Metanational Management in the TFT-LCD Industry

Research Institute of Economy, Trade and Industry (RIETI) Policy Symposium.

Metanational Management and Global Innovation: The Case of the TFT-LCD Industry

Tokyo, March 14, 2007

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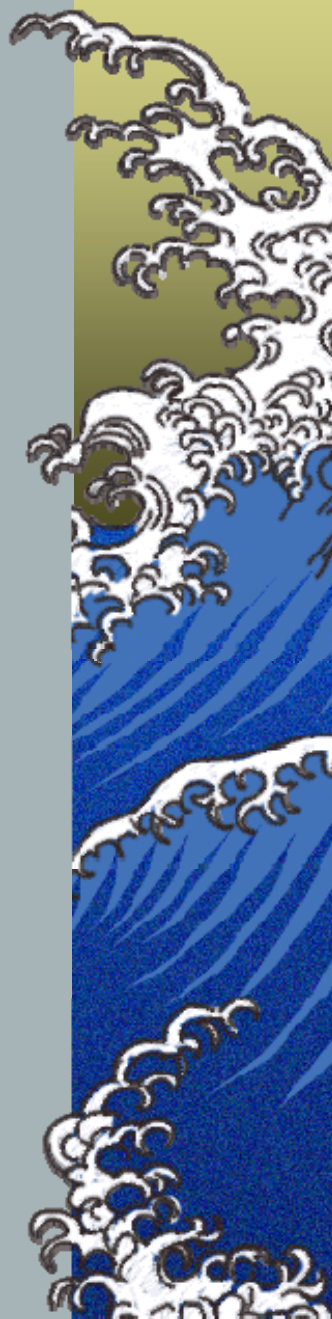
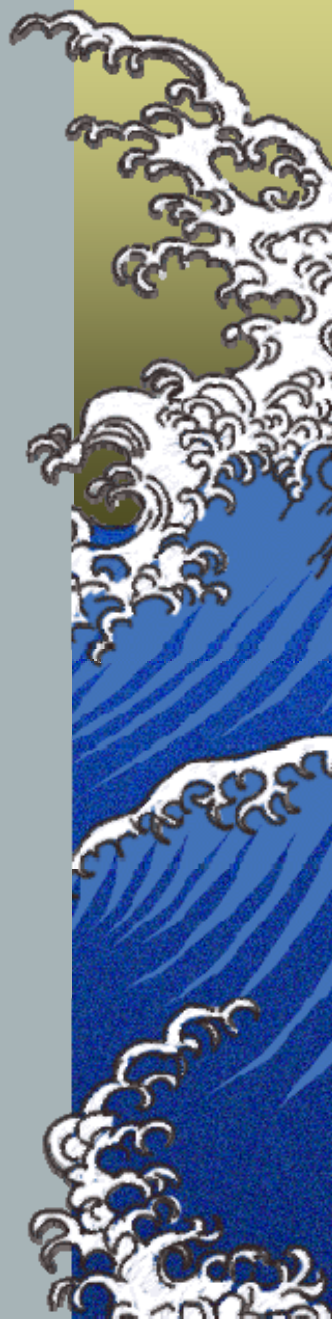


Research Sponsored by the Alfred P. Sloan Foundation

- *Sloan Foundation Industry Studies Program sponsors Research Centers and Projects on over 25 industries in U.S. Universities.*
- *FPDs: One of 7 industry projects linked into the Sloan Industry Globalization Research Program (Phase II).*
- *Program Title:"Industries as Global Knowledge Networks."*

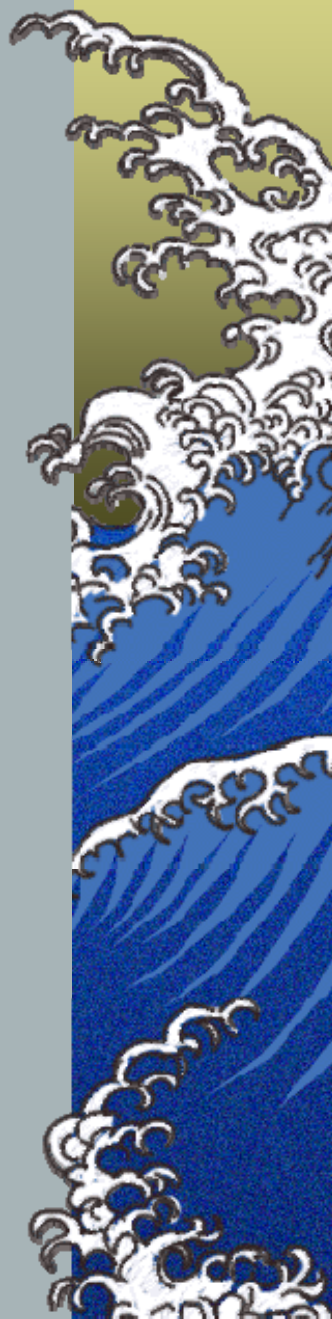
Sloan Industry Centers and Projects (partial list)

- *Flat Panel Displays*
- *Financial Institutions*
- *Motor Vehicles*
- *Trucking*
- *Airlines*
- *Managed Care*
- *Pharmaceuticals*
- *Steel*
- *Powder Metallurgy*
- *Industry Studies*
- *Industrial Performance*
- *Personal Computers*
- *Food Retailing*
- *Textiles & Apparel*
- *Paper*
- *Printing*
- *Cross Industry Studies*
- *Software*
- *Information Storage*
- *Semiconductors*
- *Tele-information*
- *Electricity*
- *Construction*
- *Internet Retailing*



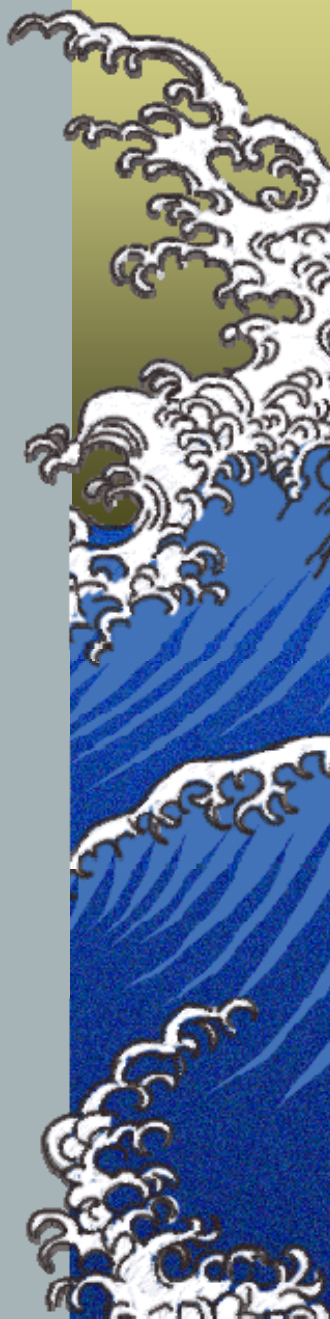
What is "Metanational Management"?

- *Enterprise inventiveness increasingly requires metanational networks that link to the best ideas of suppliers, customers, partners, and affiliates, no matter where.*
- *Survival requires firms to compete and learn in the most dynamic environments: those countries where an industry is evolving most rapidly.*
- *In ancient Greek: "meta" = "beyond."*



What is "Metanational Management?"

- *M^2 strikes a new balance between firms' needs to protect their existing knowledge and continually create new knowledge*
- *Rewards collaboration where vertical integration was once the norm.*
- *Senses, mobilizes and combines globally dispersed knowledge for radically more effective innovation processes.*



Global Knowledge Networks and Metanational Industries

- *Technology complexity, scale, specialization, capital requirements and global workforce upgrading have increased opportunities and challenges of collaboration for innovation.*
- *In metanational industries, countries and firms must collaborate with customers, suppliers, alliance partners and competitors, at home and offshore, to* ***"learn from the world."***
- *Foreign affiliates' and alliance R&D matters more and more to firms' global competitiveness.*

The FPD Industry in 1995: A Map.

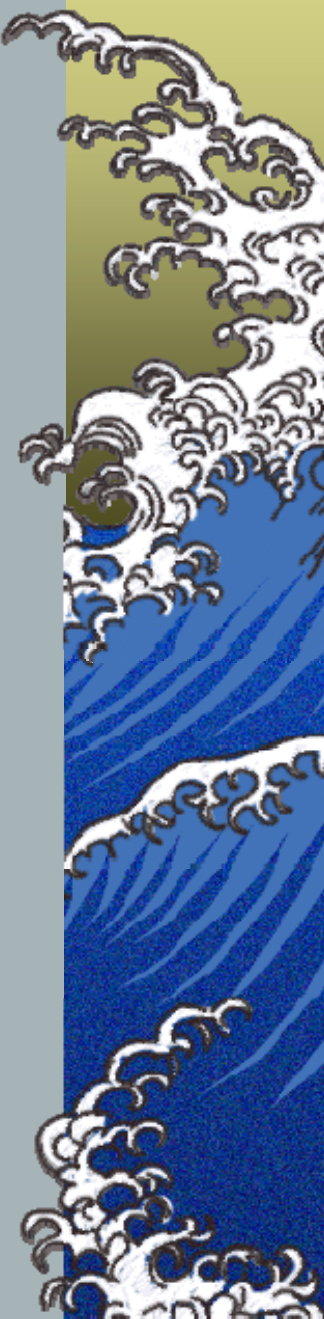
Source: SEMI JAPAN

The FPD Industry: An $86 billion (US) per year Global Laboratory

- *16-year sales growth US$3 billion to $86 billion, through continual re-invention.*
- *Continuous cost declines driven by innovation in equipment, materials and manufacturing process across 8-plus generations of increasing substrate size.*
- *Rate of change exceeds Semiconductor Industry in equivalent historic period by 2 to 18 times (depending on source).*

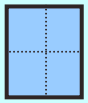
Measures of Knowledge Creation in TFT-LCDs

- *Continual increases in substrate size from Gen 1 (300x400mm) to Gen 8.5 (2200x2500mm).*
- *"Waking up" new generation production lines and bringing them to commercial yield levels.*
- *Process improvements that reduce manufacturing steps, tact time, defects.*



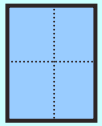
Glass substrate size comparison

Gen. 1
300x 400mm



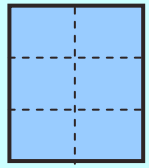
8.4“x 4

Gen. 2
370x 470mm



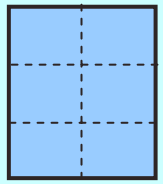
10.4“x 4

Gen. 3
550x 650mm



12.1“x 6

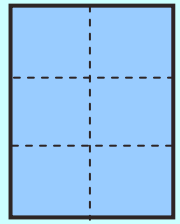
Gen. 3.5
600x 720mm



13.3“x 6

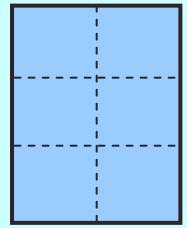
Gen. 4

680x 880mm



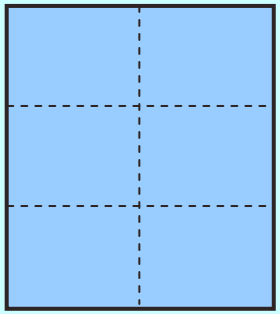
13.3“x 9
15” x 6
20” x 4

730x 920mm



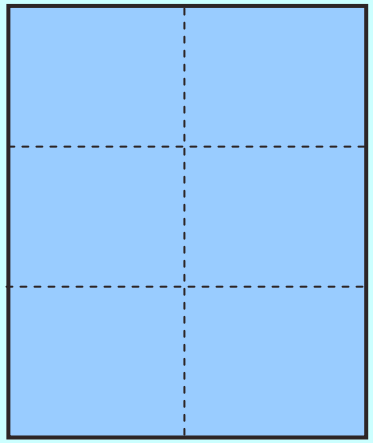
14“ x 9
17” x 6

Gen. 5
1100x 1250mm



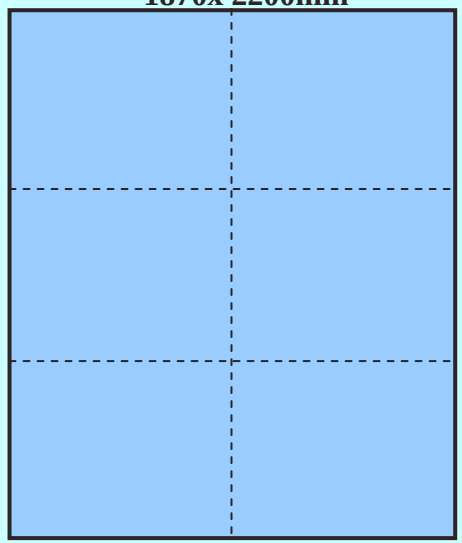
32“ x 8
37” x 6
42” x 3

Gen. 6
1500x 1800mm



32“ x 8
37” x 6
42” x 3

Gen. 7
1870x 2200mm



32“ x 10
42” x 6

Gen 8:
2160x2460
(4x G4 Area)

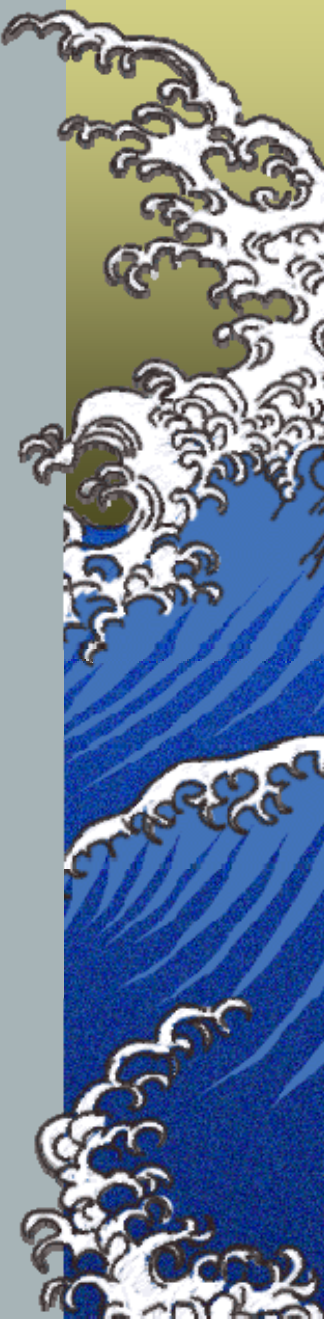
Gen 8.5:
2200x2500

Gen 9?

