Microlithography Dynamics

Social, Economic, Spatial and Temporal Implications of Developments in Computing Technology

by

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ABSTRACT

This work focuses on historical and modern geography-related analysis of semiconductor industry (specifically microlithography) and its role in Information Technology (IT). Following Professor's J.D.Sachs terminology, it would be highly desirable "to distinguish the growth effects of the various *[in my case, related to IT, VB]* components of economic policy".

Structurally, thesis offers an analysis of the latest business cases (partially from the author's experiences with semiconductor equipment makers, Integrated Circuits (IC) makers, and "agglomeration economies" such as in Europe, Asia and Silicon Valley). I explore the connection of the current microlithography status and its perspectives with the patterns of economy's macro-behavior. I scrutinize hypothesis that, with silicon technology becoming a commodity, the slowdown in introducing new generations of products, based on new integrated circuits' functionality, is critical for semiconductor's industry consistent growth. In its current stage (with microlithography stagnation) the solid-state based IC technology provides only marginal functionality improvements between so called "new" generations and has somewhat limited potential to do so in a future.

In summary, the transition processes of growth in the industry reaching the status of being mature are not very encouraging and definitely raise the question: "What happens if the IC industry will start to fail supporting the GDP growth rate established and sustained by the Information Technology ?" I hope that proposed analysis will help to understand better the unjustifiable expectations from the technology, which may lead to distorted policies of capital investment if coupled with illusions of unlimited economy expansion. The economic Long Wave Game was re-designed and developed for PC version to create a platform for possible future research in this area.

Looking broader I suggest that the ultra-densification of space implemented in the technology of microlithography is the underlying material reason for the IT & space-inferred time transformation and consequent social arrhythmia.

Finally, I consider it as important that new kind of teams with defining notion of partnership and shared best practices are operationally decisive for an effective organization in the IT environment.

Thesis Supervisor: Simon Johnson
Title: Professor, Sloan School of Management

To my father

Vladimir Alexei Boksha

who passed away soon after the Chernobyl

for his kindness, integrity,
wisdom, and vision

Acknowledgements

> Nobody ever saw a dog make a fair and deliberate exchange of one bone for another with another dog …
> The strength of the mastiff is not in the least supported either by the swiftness of the greyhound, or by sagacity of the spaniel, or by the docility of the shepherd's dog. …
> Among men, on the contrary, the most dissimilar geniuses are of use to one another …
>
> ***Adam Smith**, An Inquiry into the Nature and Causes of The Wealth of Nations, 1776*

MIT has been special for me since I started to work and familiarized myself with its leading publications on deep ultraviolet microlithography. Further more, our family life in the US would be rather much different without generous support and advice (since my first week in the country) from the several generations of the family of Mr. Richard O. Foster, especially his wife Jeannie and daughter Alison. Mr.Foster (being from the amazing group of MIT System Dynamics graduates of early 1970's) is one of the very few researchres who was referenced by Professor Jay W. Forrester in his "World Dynamics". Master's thesis of Mr.Foster is still shaking MIT community 30 years later. Silicon Valley is our home and tremendous intensity's school of business largely because of Mr.Foster.

I am highly thankful to my teachers starting from elementary school, really, and then to three special (and very different) persons in my high school years, which taught me to appreciate sophistication of literature, mathematics, and volleyball. I was lucky to learn from wonderful people during my university's study of physics and to make friends for life. I highly appreciative to Victor Lapitskii, Vasilii Balyii, Sergei Lysenko, and Vladimir Denisman for their friendship and support thoughout the years. My consequent doctoral education and Ph.D. work with Professor Eduard I.Tochitsky certainly shaped me as a professional; I especially appreciate guidance and support from the leading staff of his Institute, Dr. Vyachelsav E.Obuhov and Dr. Anatoly I.Sharendo. Work with many top-level professionals from the semiconductor equipment maker KBTEM (Minsk) has been unbelievable learning experience. Overall, I wish that this beautiful place on globe, Belarus (which I am proud citizen of), realizes its potential to the maximum extend.

Later in the United States and around the globe, many people generously shared with me their expertise; I highly value all the opportunities to work together with the world class companies and professionals. I am grateful to all my colleagues and friends from Technology Modeling Associated, Inc. (my special appreciation goes to Alfred Howell, Juan Rey, Dr.Yuri Granik, and Dr.Valery Axelrad), Sequoia Design Systems, OPC Technology (especially Mick O'Brien), Cypress Semiconductor, LSI Logic, Applied Materials, Intel, IBM, Motorola, Texas Instruments, Micron, National Labs (Sandia and Livermore), Cadence Design Systems, Chartered Semiconductor and Tech Semiconductor (Singapore), TSMC and UMC (Taiwan), Hitachi, Toshiba and Marubeni (Japan), ASM Lithography and Philips (Neitherlands), Siemens (Germany), SGS Thomson (France) and many others.

My classmates at MIT Sloan School of Management, Harvard School of Government, and Harvard Business School truly helped me to capture rich Cambridge environment and maintain sense of humor throughout the intensive year and I will remember that. I would like to thank to Professors Joshua Lerner, Felda Hardymon, and Michael Watkins at Harvard Business School for sharing with me their knowledge, intelligence, and jokes. I wish the best luck to the world class establishments at MIT: its Economics Department and System Dynamics Group. I have tried hard (and will continue to do so) to learn from them as much as possible. Certainly, I enjoyed to work with and to learn through MIT Venture Capital Club.

Working within the course of Professor Jeffrey D. Sachs at Harvard most definitely was the best experience of my Fall'1999. His drive and depth helped me tremendously to re-established my horizons. I am very thankful to him for that.

My special appreciation goes to Professor Simon Johnson at MIT Sloan School of Management for supervising this work, being "there" for me, guiding, and allowing my independence to be fully expressed.

My parents, Vladimir Boksha and Regina Dybrovskaya passed away simply too early; I did not really had a chance to give them back at least a portion of the love I always experienced from them. I still remember their stories and carry with me deeply the feel of dignity, which my family carefully saved throughout many horrible experiences of the last several centuries.

Except of "Thank you, my Dear", how else can I express the appreciation to my wife Olga for being blessed with her trust, patience, and love. Olga is the best friend, advisor, and colleague for decades by now. I really thankful for being so warmly accepted by Olga's family, by people, which I certainly view as the best representatives of the Russian nation one can imagine.

Speaking in this work about IT influence on everything I, certainly, include myself into consideration, both working in it for 20 years (since 1980 when I was doing my first serious work on clustering of defects in silicon) and being consumer of it. If my opinions look sometimes informal and emotional – they, certainly, are…, because, **It Is Personal.**

Contents

Introduction

Sem' milliardov rasteryannyix grajdan
V epoxy bol'shoii nelubvi

<u>translation from Russian:</u>
There are seven billions of confused citizens
During the epoch of big non-love

song's line by ***Andrei Makarevich,*** *leader of the non-traditional rock-group "Machina Vremeni", end of 1970's*

1. Motivation, goal, and structure.

<u>Motivation</u> for this work is twofold. First, author is aiming to make an assessment of the last 20 years of microlithography development (partially through the personal experience), which is largely determined progress of semiconductor and Integrated Circuits industry. Second, the thesis work was very much considered by me as the main learning vehicle throughout my time at MIT.

Author is fascinated with the space factor: both on micro- (microlithography) and macro- (modern economic geography and development issues) level and is trying to capture their interactions which he considers as important ones. This thesis emphasizes historical and modern geography-based analysis of semiconductor industry (specifically microlithography) and microlithography's role in Information Technology (IT). Following terminology of Professor's J.D.Sachs from Harvard University, it would be highly desirable "to distinguish the growth effects of the various *[related to IT in our case, VB]* components of economic policy" (Sachs, 1998).

Eventual **<u>goal</u>** of the work is to investigate and describe structural interrelationships of growth dynamics for critical new technology (analyzing the rapid rise of semiconductor industry, its maturing and transfer to commodity stage) and its influence on the polity. Expression by Manuel Castells "technology is society" is underlying theme of the work. I will refer to methodologies of differential geography (by Jeffrey Sachs), self-organizing agglomeration economies (by Paul Krugman), and system dynamics (by J.W.Forrester) to explore integration of highly technical issues with business-related micro- and macro-economical considerations up to the eventual technology's impact on polity (Figure I).

Critical (and maturing) technology. Rapid growth of semiconductors since the middle of 1960's shaped the explosion of Information-related Technologies (IT). However, "ultimate" recognition of the significance of IT contribution in overall economy happened only recently, when in October of 1999 the Dow Jones Industrial Average included Nasdaq members Microsoft and Intel into the benchmark index of 30 stocks (four benchmark members since 1930s – Chevron, Goodyear Tire & Rubber, Sears Roebuck and Union Carbide – were dropped at the same time). Despite of this nuisance it is now generally recognized that IT is a major contributor (up to 35%) to the economic growth while accounts for only about 8-10% of the US GDP. Such advances are not coming cheap. Consider, for example, cost of a new semiconductor fab which is currently approaching $ 3 billions (compare with the cost of the Boston Ted W. Tunnel, $ 1.3 B, or USS Enterprise aircraft carrier, $ 4 B) and is projected to reach $ 10 – 15 billions in the next ten years.

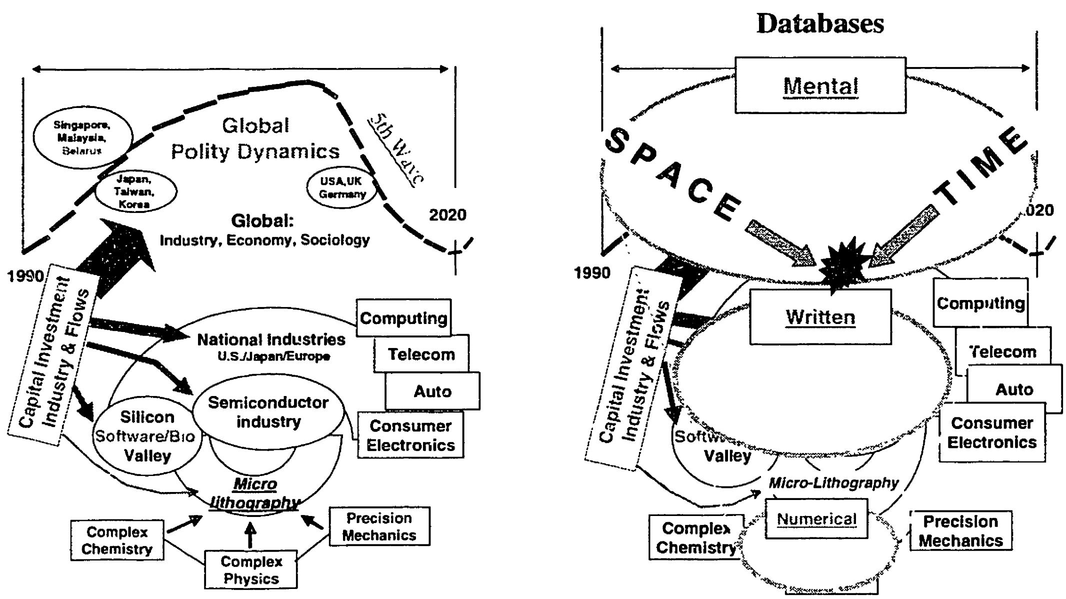


Figure I left: schematic view of the economy - IT slice of the Long Wave
right: Databases - Microstructures create the Macrobehaviour
(by Jay W.Forrester in the "Models and the Real World")

Like in European football (soccer in the U.S.) everybody has an opinion about the crises of the rapidly falling prices in PC industry. Some people are tracing it down to the corresponding disaster in the memory, especially DRAM, business. However, few are interested to take the analyses further and make the direct link between the current turmoil and the technology limitations, which at this point are somewhat obvious to semiconductor industry professionals. Problems arise simultaneously in Integrated Circuits (IC) design, physics of semiconductor devices and process technology; all together coupled with material limitations. Such situation determines controversial cost dynamics defined by the rapid increase in complexity and price of equipment on the background of dramatic fall of chip prices. These events put severe limitations on companies' ability to maintain cost reduction and eventually led to the recent wave of spin-offs, mergers and acquisitions among IC makers.

Microlithography, with its state-of-the-art technology and the most expensive equipment, is itself the major cost factor of semiconductor manufacturing. Therefore, lithography's pace of development and affordability largely determines progress in IC industry. Moreover, because of its current resolution limit, lithography has direct impact on IC design, increasing its complexity and data volume. Under such conditions a detailed microlithography analysis becomes a top priority in aiding decision making for the semiconductor industry which experiences enormous cost penalty either for under-utilization of fab capacity or for not ramping up production in time when necessary. Based on such analysis, we conclude that the industry in its amazing gallop is rapidly moving through the transition period to the status of a mature business. Consequently, **all** technologically available, solid-state based ICs are becoming a commodity. That (combined with the quite possible slowdown in microlithography advances) causes doubts in sustainability of expectations in Information Technology rate of growth.

Structurally, this work is largely based on original research conducted by author and on his experience in semiconductor industry, particularly microlithography, since 1982. On such background, expressed views on the technology role and its significance were shaped and influenced by the school of System Dynamics developed by Professor J.W.Forrester at MIT and the latest research in macroeconomic geography and development policies conducted by groups of Professor P.Krugman at MIT Economics Department and Professor J.Sachs at Harvard University. Thesis structure and several of its key components were heavily influenced by the Fall'1999 Harvard's course of Professor J.Sachs "History and Theory of Economic Development", Venture Capital courses in Spring'2000 (Professors J.Lerner/F.Hardimon, Harvard Business School and Professor S.Johnson, MIT Sloan School of Management). Final portion of the work and main conclusion were inspired by the magnificent work of Manuel Castells "Information Age" and Barbara Adam "Time and Social Theory".

Significant portion of the analysis refers to simulations and modeling approaches, both in microelectronics and economics/business/management domains (Forrester, 1961; Sterman, 2000). Following J.W.Forrester, Professor Sterman emphasizes that "the temporal and spatial boundaries of our models tend to be too narrow." Underlining benefits and limitations of a model, Sterman states once again the bold mission of system dynamics:

> The literature of the social sciences is replete with models in which elegant theorems are derived from questionable axioms, where simplicity dominates utility, and where variables known to be important are ignored because data to estimate parameters are unavailable. System dynamics was designed specifically to overcome these limitations and from the beginning stressed the development of useful models; models unconstrained by the demands of analytic tractability, based on realistic

assumptions about human behavior, grounded in field study of decision making, and utilizing the full range of available data, not only numerical data, to specify and estimate relationships.

Figure I represents somewhat my views and intention for the structure of thesis. In this scheme microlithography ultimately influences everything above it up to (and including) "space & time" level. The technology does it by means of the extremely small functional features mass produced ever, that is, by delivering the incredible densification of space.

Along with the detailed analysis of the real business cases (partially from my experiences with equipment makers, IC makers, "agglomeration economies" such as in Europe, Asia, and Silicon Valley), I explore the topic of connection of the current microlithography status and its perspectives with the macro patterns of economy behavior.

Anyone, seriously considering technology evolution (or revolution, from time to time), pretty quickly will realize how critical is government and military role in it. So, without explicit desire to analyze military and being indifferent to government, per se, I was "forced" by the logic of work to consider both of them at some level of details as part of overall picture of technology development (left re-enforcing "positive" loop on Figure II). Right side of the Figure II represents balancing "negative" loops.

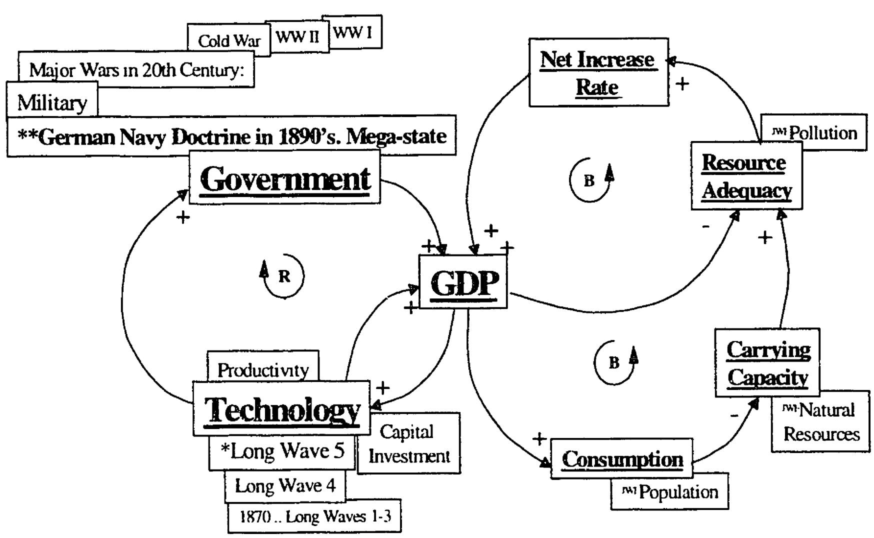


Figure II Identification of the Feedback Structure of Growth and Limits to Growth

* adopted from "The Economist", February 20, 1999, p.20

** see P.Drucker, Post-Capitalist Society, p.127-128

JWF adopted from J.F.Forrester "World Dynamics"

As underlined above, the high-tech industry is directly dependent on semiconductors manufacturing and is dominant factor in the global economy growth. Over-extended capacity in IC production is widely cited, and rightly so, as one of the major factors limiting semiconductors. *However, slowdown in introducing new generations of products, based on new integrated circuits functionality, is also critical.* The business of building hardware with "IC Inside" is not longer as profitable. Part of the reason is that in its current stage (with lithography stagnation) the solid-state based IC technology provides only marginal functionality improvements between so called "new" generations and has somewhat limited potential to do so in future. It might be the case that the current level of stress and uncertainty in IC industry will last for another 10 – 15 years until radically new computing technology (for example, molecular-based) establishes itself.

In summary, the transition processes of growth in the industry reaching the status of being mature are not very encouraging and definitely raise the question: "What happens if the IC industry will start to fail supporting the GDP growth rate established and sustained by the Information Technology ?" I hope that proposed analysis will help to offset unjustifiable technology expectations, which may lead to distorted policies of capital investment if coupled with illusions of unlimited economy expansion.

As recently as on April 4, 2000 former director of New York Federal Reserve Stephen Cecchetti wrote in Financial Times about the "unjustified expectations of future increases in economic growth". He refers to common consensus that current higher US growth (3-4% vs. 2% in 1995) has been spurred by productivity increase from three sources: information technology investment; increased hours worked; and pure technology progress. However, he emphasizes that "implications of this remain unclear". Professor Cecchetti underscores the specific imbalances: "...there is timing. The newly wealthy consumers will try to increase their purchases immediately, and the goods may not be there to quench their enlarged appetites."

2. Integrated Approach and New Data. Re-definition of Space and Time Transformation

Author strongly believes into the vital importance of ideas and diversity. Because of that I consider seriously the statement about the erosion of traditional barriers and increasing of interdisciplinary meshing.

I value work of Professor Diamond, which relates to the latest information from genetics, molecular biology, behavioral ecology, epidemiology, human genetics, linguistics, archeological data, histories of technology, writing, and political organization as well as to molecular physiology, evolutional biology, and bio-geography (Diamond, 1999).

In the same fashion, I am sympathetic to the logic of Dr. Adam, when she refers to the recent research in physics and biology, which seem to converge with social sciences in adopting a contextual notion of human time (Adam, 1990).

Throughout the thesis I am going to acknowledge various parts of the recent three-volume research "Information Age" by Professor Castells from the UC Berkeley (Castells, 1999). Moreover, in the final portion of my analysis discussing the role of microlithography I will refer extensively to his two chapters of considerable elegance where he analyses the fundamental notion of the space-time relationship in the context of the information technology.

While I sometimes disagree factually and once conceptually with Professor Castells (who might be heavy to read at times), overall, I consider his three volumes as an outstanding work. Especially appealing are: somewhat confusing but interesting definition of the "space of flows" and much more clear and extraordinary concept of the time transformation.

1. Origins and Evolution of Technology. Conceptualization of Information Age and Its Consequences

Technology is society

***Manuel Castells,** Information Age*

Reviewing the literature, which is the most relevant to the thesis' topic I am focusing on overall origins of technology and consequences of rapid emergence of Information Technology for business, economic, and social practices. From initial differentiation because of intensive agriculture and food production to the high-tech clustering of Information Age, it is amazing (and sad) to observe how consistently strong it use to be (and still exists) military's needs component as a driver for technology development.

I consider references to the works by Drucker, Castells, and Adam as directly related to the specifics of Silicon Valley, venture capital partnerships, and other IT implications; by Krugman, Sachs, and Diamond all together as an appropriate background for all the topics above and for the cases on ASML/Holland, and Belarus.

1.1 Origins of Technology Advantages

Jared Diamond is one of the several researchers who addresses the question (Diamond, 1999): "Why did wealth and power become distributed as they now are, rather than in some other way?" Professor Diamond relates to the latest information from genetics, molecular biology, behavioral ecology, epidemiology, human genetics, linguistics, archeological data, histories of technology, writing, and political organization as well as to molecular physiology, evolutional biology, and biogeography which directly overlap with his own background.

As of year A.D. 1500, when Europe's worldwide colonial expansion was just beginning, peoples on different continents already differed greatly in technology and political organization. Empires with steel weapons were able to conquer or exterminate tribes with weapons of stone and wood. Different rates of development on different continents, from 11,000 B.C. to A.D. 1500, were what led to the technological and political inequalities of A.D. 1500. It is considered as established that around 11,000 B.C. (approximately beginning of village life in a few parts of the world and the end of the last Ice Age) any of the modern continents had potential for strong development. Africa, for example, might be as well "enjoying advantages of a head start" because of: 1. at least 5 million more years of separate protohuman existence than on any other continent; or 2. arise of modern human ~ 100,000 years ago; or 3. the highest human genetics diversity. However, it was Eurasia that developed most quickly.

Author suggests that genetic-, weather-based explanations or the need in large-scale irrigation systems are not qualified to explain these different rates of development and insists, for example, that peoples of northern Europe contributed nothing of fundamental importance to Eurasian civilization until the last thousand years. They simply had the good luck to live at a geographic location where they were likely to receive advances (such as agriculture, wheels, writing, and metallurgy) developed in warmer parts of Eurasia.

Figure 1.1 Vast European-Asian East-West axis (temperate ecological zones) vs. Africa's North-South axis (Mediterranean, the Saharan Desert, the equatorial tropics, and the Southern sub-tropics)

Professor Sachs commented on this part of Diamond's work as follows (Sachs, 1998):

> Human populations in the Americas and Australasia were cut off by oceans from the vast majority of human populations in Eurasia and Africa. They therefore could not share, through trade and diffusion, in technological advances in agriculture, communications, transport, and the like. Additionally, Diamond argues that technological diffusion naturally works most effectively *within* ecological zones, and therefore in an East-West direction along a common latitude, rather than in a North-South direction, which almost invariably crosses ecological zones. This is because plant species and domesticated animals appropriate to one ecological zone may be completely inappropriate elsewhere. Eurasia, claims Diamond, therefore enjoyed the benefit of its vast East-West axis heavily situated in temperate ecological zones, while Africa was disadvantaged by its North-South axis which cut across the Mediterranean climate in the far North, the Saharan Desert, the equatorial tropics, and the Southernmost sub-tropical regions. Diamond argues that these advantages, in addition to more contingent (i.e. accidental) advantages in indigenous plant and animal species, gave Eurasia a fundamental long-term advantage over the rest of the world.

Significant part of the development process was that numerous well-equipped people were standing against (and exterminating) few ill-equipped opponents. Environmentally-induced split of initially equal people into hunter-gatherers and farmers lead to development of complex technology and political organization for later. Farmers were able to do that because of production of crop surpluses available for distribution, storage, support and feed of non-hunting craft specialists, armies, bureaucrats, chiefs and priests. Further fine differentiation was probably related to dominated religion. J.Diamond notes that "religions vary greatly in their relation to technological innovation: some branches of Judaism and Christianity are claimed to be especially compatible with it." Professor Adam Smith emphasized "the equality which the presbyterian form of church government establishes among the clergy" with consequent generation of "the most eminent men of letters whom those countries have produced, have, not all indeed, but the far greater part of them, been professors in universities. In those countries the universities are constantly draining the church of all its most eminent men of letters." (Smith, 1776).

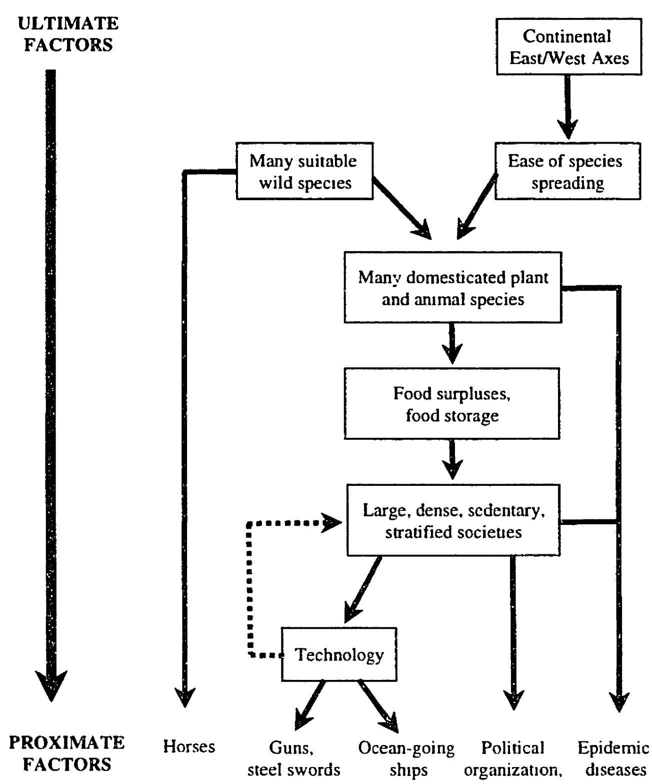


Figure 1.2 Factors underlying the broadest pattern of history (by Diamond, 1999) Food production, competition and technology diffusion between societies, led as ultimate causes (through sedentary living, large and dense populations) to the proximate agents of conquest: germs, writing, technology, and centralized political organization

In general, population size interacted with population density to influence technology (Kremer, 1993), economic, social, and political organization. The larger the size and the higher the density, the more complex and specialized were the technology and organization. The biggest political units could assemble large labor forces to construct irrigation systems and fishponds that intensified food production even further. Food production was indirectly a prerequisite for the development of "guns, germs, and steel" (see Figure 1.2). At the same time, hunters-gatherers had to learn how to leave with each other, limit population, and did not develop neither strong leadership nor organization (or adopted farmer's track much later) with lethal consequences of that. J.Diamond suggests that environment (as in his example of Moriori vs. Maori, Polynesia) can affect economy, technology, political organization, and fighting skills within a relatively short time (less than a millenium). He identified the most important sets of environmental variables (and their ranges) such as: climate, geological type, marine resources, area, terrain fragmentation, and isolation.

