The Value and Costs of Modularity

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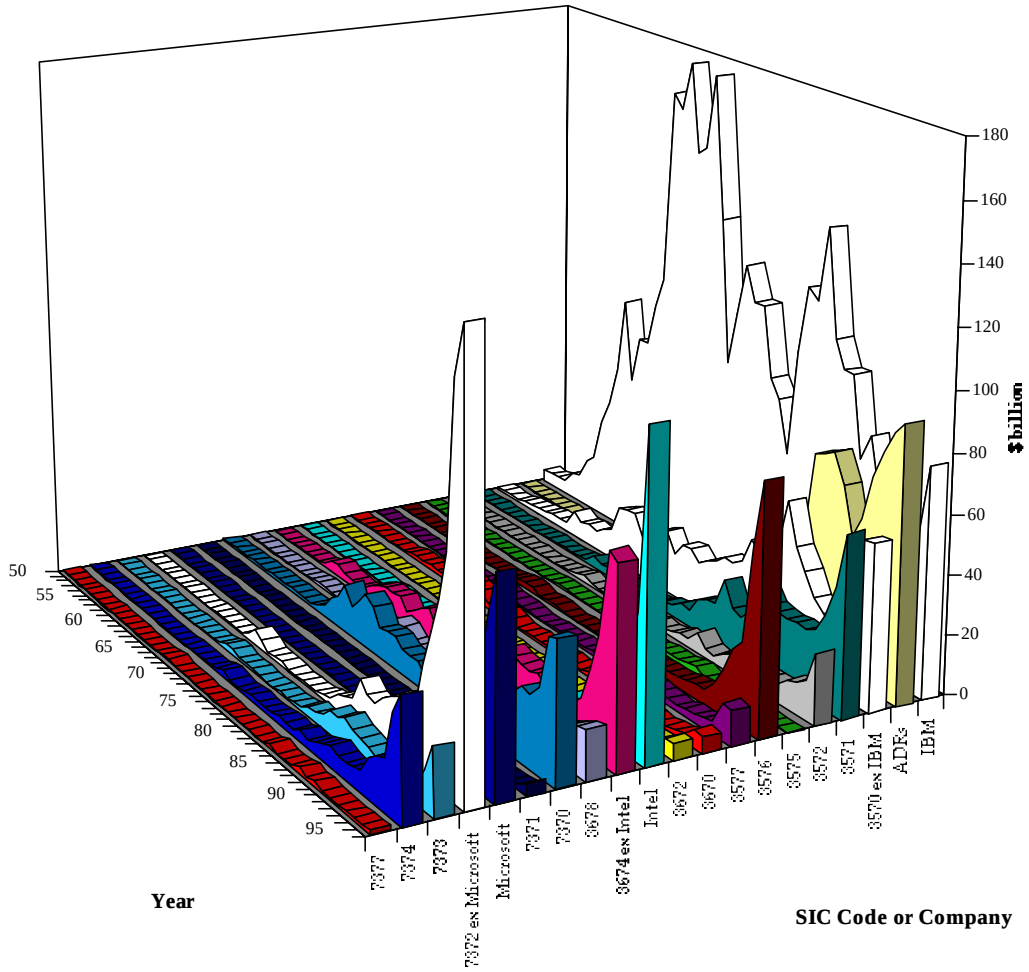
The Market Value of the Computer Industry
By sector, 1950-1996 in constant 1996 US dollars