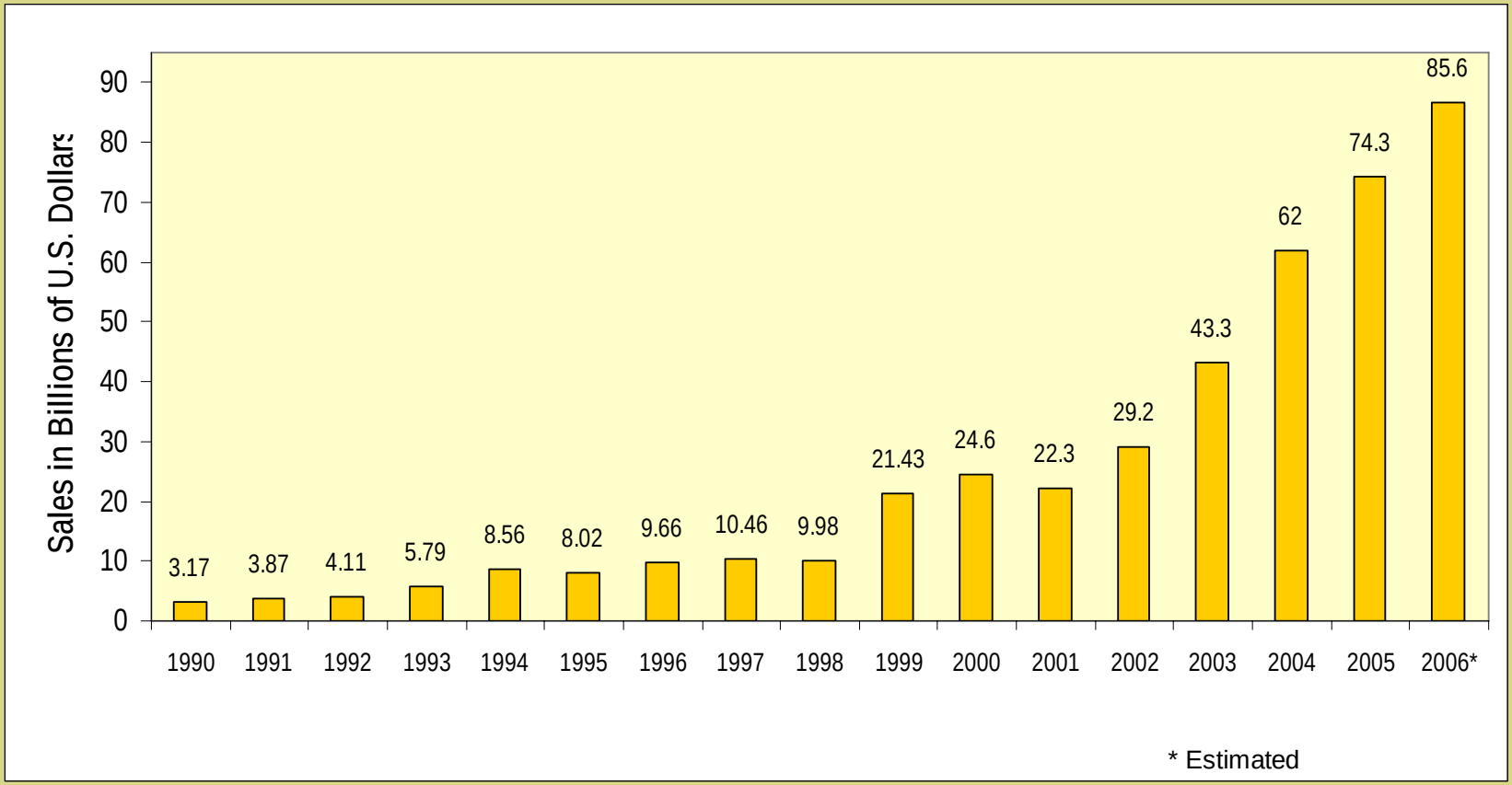
Gen 10?

Large Area TFT-LCDs: The First Born-Metanational Industry?

- *Dominant TFT-LCD mfg. paradigm emerged mid-1990s through competition and collaboration among global firms with organizational capabilities in Japan.*
- *Intense interpersonal contact among and within companies remains critical, in part because rapid technology evolution creates a knowledge codification backlog.*



FPD World Sales Volume: 1990-2006



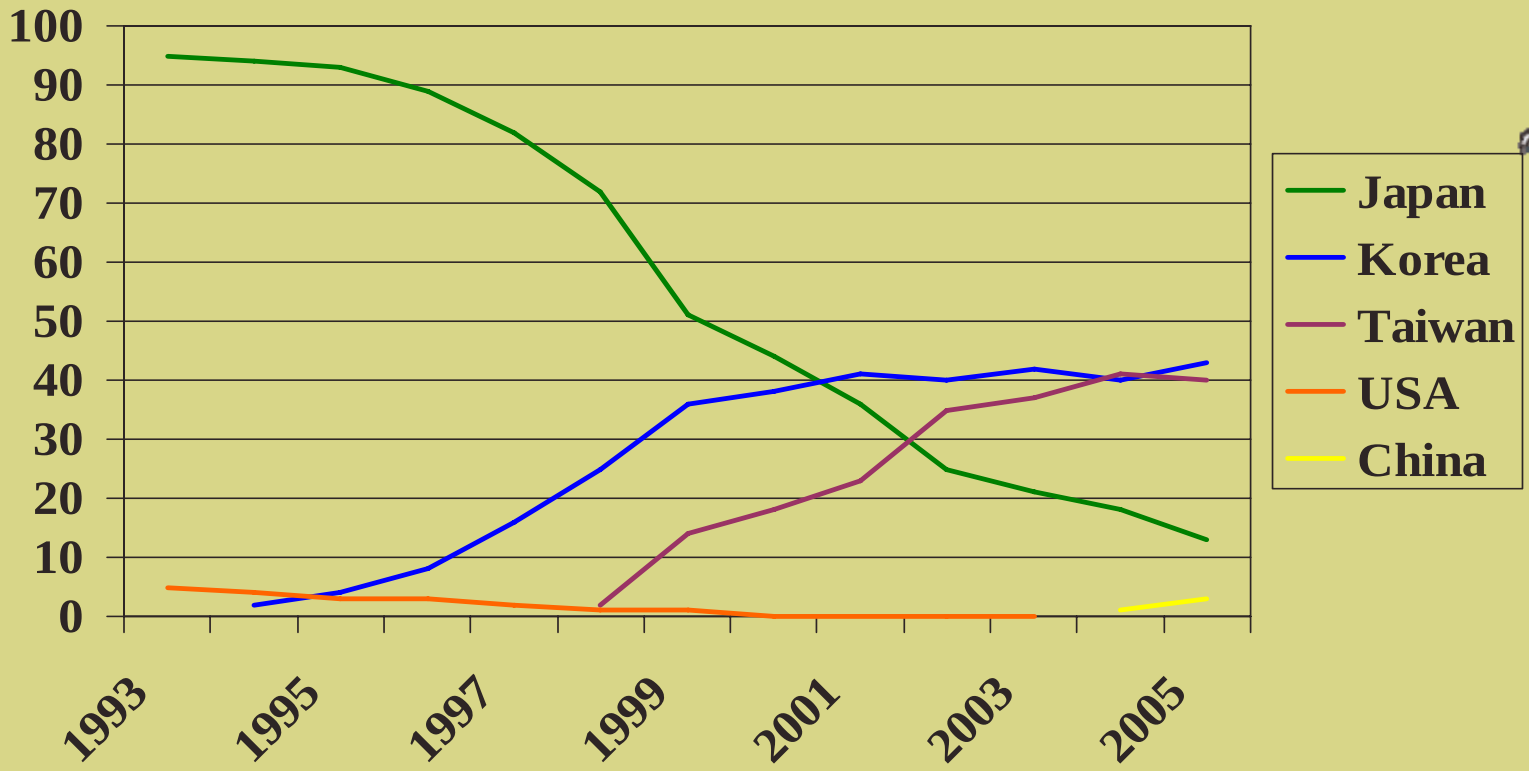
2006 Production: $85.6 B

Materials: $44 B

Equipment: $12 B

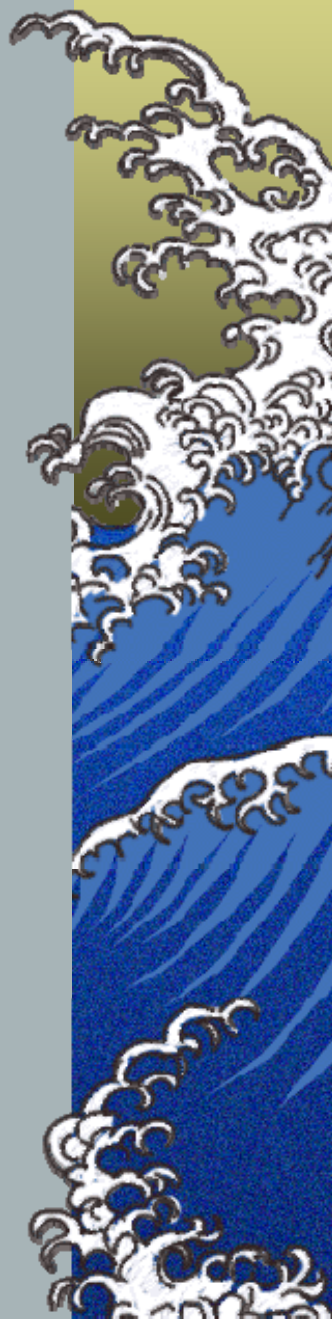
Source: DisplaySearch

Share of Global Markets for Territorially-Based FPD Production, by Country



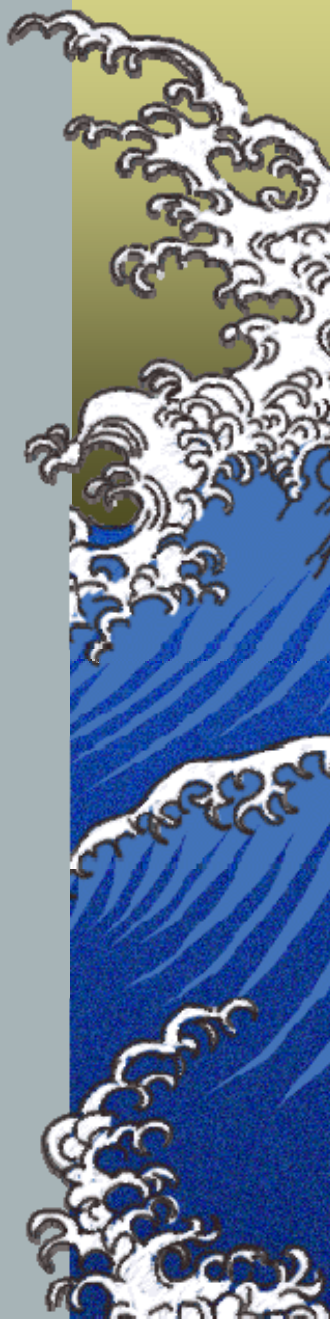
Breakthrough Metanational Collaborations TFT-LCDs

- ***Sharp, Applied Materials, IBM, Toshiba, Corning, Merck GmbH, others:*** *High volume production paradigm, Generations 2 and 3*
- ***Applied Materials/Komatsu*** *(dissolved 1998, continued as AKT, an Applied Materials Co.)*
- ***IBM, Toshiba (DTI)****: Large Area TFT-LCDs*
- ***Korean producers, Global equipment and materials providers:*** *lead/continuity in Gen 4+*
- ***LG, Photon Dynamics****: Zero defects*