The differentiation during the development process eventually led to superior military (based of guns, steel weapons, and horses) and marine technology, writing and centralized political organization. These advantages combined with the killing power of animal-derived germs, introduction of infectious diseases epidemic brought by an invaders (usually from Eurasia) were critical in eventual European dominance.

Growing economic clusters (mainly around cities), establishment of modern universities with consequent major advances in science (especially physics and biology) eventually led to the development of Information Technology which appears to be strong enough to shape the Management Revolution of the Information Age and to radically transform society.

1.2 Emergence of Post-Capitalist Society

> In the flow of money political factors are increasingly as important as interest rates.
>
> ***Peter F. Drucker**, Post-Capitalist Society*

There are several reasons why I consider the work of Professor Drucker (1993):as being ultimately relevant for a person studying modern concepts of management in the world transformed by Information Technology:

- significance of newly emerging globalization and the need to understand in depth how international development is shaping and proceeding
- increased growth in population of so-called developing countries; for developed countries it is a matter of survival to capture new trends
- clear and precise analysis of the role of knowledge and management

P.Drucker describes purpose of his book as follows: "That the new society will be both a non-socialist and a post-capitalist society is practically certain. And it is certain also that its primary source will be knowledge. This also means that it will have to be a society of organizations. Certain it is that in politics we have already shifted from the four hundred years of the sovereign nation-state to a pluralism in which the nation-state will be one rather than the only unit of political integration. It will be one component – though still a key component – in what I call the "post-capitalist polity," a system in which transnational, regional, nation-state, even tribal, **structures compete and co-exist**. These things have already happened. They can therefore be described. To do so is the purpose of this book."

While the whole book is breathtaking, extremely dense and rewarding reading because of its depth and multilevel approach, I will review only the issues, which are the most relevant to my thesis.

1.2.1 Knowledge and Sequence of Revolutions

P.Drucker considers different kinds of knowledge applications as a main drivers behind the speed of technology and capitalism diffusion across cultures, classes and geography.

Industrial Revolution (1750 – 1900) was created by knowledge applied to tools, processes, and products. Early technical schools converted experience into knowledge, apprenticeship into textbook, secrecy into methodology. After that "knowledge could not be applied in tens of thousands of small individual workshops and in the cottage industries of the rural village. It required concentration of production under one roof". This application of knowledge also created new classes and class war.

Next phase (1880 – 1945) is characterized by the knowledge applied to work and by the **Productivity Revolution**. Frederick Taylor first applied knowledge to the study of work, the analysis of work, and the engineering of work. He saw that social conflict was unnecessary. Eventually such approach transferred proletariat into middle-class, defeated class war and overcame the Marxian's "inevitable contradictions of capitalism," the "alienation" and "immiseration" of the laboring class, and with it the whole notion of the "proletarian". P.Drucker states that post-WWII economic powers – first Japan, then South Korea, Taiwan, Hong Kong, Singapore – all owe their rise to Taylor's training.

Finally, after the World War II knowledge is being applied to knowledge itself. P.Drucker lays out evolution of understanding of management. During and immediately after the WWII, a manager was defined as "someone who is responsible for the work of subordinates"; management was rank and power. By the early 1950s manager was "the one who is responsible for the performance of people". Drucker says: "Management is supplying knowledge to find out how existing knowledge can best be applied to produce results" or "manager is one who is responsible for the application and performance of knowledge. *That knowledge has become **the** resource, rather than **a** resource, is what makes our society post-capitalist. This fact changes - fundamentally – the structure of society.* Knowledge is now fast becoming the sole factor of production, sidelining both capital and labor. It creates new social and economic dynamics. It creates new politics. ... This is **Management Revolution**."

On the same note Professor Drucker uses the term "polity" (= "political society and political system") in combination with terminology of "political structure" for consequent analysis of the evolution of state and its components. New polity dynamics coupled with technology impact infer the need for society units to behave differently from the past. Organization is one of these units.

1.2.2 Polity Dynamics and New Organizations

According to the Drucker's data, US manufacturing production as part of GDP is relatively constant: 22% in 1975 and 23% in 1990. Increase in GDP itself was significant: 2.5 times. While total workforce doubled, manufacturing employment decreased to 16-17% in 1990 and is expected to fall to 12% by year 2005. In comparison with 1990, GDP is expected to double again by that time. At the same time, knowledge workers account for almost 30% of the total workforce (with skilled service workers accounting for another third or so). These people own the "means of production", that is their knowledge, which can not be taken away. It leads to the conclusion that such people cannot be supervised. Immediately it raises tremendous problems of motivation, of reward, and of recognition.

P.Drucker rightly says that organizations have to market membership in order to attract, to hold, to recognize and reward, and to motivate its people. Moreover, organizations have to serve and satisfy its own employees. More recently (Castells, 1999), it is recognized with even more clarity that interlinked networks inexorably shifting power from organizations (and nation states) to individuals, decentralizing authority.

Team work understanding and treatment by the latest Peter Drucker is exceptional. It starts in the book we are concerned with and then continues in his latest work (Drucker, 1999). He identifies "three major kinds of teams for all human work". First, baseball or cricket team; it is also the kind of team that operates on a patient in the hospital. In this team, all players play on the team but they do not play as a team; mutual assistance is not expected. All players occupy fixed positions. Second, the soccer team (concept of symphony orchestra). Fixed positions, however, assume that members only coordinate their parts with the rest of the team; this team requires a conductor or a coach. Third, doubles tennis team (or jazz combo, or four-five senior executives in the president office). Members occupy "preferred", rather than "fixed" positions, with ability to cover for each other. If well-calibrated, this is the strongest type of a team. But it requires enormous self-discipline. The members have to work together for a long time before they actually function as a team. Bottom line: Drucker warns that these three types of teams cannot be mixed. They may need to be changed in order to meet new conditions but this change is expected to be "exceedingly difficult and painful".

1.2.3 Polity and Technology Development

P.Drucker emphasizes that since 1500 or so, when the knight had become obsolete, warfare increasingly was waged with weapons produced in ordinary peacetime facilities with the minimum of delay or adaptation. Modern technology – the German admirals of 1890 argued – had changed all of this and left no choice. A modern navy meant steel-clad ships, and such enormous technologically complex vehicles had to be build in peacetime. Drucker says: "The wartime economy could no longer be an adaptation of the peacetime economy. The two had to be separate. Both weapon and fighting man had to be made available, in large quantities, before the outbreak of hostilities. To produce either required increasingly long lead times. Defense, it was implicit in the German argument, no longer means keeping warfare away from civilian society and civilian economy. *Under conditions of modern technology, defense means a permanent wartime society and a permanent wartime economy*". Because of that, German Navy doctrine in the 1890's adopted strategy of building a massive naval deterrent in peacetime and started armament race. Such policy effectively defined the structure of the modern Mega-state and dominant role of military and government in it.

1.2.4 Evolution of State

Drucker emphasizes that modern nation-state arose as a response to transnational drives imposed by empires (initially by Spanish and Portuguese, and then by English, Dutch, French and Russian) and was designed according to ideas of Jean Bodin (1576, France). Through the discussion of Megastate (to which he is highly critical) and several intermediate kinds of states, the author of the book arrives to the very compelling analysis of *regionalism and tribalism.*

Along with the large and somewhat established economic regions (such as European and North American communities) he identifies new dynamics different in scale and level of advancement. Among them: clustering of Coastal China and Southeast Asia around Japan; "Turkic Region" incorporating former Soviet Central Asia; "Baltic Region" with Latvia, Estonia, and Lithuania tilting toward Finland and Sweden; another Southeastern Region with Malaysia, Singapore, Indonesia, the Philippines, and Thailand involved. Something will emerge in the place of the main part of the former Soviet Union. The simultaneous opposite trend – tribalism is as important as regionalism. Drucker rightly goes: "Now that money and information have become transnational, even very small units are economically viable". However, he thinks that the main reason for tribalism is neither politics nor economics but rather existential. People need roots in a transnational world; they need community. "Precisely because the world has become transnational in so many ways – and must become even more so – people need to define themselves in terms they can understand. They need a geographic, a linguistic, a religious, and a cultural community which is visible to them." Author powerfully concludes: "Tribalism is not the opposite of trans-nationalism; it is its pole. ... The more transnational the world becomes, the more tribal it will also be".

With insignificantly different segmentation, Manuael Castells uses the same "polarization-bipole" analogy, however, in more pessimistic tone (Castells, 1999):

> In a world of global flows of wealth, power, and images, the search for identity, collective or individual, ascribed or constructed, becomes the fundamental source of social meaning. ... Global networks of instrumental exchanges selectively switch on and off individuals, groups, regions, and even countries, according to their relevance in fulfilling the goals processed in the network, in a relentless flow of strategic decisions. It follows a fundamental split between abstract, universal instrumentalism, and historically rooted, particularistic identities. **Our societies are increasingly structured around a bipolar opposition between the Net and the Self.**
>
> In this condition of structural schizophrenia between function and meaning, patterns of social communication become increasingly under stress. And when communication breaks down, when it does not exist any longer, even in the form of conflictual communication (as would be the case in social struggles or political opposition), social groups and individuals become alienated from each other, and see the other as a stranger, eventually as a threat. In this process, social fragmentation spreads, as identities become more specific and increasingly difficult to share.
>
> ... Space plays a fundamental role in this mechanism. In short: elites are cosmopolitan, peoples are local. The space of power and wealth is projected throughout the world, while people's life and experience is rooted in places, in their culture, in their history.

1.3 Geography Factors

> If I choose [model] parameters that made the advantages of the established industrial concentration strong, California refused to develop any industry; if I made them weak, California would industrialize, but so would Iowa.
>
> ***Paul Krugman**, "Space: The Final Frontier"*

Professor Krugman is leading the recent trend of reexamination of the field of economic geography – which is defined as "the location of activity in space" (Krugman, 1995). He emphasizes circularity of the relationships between the division of labor and the extend of the market means that countries may experience self-reinforcing industrialization (or failure to industrialize), and that regions may experience self-reinforcing agglomeration. Model offered by Professor Krugman is different from previous works on urban economics because it introduces microeconomic foundations to capture and clarify the insights of the previous works on economic geography.

The formalized Big Push model (Murphy et al., 1989) is reviewed by Krugman as a basis for consequent analysis. **Market structure** in the model is defined as having: - perfect competition in the traditional sector (e.g. there is a perfectly elastic supply from the traditional sector at the marginal cost of production); - a single producer in the modern sector (entrepreneur) is assumed to have the unique ability to produce each good; - supply price is unity (1) for both sectors. More realistic imperfect competition in modern sector is set up by assuming a set of limit-pricing monopolists (currently models of imperfect competition are very "imperfect" and always involve some set of arbitrary assumptions about tastes, technology, behaviour, or all three). At the current level, modeling in economics does not pretend to have a generality and such assumptions are considered to be reasonable and reflect the difficulties of reconciling economies of scale (and increasing returns) with a competitive market structure.

Five core ideas essential for spatial economics modeling. 1. <u>Germanic Geometry</u> (location & central-place theories): there should be hierarchy of central places with nested market areas. The trade-off between economies of scale and transportation costs leads producers to cluster together into a hierarchy of cities serving nested, hexagonal market areas. 2. <u>Social Physics</u> (involves such terms as "rank-size rule", "gravity law", and "market potential"). Market potential of a site is defined as some index of its access to markets, directly proportional to the purchasing power of all the markets to which it might sell and inversely proportional to the distance to those markets. Other things equal, firms tend to choose locations of maximum "market potential". 3. <u>Cumulative Causation</u> with possibility of multiple equilibria and self-reinforcing regional growth or decline under endogenous local decisions. 4. <u>Local External Economies</u>, which tend to promote concentration of production, as being opposed by other effects – congestion or land costs – that tend to promote dispersal. It is underlined that the sharp distinction between technological and pecuniary external economies holds only in a constant-return world; in general market-size external economies are just as real as technical spillovers. 5. Land Rent and Rent Use concept in isolated city (by Von Thunen). It assumes simultaneously of a land rent declining from the center to an outer limit, and of series of rings in which different crops would be cultivated dependent on cost of transportation and yield per acre. For example, the outmost ring would consist of either land-intensive or cheaply transported crops. By replacing farmers to commuters, this model resembles many features of the "urban economics" of late 1960s and early 1970s. However, in reality the monocentric city was abolished and is not a reasonable approximation anymore (for example, both Los Angeles and Silicon Valley have dozen or more office districts competing with each other vs. monocentric Chicago which is not #2 city in the US anymore).

Krugman's model simultaneously includes increasing returns and resulting imperfect competition (formalization of monopolistic competition suggested by Dixit-Stiglitz), transportation costs, and factor mobility. Purpose of the model is "both to validate and to integrate several of the "outcast" traditions in economic geography: central-place theory, the market potential approach, and the idea of circular and cumulative causation." The model should exhibit a tension between two kinds of forces: "centripetal" forces that tend to pull economic activity into agglomerations, and "centrifugal" forces that tend to break up such agglomerations or limit their size.

An economy is modeled with a number of separate locations. There are two sectors: agriculture, which is geographically immobile, and manufacturing, which is mobile over time. The monopolistic competition implies that from strategic point view all that firms need to do is choose an optimal location, taking into account the spatial distribution of demand and transportation costs they must pay. No special assumptions are made either about localized external economies or nontradebility (cities are not primitive concepts in the model). Instead agglomerations emerge from the interaction between increasing returns at the level of the individual production facility transportation costs, and factor mobility. Presence of immobile factors provides the centrifugal force that works against agglomeration.

The law of motion of the economy is in the core of the Krugman's model along with the formulations of the market potential and Dixit-Stiglitz model of monopolistic competition. The law of motion states that workers move away from locations with below-average real wages and toward sites with above-average real wages. The inputs into this model are the parameters μ, τ, and σ; a given allocation of farm labor across locations; a matrix of distances between locations; and an initial allocation of workers across locations. Model analysis reveals that agglomeration of production is favored by low transport cost (low τ), a large share of manufacturing in the economy (large μ) and strong economies of scale at the level of the firm (low σ). For example, for a particular case of 12 locations equally spaced around a circle and with initial random allocation of manufacturing workers across locations, model converges (in vast majority of runs) to two dominant locations with 5 or 6 spaces apart.

1.4 Space and Time Transformation

... times of nature and society....
... time, timing, temporality, and tempo ...

***B.Adam**, Time and Social Theory*

It is emphasized by Castells that on macro-level microelectronics-based manufacturing inferred a new logic of industrial location and "is characterized by the technological and organizational ability to separate the production process in different locations while reintegrating its unity through telecommunications linkages, an microelectronics-based precision and flexibility in the fabrication components". Eventually, this new interactivity between places breaks up spatial patterns of behavior into a fluid network of exchanges that underlies the emergence of a *new kind of space, the space of flows* [all italic font below is mine, VB]:

> Thus, I propose the idea that there is a new spatial form characteristic of social practices that dominate and shape the network society: the space of flows. **The space of flows is the <u>material</u> organization of time-sharing social, practices that work through flows.** By flows I understand purposeful, repetitive, programmable sequences of exchange and between physically disjointed positions held by social actors in the economic, political, and symbolic structures of society.
>
> The space of flows, as the <u>material</u> form of support of dominant processes and functions in the informational society, can be *described (rather than defined)* by the combination of at least three layers of material supports that, together, constitute the space of flows. **The first layer, the first <u>material</u> support of the space of flows, is actually constituted by a circuit of electronic impulses** (microelectronics, telecommunications, computer processing, broadcasting systems, and high-speed transportation - also based on information technologies) that, together, form the <u>material</u> basis for the processes we have observed as being strategically crucial in the network of society. This is indeed a <u>material</u> support of simultaneous practices.

While I find it as interesting and fresh, it is difficult for me to appreciate the "space of flow" concept and I do not see the necessity of its introduction to describe new macro-spatial interactions. At the same time I value highly Castells' insistence on "materiality" of changes and would suggest, in turn, that it is based on specific advances of microelectronics technology such as on densification of space provided by rapid microlithography progress.

Microelectronics-based technology eventually leads (through the space domain) to new relationships of production through the temporal separation of capital and labor. Castells calls it "fundamental dichotomy":

> **Capital** and **labor** increasingly tend to exist in different times: ... *instant time of computerized networks versus clock time of everyday life.* Thus, they live by each other, but do not relate to each other, as the life of global capital depends less and less on specific labor at a deeper level of the new social reality, social relationships of production have been disconnected in their actual existence. Capital tends to escape in its hyperspace of pure circulation, **while labor dissolves its collective entity into an infinite variation of individual existences**. Under the condition of the network society , capital is globally coordinated, labor is individualized. The struggle between diverse capitalists and miscellaneous working classes is subsumed into the more fundamental opposition between the bare logic of capital flows and the cultural values of human experience.

To better grasp modern aspects of temporality I will refer further to the work of Barbara Adam (1990) where she writes, for example: "time of our imagination knows no boundaries, the time of our thought is open-ended but has a beginning, and our sentences bounded by both a beginning and an end."

Operationally defined time of Newtonian physics, which is linked to number and the measure of motion, duration, and rate is heavily criticized. This unitary concept is kept responsible for the spatial time of the clock dominating the western world.

> ...the conceptual tools that are being used to understand this [time as] synthesis are based on an understanding of reality that abstracts bits, particles, aspects, units, events, or periods in order to understand them. It is becoming obvious that the wrong conceptual tools are being used if we seek to grasp and theorize synthesis, qualitative rhythmicity, intensity, and acausal relationships with the aid of Newtonian and Cartesian assumptions.

Adam relays to approach of quantum theory with its basic concepts of reality like "a dance without dancers": - system of observation, dependent on observers and their measurements; - interactions which happen without any direct cause or signal; - and where time as distance has become replaced by relationships, fundamental action, and the "trying out" of all possibilities before actualization. Thermodynamics gets involved as well with its notion of irreversibility.

Dr.Adam insists on including of the biological dimension with rhythmicity, reproduction, regeneration, metabolism, and morphogenesis (having no equivalents in the physical science) into the synthesized understanding of time. For example, morphogenesis, the coming into being of form, cannot be grasped through causal theories, because form, unlike energy, is not conserved. According to Adam:

> Biologists traditionally identify three time scales, which are of importance to human beings: metabolic, epigenetic, and evolutionary rates of change. However, only the middle range which covers changes of growth, development, and aging, and which includes life-spans ranging from seconds to decades is accessible to our conscious experience.

Overall the notion of the mutual implication of sociality and temporality is strongly supported by Barbara Adam; she points to the substantive evidence of it by the contemporary natural scientists: "natural and social time are therefore not mutually exclusive but implicating." The exclusion of non-symbolic expressions from social science analysis also meant the omission of artifacts and technology from social science.

Finally, on the issue of identity and mental models, it would be appropriate to note Adam's position which has direct reference to a Technology of Computing:

> In our contemporary Western world animals are no longer a dominant metaphor for self-recognition. In the age of machines natural metaphors are, to a large extent, replaced by our own creations. Every new phase of technological development, it seems, has served as a tool for self-understanding and led to new conceptualizations of reality. During the seventeenth and eighteenth century the clock constituted the prime metaphor. The universe was understood as a giant clockwork and its inhabitants were conceptualized as functioning to its principles. During the nineteenth century the principles of steam technology were embraced as additional sources for self-understanding. The imagery involved people 'letting off steam' and the need for 'safety-valves' to avoid dangerous social explosions. Emotions and social interactions were likened to a steam engine functioning under pressure with a need for the steam to escape in order to avoid disaster. During the last twenty years the computer has been elevated to the position of dominant metaphor.

2. From Macro-Lithography (stone's pictures) to Micro-Lithography (pictures on "sand"). Technology Foundations and Modeling

> I propose that it was 'oral cultures' that produced cave paintings ... Furthermore, I suggest that written language ought to be seen as a development from art rather than from spoken language since it shares the human time effects with those of art.
>
> ***Barbara Adam,*** *Time and Social Theory*

In less than four pages of Chapter 1 I went through the 11,000 years of history; here I am going to do similar thing with more than 30 years of modern history of microlithography. For more details I will refer the reader to the recent excellent works (Brunning, 1997; Wilson, 1997).

Professor Grant Wilson (University of Texas, formerly IBM), being one of the inventors of the materials (photoresists) for Deep-Ultraviolet microlithography, has the utmost right to present microlithography (Wilson, 1997). He considers that science of photolithography started in 1826 when a tar called bitumen of Judea was used as photosensitive material for printing of lithographic image (the same material is pretty much known since the beginnings of recorded history and was used by the Egyptians to embalm mummies). After that:

> When William Shockley and his co-workers at Bell Laboratories set out to make the first integrated circuits, it is not surprising that they turned to dichromated gelatin as the imaging material. Frankly, there was little else to choose from at the time. They discovered that their resist material had more than adequate resolution for the task but was not a very effective "resist". It did not serve well as a resist for hydrofluoric acid etching of silicon dioxide, a key step in their microfabrication process. So, the Bell labs team contacted Dr. Kenneth Mees, the Director of the Eastman Kodak Research Laboratory at Rochester, New York, seeking help. Dr. Mees turned to Louis Minsk for a response to this request. ... Eventually "Kodak Thin Film Resist", KFTR was developed by Martin Hepher and Hans Wagner; the material was the work horse of semiconductor industry from 1957 until about 1972 when features less than 2 micrometers in size needed to be printed (below KFTR resolution).
>
> ....
>
> Lithographic lore has it that the next generation diazonaphthoquinone/novolac resists made their way from the printing to the lithography industry through family ties. At that time, the offices of Azoplate, the American outlet for Kalle printing plates, were situated at Murray Hill, NJ, just across the street from Bell Labs. The father of a technician at Azoplate worked as a technician at Bell Labs. Apparently the father had complained one day about the poor resolution quality of the solvent developed KTFR resist systems then in use at Bell Labs, and the son had boasted of the properties of the Azoplate DNQ/novolac coating; anyway, one day the father took a bottle of the coating solution with him to Bell Labs, and the age of DNQ/novolac resists began".

Professor Wilson was one of the inventors of the current resist materials – chemically amplified resists for deep Ultra-Violet. This group of materials would be rightly credited for the big portion of the modern microelectronics miracles.

Two other major components of microlithography technology (with which I kind of intimately familiar) are masks and exposure tools. Modern masks (which by today are amazingly complex and sophisticated devices themselves), have started ion mid 1960 from rubylith (I was lucky enough to actually saw and work with it !), a lamination of dark red and clear plastic foils used to define the master pattern for replication. It was going then through the process of reduction ending with very expensive and valuable chrome master mask (again, I was making them !). Copies of a master masks were used for microlithography on semiconductor wafers (boy, I spent a lot of exciting years doing that !). In the chapter 3.1 I will touch on the latest in the mask technology; however, comments on exposure equipment would be appropriate here.

Mr. John Brunning was the president of Tropel Corporation, one of the few who was able to actually carry out amazingly complex technology of lens design for microlithography. He says:

> Achieving simultaneously high uniformity of imagery and high geometric accuracy in an image was a very tall order. The design task required simulataneously optimizing 20-30 variables.
>
> Photorepeater lenses for imaging in emulsion were usually designed to operate at the mercury e-line (577 nm). Photoresist materials more naturally operated in the blue so the lens designs and glasses were optimized for operation at the mercury g-line (436 nm). Many companies struggled with the difficulties associated with designing and manufacturing these lenses including Bausch and Lomb, Bell Laboratories, Cerco, Fuji, IBM, Leitz, Nikon, Olympus, Tropel, Wray and Zeiss, but few were willing to discuss the details.

Dr. Bruning referred to pioneer works in the field of 10^X steppers which were done in the in the Soviet Union during the 1970-1980. Specifically, he mentions work by G.Bulnov and N.Kontievskaya who (if I am not mistaken) are from the famous KBTEM, leading microelectronics equipment maker (Minsk, Belarus).

Further in this chapter I will go in somewhat significant details through the recent results of modeling and calibration work in various microlithography applications, where I was closely involved as one of the leading contributors. Once again (while many of them are noted in the acknowledgement to the whole thesis) I would like to express my appreciation to all the co-authors; each of the projects described below has been wonderful learning experience of partners growing together with the industry.

2.1 Sub-half Micron Contacts Design with 3D Photolithography Simulator[1]

The imaging of sub-half micron contacts meeting a 100% CD tolerance specification over the full image field in a production environment is one of the most difficult and often overlooked challenges facing today's optical lithographers. Much attention is usually given to line-space imaging. Typically process variables limiting the successful fabrication of contact windows in photoresist are stepper focus and tilt control, substrate reflectivity, wafer flatness, photoresist contrast, and stepper illumination. Stepper manufacturers are very reluctant to specify stepper resolution across the imaging field for contacts. This is because contacts are very difficult to image over the entire imaging field due to limitations with optical aberrations.

