Technology and Innovation Management

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Modularity and integrality

Product Integrality at Tesla: Success or Failure?

Tesla's Simultaneous Brilliance And Incompetence Revealed In Teardown Of Model 3 (Forbes, 2018)

TESLA

Source: Google images

Product design, manufacturing and profits

Tesla's Manufacturing Complexity to Blame for Thin Profit Margins, Says Analyst

'If that car was made anywhere else, and Elon wasn't part of the manufacturing process, they would make a lot of money,' said the analyst.

(The Drive, 2018)

What If Elon Musk Took Manufacturing Cars Seriously?

(Industryweek, 2019)

Source: Internet

An expert dismantled a Tesla Model 3. He found poor design and manufacturing are squandering profits

(Los Angeles Times, 2018)

Modularity and integrality

Overview of the course

Innovation Studies – the 'big' picture (session 1-3)

- The historical role of science, technology and innovation
- Stability and change in how new technologies are integrated in existing structures
  - And how to measure it

Decision-making and discovery (session 4-7)

- Switching between exploration and exploitation
- How to organize for discovering new opportunities
  - including guest lecture

The changing 'nature' of technology (session 8-12)

- What is ‚new' about new technologies?
- The emergence of new industrial structures and business models
  - With teaching cases

➢ From micro- to macro-level explanations
➢ From switching (micro) to scoping decisions (macro)

Different types of innovation

Degree of Novelty	
Radical ⟺	Incremental

Input/Output	
Product ⟺	Process

Scope	
Architecture ⟺	Component

Adapted from HKUST Business School

Learning objectives

Key concepts

- Modularity, Integrality
- Product architecture, systems integration

Methods

- Discussion of cases and examples

Abilities

- Critical assessment of different product design strategies
- Identify links between product design and strategy

Required Readings for today

- Henderson, R. M., & Clark, K. B. (1990). Architectural innovation: The reconfiguration of existing product technologies and the failure of established firms. Administrative science quarterly, 9-30
- Baldwin, C.Y. (2017). Explaining the Vertical-to-Horizontal Transition in the Computer Industry. Working Paper 17-084.

Suggested Readings for today

- Sanchez, R., & Mahoney, J. T. (1996). Modularity, flexibility, and knowledge management in product and organization design. Strategic management journal, 17(S2), 63-76.
- Baldwin, C. Y., & Clark, K. B. (1997). Managing in an age of modularity. Harvard Business Review, 46-58.
- Brusoni, S., Prencipe, A., & Pavitt, K. (2001). Knowledge specialization, organizational coupling, and the boundaries of the firm: why do firms know more than they make?. Administrative science quarterly, 46(4), 597-621.
- Chesbrough H. and K. Kusunoki (2001) The Modularity Trap: Innovation, Technology Phases Shifts and the Resulting Limits of Virtual Organizations. In Nonaka I and D. Teece (Eds.) Managing Industrial Knowledge. London, Sage: 202-30.

What's the logic behind it?

(Henderson and Clark 1990)

- Problem: why is it that incumbents fail to introduce what looks like an incremental innovation?
- Small entrepreneurial firms might be better at introducing radical changes, but incumbents should be able to introduce incremental improvements

Linkages between core concepts and components		Core concepts: Reinforced	Core concepts: Overturned
	Unchanged		
	Changed		

		Core concepts	
		Reinforced	Overturned
Linkages between core concepts and components	Unchanged	Incremental innovation	
	Changed		

Source: Henderson and Clark, 1990: 12

		Core concepts	
		Reinforced	Overturned
Linkages between core concepts and components	Unchanged	Incremental innovation	
	Changed		Radical innovation

Source: Henderson and Clark, 1990: 12

		Core concepts	
		Reinforced	Overturned
Linkages between core concepts and components	Unchanged	Incremental innovation	**Modular innovation**
	Changed	**Architectural innovation**	Radical innovation

Source: Henderson and Clark, 1990: 12

Key message (from HC)

- Product architecture defines the organization's information structure which holds together organizational units
- Products design organizations
  - Communication channels, information filters, etc
  - **(Embodied in organizational processes)**
- Subsequent research: (a) shifted locus of analysis from intra-firm to inter firm effects and (b) identified specific advantages of modularity at micro level
  - Sanchez and Mahoney 1996

Definition

Definition: modularity (Wikipedia)

- Product systems are deemed “modular” when they can be decomposed into a number of components that may be mixed and matched in a variety of configurations’
  - http://en.wikipedia.org/wiki/Modularity

Two elements:

- One to one mapping between components and functions
- Standardized interfaces

The diffusion of ‘modular’ design principles

- Aircraft
  - **But please be careful …**
- Automotive
  - **But don’t forget NVH ratios**
- Consumer electronics
  - **Commodities**
- Household appliances
  - **Low tech**
- PCs
  - **But Apple …**
- Software
  - Some, and even in OSS …
- Power tools
  - Commodities again
- Instrumentation
  - But again not all of it …
- …


AFTI

Modular networks

Definition: embedded coordination (Sanchez and Mahoney, 1996)

- **Products design organisations** defining an information structure that holds the organisation together without need for explicit **managerial authority**.