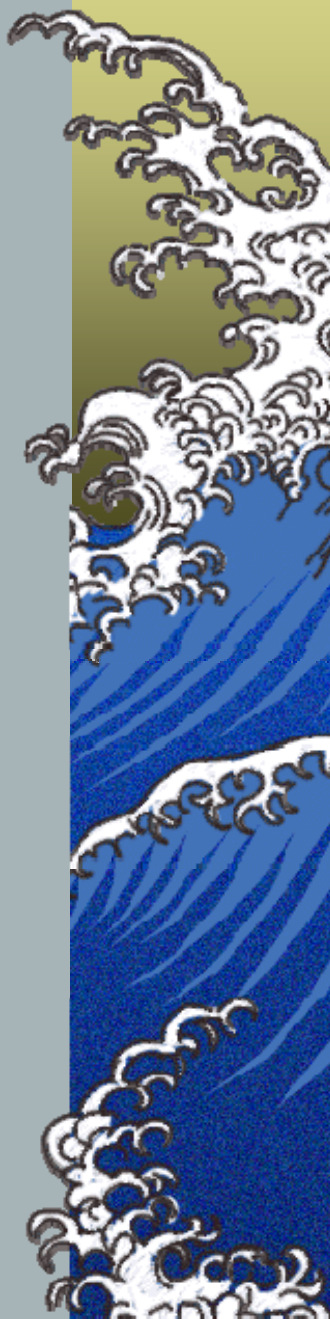
Breakthrough Metanational Collaborations in TFT-LCDs

- ***LG.Philips (LG/Philips Electronics),*** *TFT-LCD production (partial spin-off IPO, 2004)*
- ***Samsung-Corning:*** *Glass substrates*
- ***Japanese, Taiwanese producers****: process innovation, countervailing force to Korea's emerging dominance*
- ***S-LCD: Sony/Samsung*** *joint panel production, connecting technology and markets (for Sony and Samsung leading brands of TFT-LCD TV)*



Breakthrough Metanational Collaborations in TFT-LCDs

- ***SVA-NEC*** *Gen 5.5 Fab in Shanghai (2006): Chinese-Japanese collaboration.*
- ***Sharp-TCL-Shenzhen City?*** *(China) Rumored Gen 7.5 Fab for 2008.*



Rapid Evolution of Fab Generations: Consequences

- *Knowledge enters new generations before it can be written or sometimes even verbalized.*
- *Successful Gen transitions require scientists, engineers and operators to migrate forward.*
- *High capital costs create incentives for partnerships, alliances and industry-wide tools and solutions.*
- *All panel makers seek differentiation.*
- *Suppliers' knowledge is critical to progress.*

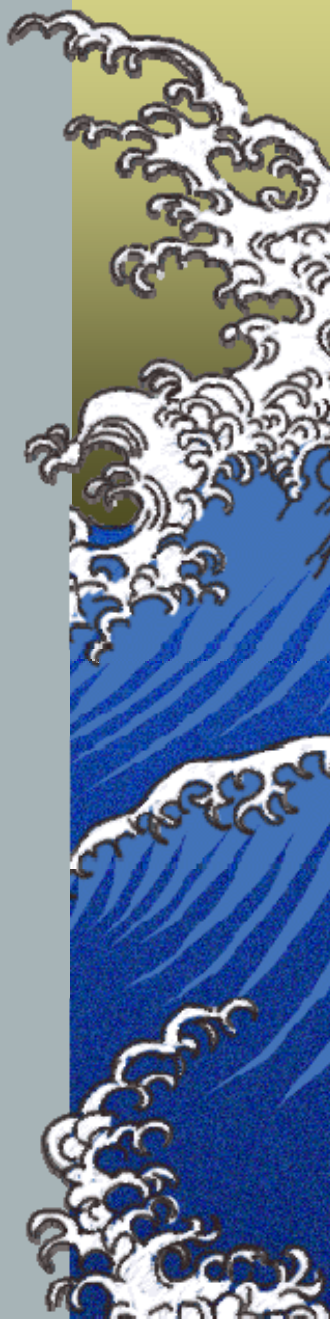
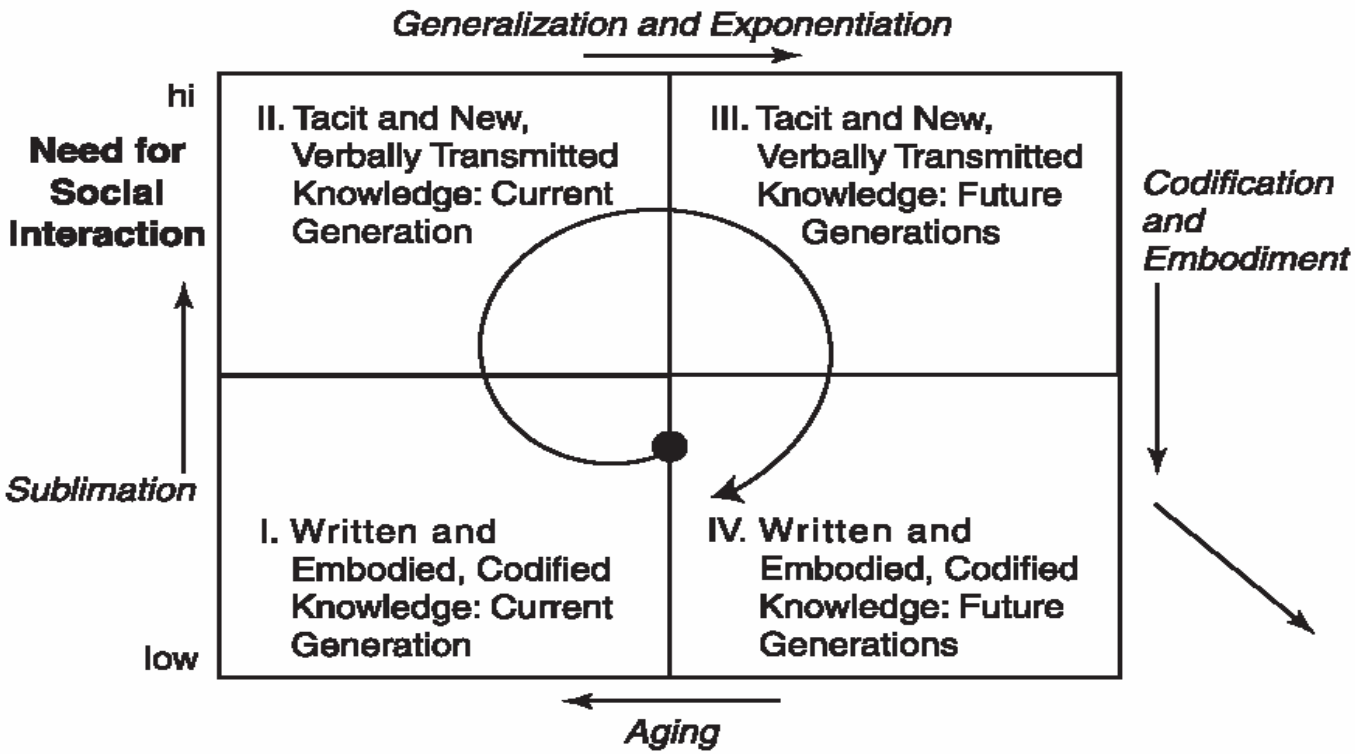
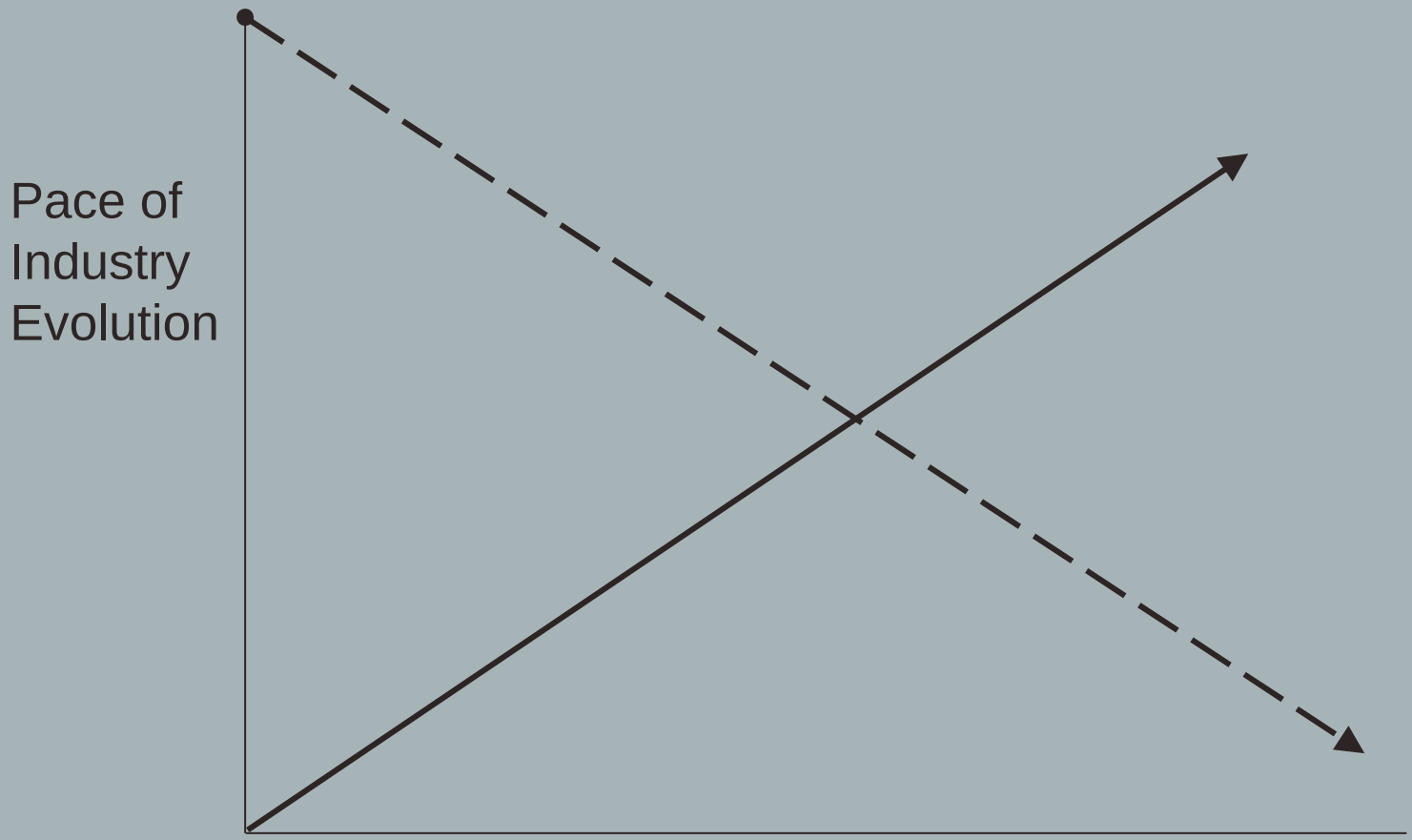


Figure 1. Evolutionary Spiral: Cross-Generational Knowledge Formation at the industry level of analysis. Inspired by Nonaka and Takeuchi, 1995, and adapted from Murtha, Lenway and Hart, 2001, p.143.