To improve the process latitude for contact windows imaging the following advanced techniques have been employed: attenuated phase shifted masks, rim phase shifted masks, optical proximity correction (serifs), off-axis illumination, optimized NA-partial coherence settings, multiple focal planes, combination techniques, CMP (chemical mechanical polish), and deep Ultra Violet illumination. Each new technique has a plethora of variables that can be adjusted that affect it's response. This presents the lithographer with the large job of determining which variables warrant investigation. The tough task is then to determine the optimal settings for these parameters that achieve maximum process latitude. In modern optical lithographic engineering simulation plays a major competitive role in determining these settings rapidly.

In the past simulation of contact holes has been presented with very limited actual data to compare to the simulator. It was the intent of this investigation to present the simulation of actual production photoresist processes. Three-dimensional (3D) simulations compared to actual Scanning Electron Microscope (SEM) cross sections.

The contact window design methodology is based on detailed calibration of the 3D Photolithography Simulator Depict 4.1 (TMA Depict, 1997). We considered full three-dimensional modeling for both aerial image and photoresist simulation is essential in the case of contact windows. It is important to note that the High Numerical Aperture (High NA) model used in Depict 4.1 accounts for oblique propagation effects such as bulk defocus and damped energy coupling, which critically influence the distribution of photo-active component in the photoresist. Among several photoresist development models available in Depict we found the Kim (U.C. Berkeley) model the most suitable for our purposes.

Main results of calibration include both CD vs. Focus dependencies (experiment and simulation) and the corresponding contact cross-sections. For the cross-sections both SEM-pictures

[1] Sub-half Micron Contacts Design with 3D Photolithography Simulator, Proceedings SPIE, 1997, v.3051. San Jose, CA

and Depict 4.1 outputs were compared (Figure 2.1). Maximum measured vs. simulated CD deviation is within 5%. Overall, results from Depict 4.1 agreed to experiment within a error of less than 10% for all manufacturing conditions, which is impressive (considering most manufacturing processes have a total variation of 10%: day to day and tool to tool). Once calibrated, simulator's full predictive capabilities can be used.

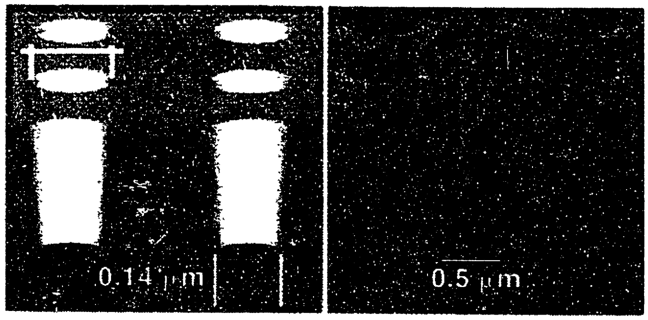


Figure 2.1 Simulated (left) and experimental (right) cross-sections for contact holes (0.45 μm design rules)

Even as modern photolithography simulators provide exceptional accuracy (as we've seen from the discussion above) any broad industrial application and acceptance of these tools will be limited until calibration is completely automated. Recent advances in modeling and extraction of arbitrary deformable contours using snake-like algorithm make it possible to fully automate the resist profile extraction process. We've developed profile-fitting algorithms, which may be used for detailed calibration; the combination of Depict 4.1 and TMA Workbench (1997), a program for generation of automated runs that emulates process lot splits) allows automation of calibration procedure.

Comprehensive analysis was facilitated by the fast algorithms used in Depict. The high performance of the simulation program (< 2 minutes per run on Sun Ultra Sparc2) allowed rapid calibration of multiple different processes.

2.2 Proximity Correction Methodology Using Contemporary Photolithography and Topography Simulators[2]

The pitch requirements for the metal I pattern are determined by the pitch of the contact and via layers, which were about 1 μm in our case. The contacts and vias must be completely enclosed by the metal I pattern, even under worst case misalignment and conditions of Critical Dimensions (CD)

[2] Proximity Correction Methodology Using Contemporary Photolithography and Topography Simulators, Proceedings Interface'97. 1997. San Diego, CA.

control. The enclosure rule uses a metal to contact misalignment budget of only 0.07 μm (3 sigma) for the stepper, so there is little room for error. If the contacts are uncovered during the metal etch, the contacts will be attacked and reliability will be compromised. At the same time, the space between metal leads needs to be as large as possible to reduce sensitivity to defects which can cause shorts. The minimum width of the metal leads is determined by current density and RC delay considerations, and was about 0.5 μm in our case.

The so called "dog bone" shape shown in the Figure 2.2 is the standard solution to these constraints. The minimum width is used except where a contact (0.40 μm) occurs and there the linewidth increases to ensure enclosure.

The OPC corrections must result in etched patterns, which meet the original design constraints. Because of such tight design simulation is really beneficial to explore all the possibilities and to greatly reduce enormous number of experiments required otherwise.

Simulation algorithms and implementation.

Photolithography simulation was based on TMA's Depict 4+ high-performance package, which includes modules for fast Aerial Image, OPC and full 3-dimensional analysis. Depict's OPC follows an iterative approach. First, the segmentation of layout polygons is performed. The placement error is then evaluated whenever a modification is made to the layout. Non-Uniform Fast Fourier Transforms is used for aerial image simulations, Fast Fourier Transforms for exposure, and Fast Marching Level Set methods for photoresist development Fast aerial image simulation is achieved through the algorithm of coherent decomposition of the partially coherent optical systems. It has been shown that this algorithm can significantly improve the speed of point intensity calculation.

Terrain (TMA Terrain, 1997) is a new generation of topography modeling simulator that can be used to create the most complex interconnect structures for state-of-the-art DRAM, SRAM, EEPROM and other critical cell technologies, and to predict IC reliability- and performance-related problems. It can currently model full three- dimensional structures to both understand the trade-off between different process alternatives in a complete process flow, and can be calibrated for many unit process conditions to analyze topography characteristics with different layout changes.

In Terrain fluxes of ions, deposition precursors and chemical radicals are combined using empirical or semi-empirical equations to obtain the deposition or etching rates at every point of the wafer surface. The rates are interpreted as the speed of the surface in the direction of its normal. Several different modeling techniques can be applied to simulate surface movement, but a recently

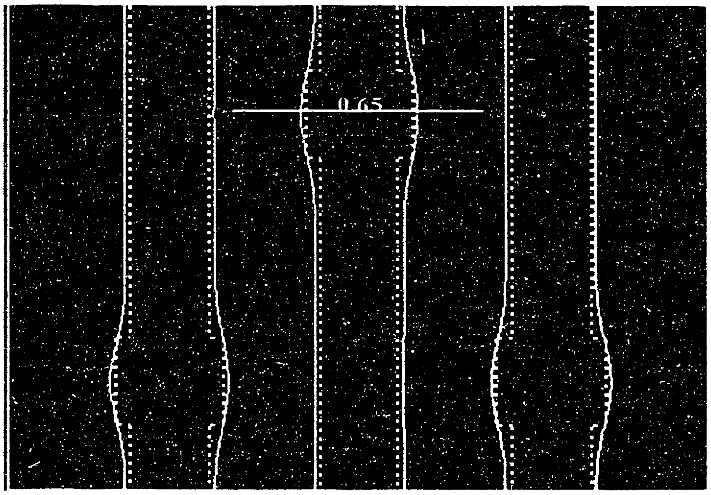


Figure 2.2 *Simulation Results:* CD Measurement on the basis of Aerial Image contours in Depict 4.+

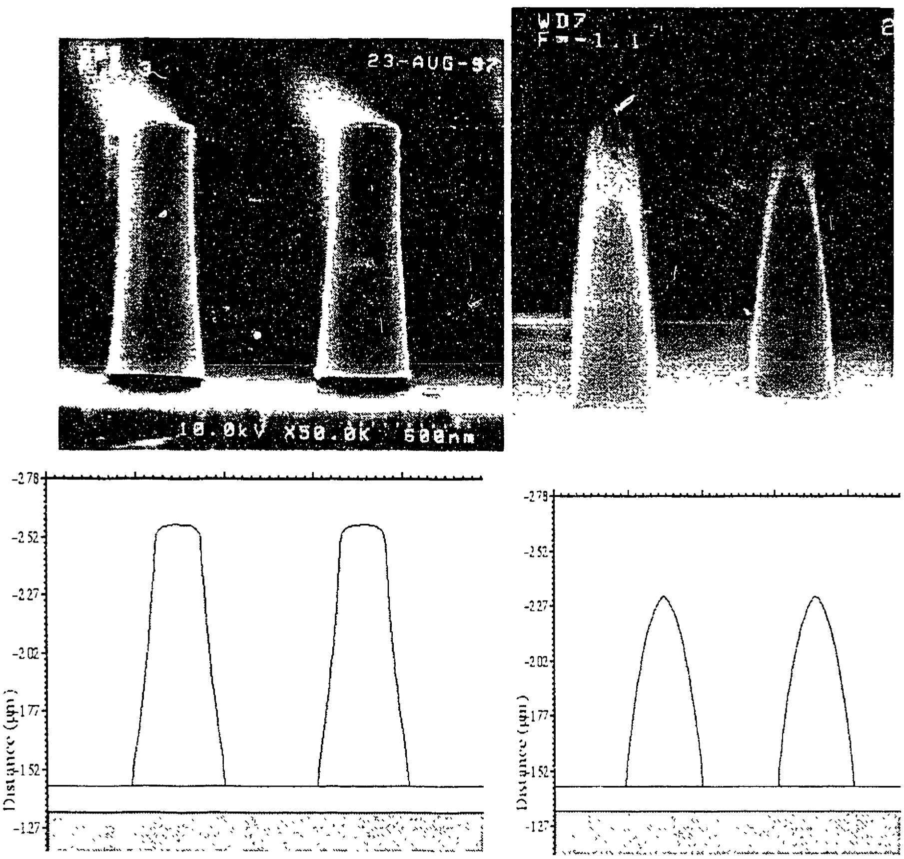


Figure 2.3 *Experimental & Simulation Results*: Resist development profiles

developed technique called Zero-Level Set offers the best advantage in terms of robustness, flexibility and performance (when the fast marching level set implementation can be applied). By assuming an intial set of parameters and matching the simulation results to the experimental SEM pictures, calibration can be conducted to obtain a correlation table between process conditions and simulation parameters.

Verification of the OPC correction with full 3D photolithography and topography simulation.

Initial and fast corrections were performed based on fast aerial image algorithms. Process characterization and calibration of the full 3-dimensional photolithography simulator were carried out to support and verify the results of the correction based on aerial image. Cross-sectional SEMs of photoresist profiles (different defocus values) used for calibration are presented on Figure 2.3 in comparison with simulation. As the next step the same profiles were passed to Terrain (Figures 2.4, 2.5). Very good agreement between shapes of experimental and simulated profiles could be observed even visually.

Earlier integration works with various TMA simulators were reported both by TMA authors over the years and by leading industry groups. By reporting results of the link between Depict 4+ and Terrain, we are extending this effort to the new generation of the industrial photolithography and topography simulators including three-dimensional capabilities.

2.3 Advanced Simulation Techniques for Thick Photoresist Lithography[3]

Photoresist films for semiconductor industry applications are typically less than 2 μm thick for critical pattern transfer operations such as dry etching and high energy implants. However, there are an increasing number of applications for thicker photoresist films in the 5 to 25 μm range. Thin film heads (TFH), micro-machining and sensor fabrication are examples of applications requiring this type of processing. The needs of the TFH industry are currently the technology driver for thick photoresist processing. Modem TFH manufacturing processes require 1μm resolution in layers ranging in thickness from 5 to as much as 25 μm. These large aspect ratios not only make the lithographic process difficult, but add complexity to the evaluation and measurement of experimental wafers. This is particularly true for the large number of measurements needed for process optimization and control. Well-calibrated and easy to use modeling techniques for analysis of the

[3]Advanced Simulation Techniques for Thick Photoresist Lithography, Proceedings SPIE, 1997, v.3049. San Jose, CA.

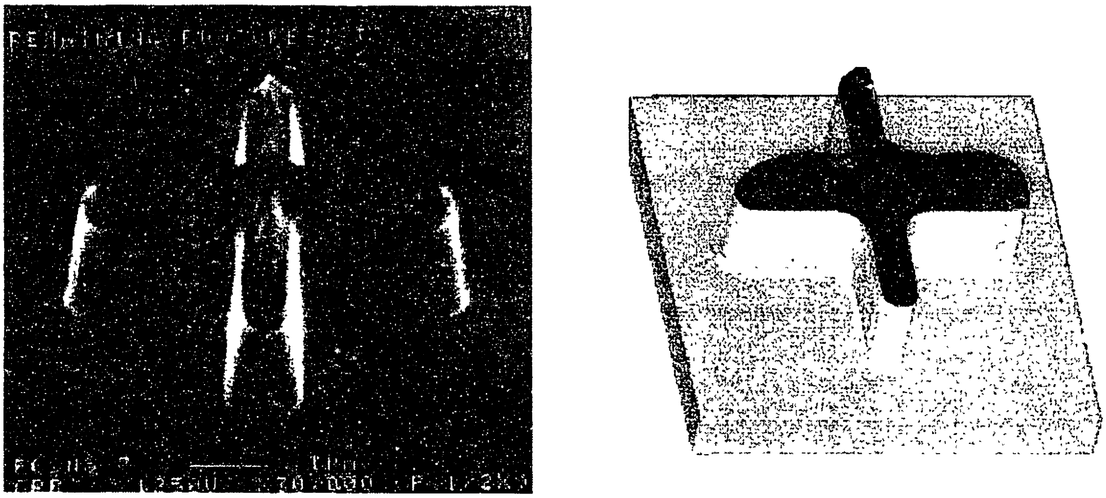


Figure 2.4 *Simulation Results*: Test structure: 3D metal etch profiles

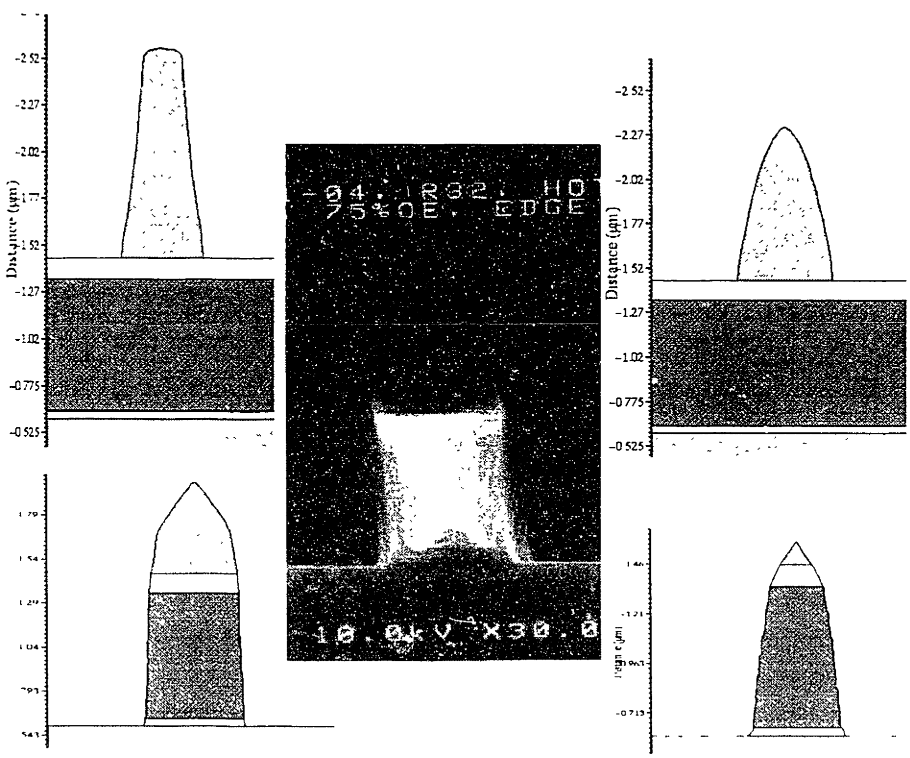


Figure 2.5 *Experimental & Simulation Results*: Integration of the Depict and Terrain: defocus +0.3 µm (left) and -1.5 µm (right)

impact of optical system design and photoresist process changes would be extremely valuable for process lithography engineers.

The purpose of this work was to simulate a 2 μm CD process in 10 μm of Shipley's SJR5740 photoresist and compare the model results to experimental data obtain using an Ultratech 2244i Wafer Stepper. A method has been developed that allows accurate simulation of pattern profiles in photoresist in excess of 10 μm thick. The method uses the DEPICT photolithography simulator to model i-line exposure, bake and development. Two of the basic effects that can occur are bulk defocus and damped energy coupling. The bulk defocus effect is a depth-wise defocusing within the photoresist of an effective aerial image. Damped energy coupling is the energy coupling shift from a maximum to a minimum, relative to the case of normally incident illumination.

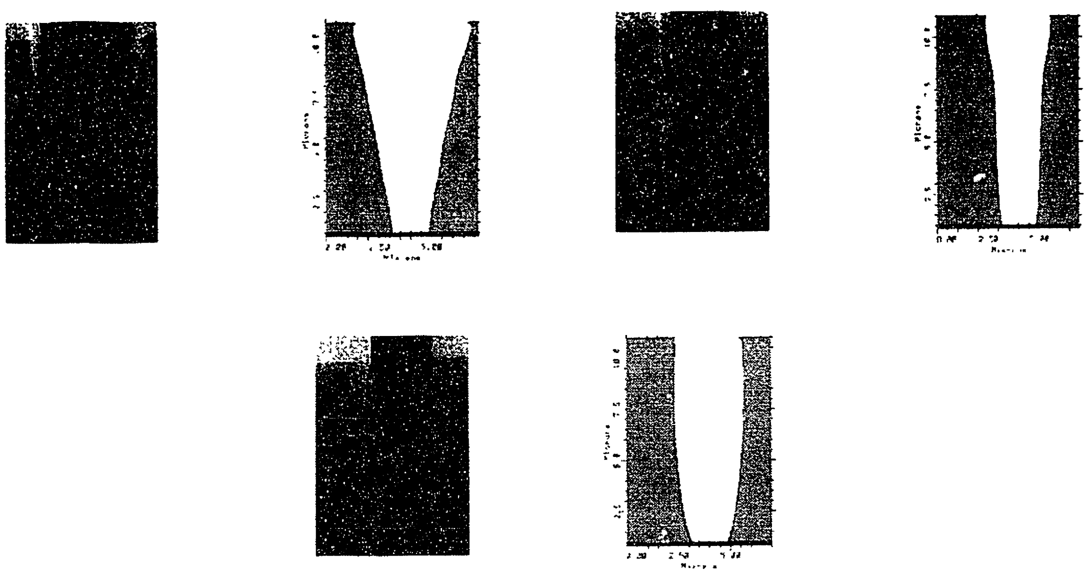


Figure 2.6 Experimental and simulated photoresist profiles at various defocuses

A photoresist profile matching optimization strategy was presented which provides well calibrated simulation results. A series of photolithographic simulations have been performed and compared to experimental results with good agreement (Figure 2.6). This technique provides the opportunity to investigate thick photoresist films under a variety of lithographic conditions with highly accurate results.

2.4 Optimal Proximity Correction: Application for Flash Memory Design[4]

Proximity Correction is the technology for which the most of IC manufacturers are committed already. The final intended result of correction is affected by many factors other than the optical characteristics of the mask-stepper system, such as photoresist exposure, post-exposure bake and development characteristics, etch selectivity and anisotropy, and underlying topography. The most advanced industry and research groups already reported immediate need to consider wafer topography as one of the major components during a Proximity Correction procedure.

We were discussing the rounding effects (which eventually cause electrical leakage, Figure 2.10) observed in the Poly2 layer for a Flash Memory Design and originated by three dimensional effects due to variation of photoresist thickness resulting from the non-planar substrate. Our major goal was to correct comer rounding for Poly2 at substrate side and keep the other side of Poly2 (on top of Poly 1) without corrections in order to examine process variations and minimize its influence.

To optimize design we use Depict which has OPC capability to perform automatic corrections in the following modes: Aerial Image only: the corrections can be done with no calibration (using only the optical characteristics of the stepper), or 2. with analytical photoresist model: the corrections can be done with some limited photoresist calibration, or 3. with full 3D photoresist model. The full 3D lithography simulation capabilities of Depict allow: first, understand the mechanism responsible for the experimentally observed rounding and 'horizontal bird beak' behavior (see Figure 2.7); second, formulate a new strategy for Process Proximity Correction (PPC); and finally, create new designs based on the described strategy.

Series of experiments were conducted with consequent analysis of after Development Inspection (DI), after Final (etch) Inspection (FI) SEMs and CD measurments. All the necessary data for simulation were generated such as: - photoresist A, B, C and refractive index; - stepper parameters; - photoresist development rate parameters; - technology layers thicknesses. Five different layout designs were investigated including ones with Phase Shift elements. Four of them were taped out and com- pared with results from manually corrected layouts.

The work was conducted under the following assumptions: - thick vs. thin resist is the major reason for different 'Poly2' corner rounding on Poly1 and Substrate; - development/etch bias need to be considered; - 3D full photolithography simulator is necessary for accurate analysis. Calibration procedure included - fitting experimental CD vs. Focus dependencies; - monitoring corresponding DI resist profiles. Our conclusion: resist side wall angle is different for the part of the structure with

[4] Optimal Proximity Correction: Application for Flash Memory Design, Proceedings SPIE, 1998, v. 3334. San Jose, CA.

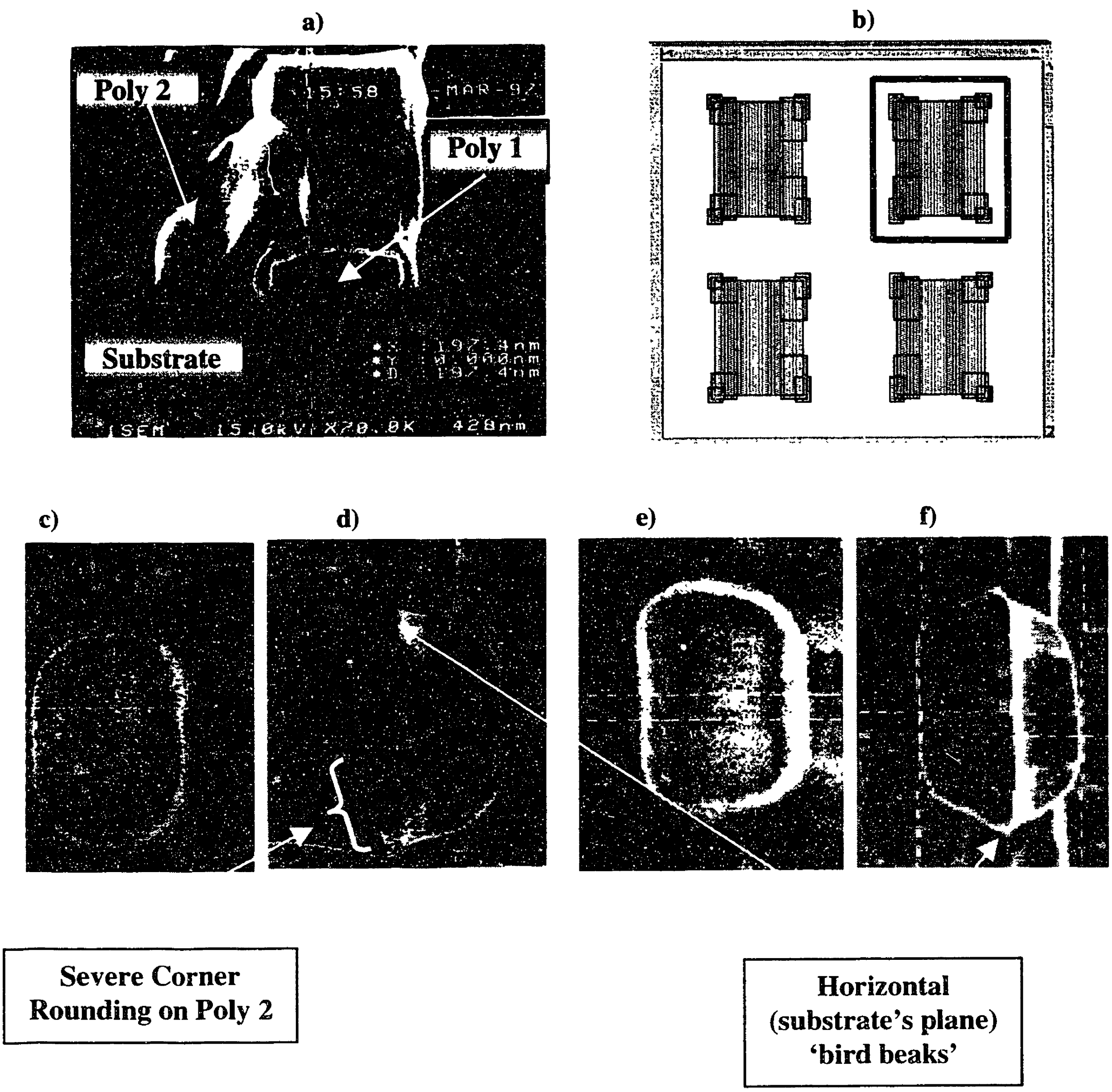


Figure 2.7 Experimental results before and after Optimal Proximity Correction (OPC):
a) **SEM (cross-sectional)** of the initial non-planar structure;
b) initial (corrected by 'trials & errors) layout;
SEMs (top view, c-f) of 'Poly2' - c) before correction, DI; d) before correction, FI;
e) after correction, DI; f) after correction, FI

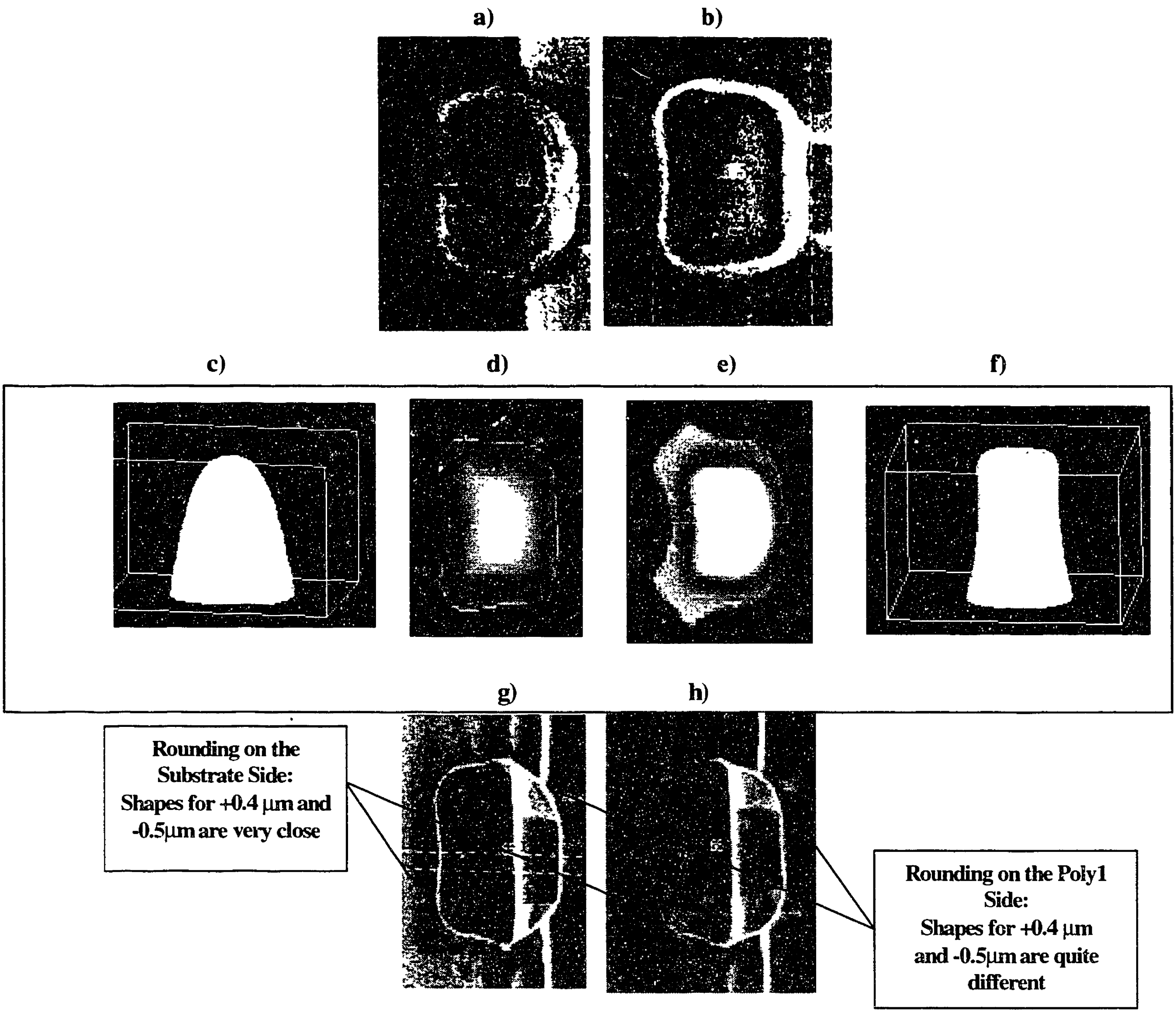


Figure 2.8 Illustration of the convex vs. concave slope (comparison of the experimental and simulation results):
Experiment (top-view SEMs, DI): a) defocus +0.4 mm; b) defocus -0.5 mm.
Simulation: c) defocus +0.6 mm, 3D view; d) defocus +0.6mm, top view;
e) defocus -0.6mm, top view; f) defocus -0.6mm, 3D view.
Experiment (top-view SEMs, FI): g) defocus +0.4 mm; h) defocus -0.5 mm.