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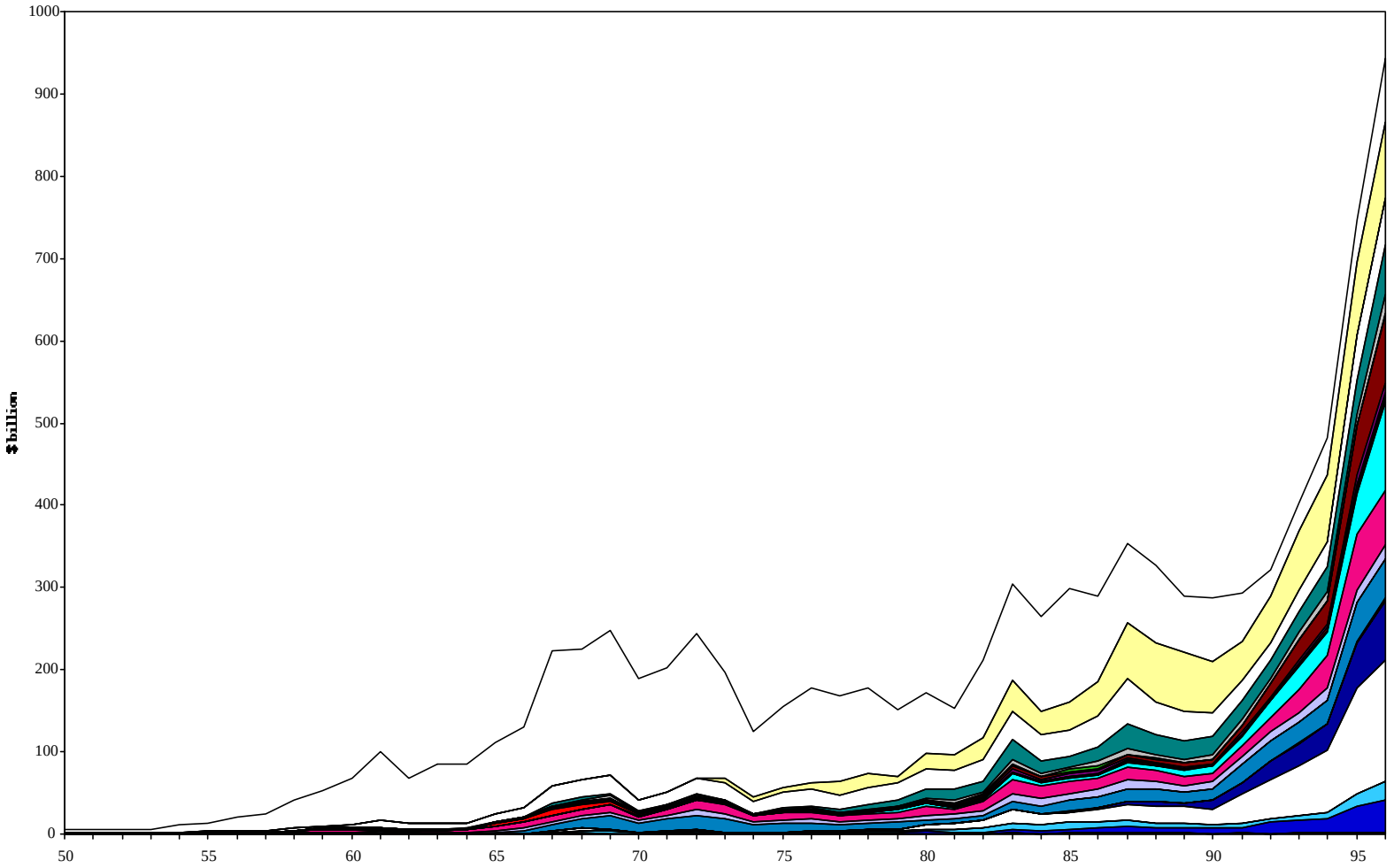