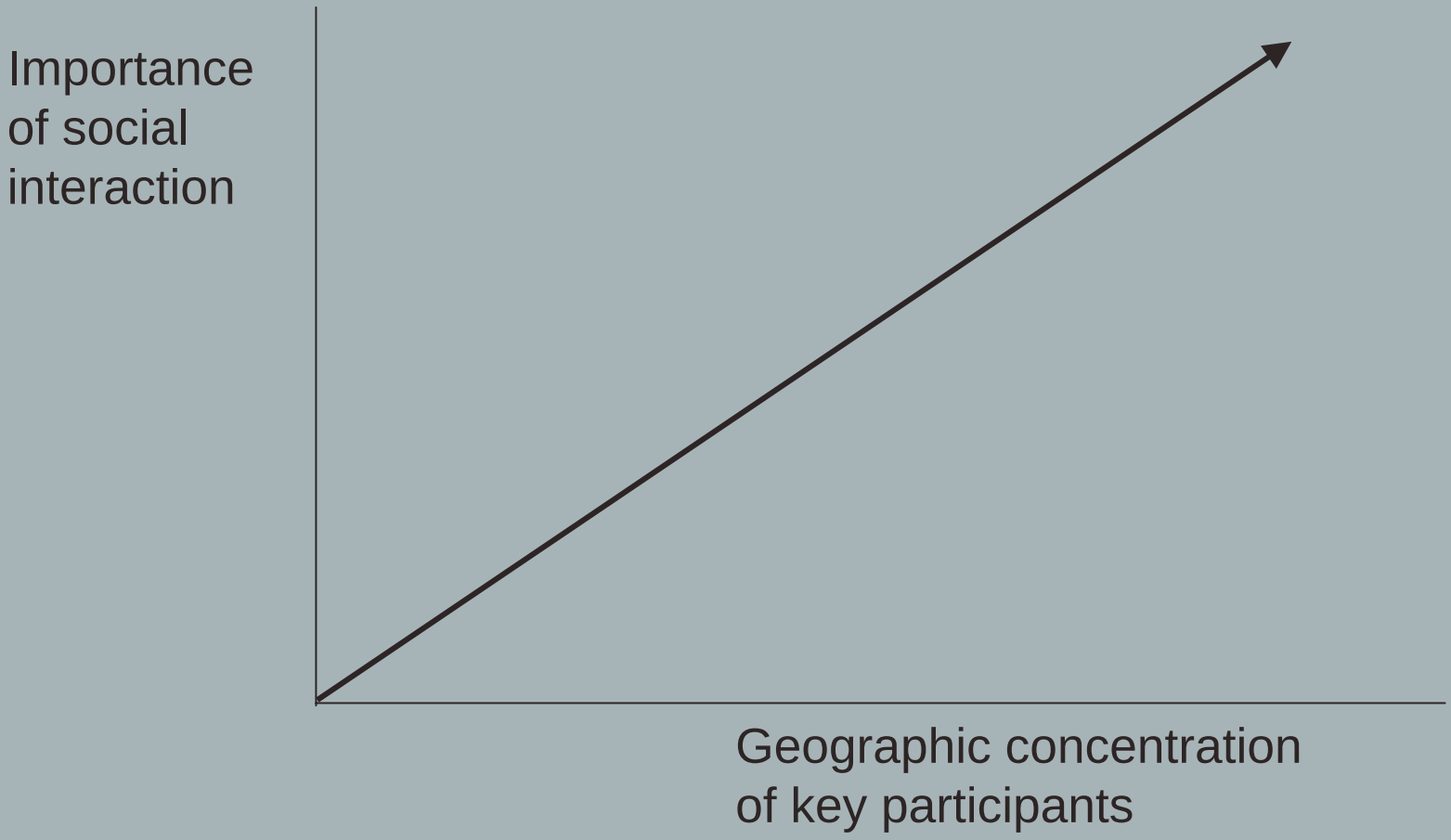


Pace of Industry Evolution, Codification of Knowledge and the Importance of Social Interaction for Knowledge Creation

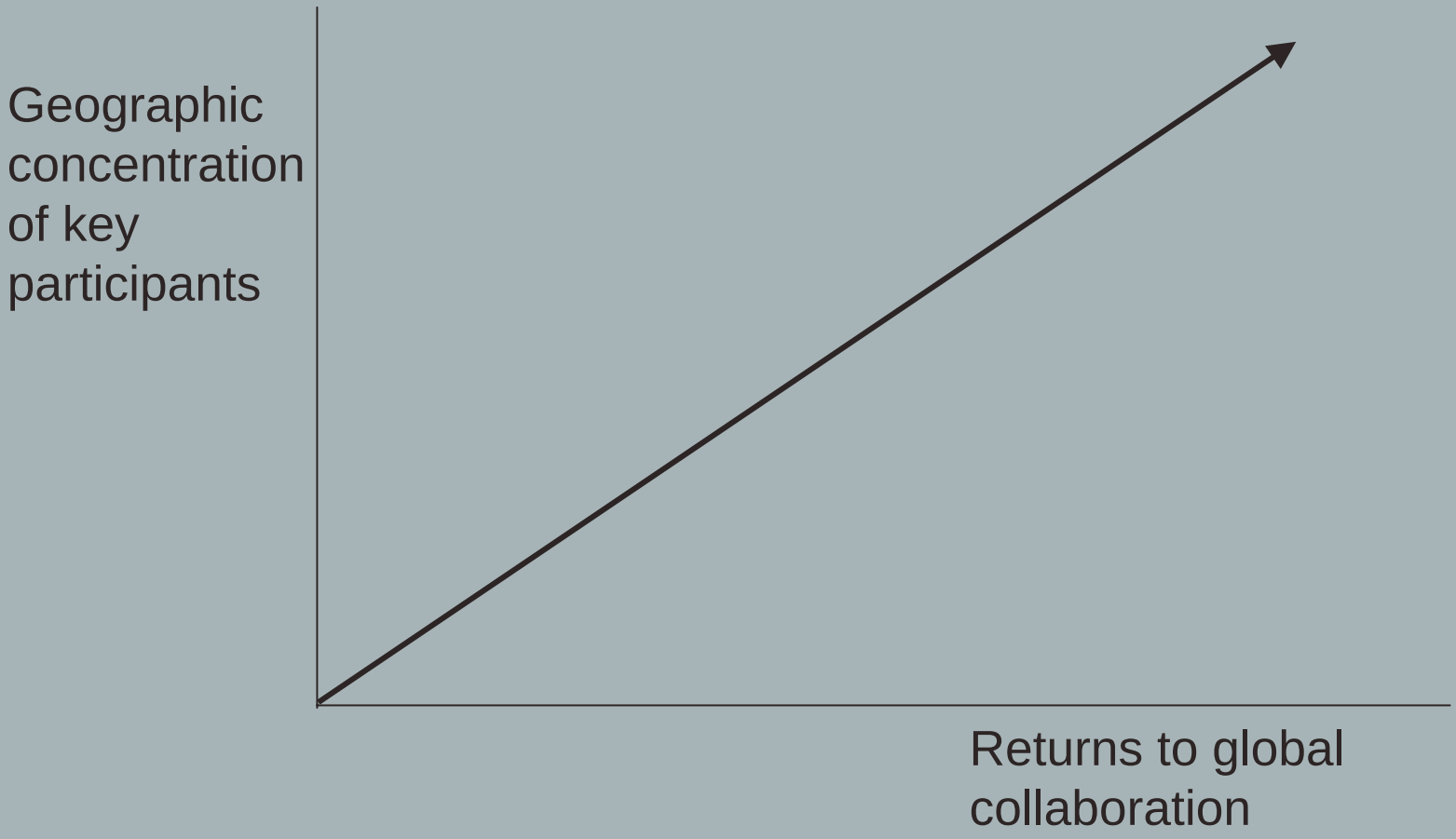


Broken: Codification of knowledge
Solid: Importance of social interaction for knowledge creation

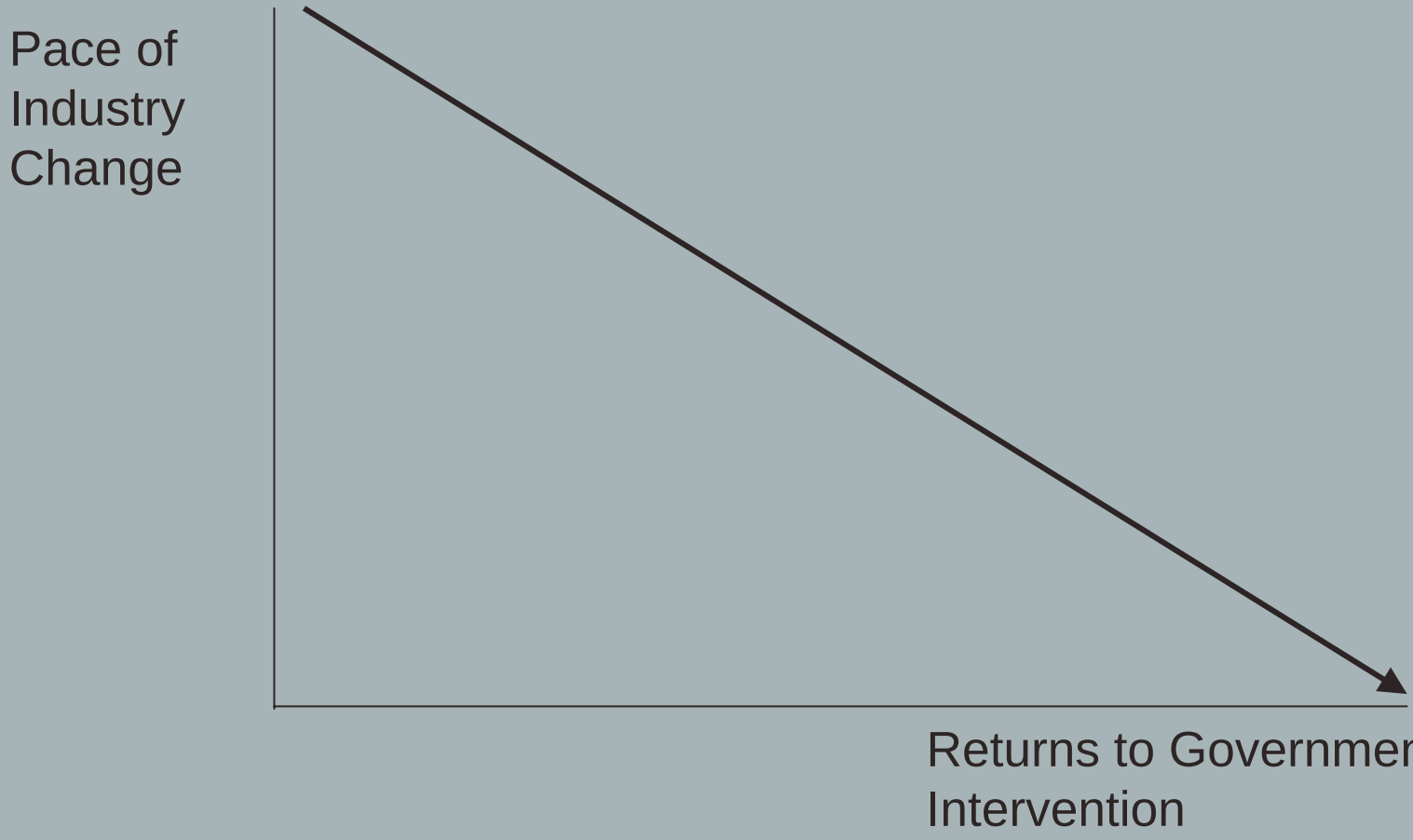
Importance of Social Interaction for Knowledge Creation and Geographic Concentration of Key Participants



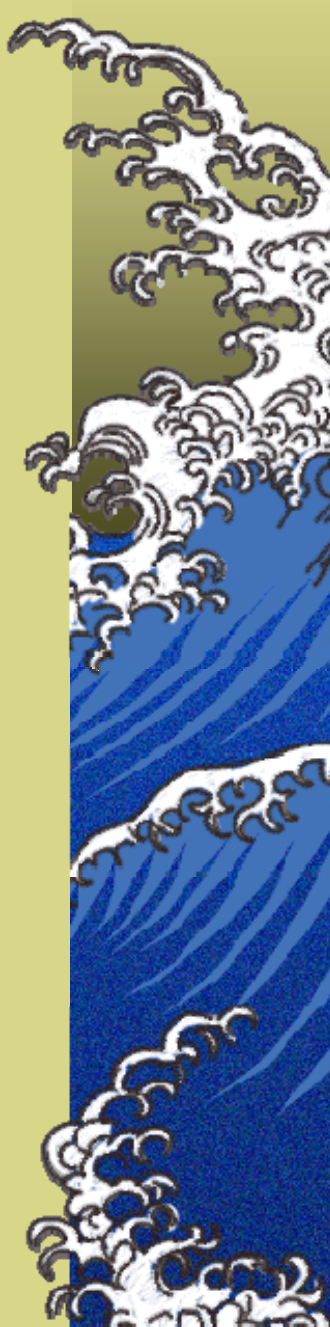
Geographic Concentration of Key Participants and the Returns to Metanational Collaboration