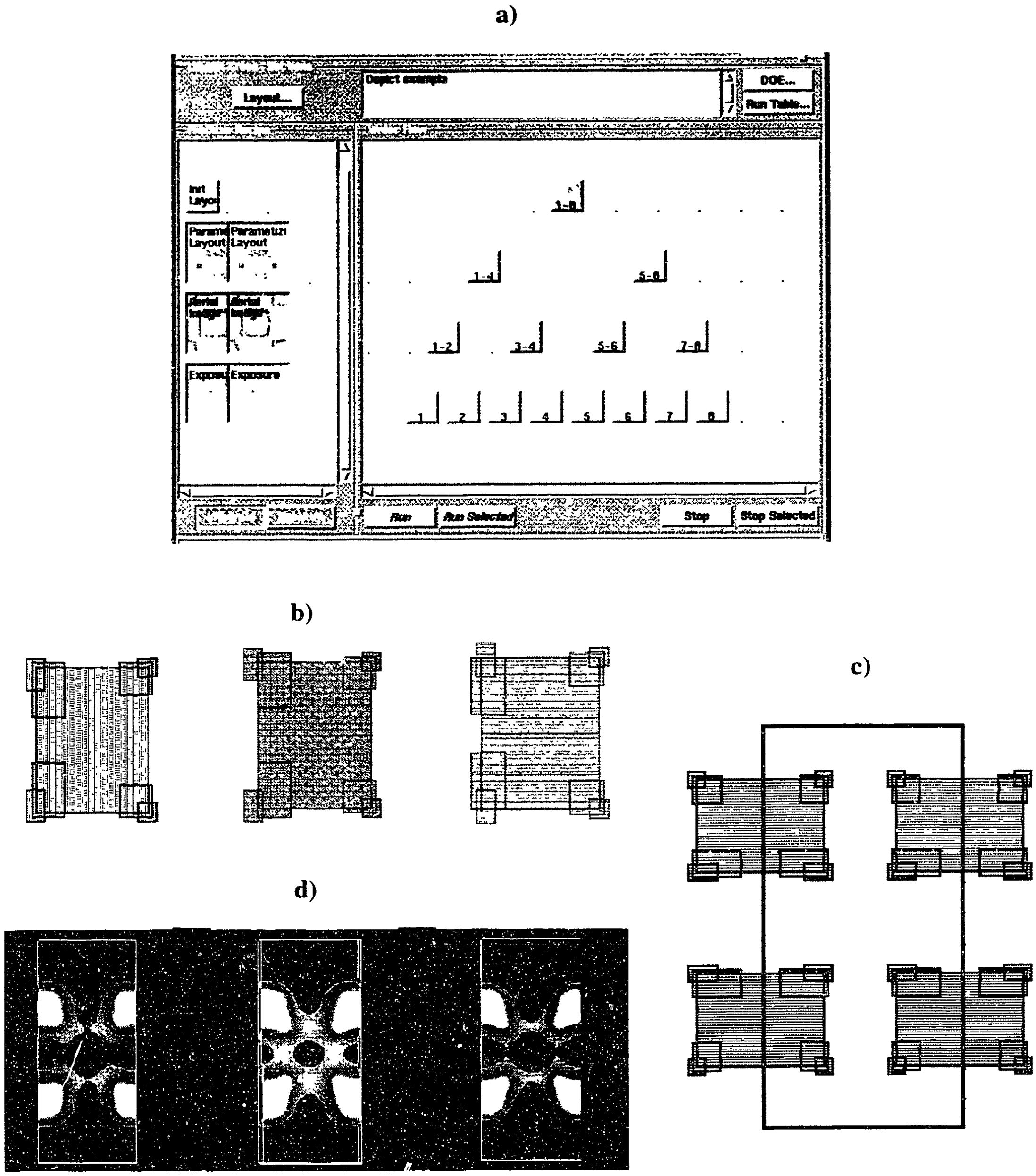


Figure 2.9 Illustration of the automated proximity correction procedure:
a) simulation splits in TMA Workbench;
b) different layouts created using parameterized layout capability of Depict;
c) selection of the simulation area (inside of rectangle);
d) examples of resist scuming because of over-corrected designs
(simulation area corresponds to the selection depicted in (c)

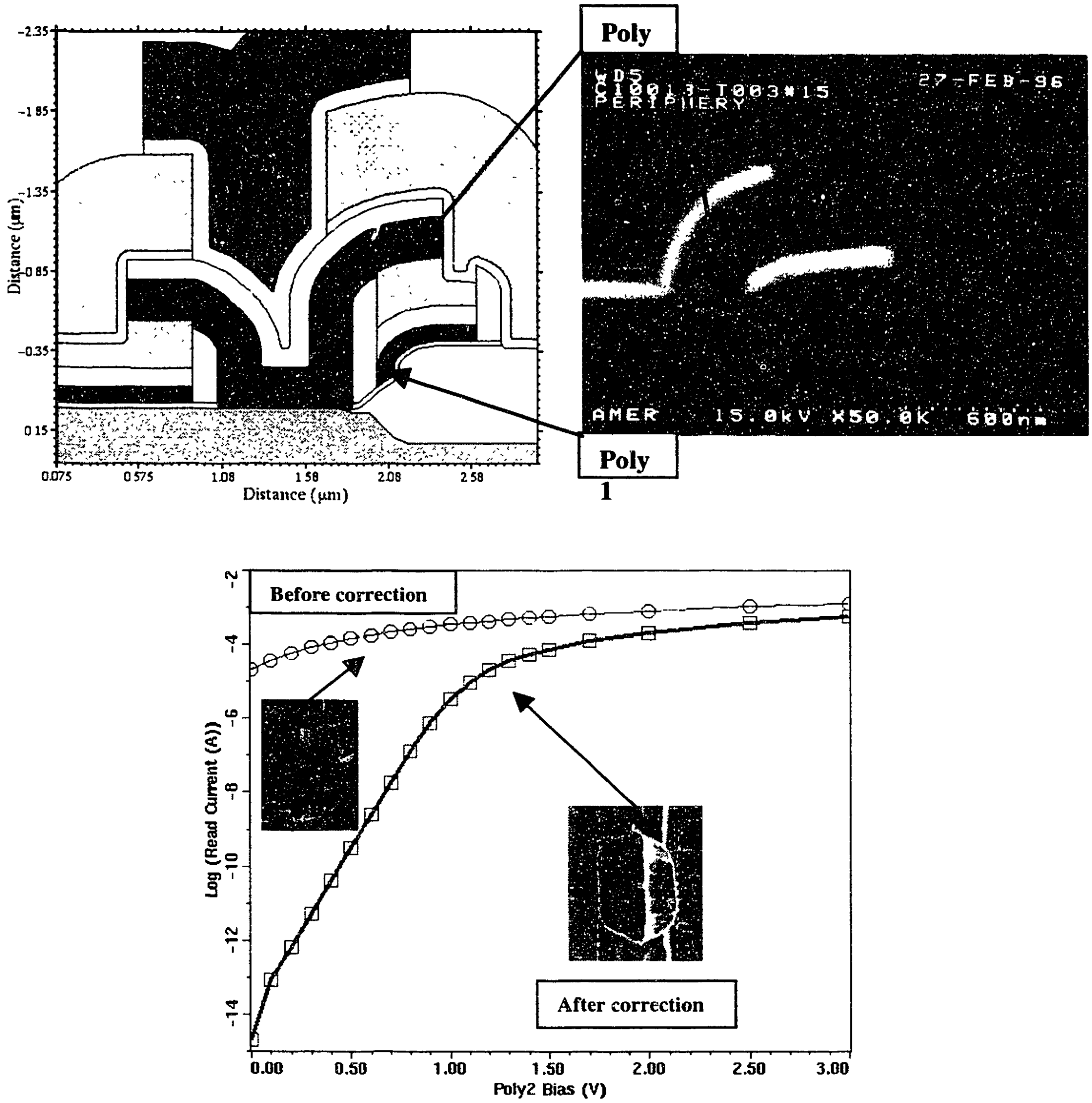


Figure 2.10 Back-end (a,b) and device (c) simulations for demonstration of the integrated process flow for Flash Memory Design:
a) device cross-section (Terrain simulation);
b) device cross-section (SEM);
c) device simulation – IV curves in reading mode (Davinci) before correction (top curve) and after correction (lower curve).

thick and thin photoresist. The difference is most visible at defocus -0.6; -0.9 µm. Then protection from resist during the etching is different at 'Substrate' level (thick resist) and at Polyl level (thin resist). Correction efforts were then focused to provide sufficient local resist protection thickness (SLRPT, Figure 2.11). Finally, GDSII files were generated and experimental confirmation of all the assumptions above were made.

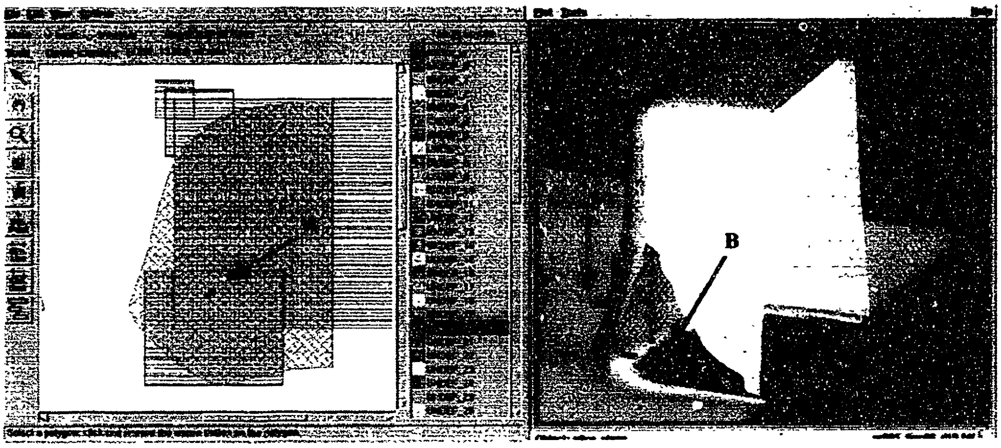


Figure 2.11 Illustration of the concept of 'Sufficient Local Resist Protection Thickness' (SLRPT). Left: layout + corresponding two-dimensional resist development footprint after correction Right: three-dimensional resist development profile with control point B inside.

As a result of this work highly effective layout correction methodology was demonstrated and manufacturable Depth Of Focus was achieved.

2.5 Alternative Methods: Dry Microlithography[5,6]

Alternatives to traditional photolithography were always in demand during the constant search for balance between the cost and performance. For example, in collaboration of KBTEM, Belarus Academy of Sciences, and Integral Corporation it has been demonstrated that the laser vacuum projection lithography combined with the dry etching can be used to produce pattern with sub-micron critical dimensions. The new technological process has been developed and used to produce a specific device (see Figure 2.12).

In the next chapter I will review in some details another one from the latest promising methods: Extreme Ultra-Violet lithography.

[5] Tochitsky, E I. Obukhov, E I. Sharendo, A I. Boksha, V V. Kasparov, K.N. 1991. Dry Patterning Through Masks of Organic Materials. Vacuum, vol.42, No.1 12

[6] Boksha, V.V. 1992. Ph.D.Thesis: Development of the Laser Dry Microlithography for Manufacturing of Integrated Circuits. Minsk, Belarus.

Dry Microlithography

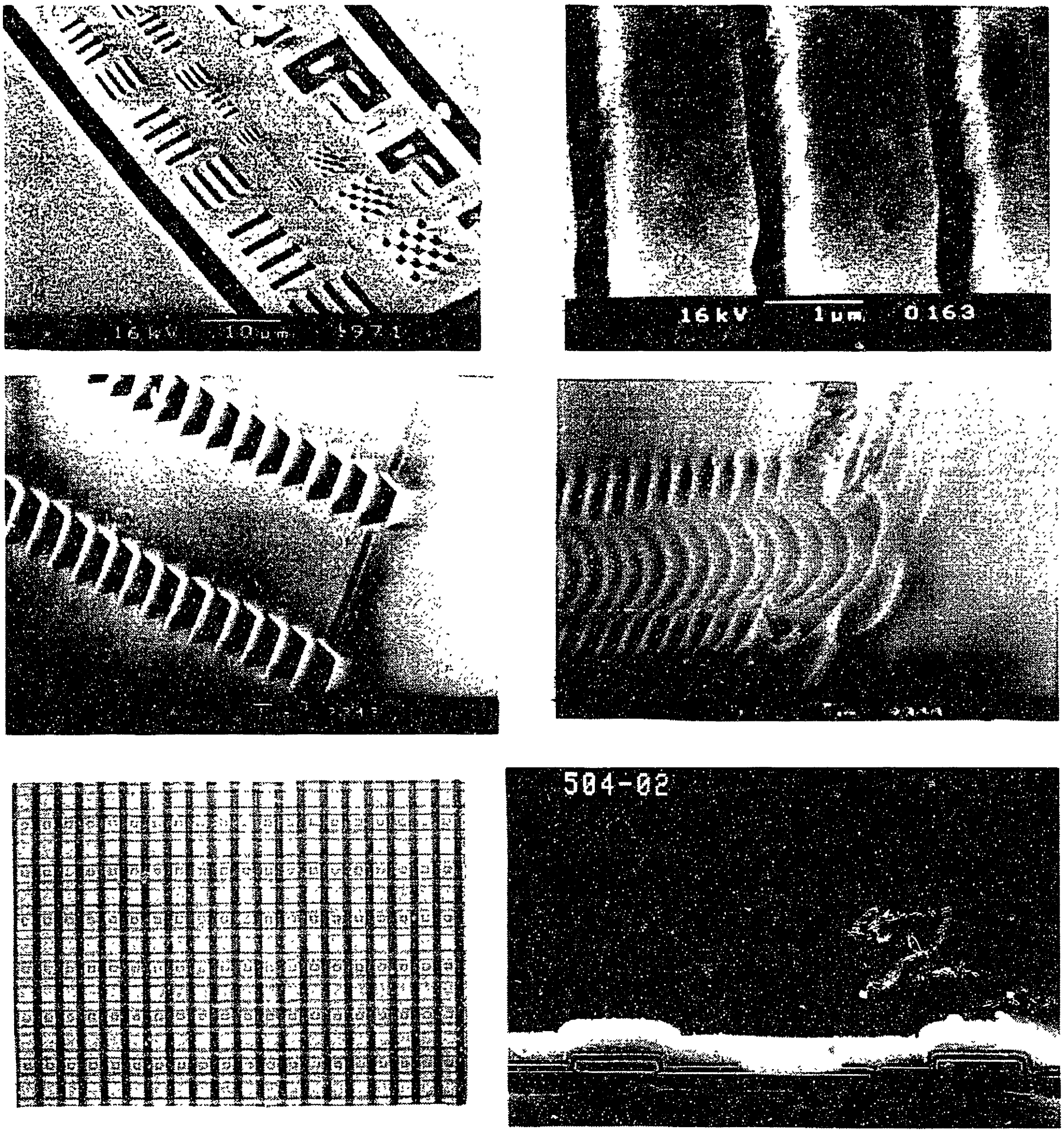


Figure 2.12 Top: test structures formed in SiO_2 (left) and Al (right)
Middle: alignment marks of various configurations
Bottom: fragments of the IC manufactured using dry microlithography

3.1 Case Study #1: Microlithography Yield and Cost Analysis

Microstructure creates the macrobehaviour

Jay W.Forrester, Models and the Real World

3.1.1 Introduction: Microlithography Status and Challenges

Rapid growth of semiconductors since the mid 60's shaped the explosion of Information-related Technologies (IT). Currently (The Economist, 1999-2), IT is a major contributor (35%) to the economic growth while accounts for only about 8-10% of the US Gross Domestic Product (GDP). Overall numbers for the semiconductor industry related revenues (1998) look impressive and healthy: Electronics Systems - \$ 960 billions; Semiconductors - \$ 121 billions; Semiconductor Equipment - \$ 31 billion. However, in the future the cost of a new semiconductor fab is projected to reach as high as \$10 – \$15 billions (next ten years) with its current value fast approaching \$ 3 billions. This enormous fixed cost (one can build an aircraft carrier such as USS Enterprise for \$4 billions) on the background of falling IC prices drives the current consolidation and spin-off waves in the IC industry which is very capital intensive and extremely volatile in nature with main emphasis on time-to-market. As we will discuss in depth, this trend has a real potential of off-setting current business practices, known to be successful. We will present our understanding of the current and converging industry structure and business models which are somewhat clear at this point.

Microlithography, with its technological complexity and the most expensive equipment, is agreed upon as being more than 30% of the cost of an entire new fab; therefore, it is critical that its actual cost is clearly understood. According to Mark Levenson (1997): "Lithography transition promises to be expensive and uncertain. Overall, we are facing a revision in the business model for the semiconductor industry".

Besides changes in business models, forced or not, other solutions will be needed to off-set and manage the extreme costs, dominating the IC world. We will discuss and demonstrate how capital asset management can be an effective means of combining technology and business roadmaps in a cost-effective way. Understanding and implementing such a strategy will be key to success in the present and projected cost dynamics of our evolving industry.

Detailed considerations of microlithography costs must become a top priority in aiding the decision making process for the semiconductor industry and will define the cost penalty either for under-utilization of fab capacity or for not ramping up production in time when necessary. Moreover, because of its current resolution limit, lithography has direct impact on IC design itself, increasing its complexity and data volume (e.g. in OPC). Careful cost calculations and comparisons will be necessary when deciding on implementing specific technology roadmaps. We will present a practical cost model and apply it to two specific examples, OPC and EUV, to demonstrate its significance.

Microlithography has finally come out of the identity crisis it has suffered for the last 2-3 years and made several important long-term decision for Next Generation Lithography (NGL) (Figure 3.1, left). For example, EUV is rapidly evolving as the technology of choice and has taken a solid position on the stepper makers' road maps and corresponding major programs in the US, Japan and Europe. However, it will require at least 5-7 years (for EUV to get into production) and design rules well below 100 nm to bring radically new IC functionality. The key issues for now are how to direct extremely fast and expensive development and survive the interim period. Economically justifiable timetables need to be developed to move from one lithography option to another (for example, from 248 nm to 193 nm) and to choose from the broad variety of resolution enhancement techniques (RET) available. A specific example of RET is presented on Figure 3.1 (right) for the case of phase-shift mask.

This work was done while I was at MIT and was thought as core part of overall thesis project. The authors' team (Boksha et.al., 1999) represents manufacturing, process development, and design communities with experience covering both fields of microlithography and Electronic Design Automation (EDA). The current research reflects their perspectives and outlines a possible approach to the somewhat controversial and not currently well-defined methodology of overall microlithography cost analysis. The presented approach is focused on practical use and is based on the concepts of total and opportunity costs.

3.1.2 Cost Model: Cost Per Wafer

While, starting from SEMATECH-based models, some literature exists on the cost analysis of the semiconductor industry as a whole, studies of the cost-related lithography specifics are known only as isolated efforts. Work done by Mr.Gomei (1999) is a good example of publicly available rare and extensive systematic analysis. At the same time detailed lithography cost analysis is rapidly emerging as a mean for every days applications.

Overall, we focused on creating a systematic and practical decision-making tool. The cost per wafer is calculated based on all of the major lithography related variables. The model is structured to

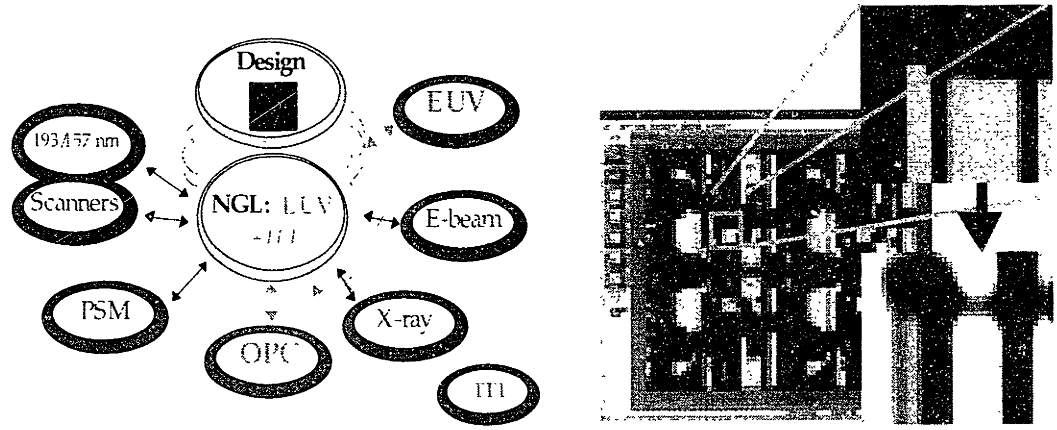


Figure 3.1 left: current microlithography options and integration with IC design; right: IC design with PSM features, corresponding aerial image contours and intensity distributions

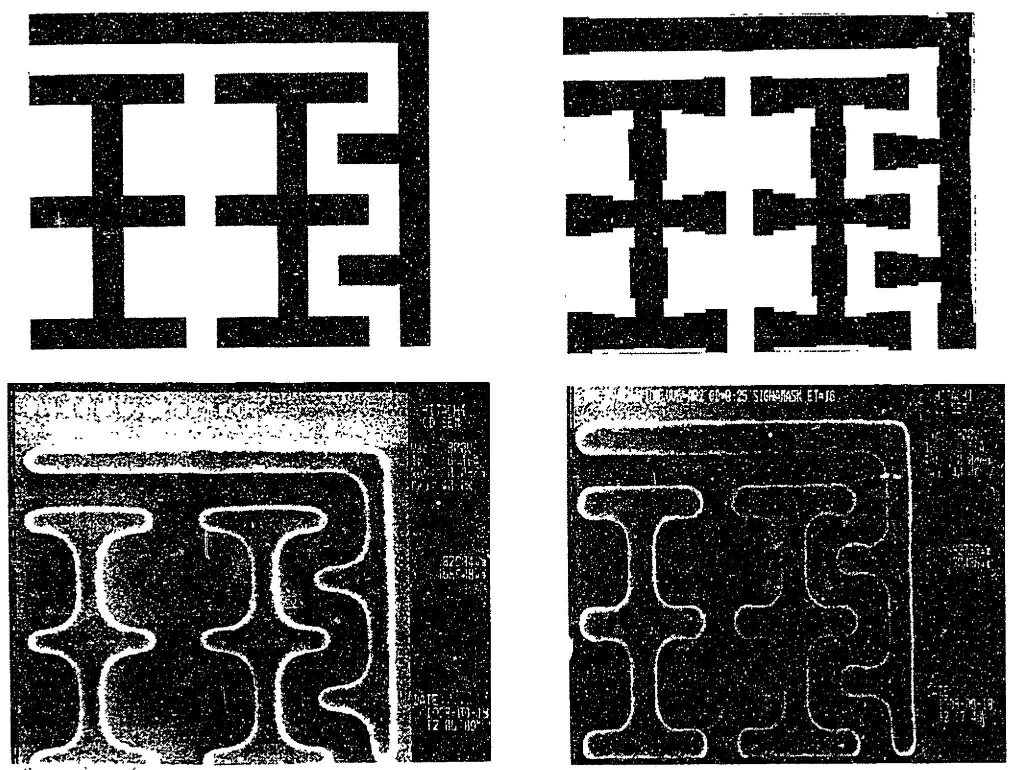


Figure 3.2 (top): reticles' patterns before (left) and after (right) OPC; full-chip engine (bottom): pattern quality improvements (top-view SEMs); before (left) and after (right) OPC

incorporate more precisely the immediate and medium-term directions for advanced semiconductor manufacturing. An example of an immediate decision to make is choosing between options such as "193 nm/ binary mask vs. 248 nm + OPC + PSM + Off-Axis-Illumination (OAI)". Our analysis is scaleable for Next Generation Lithography (EUV, for example) and allows us to address medium-term questions (2 -3 years from now); for example, benefits and drawbacks of 157 nm, 126 nm, SCALPEL, X-rays, Ion-beam and EUV-lithography. In the next sections, we will discuss in detail, yield related (OPC) applications and the cost of EUV.