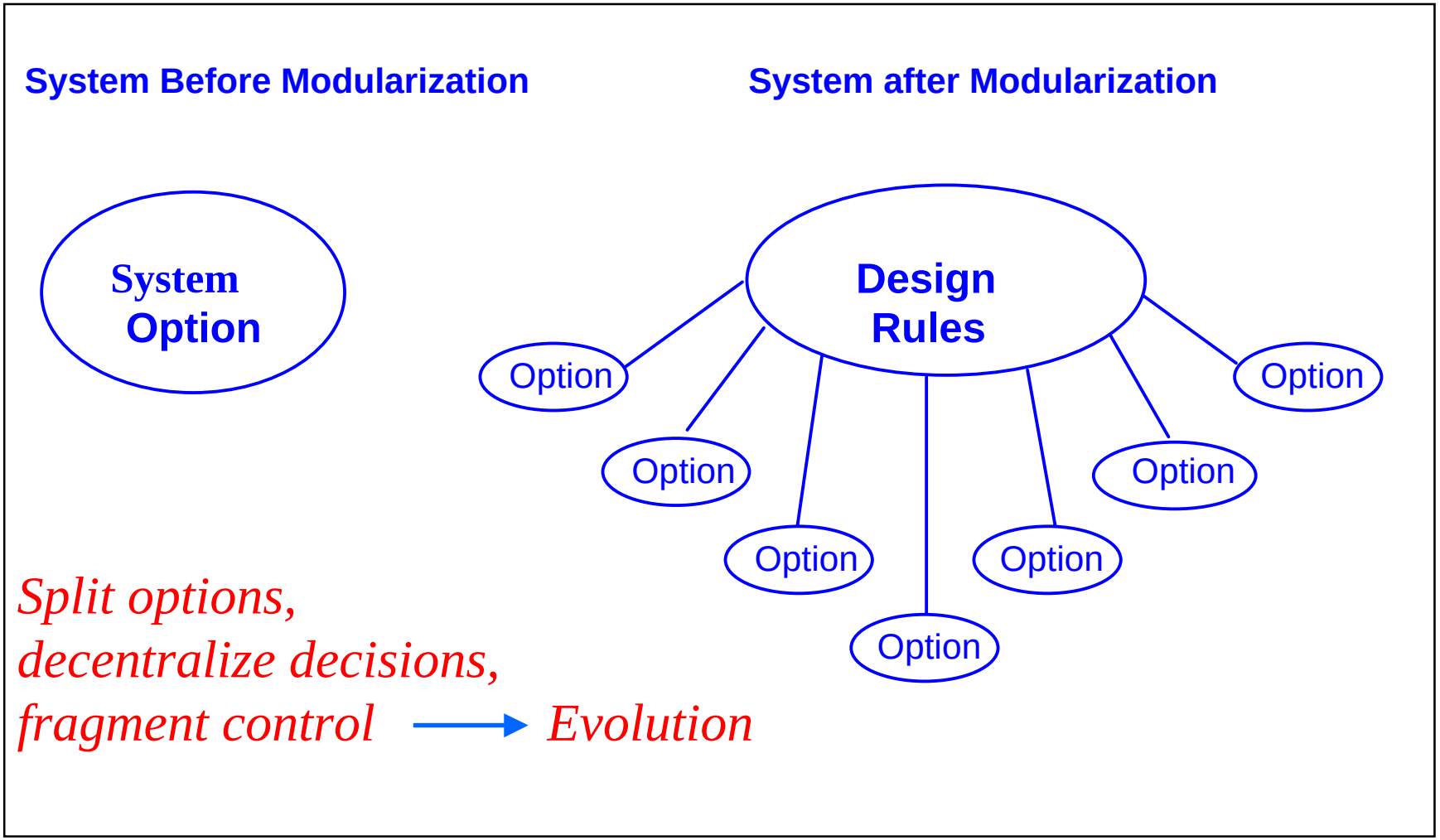
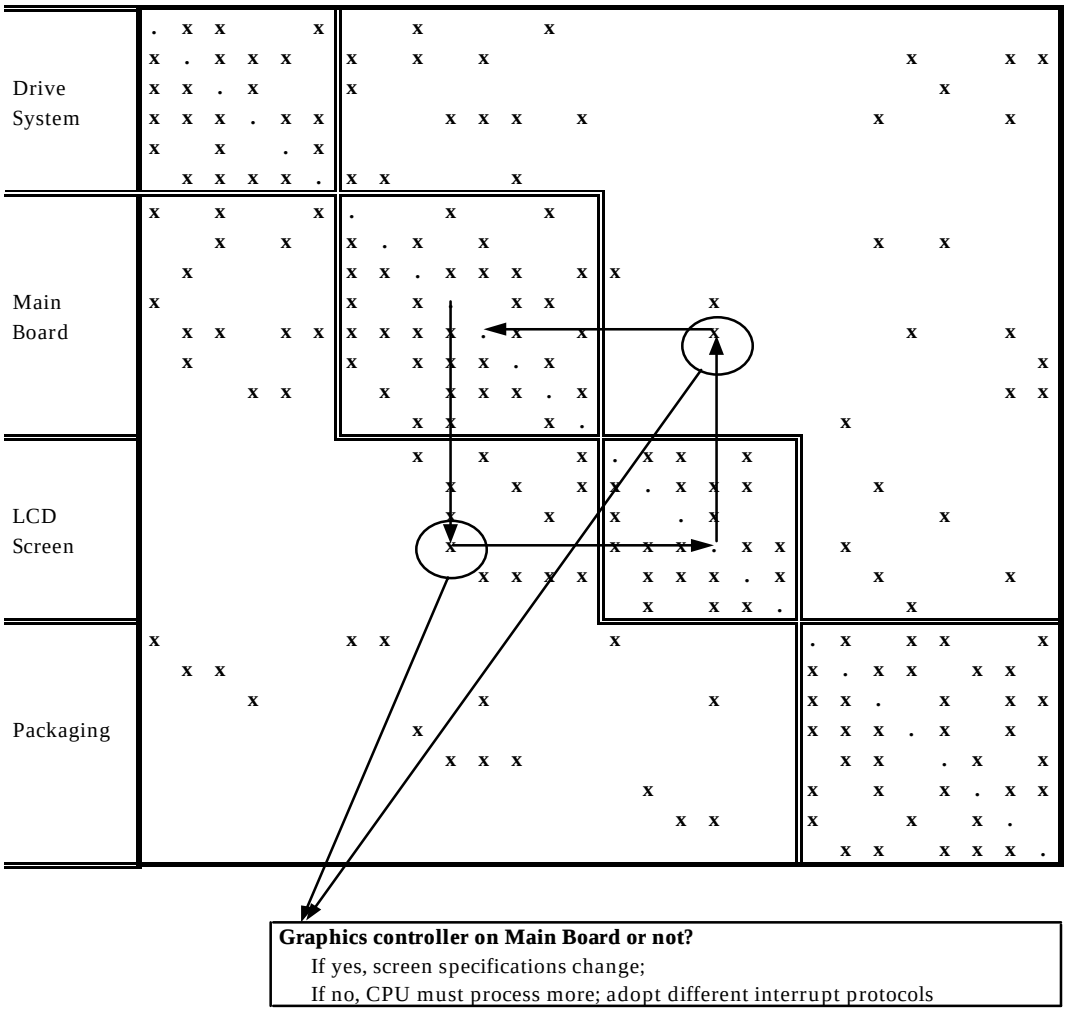