Change and Government Intervention

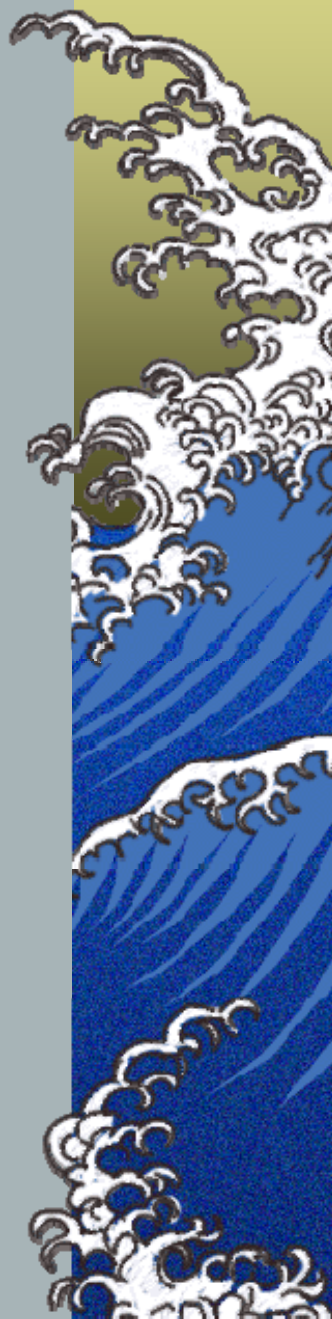


Metanational Dilemmas and Paradoxes in TFT-LCDs



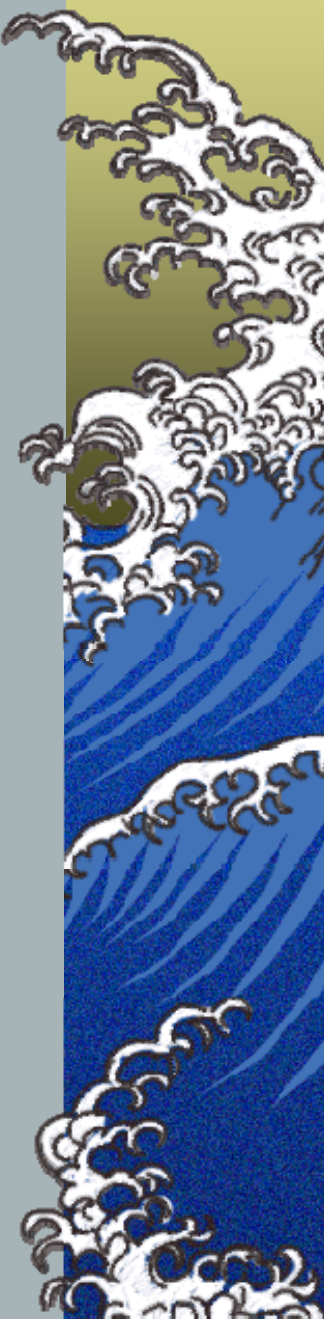
Black Box vs. Open Innovation

- *BB=complete isolation of R&D project teams (incl. no contact with colleagues).*
  - *Ex.: Sharp's continuous grain silicon (CGS)*
- *Open Innovation=engaging suppliers, customers in innovation processes early and continuously*
  - *Ex.: Start-ups of New Generation TFT-LCD Fab Lines*



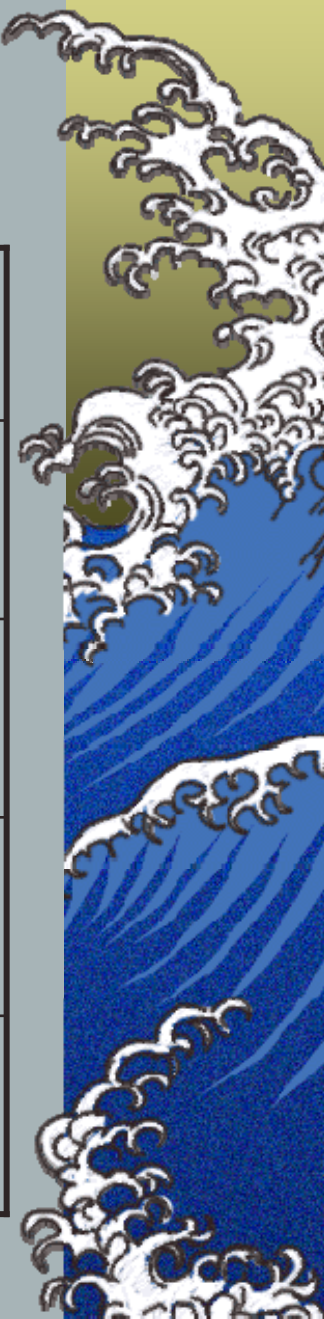
Vertical Integration vs. Vertical Networks

- *Concern: risks of components shortages, IP leakage vs. risks of falling behind the frontier.*
- *What does security of supply mean?*
  - *Cultivating knowledge access by collaborating with world class suppliers vs. assuring flows of physical inputs from captive production sources.*
- *How should producers, equipment & materials makers share benefits and costs and of rapidly decreasing prices, expanding markets?*
- *Can proximity substitute for captivity ("Display Cities" e.g., Mie (J), Gumi (K), Hsinchu (T)).*



Knowledge Migration

Mechanisms, processes	***Motivations***
Shared equipment and materials suppliers	*Leverage mastery, share costs globally*
Japanese EQ, materials sales to Korean firms	*Create cash flows*
Japanese firms license Taiwanese firms	*Wring out costs, squeeze Korean firms?*
Acquisitions of existing J, K producers by T, C	*Establish knowledge foundation to build on*



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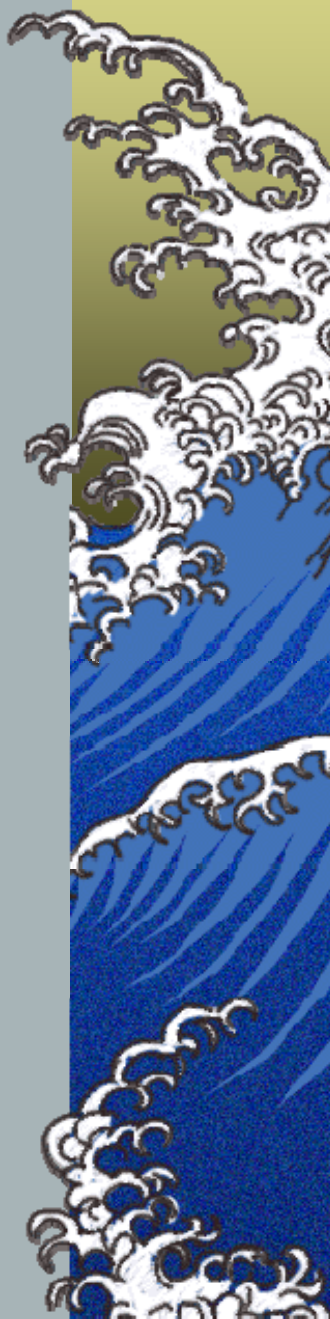
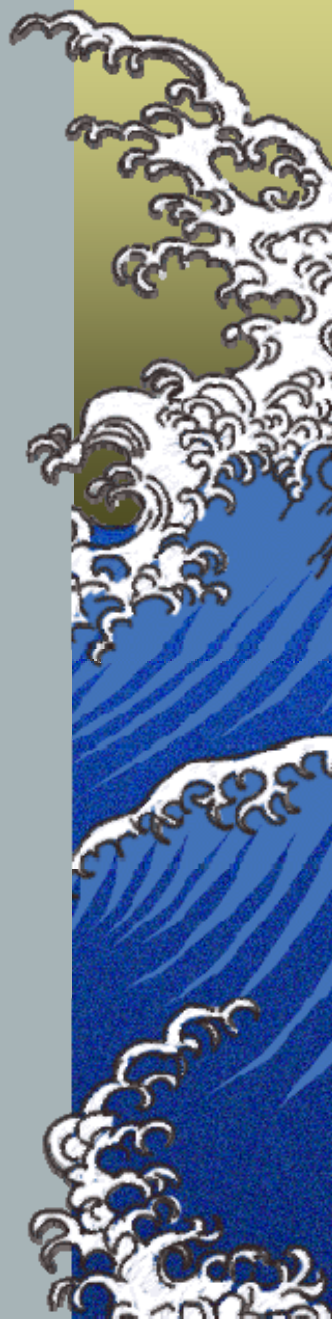


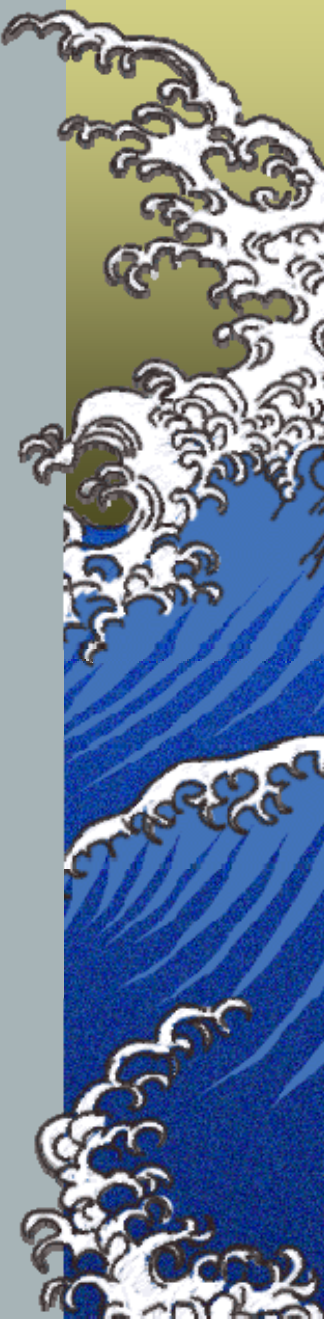
Technology Uncertainty

- *Size and yield wars continue; Skip G6, replicate G7 or move to G8, G8.5 risk G9, jump to G10?*
  - *Reward: capture greater efficiencies than competitors: leap ahead on costs.*
  - *Risk of skip: disrupt incremental knowledge creation process in generational evolution: fall behind in ramping new fabs.*
  - *Contrarian: Sharp believes it holds the teaching role; if it skips, others will trip.*
  - *When will increasing returns to generational advance end? It will be a costly experiment.*
- *Largest profits from new generations often restricted to first three movers or less.*

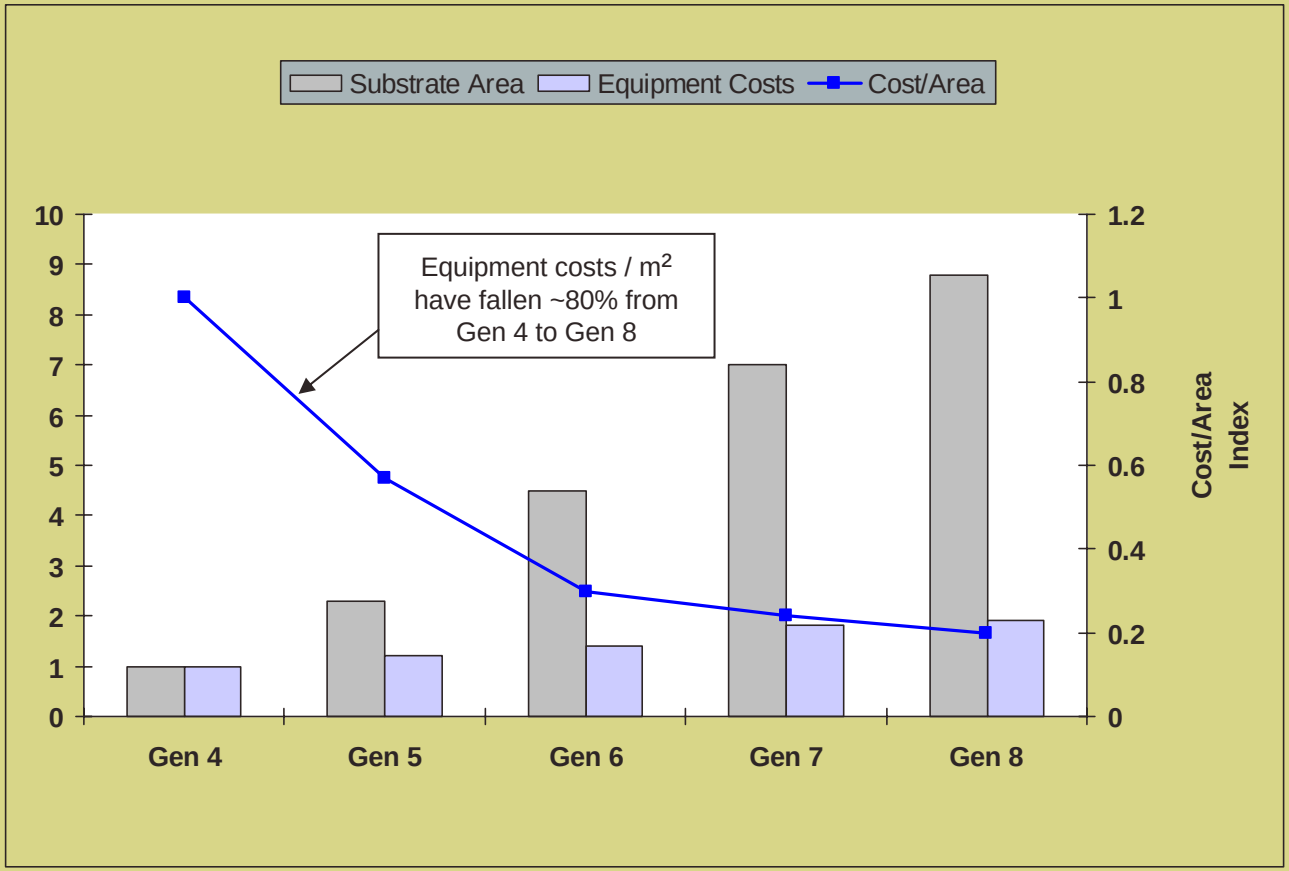


Sharing Costs and Benefits of Industry Advance

- *G8 & 8.5 fabs: $3.5 billion plus in physical assets.*
- *Rapid Generational evolution, exclusive dealing pressures aimed at limiting knowledge sharing may squeeze suppliers, especially for equipment.*
- *Vertical integration or sponsoring second sources spark intellectual property suits.*



Substrate Area and Equipment Cost* Index



*Equipment costs include equipment depreciation and gas costs.