The model accounts for total cost of capital assets and the total cost of consumables. Its major cost components are equipment (stepper and track), consumable (reticle, resist, ARC, laser and wafer) and RET (Resolution Enhancement Techniques) related. Labor and facilities cost are taken into consideration as well. The following equation expresses the cost per layer on a yearly base:

$$Cost_{per\_layer\_annual} = (C_{eq} + C_{inst})/ Y_{depr} + C_{Class1} + 168*52*WPH_{eff}*V_{die}*KD + C_{Test.W} + C_{consum.process} + C_{consum.pm} + C_{Labor} + C_{RET} \quad (1)$$

where,

C_{eq} = Capital Equipment Cost

C_{inst} = Capital Equipment Installation Cost

Y_{depr} = Years Of Capital Equipment Depreciation

C_{Class1} = Class1 Cleanroom Cost

WPH = Supplier Ideal Throughput Specification

α = Customer Supplier Ideal Throughput Deration Ratio

β (Uptime) = $[168 - (\{168\ MTTR / MTBF (1-PPM)\} + MTOL)\}/168$

γ = Utilization

$WPH_{eff} = WPH*\alpha*\beta*\gamma$

V_{die} = Revenue Per Die

K(iller)D(efects) = $0.005\ A / \pi (D/2)^2$

$C_{Test.W}$ = Cost Of Test Wafers

$C_{consum\ process}$ = Cost Of Process Consumables

$C_{consum\ pm}$ = Cost Of Equipment Consumables

C_{Labor} = Labor Cost

C_{RET} = Cost Of Reticle Enhancement Techniques

The cost per lithography layer is calculated using:

$$Cost_{per\_layer} = Cost_{per\_layer\_annual}/(168*52*WPH_{eff}) \quad (2)$$

This model also provides a simple, straightforward and common method to calculate cost per wafer for any process step. The model was verified with examples of real applications from a semiconductor manufacturer's point of view – both integrated device manufacturers and IC foundries.

3.1.3 EUV

We have applied the cost model to assess the potential and investments needed for one of the latest entrants into NGL race: Extreme Ultraviolet Lithography. Before we report the results, we would like to summarize the EUV status as we see it, because both the pace of development and technical progress achieved there are breathtaking.

Business development. While research effort was active in the U.S. starting in 1985, the commercial history of EUV is much shorter, however very dynamic and impressive. Intel, AMD, and Motorola formed EUV Limited Liability Co. (EUV LLC) in September 1997 to fund research and development of EUVL at Lawrence Livermore, Lawrence Berkeley, and Sandia National Labs. A compact reflective lens for EUV with convincing performance characteristics was demonstrated at the beginning of the next year (at SPIE's Microlithography'98). Immediately after, Japan (led by Nikon, Hitachi, and Himeji Institute of Technology) and Europe (led by ASML, Karl Zeiss, and the European Community) joined the EUV race. In December of the same year (at the NGL Workshop) International SEMATECH recommended EUV as one of two technologies it supports. Loop closed in June 1999 when ASML joined EUV LLC program. According to the latest estimations by the professionals working directly in the EUV field (Vaidya, Hector, 1999), exposure tools will be ready in 2005 - for 70 nm design rules.

Technical achievements and issues. From the beginning EUV faced challenging list of technical issues with reticle defects (and repair), mirror finishing, and multilayer coating control being the most difficult to resolve.

Multilayer, high reflective (>65%) reticles are required to have $<10^{-2}$ defects/cm^2. By 1997 defect density of $2x10^{-2}$ defects/cm^2 (ion beam sputter deposition) was already achieved. A breakthrough with the Sommargren interferometer provided critical technology for aspheric mirror surface figure accuracy. Finally, to obtain high throughput, the following characteristics are required from various components of an EUV system: 1% conversion of laser power to EUV from a Xe plasma; resist sensitivity - better than 5 mJ/cm^2 (assuming a Thin Film Imaging process with an inorganic etch mask).

We used the latest information from the US developers of EUV technology [6] as inputs for our cost estimations: - throughput (80 wafers per hour, 200 mm); - resist materials ($2500 per gallon, 2 ml used per wafer); - equipment (exposure tool including source $15M); wafer track ($2.5M); - mask ($45K per mask used for 2500 wafers per mask); source maintenance ($500K per year); - 5 year depreciation. We consider hard-mask etch as separate process and did not include it into lithography part. Our model yielded exposure cost 30.5 $/layer and total cost 40.6 $/layer. It is interesting to note that these estimations are quite different from the numbers reported even 3 years ago; such as average exposure cost only ~ $106/layer (Hawryluk et al., 1997).

Based on the above analysis we conclude that overall EUV is very competitive candidate for the NGL and without doubt is the most extendible for consequent IC generations.

3.1.4 Benefits and Cost of OPC

While there is certain insignificant cost increase associated with OPC (from $12.6 to $13.6 per layer, I-line; from $ 15.7 to 16.7 per layer, DUV), corresponding yield benefits are far surpassing the expenditures. Typical examples of successful OPC application are shown in Figure 3.2 (full-chip algorithm-engine) and Figure 3.3 (cell-level). The main effect from an OPC introduction into the process flow is the lithography-related and overall yield improvement (Balashinski et al., 1999).

The variety of approaches for yield analysis in IC manufacturing (including the classic works from IBM and Carnegie Mellon University (Stapper et al., 1983; Maly et al., 1986), may be separated into groups related to device parameters, process parameters, and environmentally born defects. OPC deals with improvements of parametric (lithography process-related) yield.

Despite the task being extremely challenging (because of numerous variables involved), industry experts are still persistently trying to find the "magic number" and use a single figure of merit to describe quality of lithography (Lin, 1999). One of such numbers, lithography-related yield (Y_{litho}), was introduced in 1994 (Mack et al., 1994) as follows:

$$Y_{litho} = \text{(sum of the frequencies of all CD within spec) / (sum of the frequencies of all CD)} \qquad (3)$$

Later, the process-window based definition of Y_{litho} has also been suggested (Grassman et al., 1996). This defines lithography-related yield as sum of probabilities for a CD to be within a certain process window, assuming normal and independent distributions of focus and exposure errors. While based on valid dependencies from focus and exposure, such approach itself depends on the specifics of the shape definition for process window, which can be quite non-trivial.

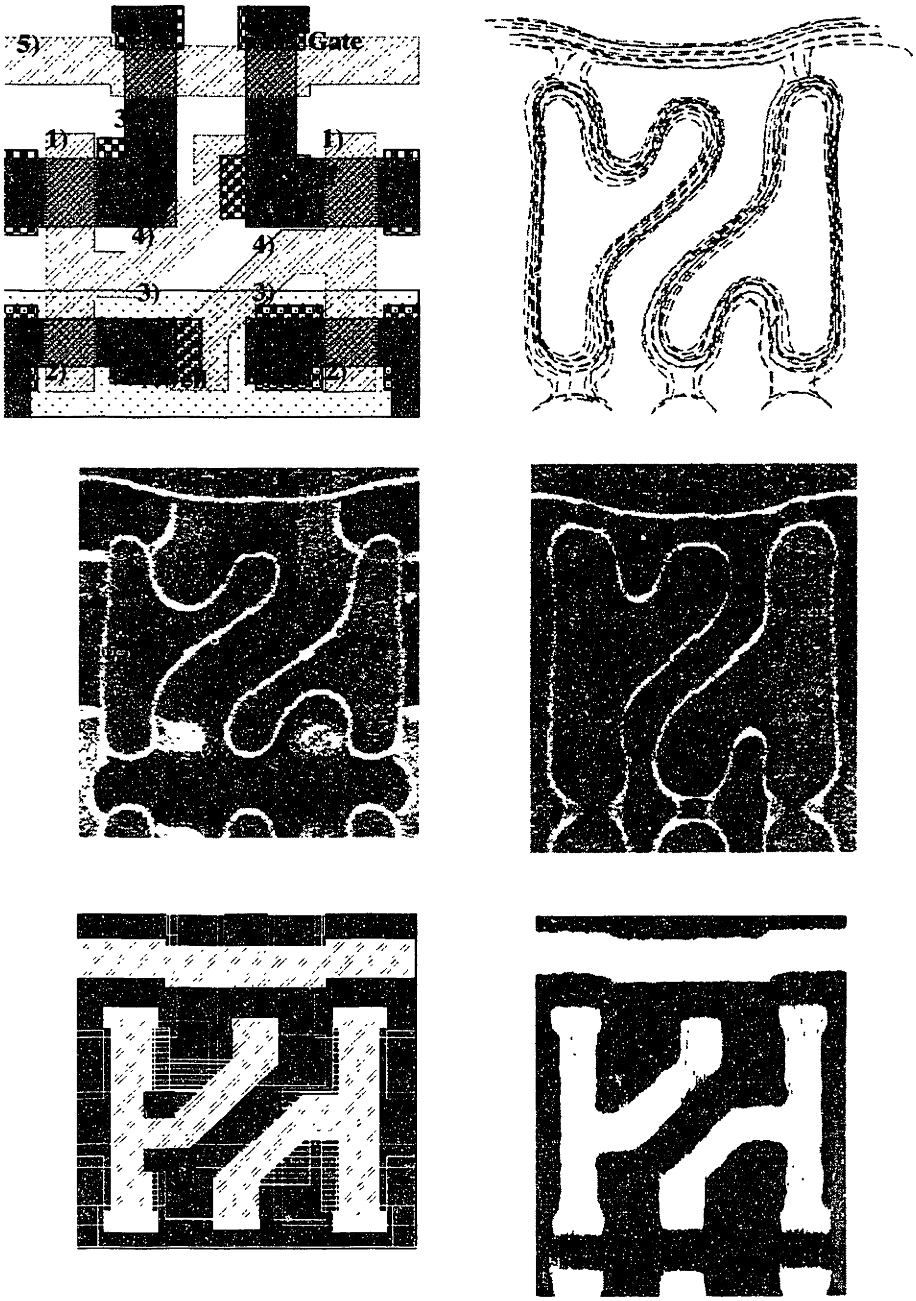


Figure 3.3 top: (left) - key layers of SRAM cell. Critical areas: endcaps (1,2), contact areas (3), 45 deg arm (4), wordline (5); (right) - simulated aerial imageon wafer
middle: examples of SEM images for different exposures: (left) - high dose, (right) - low dose (showing pattern bridging as in simulated image)
bottom: (left) - design of poly gate layer with serifs added by CAD flow; (right) - SEM picture of real mask

We defined the concept of lithography-related yield based on full-chip precise automated OPC (Y_{Full_litho}). Because of the complex interaction of modern IC layouts with manufacturing process, any meaningful yield estimation concept must include a full-chip engine with a well-established link to process details. It is no surprise, therefore, that it was impossible until the recent development of full-chip model-based automated OPC with high speed and accuracy. We are able to introduce the yield concept based on lithography/etch modeling capabilities within the full-chip proximity correction tool. Such a combined methodology captures in an integrated fashion the specifics of a process (resist, etch), a most critical equipment (stepper), and a layout (features size, shape, and orientation for different features densities) both on experimental and simulation levels. The method is layout independent, describes lithography as a whole and allows us to define full-chip lithography-related yield as follows:

$$Y_{Full\_litho} = \text{(full-chip count of all CD within spec) / (full-chip count of all CD)} \quad (4)$$

Lets consider, for example, one of the most challenging cases in proximity correction: line-end shortening. We analyzed the real process case for features with design rule 250 nm and will refer to the "line-end shortening per side" as simply "CD". Figure 3.4 (top, left) represents CD distribution across the chip before correction. It is very broad (σ = 35 nm), heavily shifted to the left (mean = – 77 nm), and extended to the range of –130 nm. After the correction the CD distribution is quite narrow (σ = 7.2 nm, mean= 2.2 nm), centered around the target (0 nm), and practically all CD are within $\pm$ 20 nm range. Full-chip lithography-related yield (Y_{Full_litho}) was improved from 9.6% to 88.4%.

Such OPC performance is observed by the authors on a consistent basis and is supported by the vast amount of the experimental data. For example, almost an order of magnitude improvement was observed for the case of lines separated by a 300 nm gap (the range of design rules was from 150 to 1100 nm). As a result, the initially specified 300 nm gap was corrected and reproduced on wafer (after etch) as 310 nm feature. Such 3% accuracy from a full-chip simulation tool is a quite remarkable, because (considering the calibration difficulties of any simulation) 10% of accuracy is traditionally recognized as an excellent one even in TCAD world.

The lithography improvements described above are directly transformed into superior device performance and higher final yield. It was demonstrated both for highly random microprocessor (up to 30 million transistors), and more periodical memory designs using various OPC schemes and Sequoia Device Designer (Axelrad, 1999) for device yield estimations. Polysilicon's line-end shortening over the active region can lead to transistor short channel effects such as threshold voltage variations, low punch through, and high leakage current. Distribution of polysilicon's line-widths determines device and circuit performance in terms of leakage current (I_{off}) and speed (drive current,

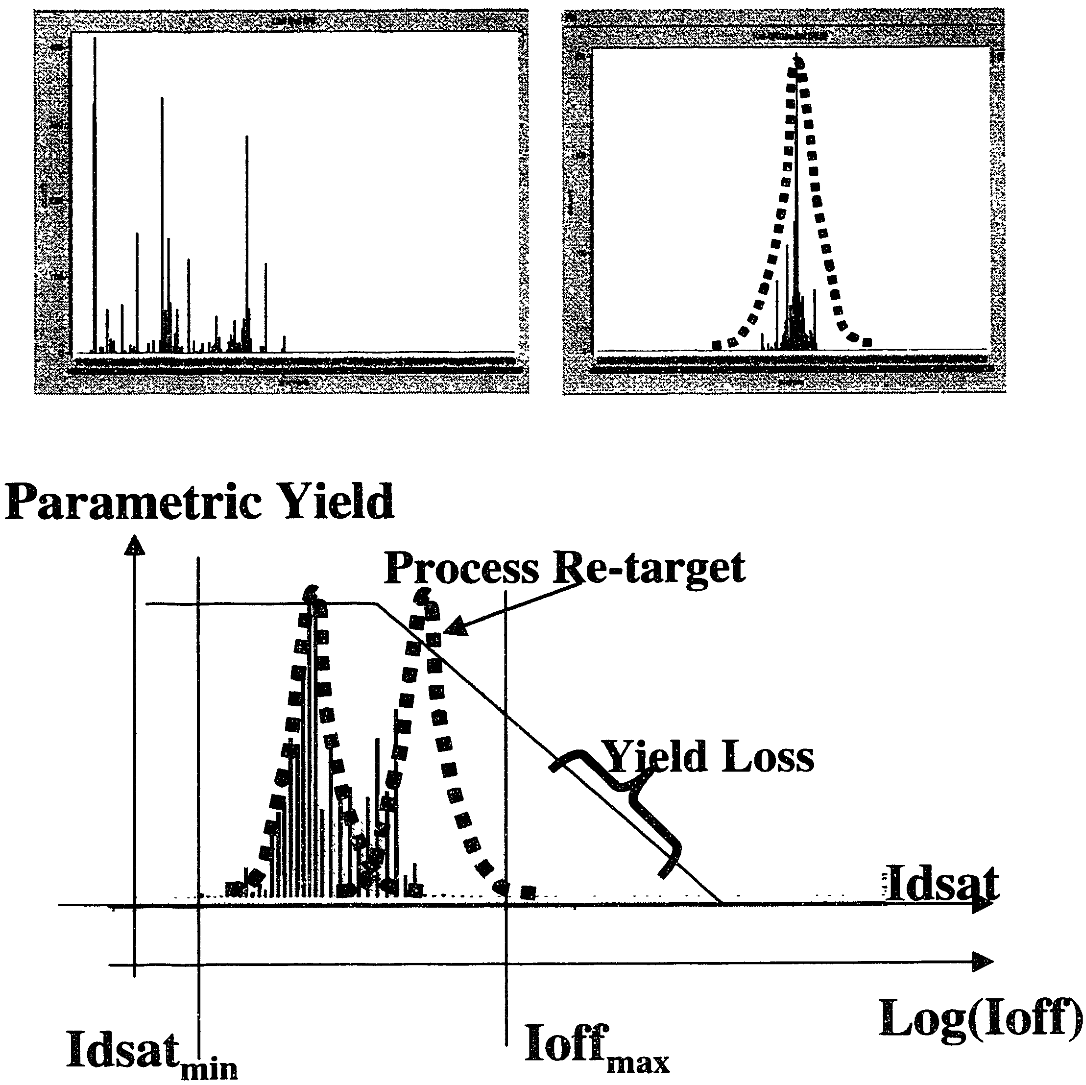


Figure 3.4 top: pattern quality improvements after OPC represented by across chip Critical Dimensions distributions (left) - before OPC; (right) - after OPC
bottom: IC performance (parametric yield) corresponding to the Critical Dimensions distributions on the top pictures

Id_{sat}). Figure 3.4 (bottom) represents distributions of I_{off} and Id_{sat} before and after OPC. In addition to providing much narrower current distributions, OPC gives an advantage of ability to re-target the process (dashed line distribution) toward the higher circuit speed (larger Id_{sat}) staying below the limit of maximum I_{off}. Functional yield improvements after OPC might be up to 40% with direct impact on cost reduction and corresponding revenue increase (Figure 3.5, bottom).

3.1.5 Capital Equipment Asset Management.

From another side, to address the escalating capital investments associated with new lithography equipment and reduce costs, IC makers revising traditional financing practices in specific and capital asset management. They are looking for alternatives to paying cash up front using a traditional capital purchase and depreciation approach for their critical dimension lithography equipment. It means to find optimum and most cost-effective acquisition and disposition profile of such state-of-the-art tools as critical lithography tools.

For example, Cypress Semiconductor teamed up with Comdisco Electronics Group to address cumulative cash and expenses while embellishing the traditional FASB-13 operating lease, to get strategic flexibility given the uncertain period of equipment use. It is based on such inputs as (a): IC manufacturing and technology roadmap and (b): possible implementation scenario of the equipment suppliers roadmap (supporting the technology roadmap from a resolution and overlay perspective). Then a standard fab capacity model calculates the amount of each different tool types needed to be acquired and disposed over time. It is concluded that leasing is the clear choice when the period of use is less than 5 years.

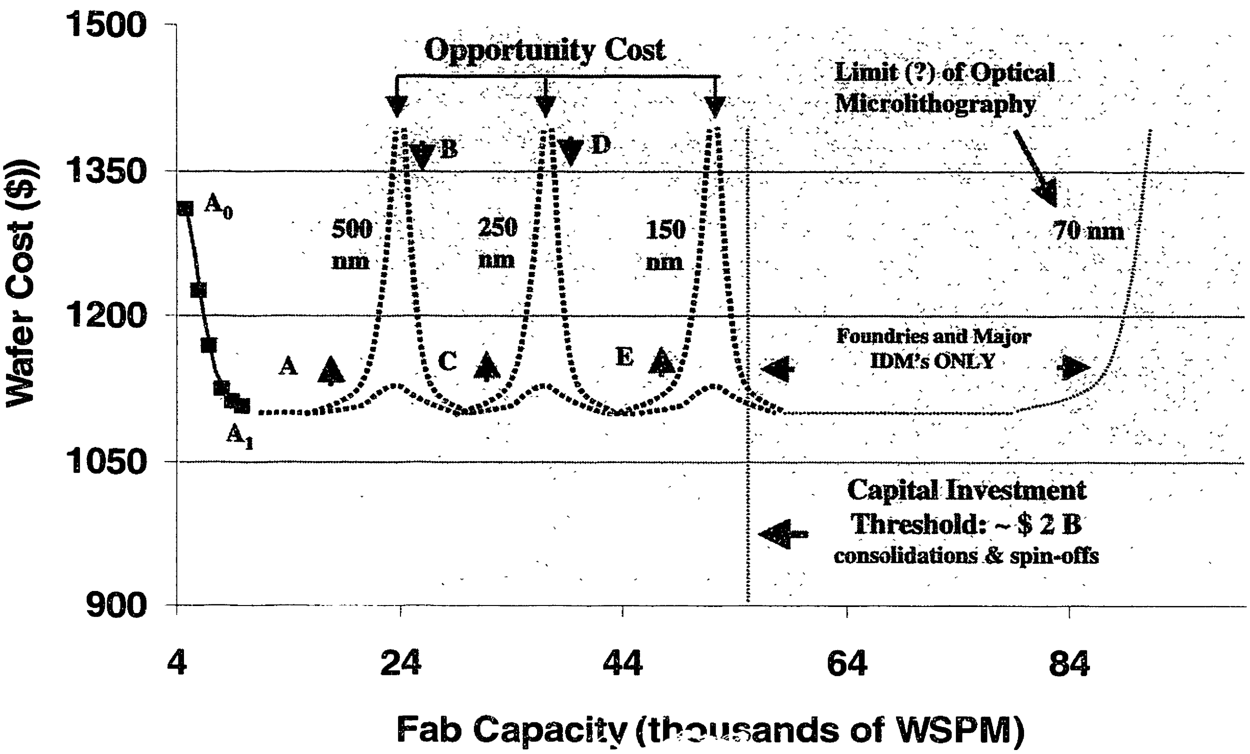
3.1.6 Short-Run, Long-Run Cost Curves and Opportunity Costs for IC Industry.

Lithography is such a significant part in the total structure of the modern IC production that we always need to consider lithography cost implications on the whole industry. Currently silicon-based technology is fast approaching several major physical limits. This situation determines controversial cost dynamics, defined by the rapid increase in equipment price (because of its complexity to address those physical limits) on the background of dramatic falling chip prices. These events put severe limitations on companies' ability to maintain cost reduction and eventually led to the recent wave of spin-offs, mergers and acquisitions.

Described arguments about the IC industry and microlithography may be depicted graphically (Figure 3.5, top) as a combination of total and opportunity cost from a pure operational and technology perspective. Cost of processed silicon wafers is presented as a function of fab capacity (number of wafers starts per month, WSPM). On first glance, the traditional microeconomics concepts do not work very well in IC production. Cost is going down (short-run cost curves, very left part of Figure 3.5, top) with increasing of number of wafers while traditionally cost of commodities is going up with increase of number of units produced. Short-term cost behavior is not surprising though: IC industry never had time to learn how to operate in a commodity mode with maximum yield. It was always forced (by competition and its customers expectations) to remain in a "barbarian" state with respect optimizing operations, utilizing the mode of long-run cost curves and to be a "commodity" industry. However, more detailed analysis reveals long-run pattern with total wafer cost being somewhat stable.

The initial ($A_0 - A_1$) part of the cost curve (Wood et al., 1997) is typical for today's IC industry short-run healthy operation: cost reduction with a quantity increase. The IC industry was living in the declining cost mode very successfully and with relatively low expenses until opportunity cost skyrocketed (up from point A) with requirements for the smallest features reaching 0.5 micron at the beginning of 90's. The opportunity cost defined as the rate of return available on the best alternative investment. Extensive R&D efforts, next generation of microlithography equipment (by that time cost of a single stepper well surpassed $ 1 million), and new materials allowed industry to bring wafers cost back (down from point B) to the comfortable level. It stabilizes with the mean ~ $1000 per wafer (see horizontal line on Figure 3.5, top) for advanced designs with average gross margins above 40%. Variations are within the range of $ 700 - 1700 per wafer, dependent on business model and type of product.

Both the demand for 0.35 and 0.25 micron designs and the fear to miss a new opportunity inferred the new cycle (up from point C). This time again, in only 3.5 – 4 years, IC industry was able to achieve a breakthrough and commercialize radically new lithography: moved from I-line illumination (365 nm wavelength) to Deep Ultra-Violet (DUV, 248 nm wavelength) illumination based on laser sources. New and reasonably inexpensive photoresist materials together with commercialization of the full-chip Optical Proximity Correction methods helped once again to bring (down from point D) wafer prices to the comfortable flat level. However, size of necessary capital was less than comfortable; at the time (beginning of 1997) advanced IC manufacturing meant ~ $ 6 millions per stepper and the price tag for a new fab ~ $ 1 billion.



