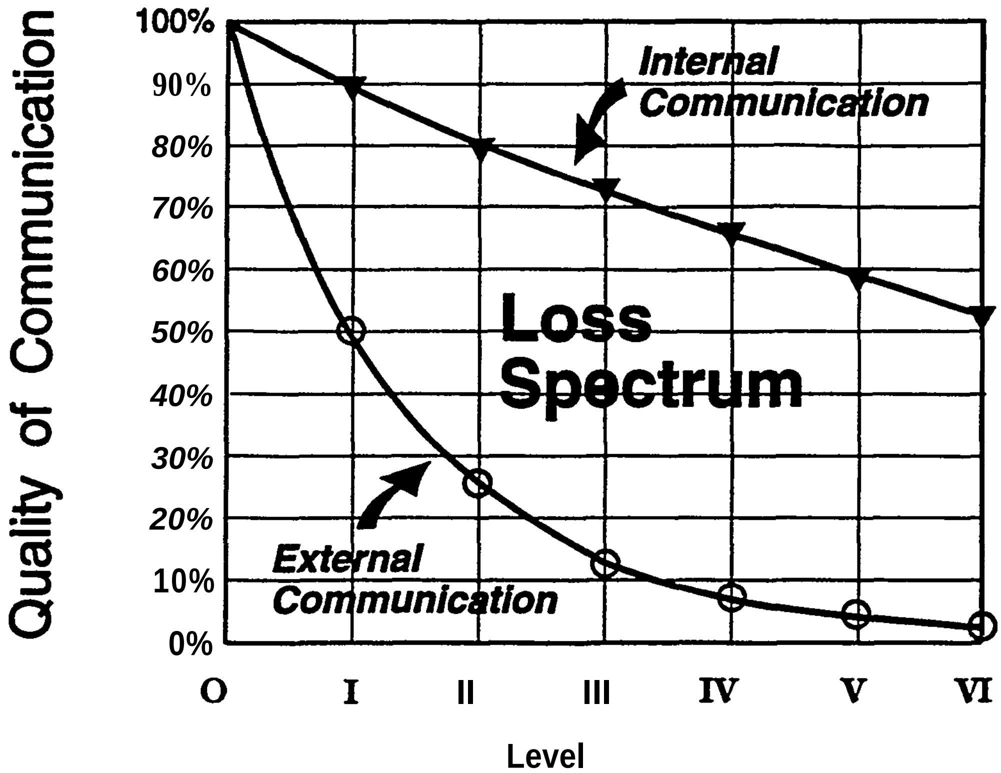
Organizational and Ownership Control

The structural control could be considered a product-driven engineering problem. Organizational and ownership control overrides the first and, driven by economy of scale and scope where communication control is exerted by nodes of organization (Figure 3) and nodes of ownership (Figure 4). Within each node, there is internal communication and, between nodes, there is external communication. Those communications can have different quality.

To illustrate, assume ranking the quality of communication from zero to 100. Zero would imply a complete collapse of communication and 100 of perfect communication, where communicating parties understand each other, unrestricted. Real communication quality will be (or must be) above zero and below 100, but how to "measure" quality of communication is an unsolved problem. Here, it can be assumed, that internal communication is always better (whatever this means) than external communication.

Rank internal communication at each level (I through VI) with 90 percent and the external communication with 50 percent (both optimistic assumptions). Next, select two extremes. First, combine the organizational Path #1 (from Figure 3) with Ownership Structure #32 (from Figure 4). Here, there is an overall communication efficiency of 0.9 to the sixth power or of a total of 36 percent. Second, combine the organizational Path #8 (from Figure 3) with Ownership Path #1 (from Figure 4). Here, there is an overall communication efficiency of 0.5 to the sixth power or of a total of less than 2 percent. The two extremes are shown in Figure 5.

The two curves in Figure 5 encompass the loss-spectrum of communication because of organization and ownership structure. The loss-spectrum indicates the range of trade-off. In the first case with 36 percent communication efficiency, there is the best possible design/production integration, but there are tremendous losses in the economy of scope and the economy of scale. In the second case, there may be the best possible economy of scope and scale, but there is a horrendous price with a 2 percent communication efficiency or, practically, impossibility for a foresight about design/production integration.



Source: Dr. Franz A. P. Frisch, DSMC Paper

Figure 5. Loss spectrum

To find an optimum between the two extremes could be an existing academic research task, based upon a menu of assumptions. As pragmatist however, trust the market forces.