Modularity and platforms (Baldwin, 2017)

- The ‘platform’ nature of products is made possible when the product has been modularized (i.e. a distinction has been *designed* between a functional ‘core’ and an interchangeable ‘periphery’ or ‘ecosystem’)
  - The platform essentials are captured in the core, provided by the platform leader (e.g. Microsoft or Apple). Complementary functions are modules on their own, provided by anyone else
    - Complementary modules don’t affect each other, nor the platform core
    - Note importance of embedded coordination in managing platform ecosystems
  - The interfaces specify how complementary products link to the platform (e.g. the USB-port; APIs, SDKs)

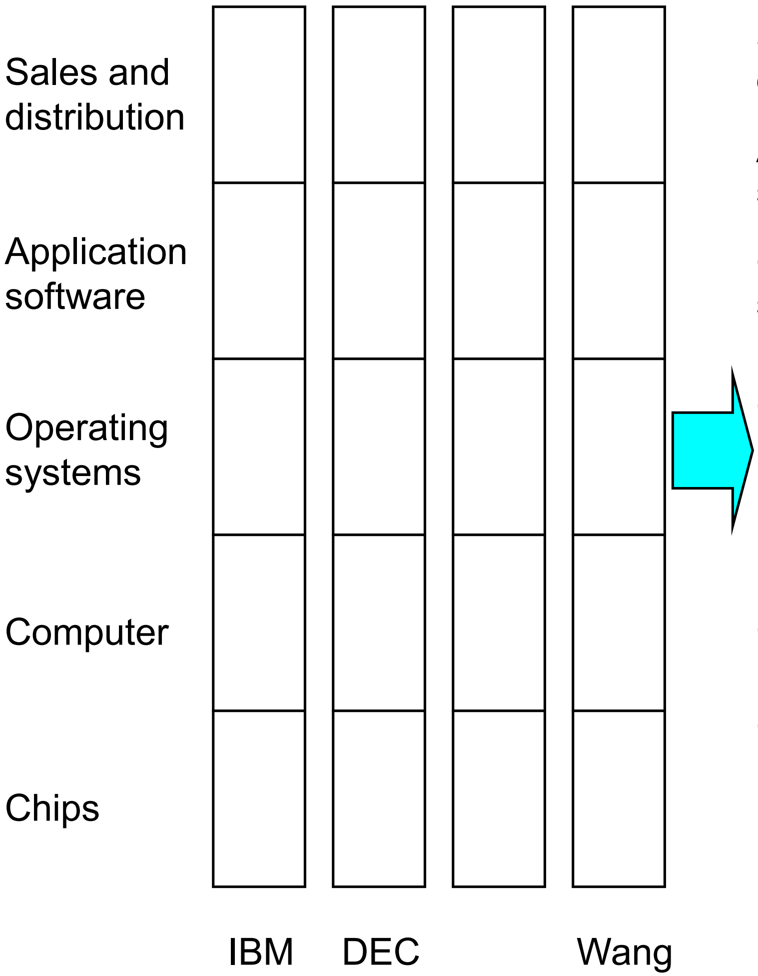
- A typical feature of such modular platforms is that users can ‘mix-and-match’
  - E.g. Smartphone and apps; game console and games; coffee machine and capsules
  - Good news for users, platform leaders, and (in some cases) complementors

Modular Products…

Source: image from the internet

… and modular industries

The Old Vertical Computer Industry - Circa 1980



Sales and distribution	Retail Stores	Superstores	Dealers	Mail Order	I-net	
Application software	Word	Word Perfect	Lotus	SAP		
Operating systems	DOS and Windows	OS/2	Mac	UNIX	Linux	
Computer	Compaq	Dell	Packard Bell	HP	IBM	Etc
Disk drives	Seagate	Quantum	Western Digital	Maxtor		
Chips	Intel Architecture	Motorola	RISC			
Contract manufacturers	Selectron	SCI	Flextronics		Celestica	
Printers	HP	Epson				

Source: Adaptation from *Only the Paranoid Survive* by Andrew Grove, 1996.