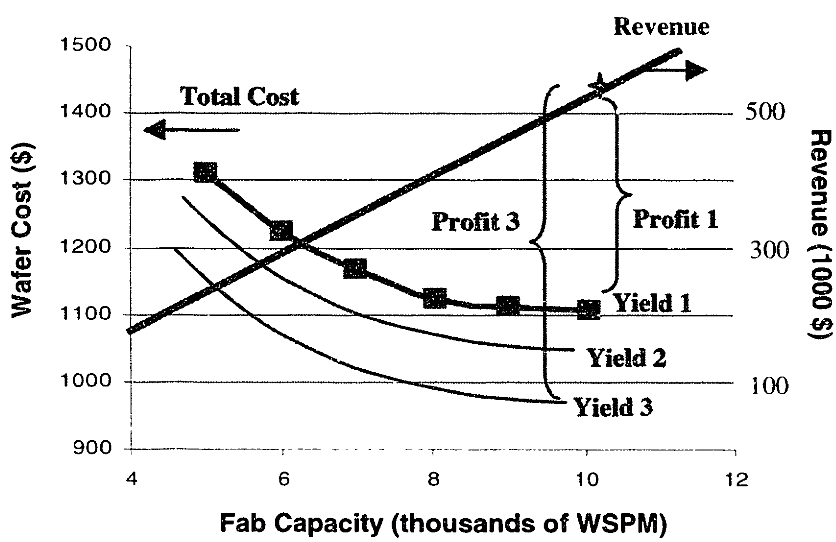


Figure 3.5 top: long-run cost curves; combined representation of operational (WSPM), business (total and opportunity costs), and technology (500nm …70nm design rules) issues

bottom: short-run cost curves with corresponding revenue and profit.

At the middle of 1999 there was a pressing need to produce in volume advanced IC's with design rules at 150 nm while the industry is still not finished with the stable transition to the 180 nm level. The necessary capital investments for 150 nm are:

- ~ $13 millions per stepper ($>5^x$ price increase since 1993)
- estimations of fab price ~ $ 2 billions

These capital investments produced the recent wave of spin-offs and consolidations (Financial Times, 1999). Among most notable spin-offs are: in memory business – from Texas Instruments to Micron; in microprocessors – from National Semiconductor to Via (Taiwan); separation of semiconductor business by Siemens and HP and memory business by Motorola. The most visible recent re-structuring, consolidations and alliances: TSMC/Acer, NEC/Hitachi, LG Semicon/Hyundai, Mitsubishi/Matsushita, LSI Logic/Symbios. We may view the situation as a certain capital investment threshold (Figure 3.5), which only major foundries and Integrated Device Manufacturers (IDM) will be able to surpass. Finally, another "absolute" limit of traditional optical microlithography (70 nm, for example) is approaching without adding much certainty into the whole picture.

Based on the above discussions, I argue that not only DRAM but practically all silicon-based IC products are rapidly approaching a commodity status and it would be appropriate to represent market dynamic in terms of long-term cost curves with wafer cost as the major cost unit.

3.1.7 IC Industry Business Model: Status and Challenges.

Microlithography cost analysis inevitably led us to consider the economic performance of IC industry as a whole. We partially described this in the previous section with emphasis on the fact that to a large extend the current shape of the industry, is determined by microlithography development and affordability. We think that from a structural point of view in the foreseeable time, the IC industry will be using specialization-type (commodity memory, foundries, standard microprocessors, ASICs, fabless, captives manufacturers) business models with an increasing role of foundries (Figure 3.6).

Foundries fulfill the industry need of controlling sharp swings in the required capacity. However, economies of scale model is not going to be sufficient to meet the variety of applications in smaller volumes. This trend, together with high risk of investments associated with large facilities may re-new the interest for mini-fabs (concept of which was first assessed in 1970s). Alternative of flexible modular/minifabs (Wood et al.) may be attractive to avoid the cost penalty of under-utilization of capacity which is far worse than the penalty of building a smaller fab (for example, efficient ASIC mini-fab for 10000 WSPM with ability to expand to 20000 WSPM). In a sense, analogy with steel industry (Port, 1994) might be appropriate; e.g. rise of mini-mills with electric arc furnace production in comparison with open-hearth steel making process.

Business Model for Chip Economics

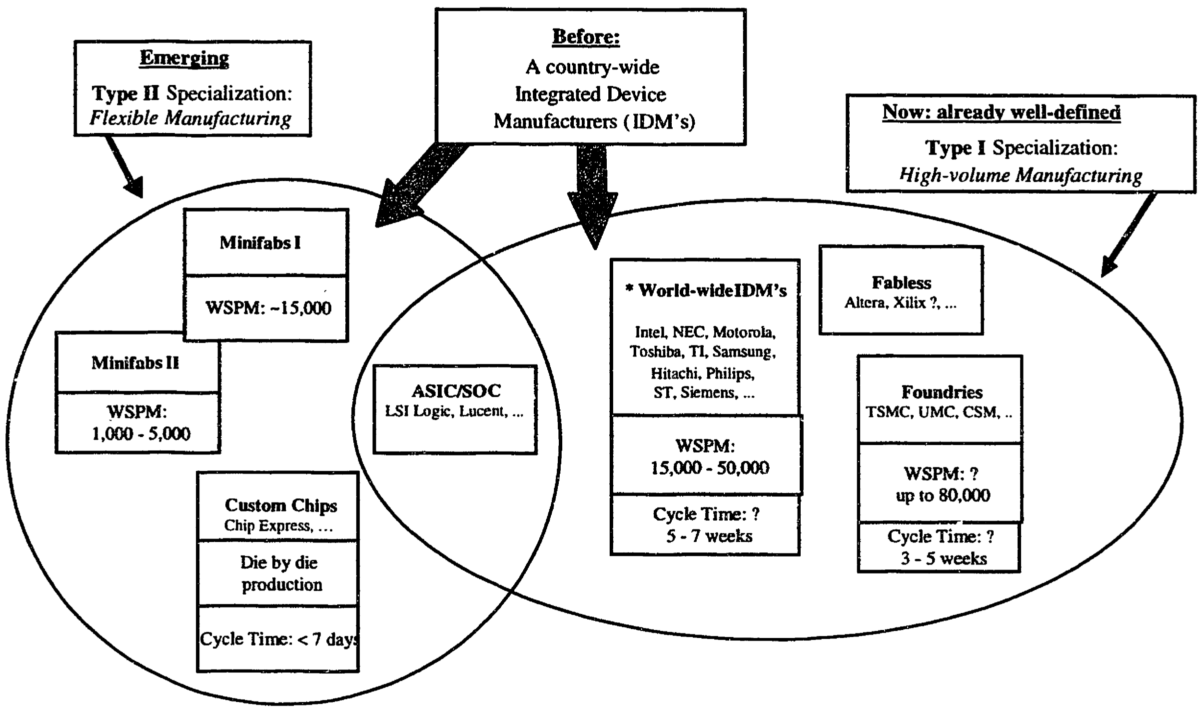


Figure 3.6 Specialization among the major multi-national players in "chip economics" vs. previously dominated domestic Integrated Device Manufacturers.
right: well-defined group of high-volume manufacturers
left: emerging business models in flexible manufacturing

Furthermore, there are several similarities in the dynamics of car and IC industries. World-wide consolidations and the introduction of common platforms for a variety of applications, to name the most significant ones. Car manufacturing consolidated from more than 1000 companies in the 20es to around 100 in 70's. Currently it counts to about 30 players with only 6 main manufacturers (Maxton, 1999). To cut cost Volkswagen introduced 'same chassis – different body' concept which is similar to IC foundry approach: use limited number of the technology processes for variety of applications. What might be a significant difference is that following the same pattern, the semiconductor industry converges faster. It took the car industry more than 100 years to consolidate to the current level. The transistor, however, was invented only in 1947 and now it would be difficult to count more than 50 significant companies world-wide (or major divisions like IBM's or Motorola's) specializing in chips production.

Previous generations of IC's were initially driven by the demand from space and military applications and then by PCs. The current upswing in semiconductor business is inferred by cellular phones, palm-type devices, high demand for network servers and telecommunications equipment, and much less by computing needs. The current wave comes together with radically new business models: IC-containing hardware (such as cell phones and PCs) is given away for free as soon as you subscribe for services: a situation which was unthinkable even 3 years ago. While exciting, it reveals that business of building hardware is not longer as profitable. Part of the reason is that in its current stage (with lithography stagnation) the solid-state based IC technology provides only marginal functionality improvements between so called "new" generations and has somewhat limited potential to do so in future. The current level of stress and uncertainty in IC industry will last for another 10 – 15 years until radically new computing technology (for example, molecular-based) establishes itself.

We hope that detailed cost analysis similar to the presented one will help to offset unjustifiable technology expectations which may lead to distorted policies of capital investment if coupled with illusions of unlimited economy expansion. In summary, transition processes of growth in the industry reaching the status of being mature are not very encouraging and definitely raise the question "What happens if the IC industry will start to fail supporting the GDP growth rate established and sustained by the Information Technology ?".

3.1.8 Conclusions

A practical and comprehensive microlithography cost model is demonstrated. The model is intended and able to capture actual experienced costs in advanced IC manufacturing. Cost per wafer is calculated based on all the significant lithography variables, and includes various support and equipment maintenance activities. The model is applied for assessing the potential of EUV lithography and for a costs vs. benefits analysis of Optical Proximity Correction.

We conclude that the semiconductor industry with its amazing development is rapidly moving through a transition period and to the status of a mature business. Consequently, the technologically available solid-state based Integrated Circuits are becoming a commodity. This, combined with the possible slowdown in microlithography advancements, causes doubts in the ability of current Information Technology to continue contribute at the same level into the economy growth.

3.2 Case Study #2: Amazing Rise of ASM Lithography

You do not match if you are not a Dutch.

Saying of the U.S. sales people

3.2.1 Introduction

What made the small Dutch company ASM Lithography (ASML) so successful that they displaced Canon in 1997, established absolute leadership in latest technology, and currently are overall #2 in stepper's market, immediately after Nikon ? I will take a look into decisions on business strategy ASML faced with reference to the market environment described in the Chapter 3.1, and will finish with their current corporate dilemma: in which one of the emerging new technologies to invest. What is the next thing: is it Extreme Ultraviolet (EUV), Ion-Beam, Electron-Beam (SCALPEL), or X-rays microlithography ? What is after that and what ultimate corporate strategy is necessary ?

3.2.2 Company Background: ASM Lithography

ASML's core competence is in the design and integration of photolithography equipment. Steppers as supplied by ASML are the principal pieces of production equipment in semiconductor industry. Now ~90% of semiconductor business is Integrated Circuits design and production and it is thought as one of the most complex modern manufacturing human activities. Capable of printing features less than 1/500th the width of human hair, the stepper is considered to be the most sophisticated piece of production equipment in ***any*** industry.

Three companies, ASML, Nikon and Canon, dominate the stepper's market segment, controlling an estimated 90% of it. According to Dataquest, ASML increased its share from 8% in 1990 to more than 25% (35% excluding Japan) in 1997, reaching the number two position behind Nikon (which had declining 45% market share).

ASML was founded in 1984 with 50% participation from both Philips and ASM International NV. The objective of the new company was to develop photolithography systems and processes, an activity which until then had been, to a large extend, handled internally by Philips. ASM International ceded its participation in 1988 to Nederlandse Merchant Bank NV. In 1994 the company was incorporated in Holland and in March 1995 held its IPO on NASDAQ and on Amsterdam Stock Exchange. Philips share was reduced to 23.9% (since 1997).

While semiconductor's market is as famous as the oil's one for its cyclicality (Figure 3.7), sales of ASML look impressive (Figure 3.8) with its stocks (Figure 3.9) being among the top performing in the industry (compare, for example, with Applied Materials) and sometimes outperforming Wall Street IT's darlings (Intel & Microsoft).

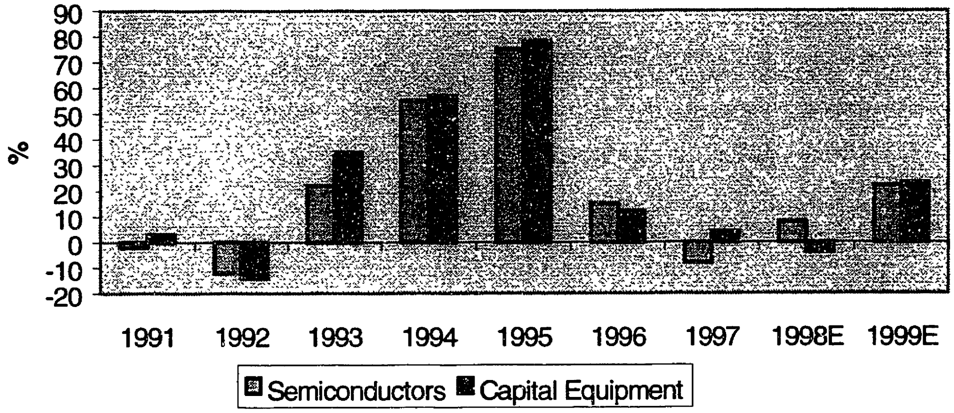


Figure 3.7 CAGR: Semiconductors and IC Capital Equipment

3.2.3 Description and Assessment of ASML Strategy

<u>**Business level strategy**</u>

ASML business strategy is centered upon four separate axes:

1. Focusing on value-of-ownership
2. Technological leadership through strategic partnership
3. Maintaining operational flexibility
4. Customer focus

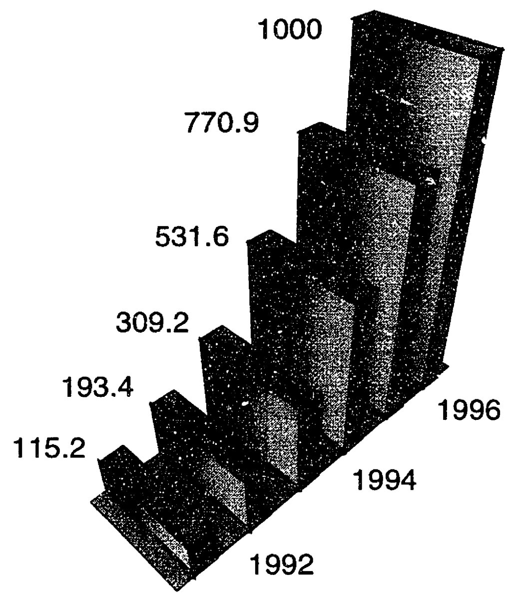


Figure 3.8 ASML Net Sales (millions $ US)

Providing greater return on investment. What does an IC manufacturer get for his money (assuming cost of latest steppers is well above $10 M) ? ASML introduced 'value-of-ownership' market terminology instead of traditionally accepted 'cost-of-ownership' (i.e. how much the customer

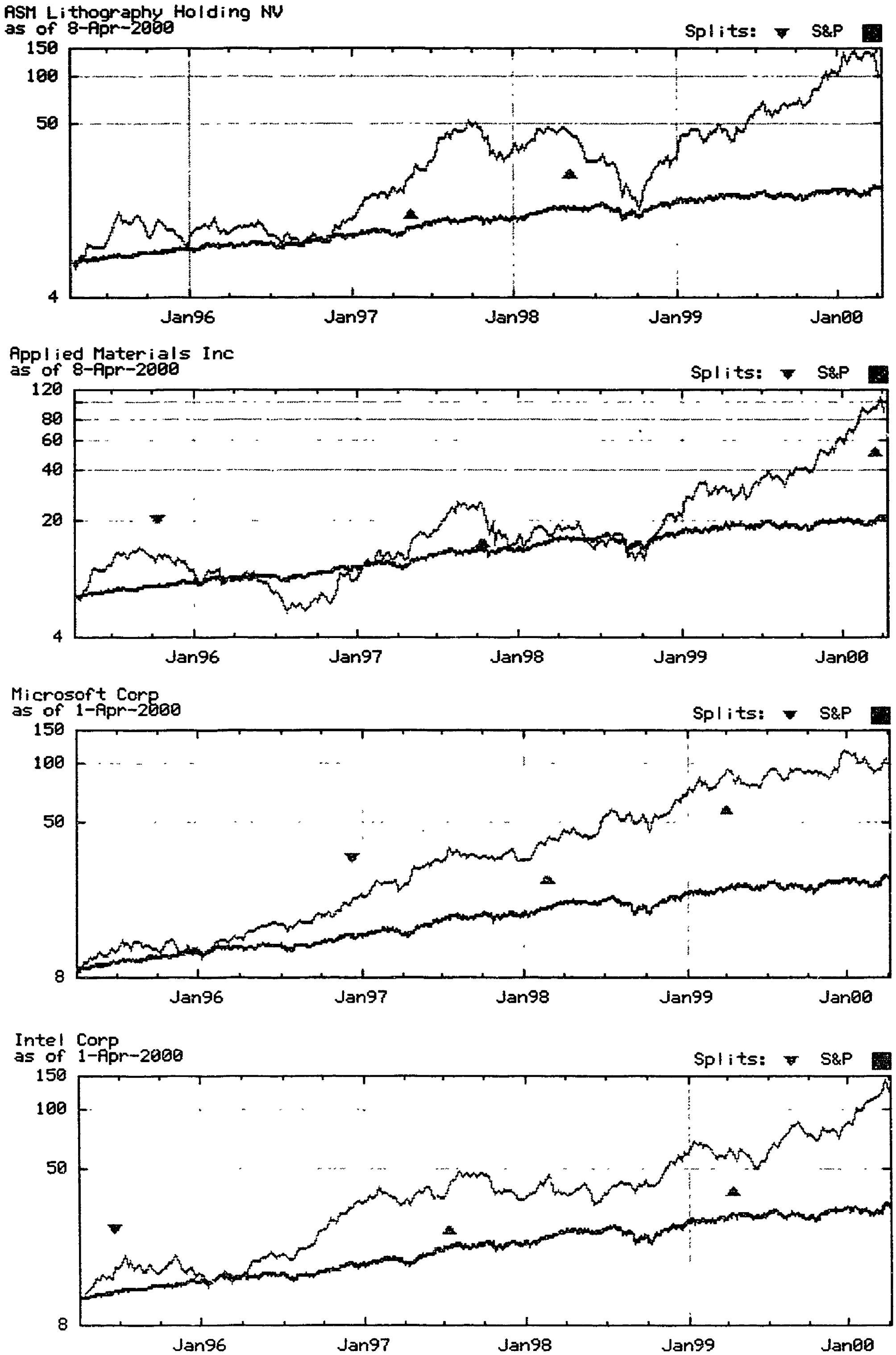


Figure 3.9 ASML stocks performance

has to pay over the lifetime of the product in terms of spare parts and maintenance ? The greater value of ASML steppers, justifying higher average selling price, has traditionally been derived from greater wafer throughput and superior overlay. These two sources of competitive advantage are tied closely to proprietary ASML precision mechanics know-how, enabling the wafer stage to move more quickly (increasing throughput) and more precisely (improving overlay accuracy and therefore yield).

For the latest product generations (step-and-scan systems with two moving stages, one for the wafer and one for the reticle) such expertise in precision mechanics should prove even greater productivity. An historical weakness in optics relative to its Japanese competitors has been improved in recent years through closer cooperation with Zeiss and now ASML steppers achieve comparable and better linewidths (characterized in semiconductor industry by minimum or Critical Dimensions, CD) and CD uniformity across the wafer. Although not a supplier of other categories of processing equipment, ASML offers hardware and software options to enable integration of its steppers with those other equipment. The modular concept of ASML steppers allows easy upgrades of existing equipment to benefit from the continuous flow of new productivity enhancements.

Strategic Alliances. Due to the enormous potential for return on investment through significant chip's cost reduction, customers are paying a premium for a production-worthy stepper providing resolution, field size, cost-of-ownership or overlay advantages. Leadership in these customer satisfiers is achieved through successful execution of focused R&D activities. As semiconductor processing has become more complex, no one company can have sufficient resources or competence to undertake development of next generation technologies alone. Hence the emergence of industry consortia such as Sematech and I300I in the US, or ASET and SELETE in Japan. Though a participant in several industry initiatives, ASML has also developed its own R&D network with IC manufacturers, its key subsystem suppliers, and suppliers of equipment and material complementary to the photolithography process, and lately actively participates in US NGL programs; both in EUV and SCALPEL initiative.

Sunce the formation of ASML, Philips Semiconductor has been a key partner in developing next generation lithography processes. This IC manufacturer cooperation has been enhanced in recent years through close co-operation with Micron (generally considered to be the most cost-effective DRAM manufacturer) and other leading global IC manufacturers (AMD, TSMC).

As the supplier of the critical lens subsystem, Carl Zeiss Stiftung has been integrated as closely as possible into ASML development activities and operations. ASML suffered in 1995 from not being able to meet customer orders due to production capacity constrains at Zeiss. Subsequently, it granted $19.4 million loan to boost Zeiss' capacity, which is now above any "best case" order scenarios which ASML can envisage. The lens subsystem represents approximately 40% of a stepper cost. Currently 150 R&D

staff from Zeiss work on ASML lens development. Such close cooperation is essential to put ASML on the same par as the optics-integrated Nikon and Canon.

In February 1996, ASML acquired a 4% stake in the privately held Cymer Laser Technologies, a supplier of the enabling eximer laser light source for DUV, in order to provide much needed working capital to this key supplier. The stake was re-sold in 1997.

ASML signed a development accord with the leading capital equipment supplier Applied Materials in 1997, in which the ASML 5500 system was chosen as the preferred supplied in Applied's US$ 430 million development facility, focusing on improved cross-process understanding. Hewlett-Packard also has a crucial role in developing the alignment system to go with ASML's proprietory stage system.

Maximizing operational flexibility. No matter how desirable it may be, IC manufacturers and capital equipment suppliers have been unable to iron out the cycles in the semiconductor industry. Because of that, results for market participants can exhibit sharp swings. This is the industry where vertical integration and tremendous fixed cost investment can be a huge liability. Capital equipment suppliers are, increasingly, moving to a business model which ASML has had for several years, of focusing on the intellectual property (design) and integration aspects of the business, and subcontracting the subsystem manufacturing. Thus approximately 90% of ASML's cost of goods sold comes from European suppliers (primarily European-based) and its break-even point is at about 26% capacity utilization (down from 55% in 1993). Thus, in terms of operating margins, ASML has been better able to weather market downturns than most of its counterparts. There are approximately 8,000 people working for ASML in its supplier base.

Corporate level strategy (EUV, SCALPEL, OPC/PSM/MaskTools)

On a corporate level ASML faces short-term (5-10 years) challenges of pressing necessity to invest in Next Generation Lithography (NGL) and to keep up with latest developments in software and algorithms-intensive lithography enhancements (OPC/PSM). For example, ASML needs to execute with precision and to assess the potential and investments needed for one of the latest entrants into NGL race: Extreme Ultraviolet Lithography (EUV). With its June 1999 purchase of MicroUnity's MaskTools technology (and people) and partnering with Mentor Graphics (December 1999) ASML entered IC design world which is merging rapidly with IC manufacturing. Both MaskTools and Mentor Graphics provide the latest software for OPC/PSM; the main effect from an OPC/PSM introduction into the process flow is the lithography-related yield improvement.

Long-term (15-20 years) ASML challenges may require radical structural changes.

3.2.4 Summary.

I concluded before (Chapter 3.1) that semiconductor industry with its amazing development is rapidly moving through a transition period and to the status of a mature business. What does it mean for our favorite: ASML ? I would say that on a business level and on a corporate level (short and medium terms) these distinguished people are doing just fine – they are the best. While I was trying to understand both why these Dutch are so good and what they suppose to do next, eventually I deviated couple of centuries back to development of coastal Europe and its free cities.

In 1776 Adam Smith wrote about Holland: "In a country which had acquired its full complement of riches … it would be necessary that almost every man should be a man of business, or engage in some sort of trade. The province of Holland seems to be approaching near to this state. It is there unfashionable not to be a man of business. … As it is ridiculous not to dress, so is it, in some measure, not to be employed, like other people." While constantly referring to Holland in both volumes (Smith, 1776), Professor Smith nails deep cultural roots of ASML success in two things. First, "the equality which the presbyterian form of church government establishes among the clergy" with consequent generation of "the most eminent men of letters whom those countries have produced, have, not all indeed, but the far greater part of them, been professors in universities. In those countries the universities are constantly draining the church of all its most eminent men of letters." Second, "the republican form of government seems to be the principal support of the present grandeur of Holland. The owners of great capitals, the great mercantile families, have generally either some direct share, or some indirect influence, in the administration of that government. … the residence of such wealthy people necessarily keeps alive, in spite of all disadvantages, a certain degree of industry in the country."

Well, such inheritance and history difficult to match; things take time. But, because of the deep cultural roots of its business practices, I believe that ASML is capable to repeat what Philips did: spin-off new radically different business with core competency of assembling of "ordinateur" ("ordinateur" is French for computer. However, the meaning of ordinateur goes beyond computing, literally, "machine that arranges things"). The idea here is that we should aim at significantly new functionality from new types of "ordinateurs", which will satisfy the market expectations" (we came up with this terminology earlier in the fall of the year 2000 in one of the MIT's projects.) Then we would be calm and confident about seriousness of Professors S.C.Myers and R.A.Brealey suggestion for innovative musical devices (gargle blasters) made with use of integrated circuits to control genetic engineering process (Brealey, Myers, 1999).

3.3 Case Study #3: Transition Between Microlithography Generations.

System Dynamics Modeling

Introduction and Problem Statement

The main focus of our project was twofold: 1. to explore the dynamics of transition to Next Generation Lithography (NGL); 2. re-development for PC of the Professor's Sterman Long Wave Game (see section 3.3.2 and Appendix D). Logical continuation of the present work would be to merge the two: formulate and understand better lithography dynamics and then develop a bridge to long-term macro-economics behavior in order to eventually distinguish the GDP's growth effects from semiconductor's industry (and, consequently, from IT's) economic policy.

3.3.1 Modeling of Transition to NGL

We were concerned with the transition period between the best possible microlithography technology and the next new technology. For simplification sake, we will deal with the transition between two lithography technologies, the current one (DUV or Deep Ultra Violet) and the new one (EUV or Extreme Ultra Violet) which is currently strong candidate for Next Generation Lithography (NGL).