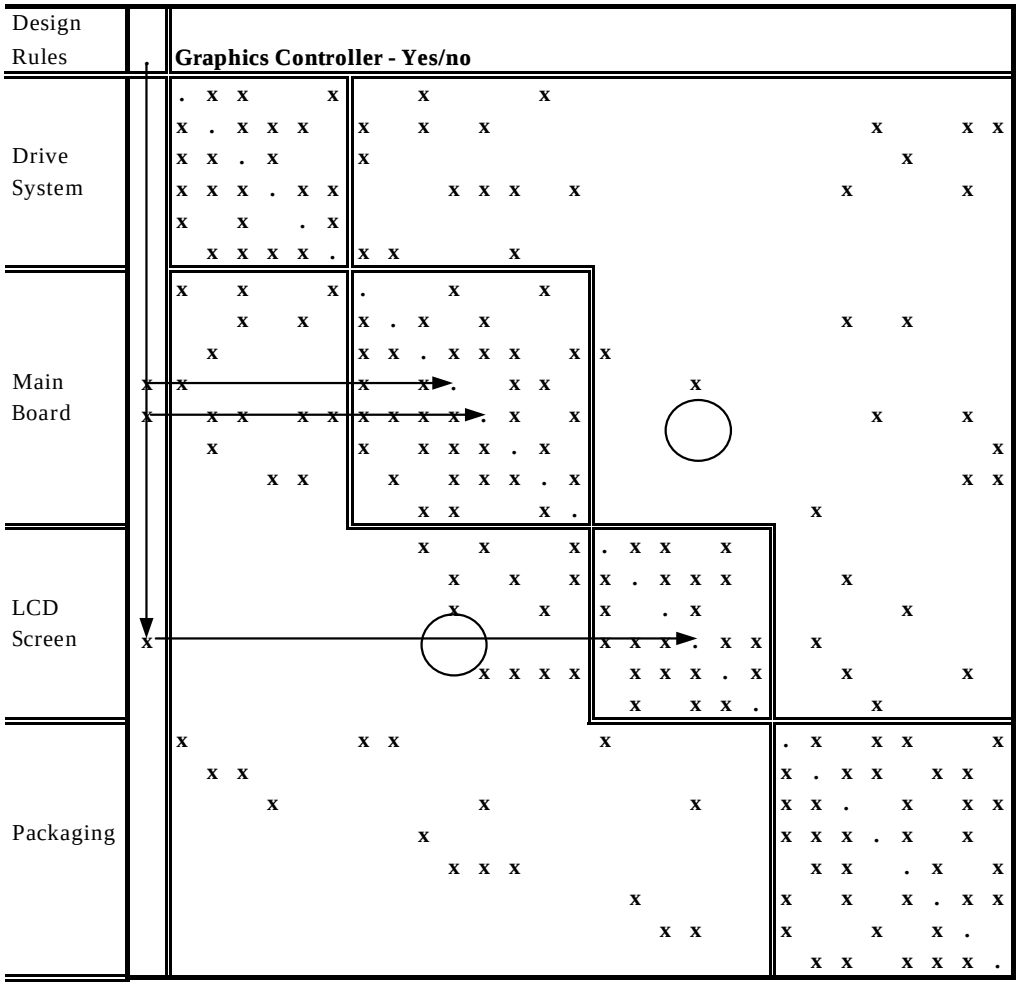
Modularity Creates Design Options



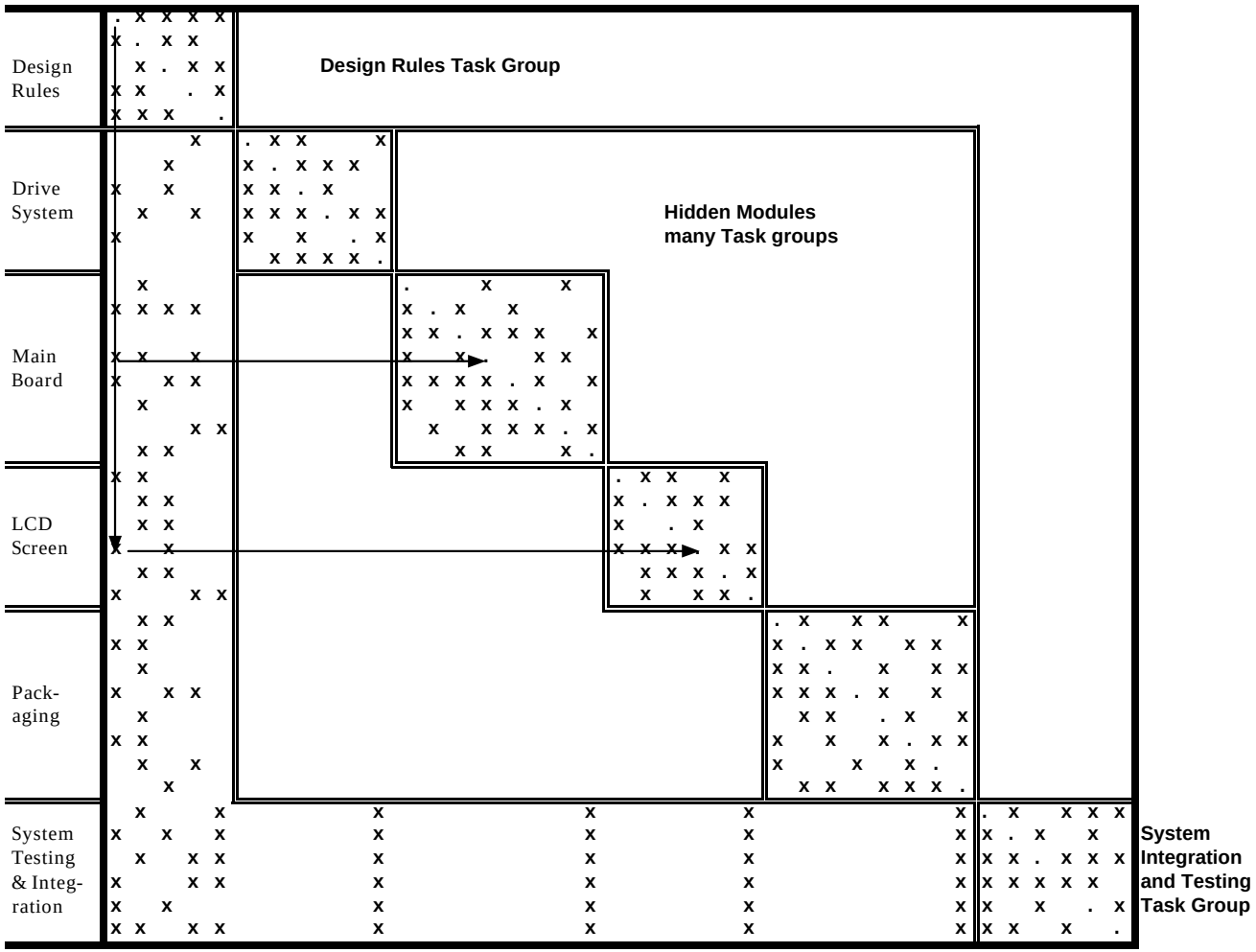
Design Structure Matrix Map of a Laptop Computer