Advantages (efficiency AND effectiveness, again)

Increase efficiency:

- Through an increase in division of labour …
- …and the use of market coordination

Increase flexibility:

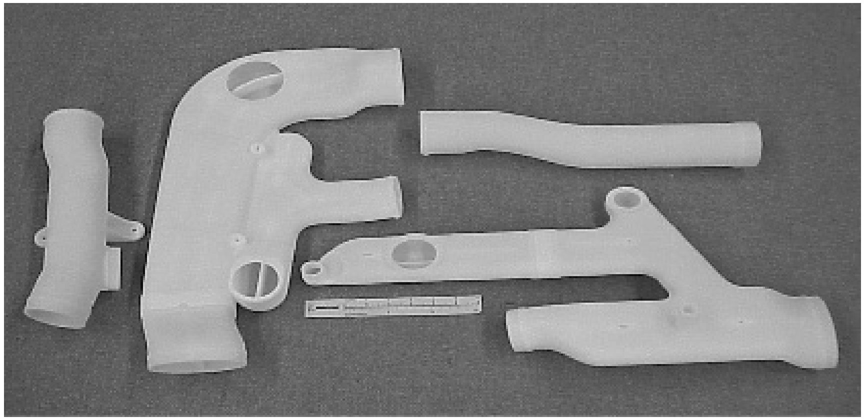
- Parallel search (speed of experimentation)
- Upgradeability (speed of entry)
- Economies of substitution (without cannibalization)

ARCHITECTURAL PROPRIETARINESS / ARCHITECTURAL STRUCTURE	CLOSED	OPEN
INTEGRAL	**Minicomputer industry** Niche strategy, sophisticated users, in-house development. Challenge from producers of complementary assets	**Open Source software (some)** Strategic choice of key components and capabilities to keep the control of 'supply chain'.
MODULAR	**Networking industries** Incumbents maintain competitive position if innovative processes are fast and incremental in nature	**Workstation and PC Industry** **Consumer electronics** Short term success in terms of entry into new segments Loss of control in the long run (e.g. IBM OS/2)

Integrality still matters (?)

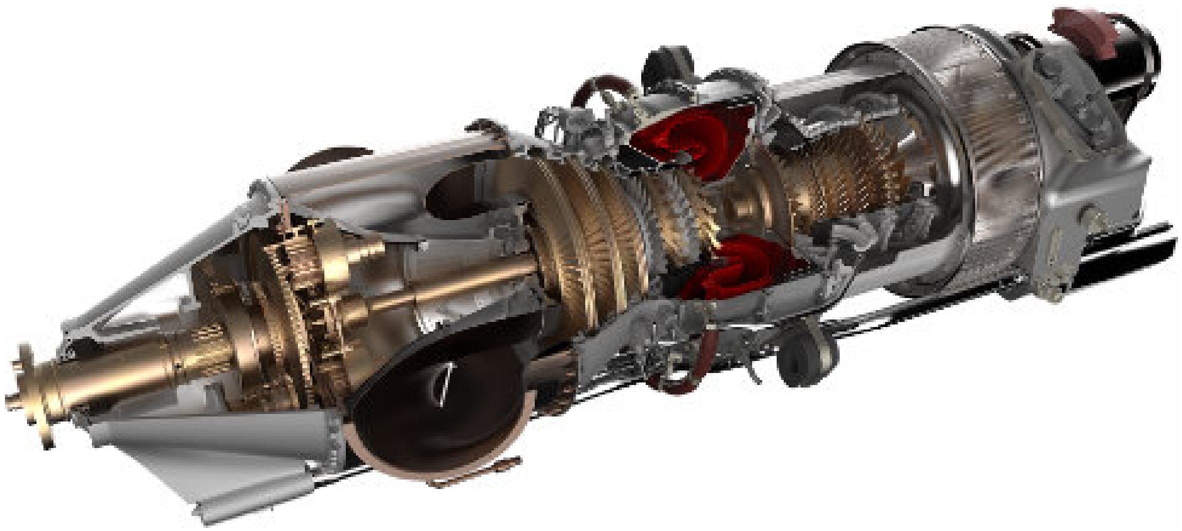
3D printing making integrality desirable / necessary?