We believe and concern about that while market expectations continue to grow, capital investments per fab will hit a plateau, then may decrease (and slow down the IT industry that depends on semiconductors), before increasing again, perhaps, with investments into different business models (see chapter 3.1) or other than semiconductors-based computing technologies. From the comprehensive list of variables (see Appendix A), we extracted and used the following ones:

- investments
- investments in EUV Technology - new technology
- investments in DUV Technology - old technology
- Critical Dimension for EUV
- Critical Dimension for DUV
- Market expectations

Reference Modes and Main Loops for Investment per Fab. Our concern is represented by the lowest curve (Figure 3.10) and specifically by the dip around years 2006-2008. We are concerned that, for example, the investment per fab will go from having grown close to exponentially through an inflection point, then will dip for a few years before regaining strength.

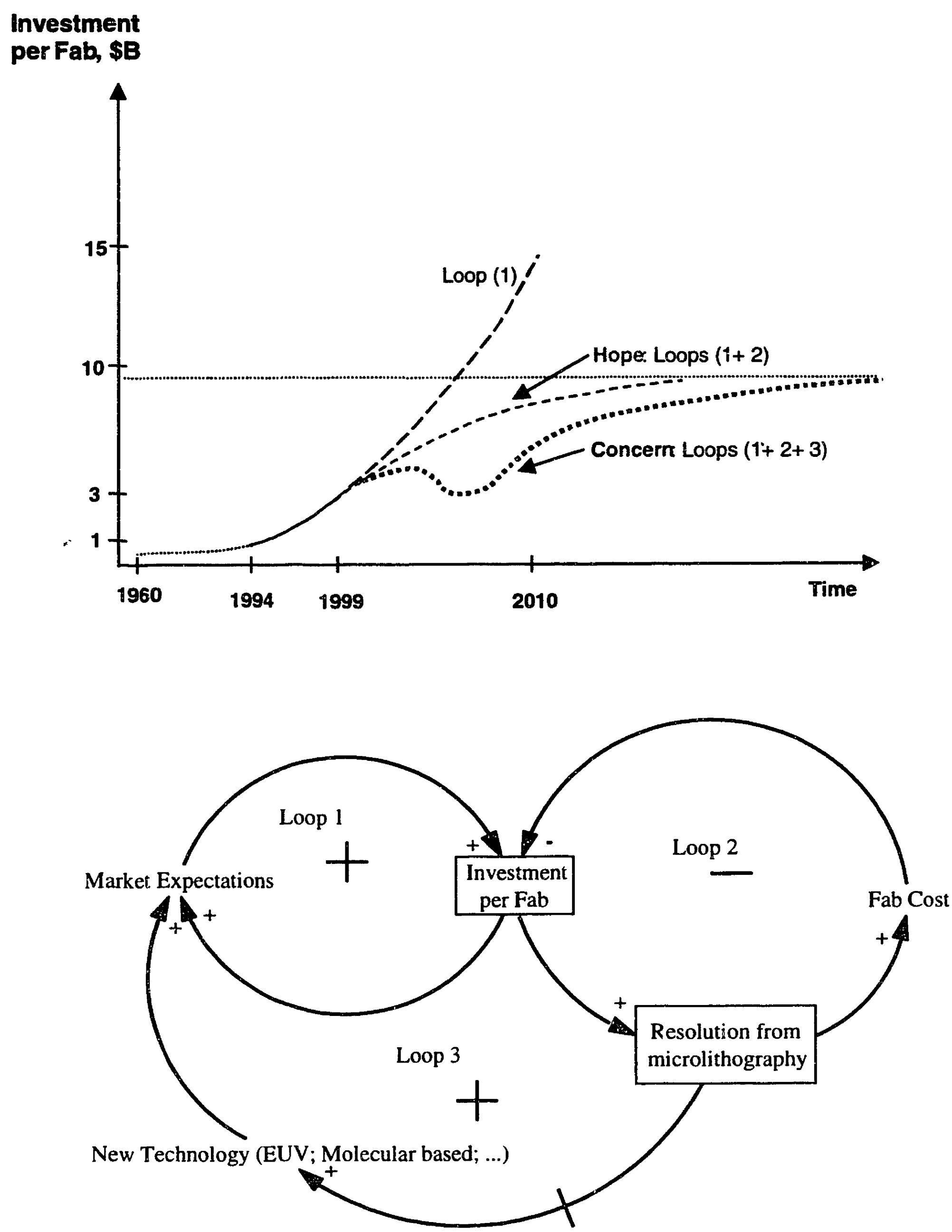


Figure 3.10 Reference modes (top) and main loops(bottom) for modeling of a transition to Next Generation Lithography

In loops representation, we believe, Loop 1 is causing the growth of Investment per Fab observed so far and that Loop 2 might initiate the inflection of the curve. We felt that after a delay, Investment will "switch" from Loop2 (which represents previous generation lithography) to a Loop 3 which represents "post-optical" technology. Eventually, this switch was expressed through formulation of "attractiveness" of one or another type of technology. As we entered the modeling stage, we focused on a subset of the loops described before. We specifically wished to formulate the fact that investments will be shared between two manufacturing technologies: the DUV technology (older technology) and the EUV technology (newer technology). Corresponding "final" model is presented on Figure 3.11.

Note 1: in final formulation we were working with DUV (older technology) and EUV (instead of 'Molecular Based') technologies. Due to the time constraints, we did not consider the loop involving Market Expectations.

Before reaching final formulations, we went through several stock and flow diagrams which we included here (in the Appendix B) because we believe they contain interesting ideas worth exploring in the future.

Effect of Investment in Microlithography on Its Performance. DUV and EUV technologies are characterized by their respective critical dimensions (CD). We define "performance" as the inverse of the critical dimension (1/CD) so that, the smaller the critical dimension the higher the performance. Both DUV and EUV technologies have associated performance limits (physics constraints). DUV is the technology used the most today, and its performance limit is below the expected EUV performance limit.

Figure 3.11 (top) illustrates how the "Investment in EUV" affects the "Performance of EUV". Investment dollars turn into EUV research projects. The more dollars per year, the more projects get started. The more projects the more completed projects. The more completed projects, the closer EUV technology gets to its physical CD (critical dimension) limit or performance limit. This is because, each time a project is completed, it contributes to a reduction in the gap between current performance and performance limit. A similar structure is applied to DUV.

Effect DUV/EUV Performance on Its Share of Investment. With total investment that is constant, and two competing technologies, we face a "relative attractiveness" situation. The technology with better performance becomes the most attractive and will receive the most investment. Figure 3.12 illustrates the impact of technology performance on investment share.

We define attractiveness of a technology as its performance. If EUV's (respectively DUV's) performance increases, its attractiveness (to investors) increases. However, it takes some time for this

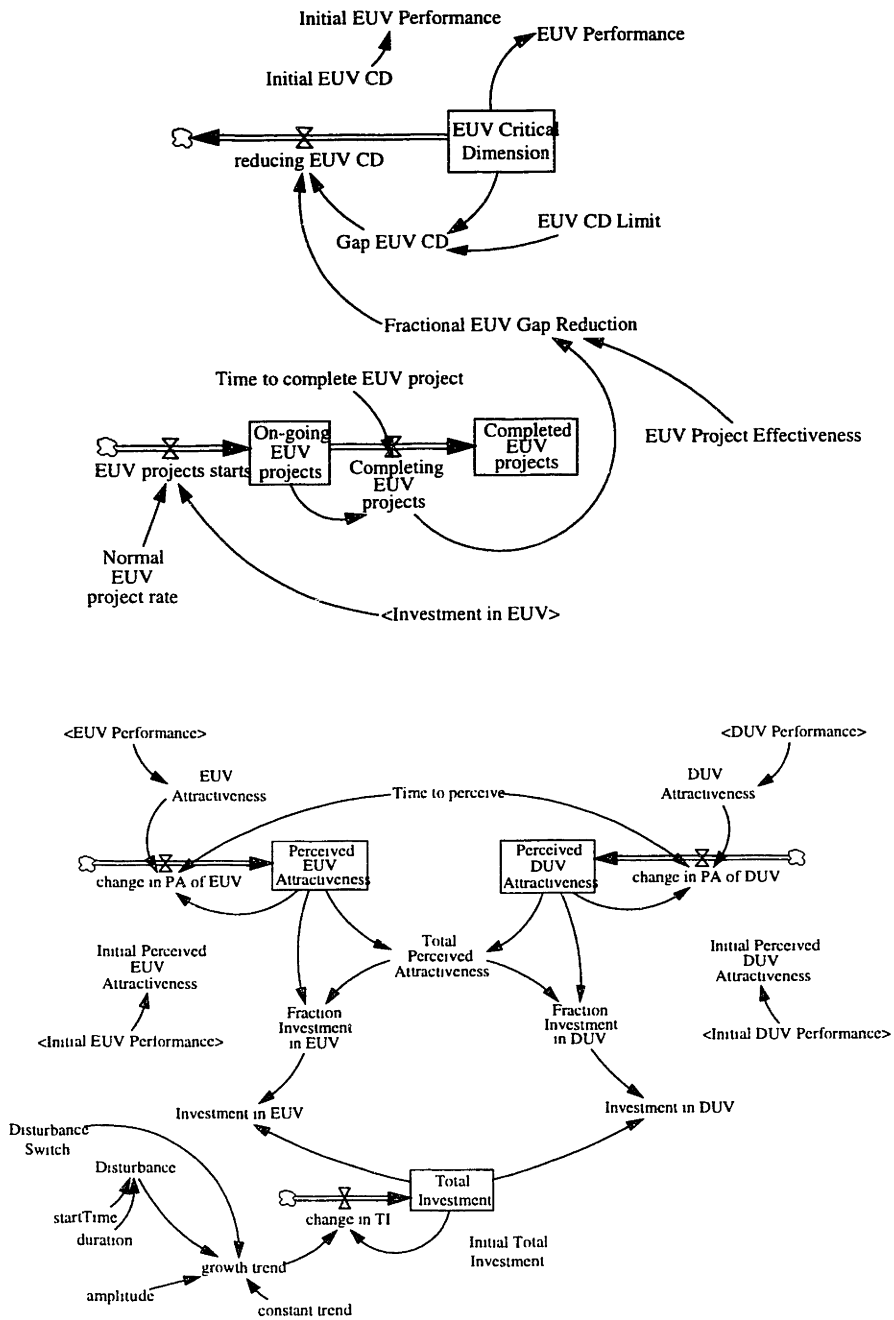


Figure 3.11 "Final" model

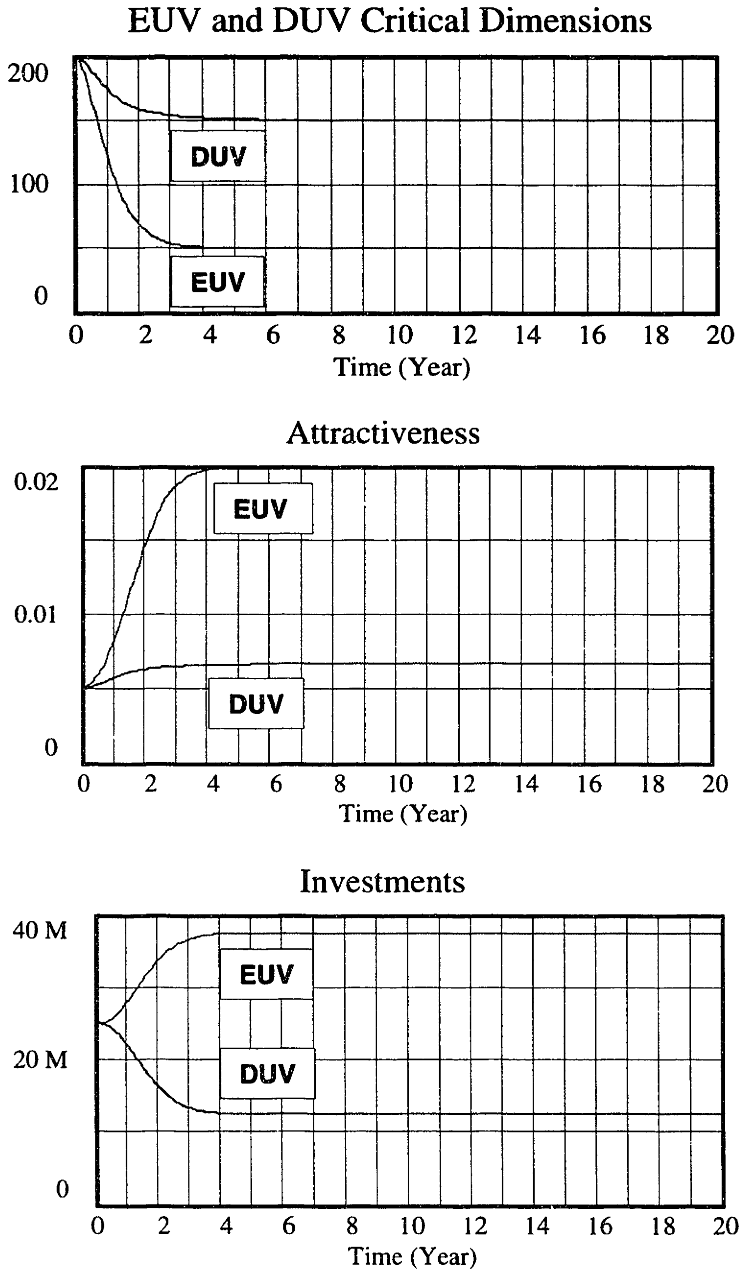


Figure 3.12 Simulation outputs: relationships between the technology performance (e.g.achievable critical dimensions for microlithography), attractiveness, and expected investments

attractiveness to be perceived. The investment in EUV (respectively DUV) increases proportionally to the increase of EUV's (respectively DUV's) attractiveness. By using fractions based on technology attractiveness, we ensure that the total investment is split in two quantities ("Investment in EUV" and "Investment in DUV") with each quantity being a positive value and bounded within the "Total Investment" limit.

Partial Testing of the Model: Equilibrium. We tested the equilibrium conditions ("Total Investment" is constant, e.g. growth is zero). We set the EUV parameters equal to the DUV parameters (which is not true in reality):

- Normal EUV project rate = Normal DUV project rate
- EUV project effectiveness = DUV project effectiveness
- Time to complete EUV project = Time to complete DUV project
- Initial EUV CD = Initial DUV CD = 200 nm *(in reality not true, EUV is already better than DUV)*
- EUV Limit CD = DUV Limit CD = 150 nm *(in reality not true, EUV better than DUV)*

We ran the model and verified that the behaviors were as expected: constant investment fractions at 0.5, constant and equal attractiveness of EUV and DUV, goal-seeking behavior for EUV and DUV performances (seeking their performance limit). Both technologies are assumed to start at the same CD (200 nm) and end at 150 nm. The goal-seeking behavior is verified.

Partial Testing: Different CD Limits for Each Technology. We set EUV CD limit as 50nm (close to reality) while DUV CD limit is 150 nm (EUV's performance is better than DUV's performance). EUV becomes more attractive than DUV, the fraction of investments for EUV increases while the fraction of investments for DUV decreases; same behavior is observed for the absolute investments in EUV and DUV. Stabilization occurs when the performance limits have been reached.

Partial Testing of the Model: Disturbance in Total Investments. We inflict a step function to the "Total Investment" by introducing a pulse-disturbance in the growth trend. We started from a zero growth trend applied to the "Total Investment", then at time 6 months, an 80% drop occurs in the growth trend, lasts 5 years and goes back to zero (Figure 3.13, bottom). As shown above, the performance (or CD) of EUV and DUV behave similar to the previous case. However, as investments are low, the projects are fewer and it takes a very long time for the two technologies to reach their respective physical performance limits. We used this "extreme" example to test the model and make sure we understand it.

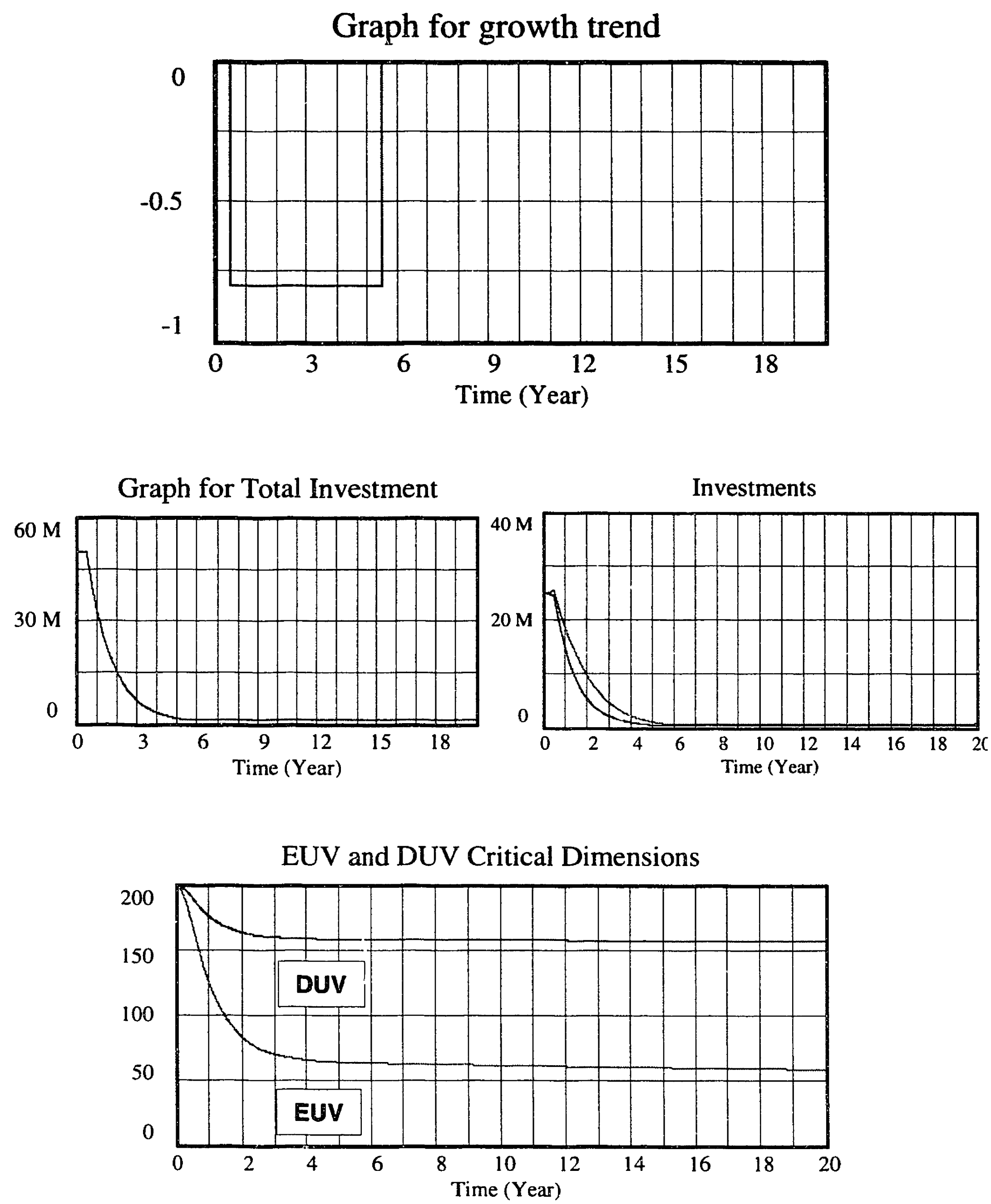


Figure 3.13 Model testing: behavior after the introduction of pulse-disturbance

3.3.2 Summary and Future Work

Introduction of PC Version of the Game: Economic Long Wave

In order to describe microlithography dynamics we identified and formulated the notion of "performance" and introduced "switch" function. Initial model of the transition to Next Generation Lithography was created and verified.

In future, obviously, we would like to clarify and formulate in more detail variables of "Total Investment" and "Market Expectations". Finally, it would be nice to come up with something meaningful for the passion of ours - "Ordinateur" concept (see Appendix B); but it might be a different and separate task all together.

I strongly emphasized in the Chapter 3.1 that notion of "investment" is a core one in an analysis of microlithography dynamics if simply because the investments needed are getting out of control. It strongly contributes into overall severe cyclicality of modern semiconductor business and increases uncertainty, "which may be a major factor in delaying or stopping investment and R&D" (Aghion, Howitt, 1999).

In that regard I found it to be an imagination stretching exercise to look into the investment matters through the Economic Long Wave (LW) discussion. Certainly, I appreciate directions from Professor J.W. Forrester and Professor J.D. Sterman who themselves made major contributions into the modern LW-theory.

While this thesis work is not focusing on LW-theory or applications, I consider the topic fascinating and discussion on the subject as far from finished. Schumpeter's attention (with later notion of Kondratieff's work in early 1920s) and first classification of the first three "waves"/ Industrial Revolutions (Schumpeter, 1939) from 1785 to 1940s is roughly coincides with the latest estimates by The Economist, which added two more LW (The Economist, 1999-3). Vast literature on LW exists and some of that is reviewed in elegant and sophisticated way by Professor Sterman (Sterman, 1994).

I found LW perspective as relevant to the thesis' topic to the extend of initiation of the development for PC of LW simulation [previously existed in the Macintosh version (Sterman, Kampmann, 1989). PC version (v.2.0) of the Long Wave Game (Sterman, Granik, Boksha, 1999) was build on algorithms described in (Sterman, 1989). The Graphical User Interface and preliminary results from version 2.0 (alpha) are presented on Figure 3.14. Code of the basic algorithm and enhancements (vs. Macintosh version) were implemented in an open TclTk development platform which allows easily modify package as needed in the future. Current design and formulation of the Game allows to experiment freely with all components of the algorithm and supports flexible output.

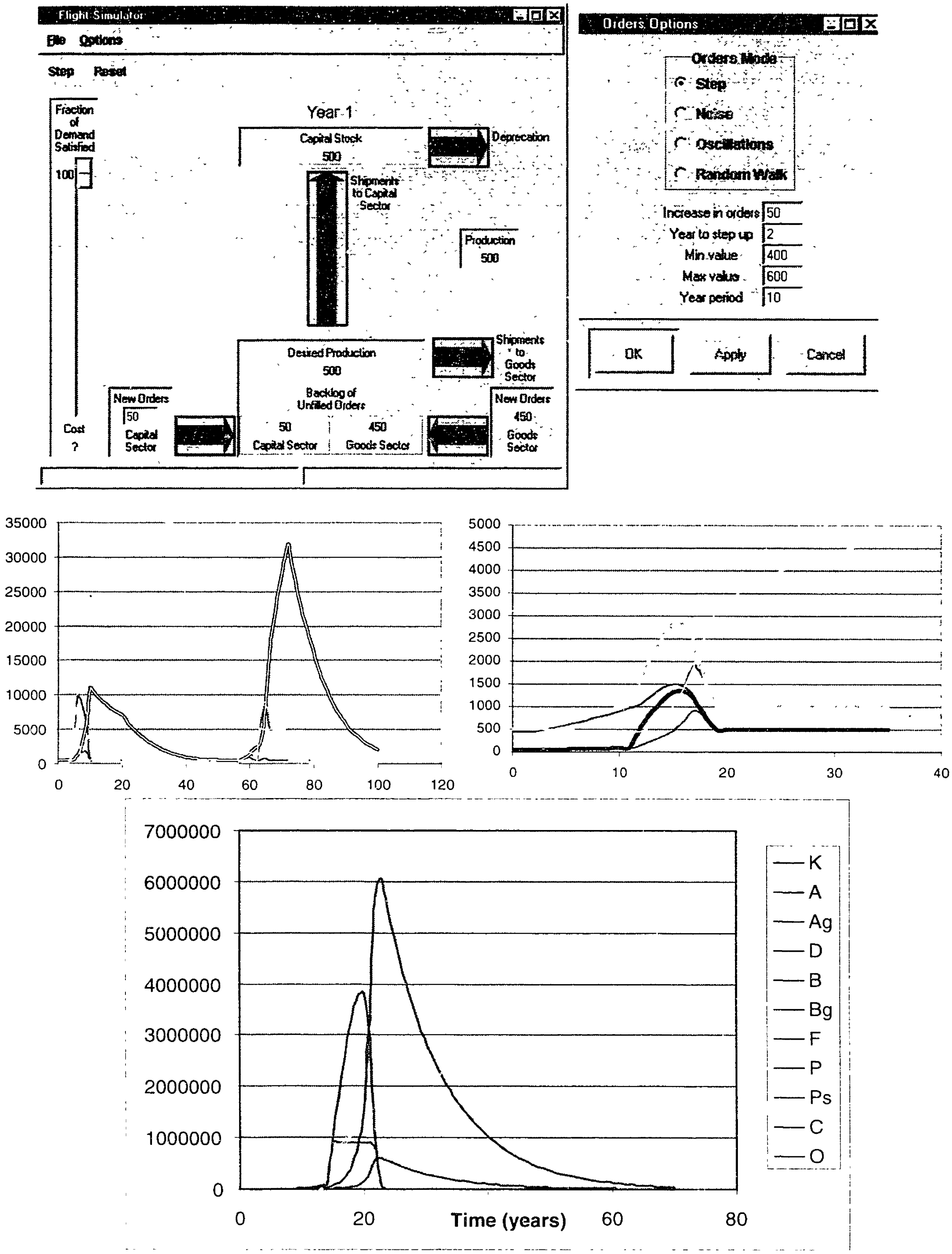


Figure 3.14 Economic Long Wave (version 2.0, PC-based). Main interface with optional menu and outputs - results of alpha-testing.

In addition of being happy because the nice LW-Game idea of Professor Sterman is back for everybody's use, we hope to benefit from this. We expect that such approach will help to formulate and understand better lithography dynamics and then develop a bridge to long-term macro-economics behavior in order to eventually distinguish effects on the GDP's growth induced by economic policy from semiconductor's industry (and, consequently, from IT's). In other words, to study semiconductor's/IT related "slice of the Long Wave", term coined by Dr. Alan Graham during our last conversation.

Note 2: In the Long Wave Game (v.1.1) the economic long wave or Kondratiev Cycle described as "a cycle of prosperity and depression averaging about 50 years".