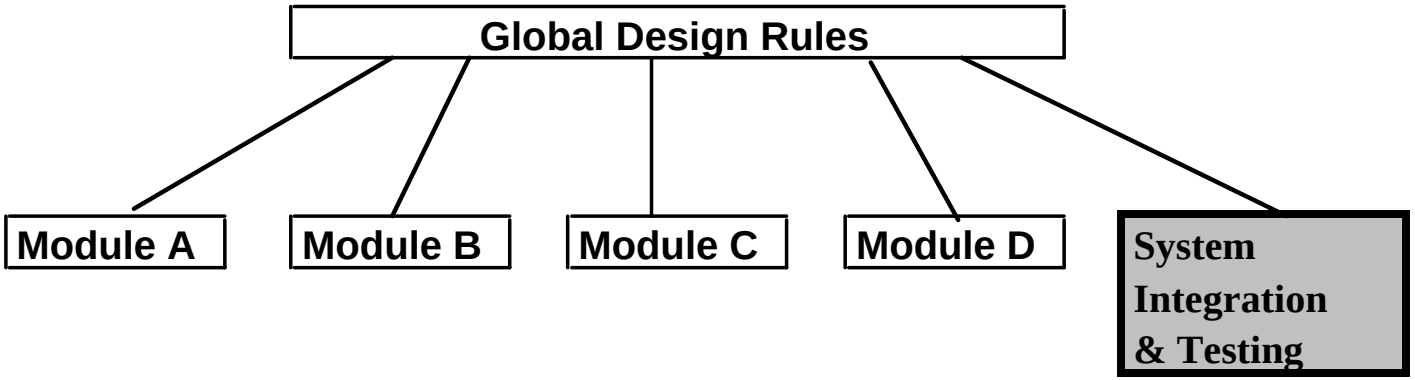
Eliminating Interdependencies by Creating a New Design Rule