Source: AKT, an Applied Materials Company, *AKT News, January, 2007*

Current Situation: TFT-LCDs as heavy manufacturing

- *Gen 6 fabs optimized for up to 37-inch diagonal televisions, G7 up to 46-inch, G8.5 up to 55-inch, all 6x per substrate.*
- *New fabs rank among largest buildings ever built.*
- *New lines cost upwards of US$3 billion.*
- *Some equipment requires setup space as large as a basketball court.*

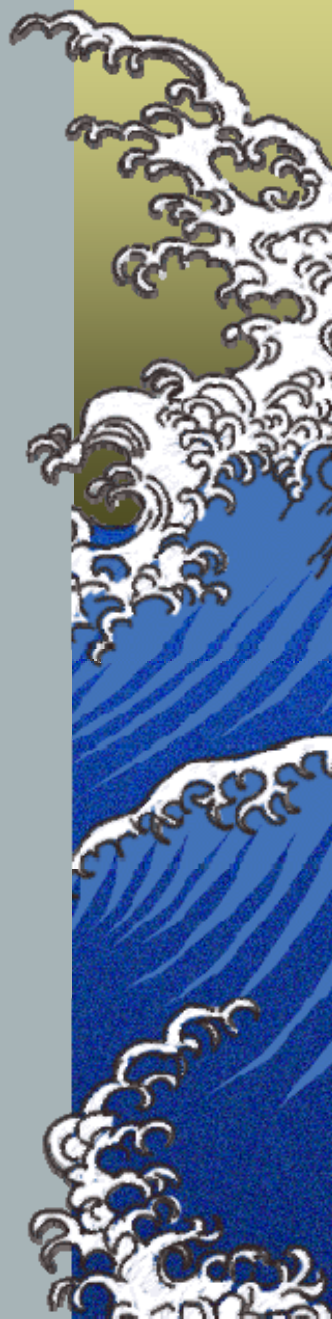
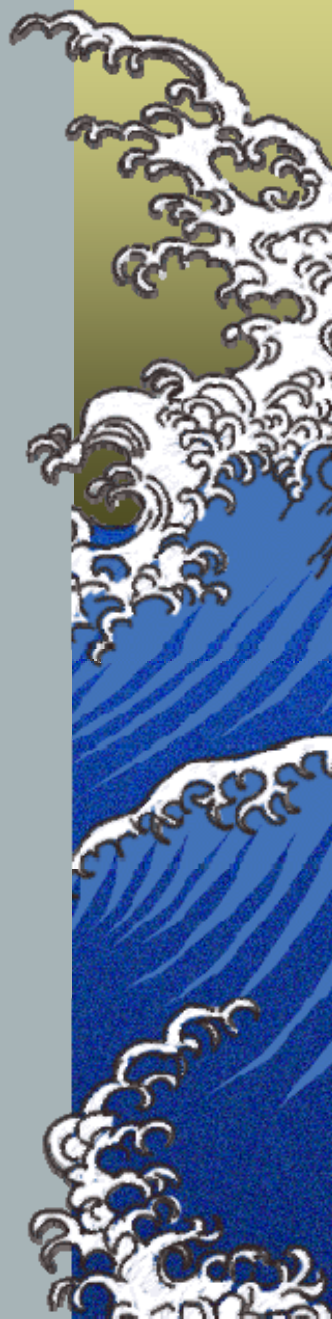


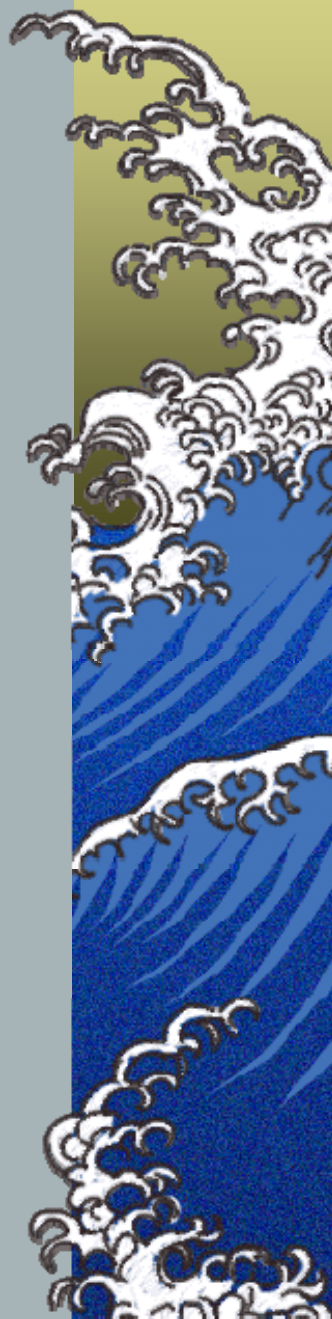
Illustration as Example of Massive Gen 8.5 Equipment Size

(Photo from original presentation does not appear, for copyright reasons. Please contact author if you wish for further information.)



Knowledge and Place

- *Intensifying physical co-location trends for producers, suppliers, customers due to massive size of equipment, some materials, esp. substrate.*
- *Increasing mobility of people among physical locations for knowledge sharing*
- *Onsite construction at producers' fabs of EQ makers' new Beta* and *Alpha tools*



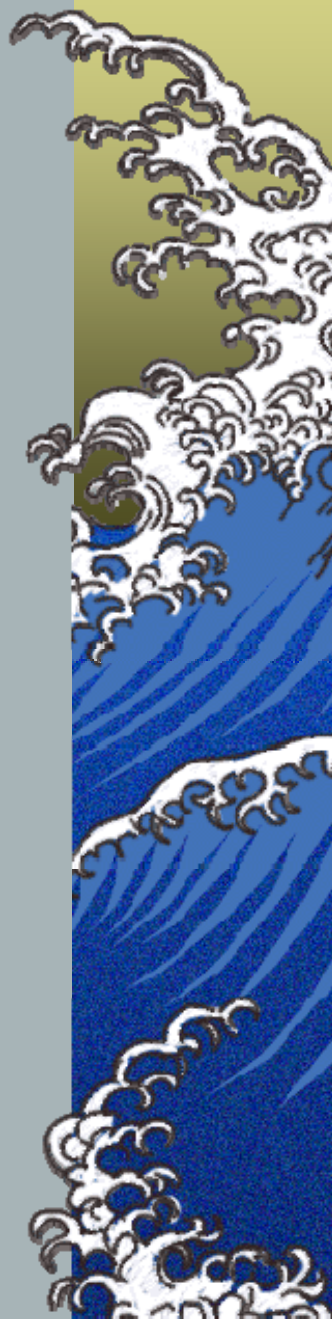
Continuing Metanational Drivers in TFT-LCDs

- *Location-specificity of knowledge (particularly tacit and verbal)*

+ *requirement to leverage suppliers' and customers' firm-specific knowledge*

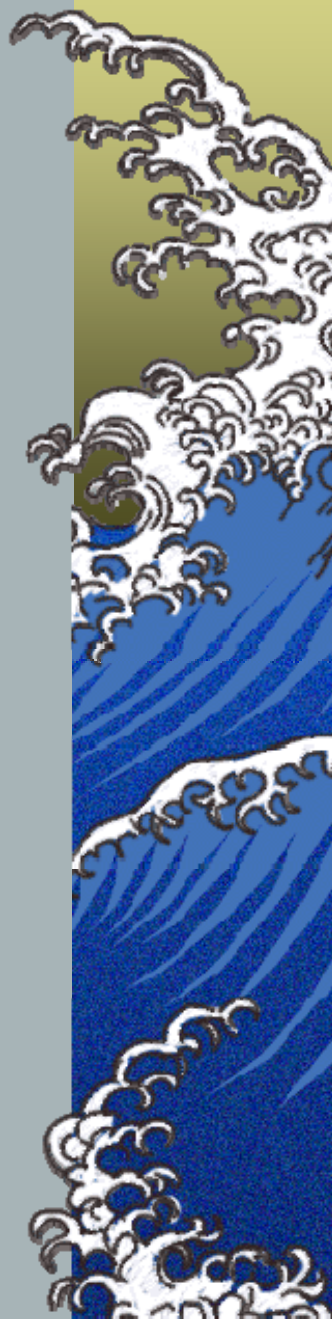
+ *conditions of rapid change*

= *need to create cross-border intra- and inter-firm links even if knowledge is complex, tacit and competitively sensitive.*



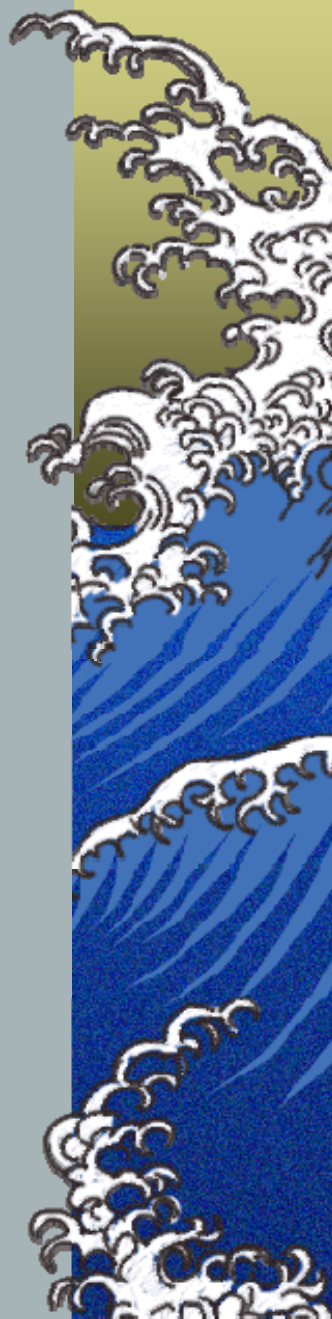
Continuing Metanational Detractors in TFT-LCDs

- *Property rights concerns in relationship-specific, jointly-created knowledge.*
- *Confidentiality concerns*
- *Industry generalization of knowledge through multi-client suppliers and OEMs' shopping of specifications.*
- *Lack of consensus on next Gen specs*
- *Lack of supply/demand consensus.*



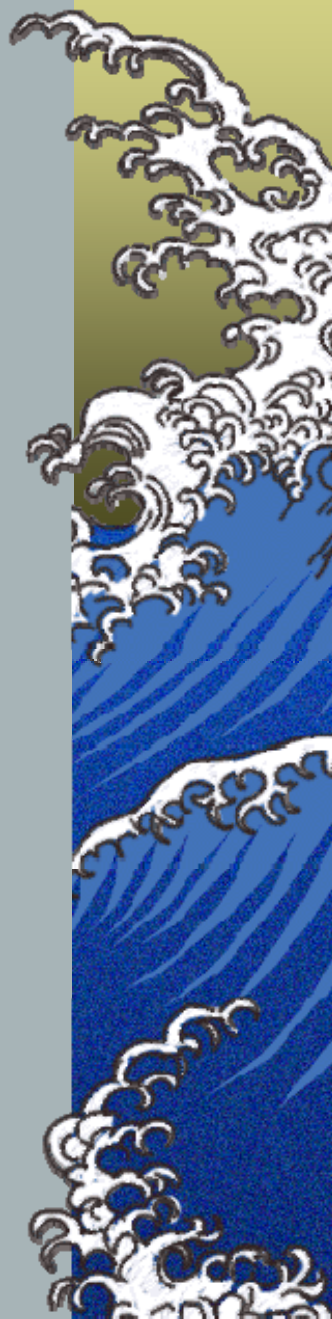
Fab startup as an example of Metanational Managerial Process

- *New Generation fabs create new technical challenges, new knowledge in startup and line integration.*
- *Suppliers gain extensive, unique knowledge by experiencing equipment and processes in multiple settings.*
- *Some suppliers may know more about yield enhancement than producers.*