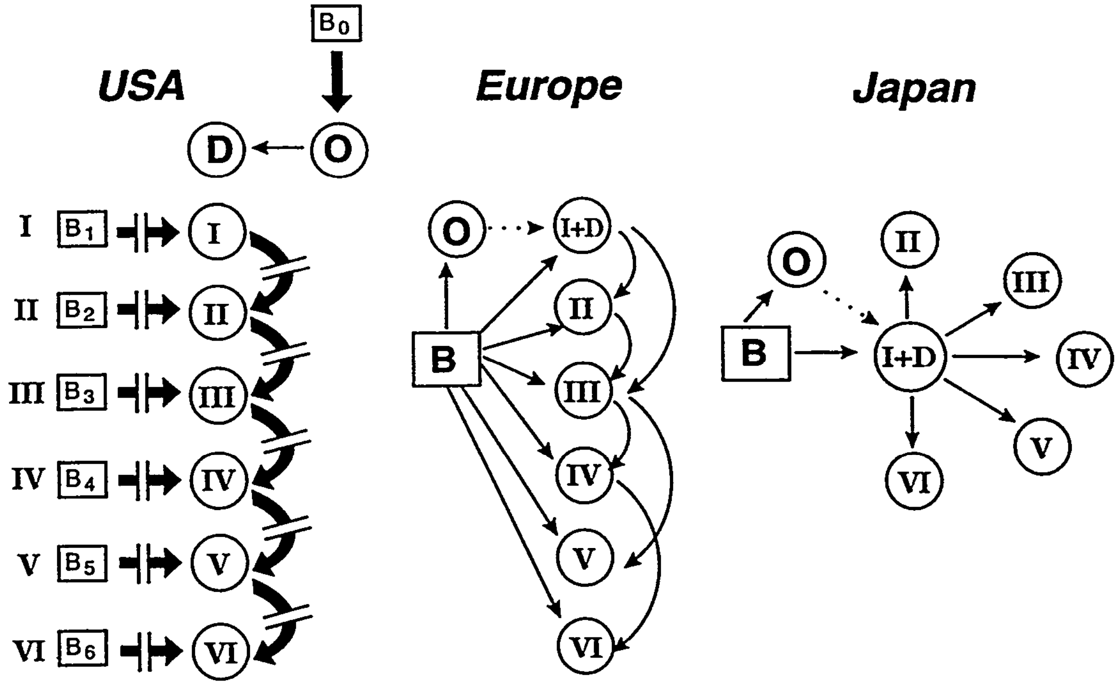
External Control Mechanism

The structural control dealt with engineering aspects, and the organizational and ownership control with economic aspects. The present external control mechanism finely deals with legal aspects of integration. Also, the three aspects are inseparable. This paper deals with the third aspect in isolation and compares American, European and Japanese concepts of the external control mechanism in the simplest form. In Figure 6, concepts are sketched.

The American is shown at the left side of Figure 6. The only firm communication link before bidding and source selection is the link between the ship owner (0), or the customer with the designer (D) as the owner's representative. Otherwise, no firm communication link exists. Communication between the ship yard, Level-I, and the subcontractors, Levels-II through VI, cannot be established before contract award; even then, companies might have to deal at arms length to avoid conflict with selected antitrust laws. Financing the owner and level activities is performed by different banks (B_i) and each bank, as lender, must work at arms length with the individual borrower according to the Glass-Stiegel Act of 1933. Hence, there **is** neither solid communication possible between the banks and the borrower, nor among the banks.

The European is shown in the middle of Figure 6. Note the designer (D) is an integral part of the prime contractor, or the ship yard at Level I. The Level I can freely associate with any level according to choice, but the owner (0) and all six levels of the supply hierarchy are linked to one bank (B), and the bank will have its employees on the board of directors at all six levels and at the shipping company or the owner's company. In this way, the bank (B), or a group of coordinated banks, takes the roles of communicator and coordinator during the entire process, from design to production. Within this bank-controlled system, all lines of communication are open.

The Japanese is shown at the right side of Figure 6. The bank (B) controls only the owner's



Interrupted flow
G Not interrupted flow
Optional (not interrupted) flow

0 = Owners
B = Bank
I, II, . . . = Levels
D = Designer

Source: Dr. Franz A. P. Frisch, DSMC Paper

Figure 6. External control **of communication**

corporation (0) and the prime contractor at Level I, also synonymous with the designer. Here, the "direct" bank control stops, BUT the Level I operator is the major shareholder of subcontractors, and thus controls the entire production operation, and all parties of the game can communicate completely unrestricted as when designer or architect start the first sketch for a new design. Lower levels can function as co-designer, supporting the process or production needs at their specific levels.

SUMMARY

This paper starts with an observation, declaring the possibility of the design/production integration as a problem of communication.

Necessary communication is product- and process-driven, but necessity and possibility do not always blend. Possibilities are given by the industrial structure, the economic goals of the participants and ultimately by the legal environment, supporting or hindering the necessary communication.

The possible form of formal communication, or the communication environment is compared for the United States, Europe and Japan. However, no judgment is made about the relative possibilities to communicate because each system has **its** strong and weak points and no system can be perfect. There are trade-offs based on value judgments as expressed by the law-of-the-land expressing the philosophy of the Common Law World (the United States) and of the Codified Law World (Europe and Japan).

EPILOGUE

It may be irritating to find that impediments for a design/production integration are dominating the American picture, while the European-Japanese environment fosters integration. This is correct but shall not be the basis for judgment. Think about advantages the American system provides, unknown to others, like freedom of choice, healthy competition and support for entrepreneurial spirit. Our past successes prove this point.

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