Modularization of a Laptop Computer Design

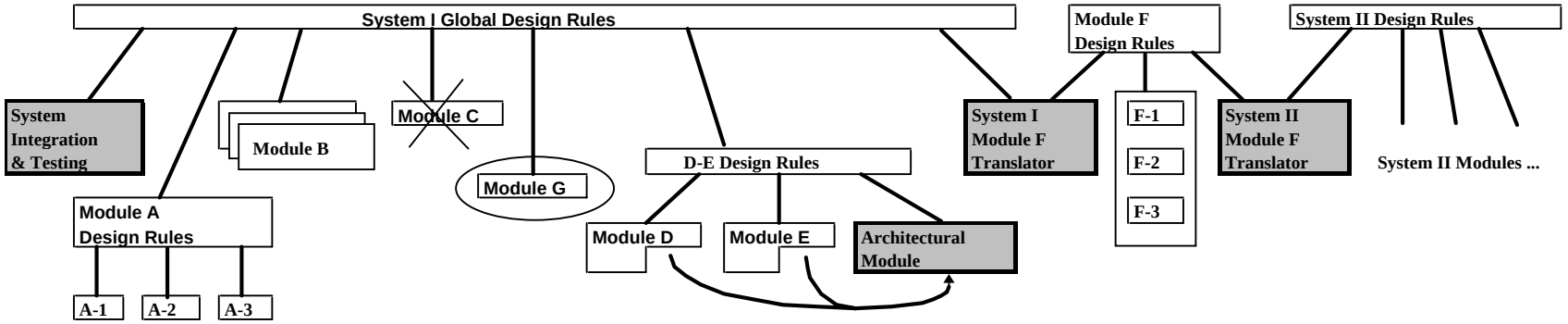


A Two-level Modular Design Hierarchy



The system comprises four "hidden" modules and a "System Integration and Testing" stage. From the standpoint of the designers of A B, C, and D (the hidden modules), system integration and testing is simply another module: they do not need to know the details of what goes on in that phase as long as they adhere to the global design rules. Obviously, the converse is not true: the integrators and testers have to know something about the hidden modules in order to do their work. How much they need to know depends on the completeness of the design rules. Over time, as knowledge accumulates, more testing will occur within the modules, and the amount of information passed to the integrators will decrease. The special, time-dependent role of integration and testing is noted by the heavy black border around and gray shading within the "module."

The Effect of Six Operators on a Modular System



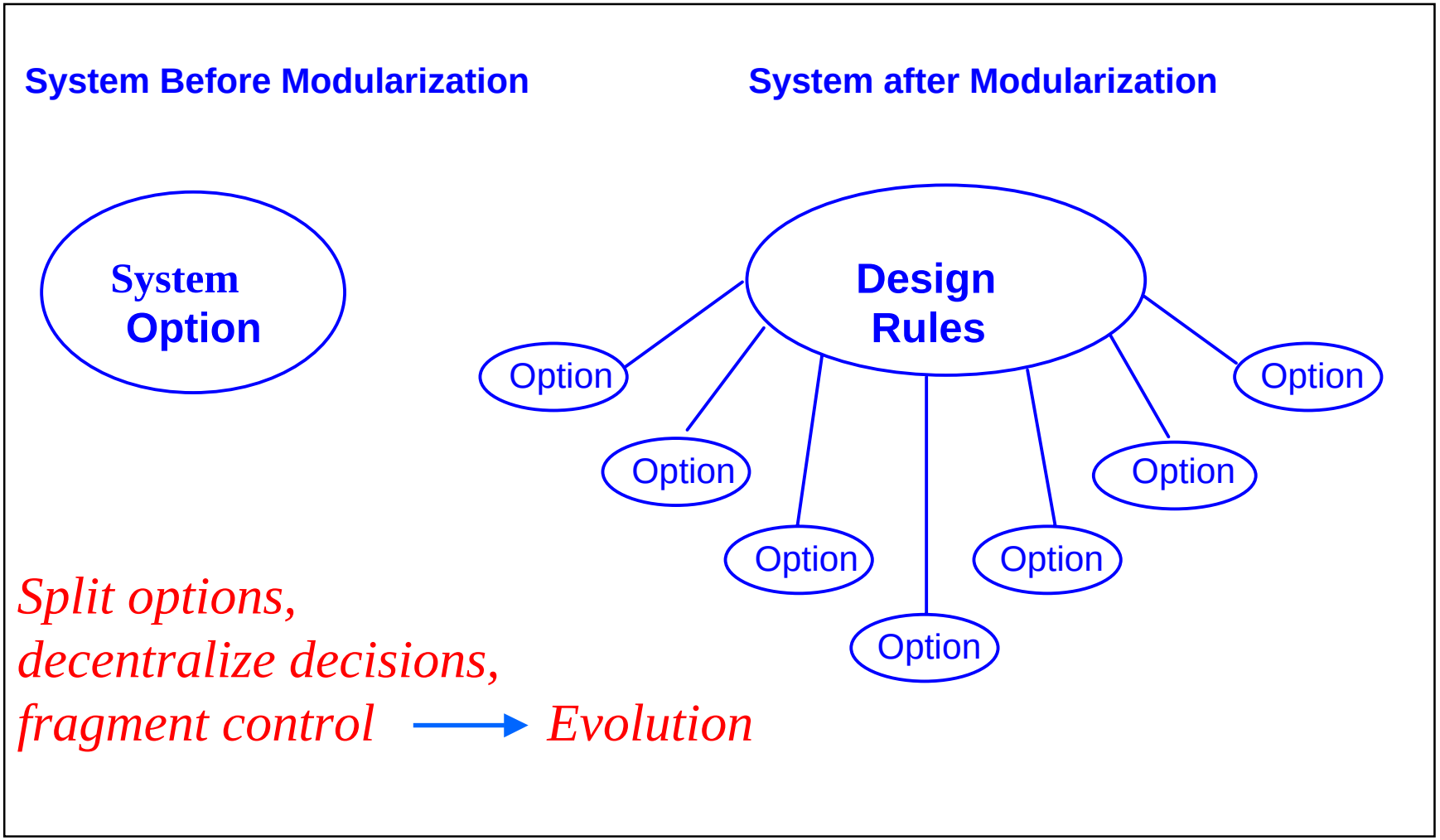
We started with a generic two-level modular design structure, as shown in Figure 5-3, but with six modules (A, B, C, D, E, F) instead of four. (To display the porting operator, we moved the "System Integration & Testing Module" to the left-hand side of the figure.) We then applied each operator to a different set of modules.