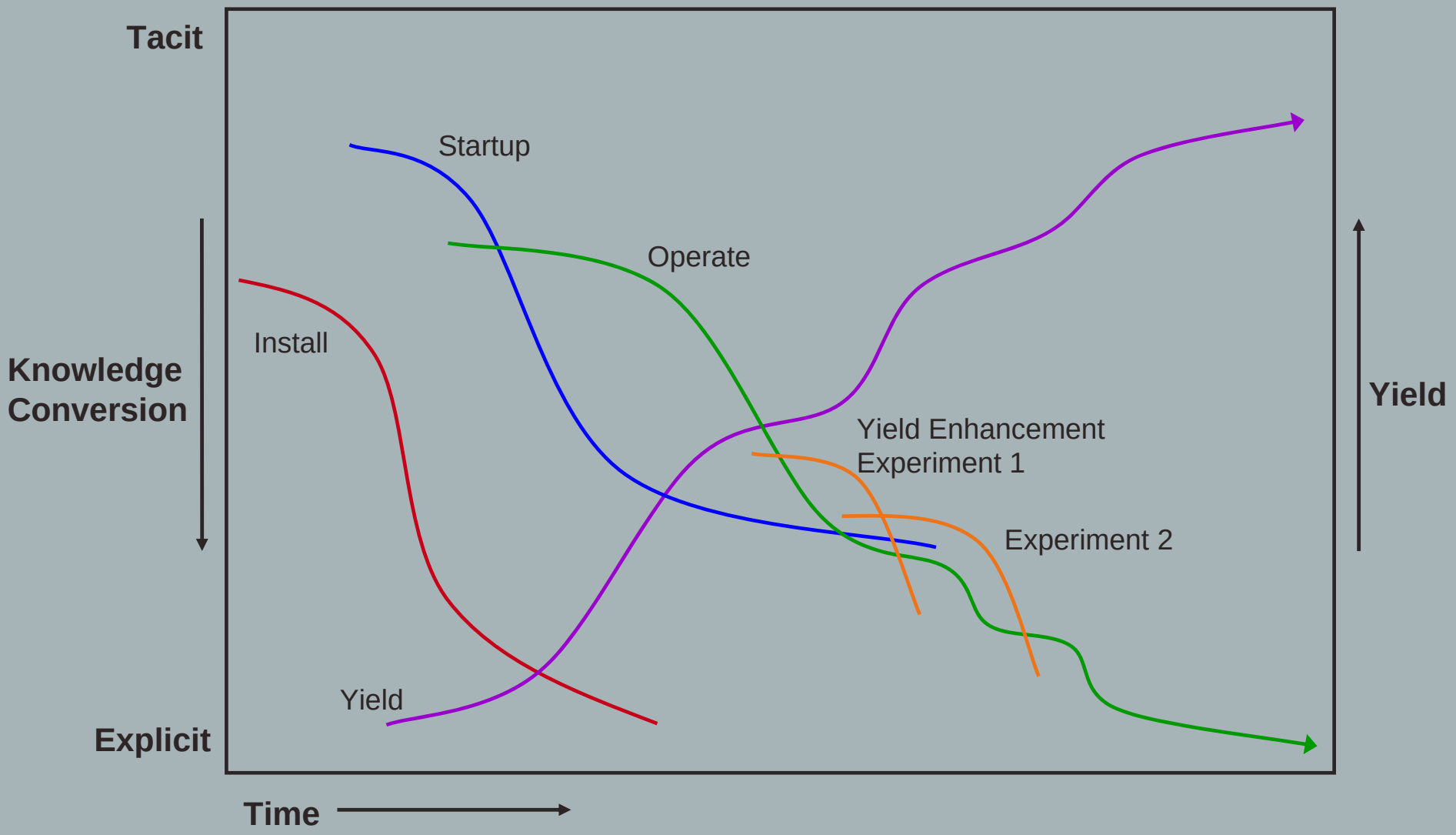


Metanational Process and Risk Mgmt: Fab startup example

- *Knowledge = principal leverage to maintain intimate customer relations and secure share of innovation rents.*
- *Tacit and verbal elements require close personal interaction on shop floor.*
- *Service groups remain in fabs until client risk of proprietary knowledge diffusion exceeds value of co-creation and transfer.*



Waking up a new Gen TFT fab: Phases, functional service teams, knowledge conversion, and yields



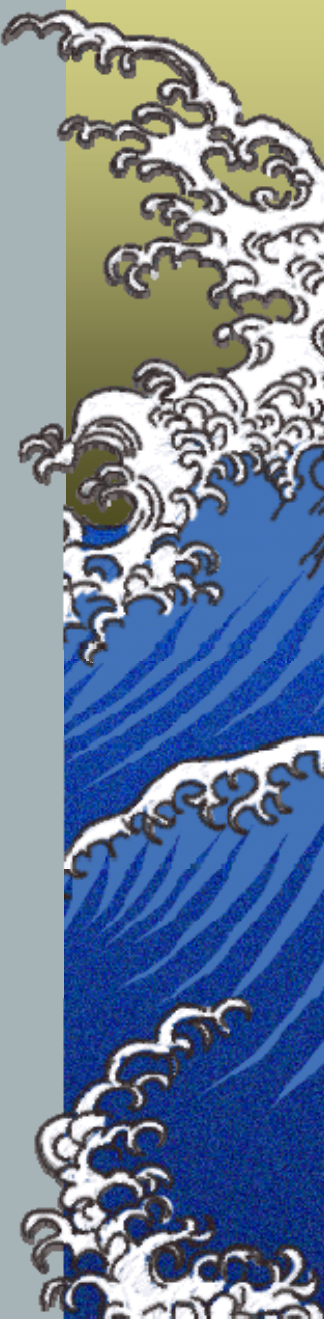
Factors that mitigate vertical integration in the FPD industry innovation system

- *Suppliers' IP and human knowledge capital.*
- *Rapid Gen changes: between 2x and 18x equivalent semiconductor historic phases.*
- *"Bandwidth:" producers' most experienced personnel spread increasingly thin.*
- *Large R&D investments shared by industry.*
- *Collective interest in industry advance: mutual dependence recognized.*

Will firms need more vertically integrated innovation systems?

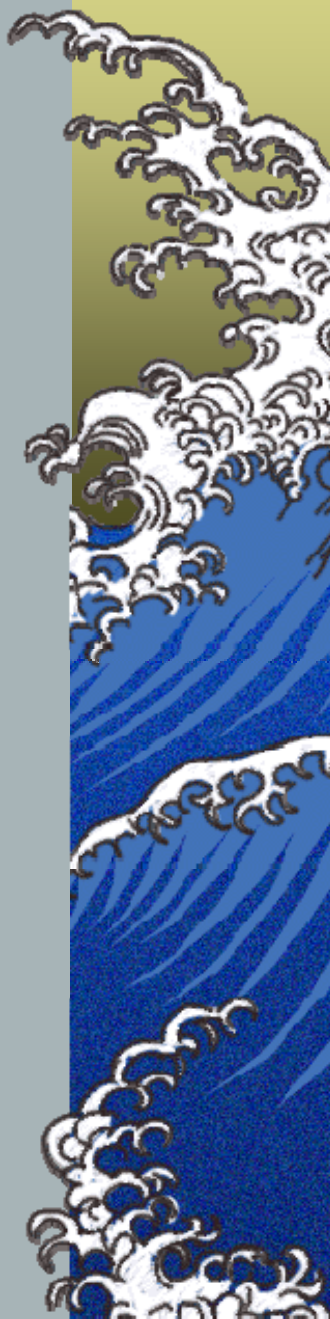
- *Will diminishing returns to scale end cost advantages of generational advances to larger and larger glass sizes?*
- *Will firms invest in greater numbers of identical generation fab lines, and "relearn how to build their own fabs"?**
- *Will benefits of sharing a knowledgeable, industry-wide supplier base diminish?*

**Interview, David Hsieh, DisplaySearch, November 22, 2004*



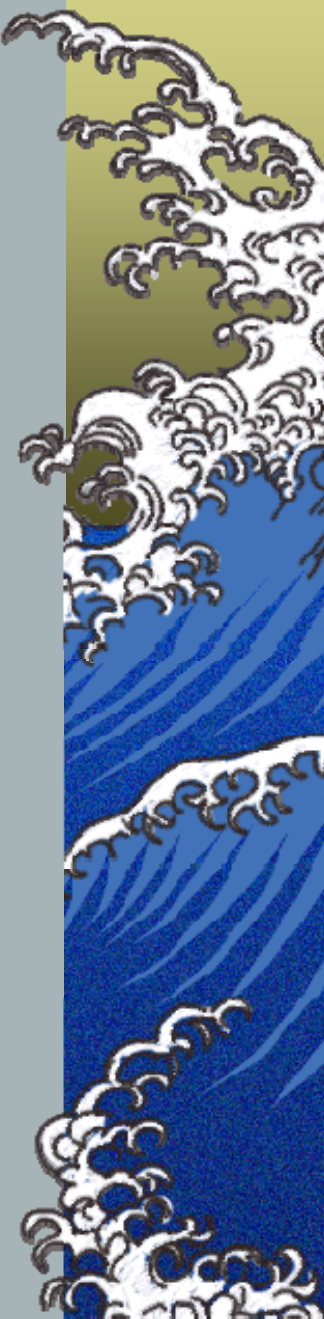
What should be the role of Government? U.S. Experience.

- *Policy failure: Strings attached to U.S. R&D subsidies in 1990s distracted many firms from establishing learning relationships in Asia.*
  - *Out-of-touch with industry developments*
  - *Unable to master high volume production*
  - *Reluctance to source equipment, materials, process recipes from Japan.*
  - *Targeted leapfrog without current mastery*



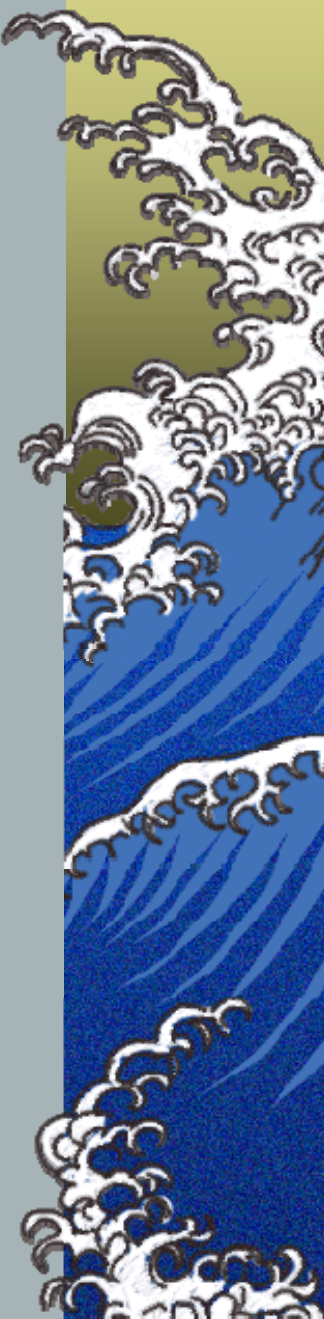
Roles and Issues for Government Policy

- *Avoid policies that discriminate against non-national firms as collaborators, investors, R&D centers, suppliers.*
- *Address people shortages: promote education, alternative government service models (e.g., Taiwan).*
- *Promote basic research for broadly applicable technologies.*



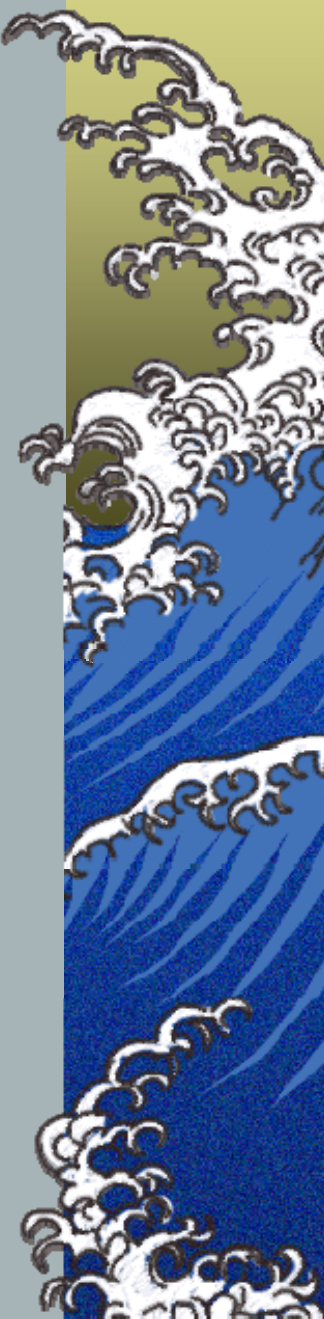
Roles and Issues for Government Policy

- *Efforts to "nationalize the supply chain" or restrict exports to potential new national entrants will backfire.*
  - *Insist on level playing field in export markets for global equipment and materials suppliers*
  - *Industry growth will continue downward cost pressures.*
  - *Consider interests of infrastructure companies, final goods producers, and consumers.*



Roles and Issues for Government Policy

- *Planetary scale of new fabs complicates already massive land use issues.*
- *China's industrial strategy: Local governments provide funding, take equity and/or provide tax breaks for new TFT-LCD fabs.*
  - *Should other governments respond, and if so, how?*



Appendix:

Alfred P. Sloan Foundation Industry Studies Program

Flat Panel Display Team

Fieldwork and Methodology

(not for live presentation)

Methodology: Alfred P. Sloan Foundation FPD Team

- *Semi-structured interviews with over 200 senior managers, engineers and scientists since 1996.*
- *Comprehensive archival documentation of trade and business media.*
- *Company, industry and government documents.*
- *Site visits to all major FPD producers in U.S., Japan, Taiwan, Korea, Europe between 1996 and 2004, often multiple over time.*
- *Trade shows and industry conference attendance and presentations of findings.*
- *Acquisition and analysis of data from leading industry market research firms.*