- Boeing, 2000: The first application of 3D printed parts was to make air ducts more integral



Source: Hopkinson et al., 2006

The impact of new technologies on complex products



GE Catalyst ATP engine, 2017

*"With advanced manufacturing techniques like 3-D printing, **we have reduced 855 parts to 12 components** thereby reducing weight, wear and leakage."*

Tesla Video

Video used in class: https://www.youtube.com/watch?v=Lj1a8rdX6DU&t=2s

Lessons from Tesla video

"Car body is complex, difficult to manufacture, heavy" "This is the reason why Tesla has problems"	There is a difference between being good in developing elements, and being good in making the system
The car is not designed for manufacturability → Part count, too stiff, fastening method "This design is so poor, surprised that no one caught this"	Signs of a not well developed product architecture are complexity, part count, and linkages that perform poorly
If had been made by Ford/Toyota, would have been big success	Competition of system vs component
"Battery module is brilliant piece of engineering", electro motor is good, cheap, and light	High performance in one module can be window of entry into industry, and improvements in "new" module is likely to come from outside
Tesla's comments → processes have gotten more efficient in body work	New products start integral, later become better decomposable

Modularities

- Modularity in products (and now in platforms)
  - E.g. PCs (old) and smart phones (less old)
  - **Advantage: leverage customers' and users' skills**

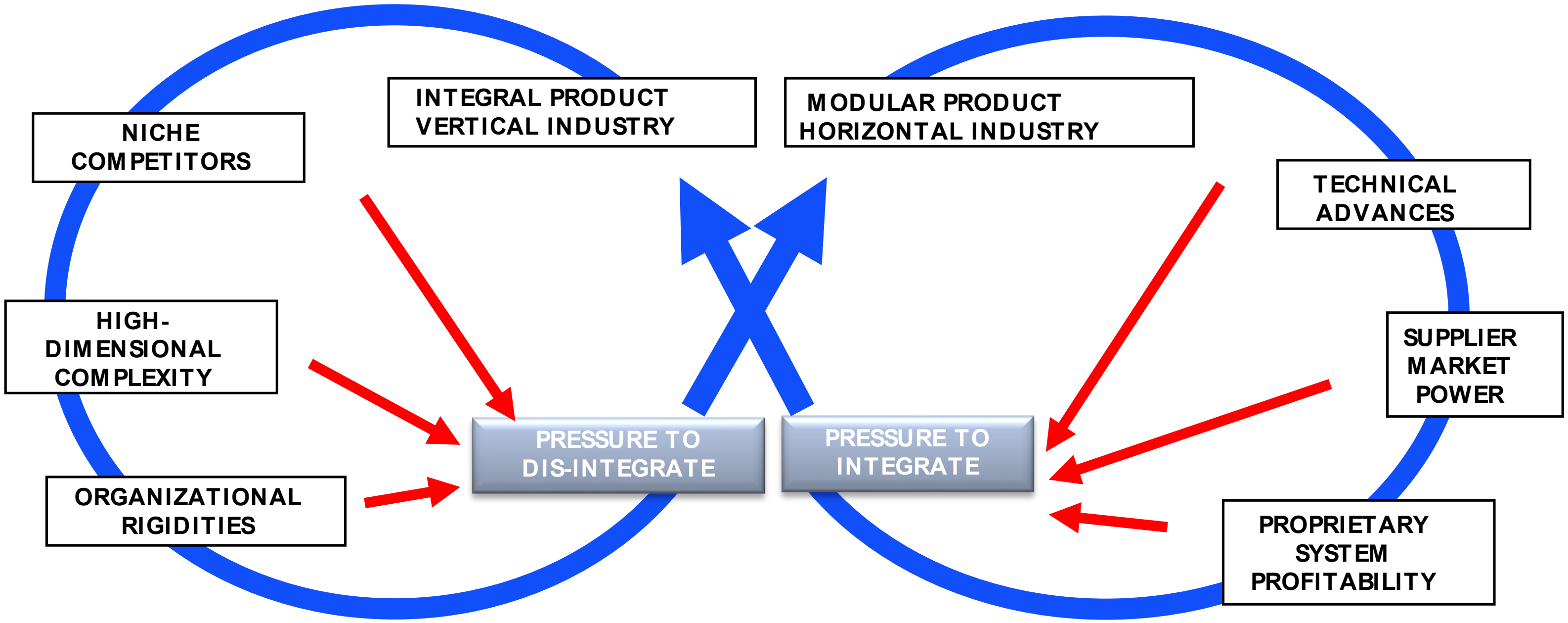
- Modularity in design
  - E.g. Chemical processes (old), chip design and software (less old), very common nowadays
  - **Advantage: design variety of products using similar set of components, parallel decentralized developments**

- Modularity in production
  - E.g. Automotive (old), construction (very old), [fading away?]
  - **Advantage: global outsourcing**

The costs of modularity

- Very costly architecture to put in place
  - Needs to achieve a thorough understanding of the system
- Trade off at strategic level
  - Performance vs. variety
- Hold up problems and transaction cost issues
  - Suppliers may gain power
- Learning trade off
  - **Speed of search vs. breadth of search**
  - (remember exploration-exploitation?)

The Dynamics of Product and Industry Structure



Source: Fine 1998

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