Module A was **Split** into three sub-modules.
Three different **Substitutes** were developed for Module B.
Module C was **Excluded.**
A new Module G was created to **Augment** the system.
Common elements of Modules D and E were **Inverted.** Subsystem design rules and an architectural module were developed to allow the inversion.
Module F was **Ported.** First it was split; then its "interior" modules were grouped within a shell; then translator modules were developed.

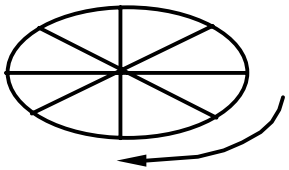
The ending system is a three-level system, with two **modular subsystems** performing the functions of Modules A, D and E in the old system.
In addition to the standard hidden modules, there are three kinds of special modules, which are indicated by heavy black borders and shaded interiors:

System Integration & Testing Module
Architectural Module
Translator Module(s)

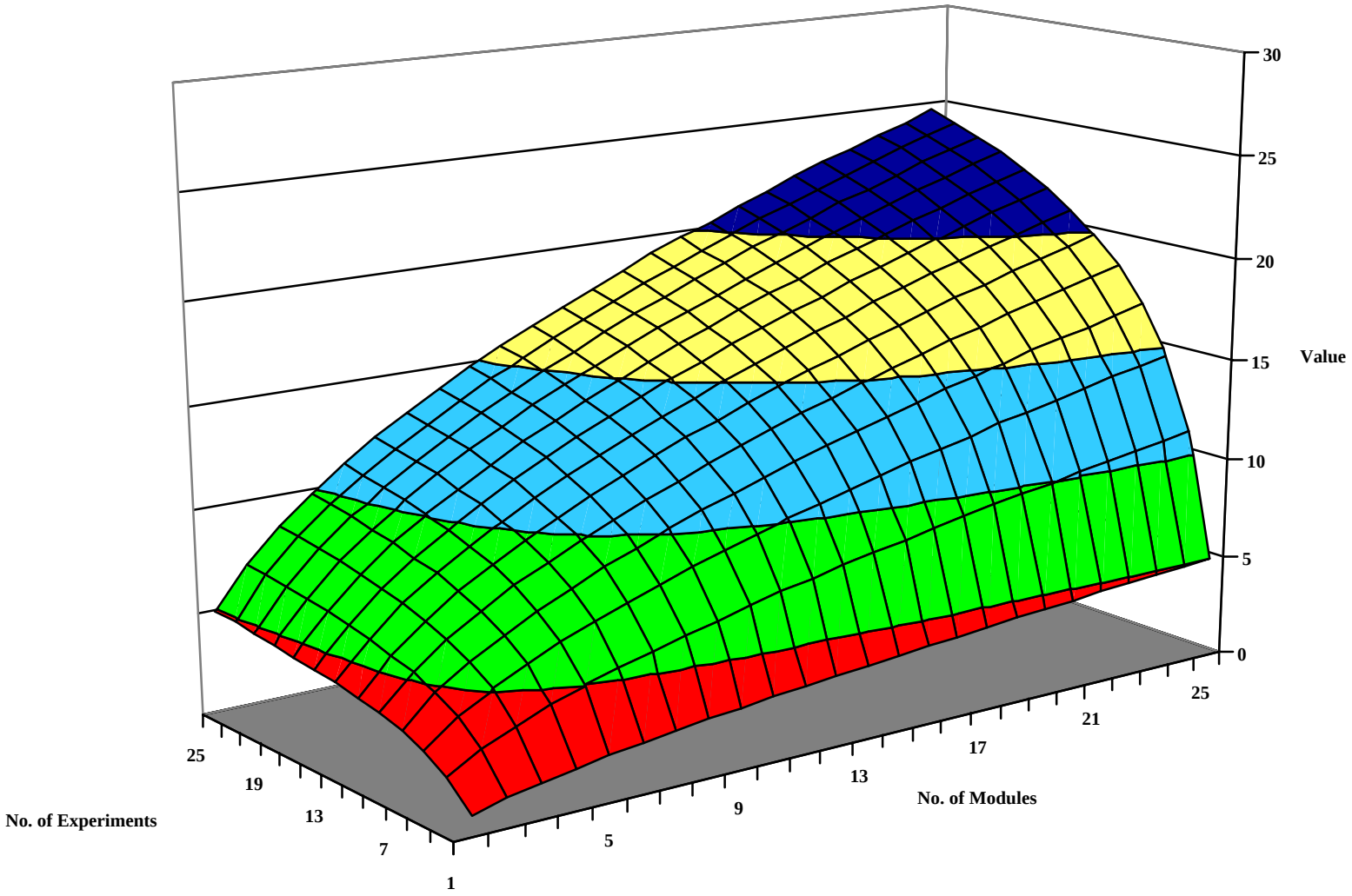
Modularity Creates Design Options



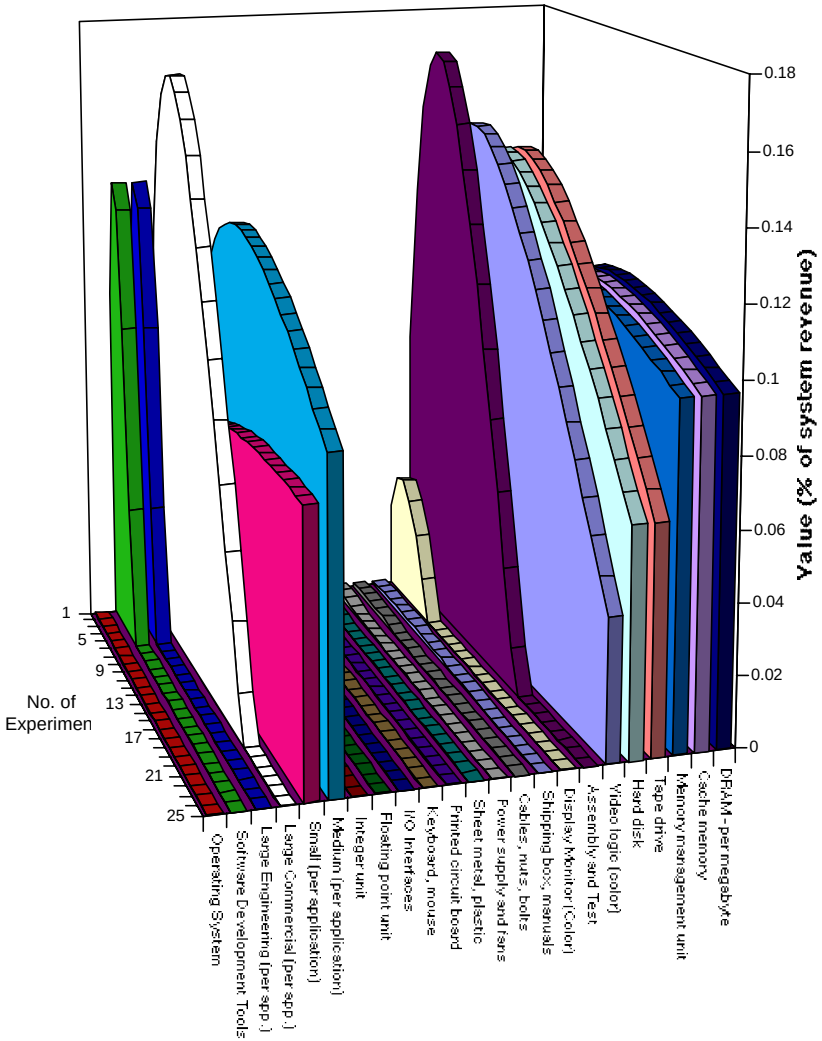
The Basic Framework of our Model of Modular Design Process

Stages	Stage 1	Stage 2	Stage 3
Time Line			
	Create Task Structure & Design Rules	**Implement Task Structure for Modules**	**Test, Integrate, Evaluate System**
What Actually Happens			
Actions	Choose operators	Carry out tasks	Test results & Exercise options
Events	Splitting Substituting Augmenting Excluding Inverting Porting	*"The Wheel Spins"* 	Economic value is revealed; Best outcomes are selected
Mathematical Representation			