Site Visits: U.S.: 1996-2002

- OIS
- ImageQuest Technologies
- dpiX, A Xerox Company
- IBM
- Planar Inc.
- Plasmaco
- Candescent Technology Corporation
- FED Corp.
- PixTech
- Motorola
- Raytheon
- Display Technology Systems
- Applied Komatsu Technologies
- Applied Materials, Inc.
- MRS Technology, Inc.
- Photon Dynamics
- Lam Research
- Corning Inc.
- 3M
- Honeywell
- Compaq
- Lucent Technologies
- United States Display Consortium
- Technical Visions
- InFocus
- Sharp, U.S.A.
- Department of Defense
- DARPA
- National Economic Council

Site Visits, Japan: 1996-2002

- IBM Japan
- Toshiba
- DTI
- NEC
- Hitachi
- Hosiden
- Philips Hosiden Flat Panel Co.
- Seiko Epson
- Sharp
- Matsushita Electric
- Sumitomo 3M
- MITI/METI
- SEMI
- U.S. Embassy, Japan
- Corning, Japan KK
- Corning Advanced Display Products
- Applied Komatsu Technologies
- Canon
- Futaba
- Asian Technology Information Program (DARPA/USDC)

Site Visits, Korea and Taiwan: 1996-2002

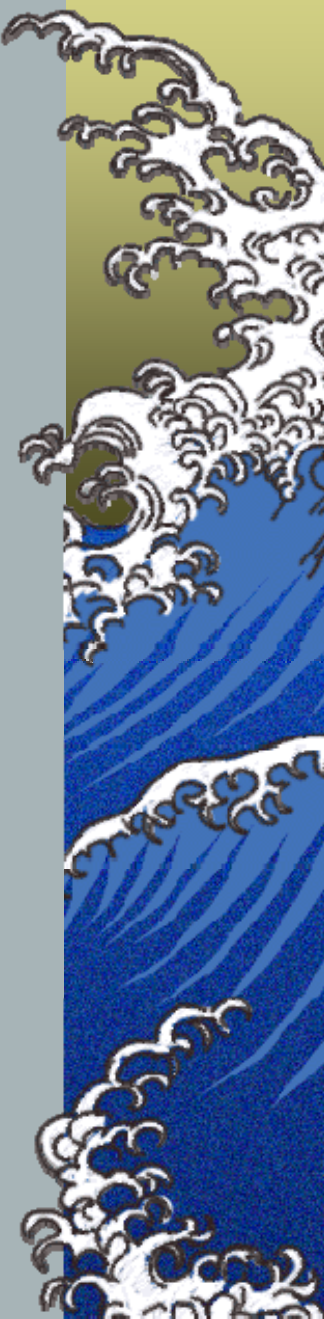
- Samsung Display Devices
- Samsung Electronics
- Samsung Corning
- LG Electronics
- LG.Philips
- Hyundai
- Daewoo
- EDIRAK
- Korean Ministry of Science and Technology
- Korean Ministry of Trade, Industry and Energy
- Nan Ya Plastics
- First International Computer
- Prime View
- ITRI
- Unipac
- Chunghwa Picture Tubes

Site Visits: Europe: 1996-2002

- Philips
- LG.Philips
- PixTech

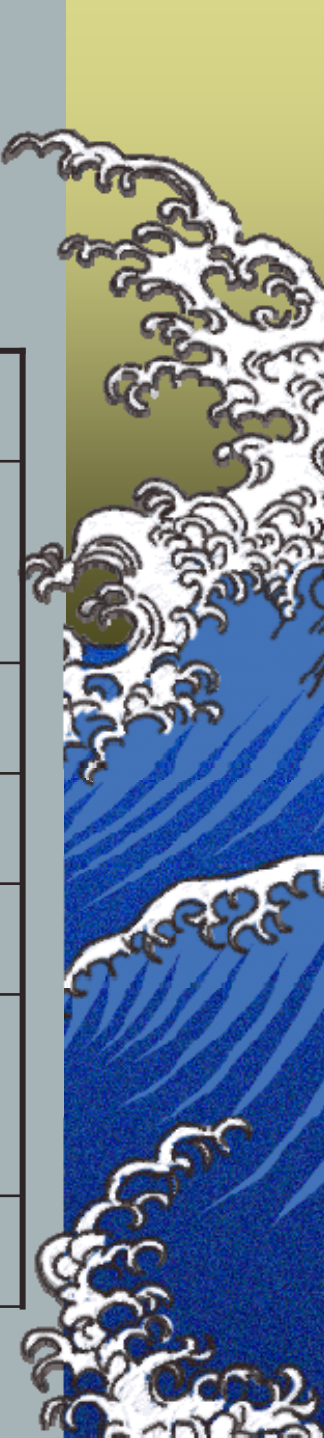
Site Visits, Field Work: 2003-2006

- *Sony (Tokyo) (x2)*
- *Corning Advanced Display Products World Headquarters (Tokyo)*
- *Applied Materials Japan (Tokyo)*
- *AKT/Applied Materials (Santa Clara, California)*
- *IDTech/CMO (Yasu, Japan)*
- *Matsushita Electronics (Osaka)*
- *DisplaySearch U.S. Display Forum, 2003, 2004, 2005 (San Diego)*
- *Society for Information Display Annual Meeting, 2004 (Seattle)*
- *Photon Dynamics (San Jose, California)*
- *FPD International, Yokohama*
- *Sharp (Kameyama)*
- *LG Electronics (Gumi, S. Korea)*
- *LG.Philips (Seoul)*
- *Philips Electronics (Amsterdam)(x3)*
- *Samsung-Corning Precision Glass (Gumi, S. Korea)*
- *Corning Display Technologies, Taiwan (Taipei)*
- *Center for Innovation, Kyungpook University (Daegu, S. Korea)*
- *European Display Forum (Den Hague)*
- *LUMILEDS (San Jose, California)*
- *Merck KGaA (Darmstadt, Germany)*
- *CPT (Taiwan)*
- *AUO (Taiwan)*
- *AMTC (Taiwan)*
- *ITRI (Taiwan)*
- *DisplaySearch Taiwan (Taipei)*
- *AKT Taiwan (Hsinchu)*
- *Kaiyuan Security Investment Consultants Co. Ltd. (Taipei)*
- *National Chiao Tung University Display Institute (Hsinchu, Taiwan)*
- *CMO (Taiwan)*
- *Unaxis Taiwan*
- *Toppoly (Taiwan)*
- *Canon*
- *Nikon*
- *RIETI*



Sloan Foundation Globalization Network: Projects and Teams

Flat Panel Displays	*Minnesota*
Contract Manufacturing	*MIT*
Semiconductors	*UC Berkeley*
Personal Computers	*UC Irvine*
Venture Capital	*UC Davis/BRIE*
Business Process Outsourcing	*Stanford/UC Davis*
Direction:	*Minnesota/U Pittsburgh*

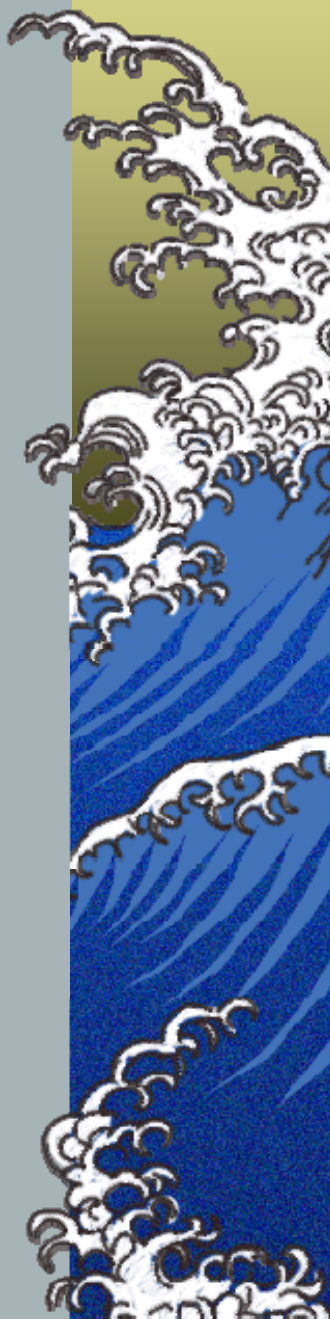


Sloan Globalization Network Research Issues

- *Competitive implications of deverticalization for countries and companies.*
- *Competitive and welfare implications of global workforce upgrading.*
- *Managing dispersed people, processes and assets, with increased competitive pace.*
- *Balancing IP protection and knowledge co-creation with suppliers, partners, competitors.*
- *Small enterprises' growing roles in the global knowledge economy.*

Sloan Globalization Network Study Phenomena

- *Fabless Semiconductor firms*
- *Semiconductor foundries*
- *Manufacturers that manufacture without factories (AKT)*
- *VCs as knowledge agents*
- *Manufacturers* sans *manufacturing (HP)*
- *Total Mfg. Service providers (Flextronics)*
- *Business process outsourcing (India)*
- *Pervasive modularization (PCs)*

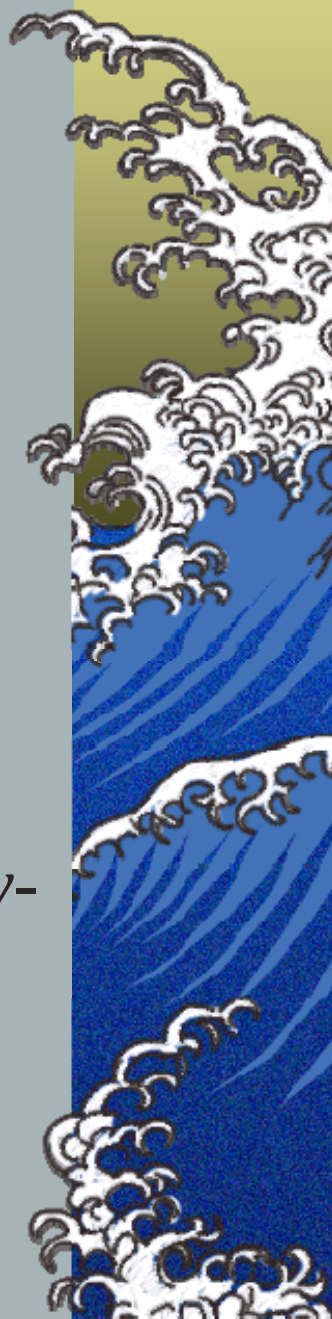


Book available!

Background for this presentation and some of the content came from the book, **Managing New Industry Creation**, *by Thomas P. Murtha, Stefanie Ann Lenway and Jeffrey A. Hart.*

Available from these Web sources:

- *Stanford University Press, www.sup.org*
- *www.amazon.com (available through any country-based amazon site, e.g., uk, fr, jp, etc.)*
- *Or request at your local book store*



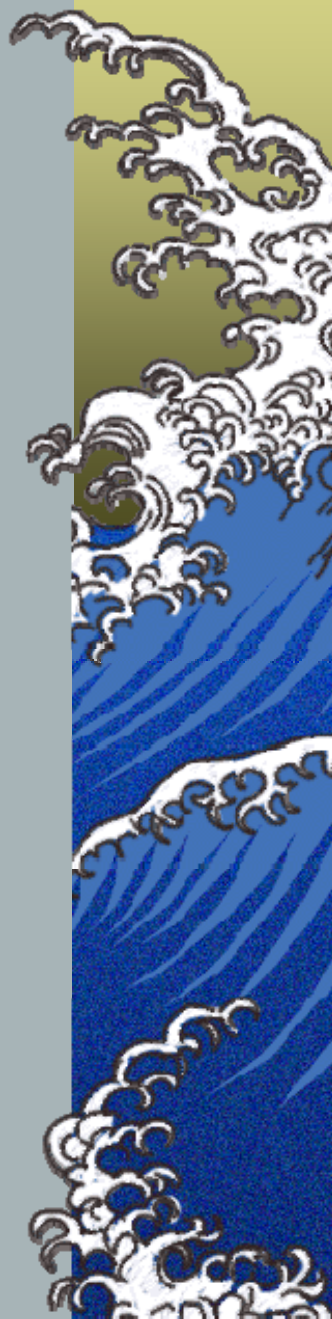
References and copyright info:

Unpublished data *in tables derived from author's primary research, informed estimates, and DisplaySearch, Inc.* ***Do not cite without permission.***

Doz, Yves, José Santos and Peter Williamson. **From Global to Metanational: How Companies Win in the Global Knowledge Economy**. *Boston: Harvard Business School Press: 2001.*

Thomas P. Murtha, "The Metanational Firm in Context: Competition in Knowledge-driven Industries." **Advances in International Management**, *Elsevier, 2004: 101-136.*

Thomas P. Murtha, Stefanie Ann Lenway and Jeffrey A. Hart. **Managing New Industry Creation: Global Knowledge Formation and Entrepreneurship in High Technology**. *Stanford: Stanford University Press, 2001.*



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