Benefits	A payoff in the form of a random variable is chosen.	An outcome is drawn from the distribution of the random variable.	The value corresponding to the outcome of the random variable is revealed; where options exist, the best outcomes are selected.
	X	$X \xrightarrow{\bigcirc} X$	$\max(X, 0)$
Costs	Cost of designing task structure	Cost of implementing task structure	Cost of testing and integration
Basis of Choice	Highest Net Option Value	Highest Net Option Value given task structure	Highest Value given outcomes and tests

The Value of Splitting and Substitution



The Value of the Modules of a Workstation



Co-evolutionary Dynamics across the Levels of the Economic System

Level	Elements	Structure
	Knowledge of How to Design Property Rights; Valuation Technologies	
Governments	Mechanisms to Create and Enforce Contracts; Systems of Adjudication and Dispute Resolution	**Contract Structure**
Capital Markets	Accounting and Payment Systems based on Money (a Contractual Claim on a Government); Practices that standardize the Exchange of Money and other Contractual Claims	**Contract Structure**
Financial Institutions	Firms (= Enterprises) that Design and Supply Monetary and other Contractual Claims	**Contract Structure**
	Contracting Technologies	
Goods and Labor Markets	Marketplaces for Goods and Services; Practices that standardize th Exchange of Goods, Services and	**Contract Structure**
Organizations	Firms (= Enterprises) that Design and Supply Goods and Services	**Contract Structure**
	Scientific and Technical Knowledge	
Design Processes	Tasks	**Task Structure**
Designs	Design Parameters	**Design Structure**
Artifacts	Molecules, Spatial Forms, Programs, Words Colors, Sounds	**Artifact Structure**