According to (Sterman, Kampmann, 1989): "Since 1975 the System Dynamic National Model has provided an increasing rich theory of the long wave. The theory emerging from the National Model explains the long wave as the endogenous result of decision making by individuals, corporations, and government.

However, the complexity of the National Model makes it difficult to explain the dynamics underlying the long wave. This game demonstrates how long waves can arise by focusing on the role of capital investment.

There are two basic kinds of industries in modern economies: capital producers and producers of economic goods and services. Good producers sell primarily to the public. Producers of capital make and sell the plant and equipment that the consumer sector needs in order to produce goods and services.

But in addition the capital producing sector of the economy (construction, heavy equipment, steel, mining and other basic industries) supply each with the capital, plant, equipment and materials each needs to operate. Viewed as a whole, the capital sector of the economy orders and acquires capital from itself.

You will manage the capital producing sector of the economy. Your goal is to balance supply and demand for capital. To do this you must keep your production capacity as closely matched to the demand for capital as possible.

The game is won by the person or team with the lowest score. The score is the average absolute deviation between production capacity and desired production. For example, if capacity were 500 and demand were 600, your score for that period would be 100. Likewise, if capacity were 600 and demand only 500, your score for that period would also be 100. A score of 0 means supply and demand are in perfect balance. You are therefore penalized for excess capacity (which implies some of your factories are idle) and also for insufficient capacity (which means you are unable to meet demand for capital).

Time is divided into two-year periods. At the beginning of each period, orders for capital are received from two sources: the goods sector and the capital sector itself. Orders for capital arriving from the goods sector are determined by the computer. Orders for capital you placed in the previous period are moved into the unfilled order backlog for the capital sector. Orders placed by the goods and capital sectors accumulate in the backlog of unfilled orders for each sector. The total backlog of orders is desired production for the current two year period, the demand you must meet.

Production itself is the lesser of desired production and production capacity. Production capacity is determined by the capital stock of the sector. Capital stock is decreased by depreciation and increased by shipments. You lose 10% of your capital stock each period. If capacity is inadequate to meet demad fully, available production of capital is allocated between the capital and goods sector in proportion to their respective backlogs. For example, if the backlog were 500 and the backlog for the goods sector were 1000, desired production would be 1500. If capacity were only 1200, production would be 1200 and the fraction of demand satisfied would be 1200/1500=80%. Thus 400 units would be shipped to the capital sector and 800 would be shipped to the goods sector. Any unfilled orders remain in the respective backlogs to be filled in future periods. In the example, 100 units would remain in the backlog of the capital sector and 200 would remain in the backlog of the goods sector.

The Long (economic) Wave Game was re-designed and developed for PC version. Logical continuation of the present work would be to link the model of transition to Next Generation Lithography with Long Wave Game to quantify, for example, an important aspect of macro-economic behavior: effects of semiconductor's industry (and, consequently, of IT's) economic policy on GDP growth.

LW-Game: Main Variables (PC-based version 2.0)

```
class Economy {
        private {
                #Capital stock
                variable _K

                #Aquisitions by capital sector
                variable _A

                #Aquisitions by goods sector
                variable _Ag

                #Deprecation
                variable _D

                #Order for capital sector, backlog
                variable _B

                #Order for goods sector, backlog
                variable _Bg

                #Backlog fraction
```

```
        variable _F

        #Production
        variable _P

        #Desired Production, P*
        variable _Ps

        #Production capacity
        variable _C

        #Model parameters

        #Capital orders: determined by subject of simulator
        variable _O

        #Goods orders: extrogenious variable
        variable _Og

        #Ed parameter tau, average life of capital
        variable _tau

        #Capital/output ratio
        variable _kco
}
constructor { {tau 10.0} {kco 1.0} } { }
```

4.1 Geography Factors. Case Study # 4:

No-nonsense Valley (Dynamics of Silicon Valley)

> the polis of Sparta was remarkable for the absence of walls …
> it despised walls precisely because it was the
> permanent open military camp of Spartans
>
> ***Max Weber,*** *Economy and Society*

4.1.1 Facts on Silicon Valley. Individuals.

I believe that the Max Weber's quote reflects somewhat both (seemingly) simplistic structure of the Valley and the intensity of its rhythm. According to a forecast (by Tom Lieser from UCLA Anderson Business School, September 1999) the Silicon Valley would be unable to deal with the problems of success: it is not expanding much neither to the south or to the east producing by this the highest – by far – home prices in the US. Because of that the average annual growth rate in financial and business services over the next 20 years will be half that of the last two decades. The sector, which includes high technology, has expanded by 7% a year since the late 1970s, and has become one of California's main growth drivers. After expanding at an annual rate of 3.5% since 1950 – twice the national average – overall Californian growth is likely to slow to little more than 2% in the next 20 years. However, Mr.Lieser concludes that Silicon Valley and Hollywood will remain pre-eminent in their fields because of their concentration of creative, financial and corporate power.

Core of Silicon Valley is Santa Clara County including significant portions of the neighboring counties of San Mateo, Santa Cruz, and Alameda. The Valley is a mix of relatively large San Jose, and small cities with tiny downtowns: Western Belt (mostly residential) – Los Gatos, Monte Sereno, Saratoga, Cupertino, Los Altos, Palo Alto (special because of Stanford University), Menlo Park (special because of Sand Hill Road with biggest in the world Venture Capital concentration), Redwood and Woodside; Center (business & residence) – San Jose, Campbell, Santa Clara, Sunnyvale, Mountain View, and Eastern Belt (business & residence) – Milpitas, Fremont, Pleasanton. It is a mix of simplistic (and somewhat depressing because of that) architecture with an excellent weather (however, with polluted, especially visible in August, air) and is nothing more than an unplanned, amorphous sprawl of freeways, low-built factories, shopping malls and unremarkable (but extremely expensive) suburban California houses.

By estimations of the Center for the Continuing Study of the Californian Economy (The Economist, 1997), GDP of the valley 2 million inhabitants is around $65 billion (much the same as Chile's 15 million people), with 6,000 high-tech companies with sales more than $200 billion a year. In 1997 Santa Clara county has 355 Internet hosts (permanently connected computers) per 1,000 people, twice as wired as any other county anywhere in the US. Average pay in the Valley (1997) was $43,510 (nearly double that if consider software industry only) vs. US average $28,040. Most visible technology leaders are Sun Microsystems, Hewlett-Packard, Oracle, 3Com, Applied Materials, KLA-Tencor, Netscape, Cisco Systems, and Intel (not too many outsiders: Microsoft, Dell, Texas Instruments, Motorola, and Micron). Local VC's control 1/3 of the US's and 1/6 world's venture capital.

Virtually every government in the world wants to create its own Silicon Valley (with the US itself trying hard to replicate elsewhere the Valley's dynamism: Silicon Desert (Utah), Silicon Alley (New York), Silicon Hills (Austin) and Silicon Forest (Seattle and Portland); the latest one is Silicon Corridor (Washington, D.C.)). Closest to the US came Taiwan, Israel, India, and Britain with the next tier in Cote d'Azur ("Europe's California") and Egypt's Pyramid Technology Park. Malaysia's Dr.Mahathir, for example, set aside 750 square kilometers south of Kuala Lumpur (and $40 billion) for its own version of The Valley: a brand new "multimedia super corridor" that will include an IT city of 100,000 people (I will consider both Malaysia and Singapore in more details later). I do believe that these efforts are going to be successful; according to one VC from California, Israel is eerily similar to his home beat: "Lots of geeks. Nobody wears ties. It's hot. We have the San Andreas fault; they have the *intifada*. It could be home."

In a sense (discounting the government involvement for now) the Valley is an "existential creation: nobody said 'lets build an entrepreneurial technological center' (according to Ed Zschau, Harvard Business School). However, one chain of events is considered to be among dominant: - Fred Terman (EE Professor, Stanford); - 1938, HP by Bill Hewlett and David Packard (students of F.Terman); - 1950's, Stanford's Industrial Park; then Shockley's laboratory; - 1957, first attempt by Arthur Rock (VC) to fund Fairchild Semiconductor (with consequent spin-off of Intel, Cypress Semiconductor, LSI Logic, and so on); - 1971, name "Silicon Valley"; - 1976, Apple Computer; - mid-1980, crisis (end of Cold War, memory is gone to Japan); - 1992, new boom (Cisco and Netscape era, with some glitch during the 1997-98 Asia crisis) with software, Internet, telecommunications, and mobile devices as a driving force. While the chain above is the base for popular (and true) legend, we would like, however, to list several more key individuals who are not publicized as frequently:

- A.P.Gianini, founded the Bank of Italy in San Francisco in 1904 and his Bank of America was the world's largest by the end of World War II
- Mr.Leland Stanford (California governor and U.S. senator, formerly, merchant prince and railroad baron, formerly driver of the golden spike) and Mrs.Jane Stanford took seriously Harvard's President Eliot remark that it would take at least $5 million to start a university
- Biotech pioneer Carl Djerassi who is now mostly writing from his home in Woodside after developing

the Pill in 1951.

- Douglas Engelbart, developed the computer mouse and headed the Stanford Research Institute's team which developed (as early as in 1968): the graphical user interface, windows-based computing, computer networking, hyperlinking, e-mail and video conferencing.
- Robert D. Ingle (president and executive director of the San Jose Mercury News from 1981 until 1994) was the guiding force who transformed the newspaper into one of the most respected dailies in the country reflecting the Valley face with high precision.
- James Clark is working hard to offset his controversial image with astonishing $150 million gift to establish J.H.Clark Center for Biomedical Engineering and Sciences at Stanford. The place will link the disciplines of medicine, biology, chemistry and engineering, and could transform Silicon Valley into Gene Valley in the next century.
- Gib Myers, senior partner with Myfield Fund, a VC firm in Menlo Park, established Entrepreneurs' Foundation which will fund non-profit agencies through the stock options of the participating pre-IPO companies. The Foundation states that "we will develop an exciting new philanthropic model for supporting community organizations and their leaders".

Such pattern of behavior is observed among many talented and successful Valley's people (for example: John Sobrato/real-estate; Tim Draper/VC; some partners at the VC group Kleiner Perkins; Jim Barksdale/FedEx/Netscape/VC).

Profiles of Real-Estate Developers. According to Prof. Saxenian: "the beauty of Silicon Valley is that culture and the structure reinforce each other" (Saxenian, 1994). One slice of the structure is the interaction between the enormous concentration of talent and knowledge with no-nonsense real-estate policy and practices (vs. Europe real estate, for example). Top real estate people are very secretive and don't talk to the press much; however, some information is available.

Carl Berg operates real estate company Berg & Berg which controls 5 million square feet of prime Valley commercial real estate (prices are comparable with Manhattan's) and almost 200 acres of raw land right in the heart of where the digital revolution is taking place. Berg is sensitive to technology development needs and (after the serious due diligence) would agree to swap space for stock.

Educated in corporate finance, Berg is excellent at the getting buildings build, hiring contractors and arranging financing. His pure professional touch is quite precise; knowing that the Valley was getting overbuilt, he stopped buying and building from 1984 until 1994. That year he noticed that both payrolls and product demand were rising at the companies that rented his buildings. While others developers were still licking wounds from late 1980s-early 1990s, Berg bought 100 acres of prime land and several buildings. Those purchases tripled in value by middle of 1998.

Berg's drab glass-and-steel prefabricated structures (called "tilt-ups" in the Valley's jargon) take just a few months to put up and are home of R&D complexes of companies like Apple, Cisco and NEC. Overall, however, his buildings are low-profile structures that contrast sharply with the rival property put up by developers like Dick Peery and John Arillada. Berg's buildings are plain vanilla tilt-ups, some modeled on 20-years old architectural plans. Established outfits may prefer the more expensive places, but struggling startups like Berg's relatively low rents and proffered finance. Most of Berg's buildings are one story. According to Berg, the high-end buildings are the ones you are going to lose money on because, in a downturn, it's almost impossible to lease a vacant top floor to another tenant. I hypothesize that it might be changing because of the critical shortage of free space and Silicon Valley will "grow up" with multi-store buildings in next 10-15 years.

While Berg's approach worked for him, Arillada/Peery alliance did well during the 80s/90s downturn mostly because of sophisticated financing (low-leverage and self-financing structures) and long-term leases. They definitely trying to offset the Valley's previous architecture of 1960s, which is characterized by some as coming "in two styles: ugly and uglier." In a sense they are continuing traditions of Joseph Eichler, visionary developer, who beginning in the late 1940s put up 11,000 uniquely designed single family homes in places such as Palo Alto, Sunnyvale, Mountain View, Cupertino and San Jose. With their walls of glass, atriums, flat rooftops and radiant-heat floors, "Eichlers", as they came to be known, defined a new California-style, modernist aesthetic focused on indoor-outdoor living.

Like with any of local developers, picture is not at all rosy. While Sun's Scott McNealy is preaching Berg (he calls him "one of the structural underpinnings of the Valley"), the later has a history of fighting with VCs as an angel and throwing Steve Jobs out of his office in late 1970s, calling the plan for a "plastic computer" a "stupid idea". In 1979 he broke up partnership (to spend more time on VC/angel-type activities) with John Sobrato with whom he worked since 1963.

Carl Berg/John Sobrato team (before the split) was amazingly similar to Peery/ Arillada one: charming salesman backed up by the rigorous financier. Currently Sobrato (from a well-connected California real-estate family) runs a firm, which became a top choice of elite technology companies to design, build and manage their sprawling buildings and campuses. Sobrato oversees12.5 million square feet of commercial space including Apple, Amdahl, HP, Netscape, Yahoo, Siemens, Cisco, Nortel, Applied Materials, Hitachi, and Siebel Systems. In 1996 the billionaire entrepreneur started a Silicon Valley foundation that funds programs in community development, education, health and human services, and youth assistance.

Another example is the four generations of Swanson family which is active in the Valley real estate development since 1926 when Carl Swenson arrived in San Jose and built DeAnza hotel for about $172,000. They were involved into the development of Moffett Field and Ames Research, Willow Glen and San Jose high schools, IBM campus, and the Mercury News plant. Tom McEnery (San Jose mayor, 1983-1990) and Frank Taylor (ran San Jose Redevelopment Agency from 1979) are largely credited for the development of downtown San Jose as the formal capital of Silicon Valley.

4.1.2 What Makes The Valley Special ?

Role of government and military needs are undeniable in the Valleys set-up and development of its initial structure. From the other side, the Valley's success in just about any area turns out to be based on either some liberalizing legislation or the absence of any legislation at all. Definitely America's bankruptcy and patent laws are helpful. Another one is California's tax structure, which has historically treated capital gains more generously than income. Special one is the Californian law (unlike its Massachusetts equivalent) regards "post-employment covenants not to compete" as unenforceable. That makes it mach harder to tie down staff. Even law firms behave differently; prominent in the Valley Wilson & Sonsini got criticized by the American Layer magazine for treating labor laws too freely.

The Valley does business differently; after all Silicon Valley may be seen (The Economist, 1997) "as a way of doing business, with a product that happens to be technology". In building clusters, social and political factors, such as tolerance to immigrants, often matter far more than either technology or economic clout. Silicon Valley most important contribution may well be organizational, not technological. It is curious how "The Economist" determines that "Silicon Valley displays remarkable lack of vulgarity compared with (now poorer) New York or Los Angeles". It means limited adherence to Tiffany (which moved into the Stanford Shopping Center just recently), driving "an engineer's car such as a Lexus or BMW rather than a Ferrary" and house in Atherton (where the average price was over $1million even in 1997, double the figure for Beverly Hills).

The latest trend is emphasis on the importance of distribution channel. Emerging pattern is somewhat converging to the Hollywood studio system, with the big companies still responsible for some of their creative output, but acting mainly as bankers-distributors for smaller companies' ideas. Spreading the bets reduces risk for big players. Cisco Systems are leading the way establishing the trend and positive norms, closely followed by Microsoft and Intel (each having own culture). Well, when I was writing these lines, literally what happened (February 3, 2000, 8.30 pm): 1. I was scanning through the Web for a break – Numerical Technology, Inc. (one of my former competitors supported by Mohr, Davidow VC group) filed for an IPO (February 2, 2000) and successfully went public two month later (when I was editing the text); 2. Finle Technologies, Inc. (competitor of my previous company) was bought by KLA-Tencor. This is not to say that in six years only I myself went through the IPO with one company (TMA) and was successfully acquired with another one (OPC Technology, Inc.).

Why is the Valley so dynamic (I avoid term "successful" because of difficulties with the definition of success for the entity)? Traditional (historical and geography related) factors are supportive there: - size and flexibility of the labor pool; - the breadth of the network of suppliers; - access to venture capital, legal and finance services; - excellence of Stanford and Berkeley as educational and research institutions. However, UC Berkeley's Professor Saxenian points into the culture and structure of organizations involved as the most critical factor (Saxenian, 1994).

Famously de-centralized West companies perfected Schumpeter's "creative destruction" in the form of "flexible recycling". Richard Tedlow (Harvard Business School) underlines the following lethal factors for a cluster: self-absorption with the most current competition; forgetting what your customers want; or some kind of a serious outside shock (for example, "technological discontinuity or a political event such as a war"). For example, I discuss in this work microlithography role as an example of a technological discontinuity with possible broad implications. Such technology turning points are never obvious and devilishly difficult to spot. For Studebaker it was not at all clear 100 years ago that they should switch from making horse-drawn carriages to making cars (because in the previous five years New Yorkers had bought 350,000 carriages and only 125 cars).

Once heavily relied on semiconductors, the Valley's networked economy was able to successfully re-configure allowing capital, ideas and people to be reallocated after the right identification of new trends and markets. The Valley responded to the mid-1980s crises by revamping its own manufacturing operations, outsourcing many of them, and diversifying into other areas, particularly software. It is a huge market (~ $120 billion in 1997) which covers a maze of different industries, including applications, operating systems, databases, the Internet, computer-aided design and networking. Moreover, the diversification is in at least seven different industries, including biotechnology, telecommunications, and environmental science. And, of course, the local cluster of VC-lawyers-accountants-banks is a very special thing itself and is doing well by any standards. Many would argue that local big law firms – such as Brobeck Phleger, Gunderson Dettmer, The Venture Law Group and especially Wilson Sonsini Goodrich – are at least as powerful as venture capitalists. I will repeat again after Professor Saxenian: "the beauty of Silicon Valley is that culture and the structure reinforce each other".

Being at MIT, I do not appreciate Professor's Saxenian tone of consistent hammering and aggressive stand on Route 128/MIT and contributing into the strange East vs. West Coast picking on each other. However, she has a point emphasizing common origins of initial successes of both regions: research based in top universities (MIT and Stanford) and largely applied for military and aerospace purposes through government contracts. California were and still more component/ small_systems-based vs. East Coast more final_product/large_systems-based. My only note into the famous Route 128/MIT/Harvard vs. Silicon Valley/UC Berkeley/Stanford discussion is that Boston area might be a victim of the Krugman's "shadow" of well-developed larger East Coast region as a whole vs. attractions of mainly agricultural California which has beaches as least as good as Cape Cod's ones.

Instead, I would like to emphasize much more the notion that contribution of the companies and individuals, regional-bases cooperative interactions are very significant for understanding why is that the Valley is still so consistently impressive. Two stunning executive's quotes from the Professor's Saxenian book put it the best:

> 1. "Here in Silicon Valley there's far greater loyalty to one's craft than to one's company. A company is just vehicle that allows you to work. If you are a circuit designer, it's most important for you to do excellent work. If you can't in one firm, you'll move on to another one."
>
> 2. "In the early days of the semiconductor industry it was not uncommon for production engineers to call their friends at nearby competing firms for help when quartz tubes broke or they ran out of chemicals".

Only thing that I can comment on is that the spirit expressed in both quotes is still very much alive in the Valley and was witnessed by the me consistently. As a result in the intensely dynamic environment "specialized producers [and individuals, VB] learn collectively and adjust to one another's needs through shifting patterns of competition and collaboration".

One of possible lists of the Valley advantages (on which I would like to comment) includes:

Tolerance of failure: it is widely perceived as such but author (being very lucky in the Valley so far) has reservations about it. I am more comfortable with the Russ Siegelman (partner at the Kleiner Perkins VC group) who is saying that failure is not good nor bad in the Valley but he does not advise to collect too many of them.

Tolerance of "treachery" which is really collaboration: it is true that the place is a strange mix of rampant individualism and collaboration: staff are borrowed, ideas shared, favors exchanged

Risk-seeking: turn problem into opportunity. According to Tim Draper (well-known VC), typical portfolio of 20 companies has five portions. Four will go bankrupt, six will stay in business but lose money, six will make a modest return, three will do well and one will scoop the jackpot.

Reinvestment in the community: according to Howard Stevenson (HBS), many clusters die because their founders (or founders' children) reinvest their fortunes elsewhere. So far in the Valley, most of the money made of the technology industry has gone straight back in, either via people starting their own companies or via "business angel" investors.

On the other side, it is very popular to predict the cluster's failure from within. While infrastructural (traffic and price of real estate) and pollution problems are the most significant, they are not much different from other high-tech (real-estate-wise, such as Boston) or highly-congested places (traffic-wise, such as Seoul or Bangkok). The most serious charge is in not giving back to community more substantially. However, the strong local re-investment patterns have been discussed above; it created new jobs. Sure, the Valley needs service and maintenance jobs, which are not as highly paid. But again these are fundamental society problems not specific to the location. Perhaps, in future the Valley will lead the trend to re-structure these low-paid service and maintenance jobs.

Passionate analyses of the Silicon Valley started to appear since its beginning. It is curious to note that even 15 years ago very intelligent people were extremely and very emotionally concerned about overpopulation, traffic, and stress induced by the Valley (Malone, 1985). In his excellent book Mr.Malone insists that the ruthless style and spirit of Dr. Shockley dominate the Valley. I relay easily to Mr. Malone's emotions and penetrating precise captions of the Valley's specifics, for example, the moving description of the Fremont Avenue nearby which our house is situated. However (and it heavily depends on luck and attitude), I would disagree with Mr.Malone's tone and suggest that the Valley, being a very competitive place, maintains the style introduced by Hewlett and Packard with their "unusual sensitivity to feelings of others" at least as consistently and successfully.

4.1.3 Politics and Silicon Valley

> "In the last presidential election campaign (1996), references to a high-tech future were vague and perfunctory, and Silicon Valley or Seattle were not particular ports of call. Washington, DC and the geeks existed in different worlds" (The Economist, 1999).

Things have changed significantly since then. According to the Center for Responsive Politics, a Washington watchdog group, by the end of June 1999 contributions from the computer industry were already three times those given to Bill Clinton and Bob Dole combined during the 1996 campaign. Of the $843,000 direct industry contributions do not include these from telecommunications and biotech, nor the millions of dollars the candidates have received in fund-raisers organized by computer executives and venture capitalists. Among the active participants are: Michael Dell, James Barksdale, John Chambers, Bill Gates, T.J.Rodgers, Scott McNealy, ... In addition, the computer industry gave $8 million to congressional campaigns in 1998, more than twice what it gave in 1994. High-tech businesses have to work in a world of taxes, regulations, lawsuits and legislation; they need politicians as much as politicians need them. People realize that government is not always force for evil. Public sector may help to solve the social problems that now plague the high-tech industry: the shortage of educated labor, the over-strained transport system and the rapidly growing gap between rich and poor.

However, there were no (and still not much) consensus what to lobby for. This is because the interests of hardware companies are not necessarily those of software or e-commerce companies and all together mixed in competition. This is changing because: 1. high-tech industry does not want to be exposed to litigation like these sponsored by California trial layers in 1996; 2. the government has the power to turn off one of the Valley's most important resources - the supply of foreign brain; 3. The government has the power to restructure the entire computer industry (Microsoft and, possibly, Intel cases). The Technology Network (TechNet, with Silicon Valley & Austin offices, founded in 1997) – a political action group, CapNet (Washington, DC) – lobbying group, Joint Venture – Silicon Valley, and the latest think-tank New America Foundation (Washington, DC, largely funded by Silicon Valley) are some of the examples which involve hundreds high-tech bosses.

Andy Grove recently suggested that Internet is about to wipe out entire sections of the economy and America may see repeat of social disaster that followed the mechanization of agriculture. According to Eric Schmidt (Novell's boss), the high-tech industry is beginning to realize that it is doing nothing less than "defining the economic structure of the world". And with that realization comes a heavy sense of responsibility. People are looking outside cyber-land for the answers about the future of society and government. At the same time, the intellectual and policy establishments are increasingly looking to the Valley, and other high-tech corners, for clues as to the shape of things to come.

From the other side, many feel or realize that increased information flows and interlinked networks inexorably shifting power from organizations to individuals decentralizing authority [and accelerating innovation]. Computers are shifting balance of power from collective entities such as "society" or "the general good" and handing it back to those whom governments once referred to as their "subjects". The cult of individual effort, completely detached from the old hierarchical or social structures can be found everywhere in Silicon Valley. The Valley takes the idea of individual merit extremely seriously and exists "in a ruthlessly entrepreneurial environment".

Further I will quite a few times refer to views of Manuel Castells who enjoys a growing reputation as the first significant philosopher of cyberspace dealing with transition of capitalism from "Industrial" to "Global Informational" stage. Three volumes of his "Information Age" are about the way in which global networks of computers and people are reducing the power of nation states, destabilizing elites, transforming work and leisure and changing how people identify themselves.

He very convincingly quotes Alain Touraine in regard of the issue of "shifting power":

> Power used to be in the hands of princes, oligarchies, and ruling elites; it was defined as the capacity to impose one's will on others, modifying their behavior. This image of power does not fit with our reality any longer. Power is everywhere and nowhere: it is in mass production, in financial flows, in lifestyles, in the hospital, in the school, in television, in images, in messages, in technologies ... Since the world of objects escapes to our will, our identity is no longer defined by what we do but by what we are, thus making our societies somewhat closer to the experience of so-called traditional societies, searching for balance rather than for progress. Such is the central question to which political thought and action must respond: how to restore a link between the excessively open space of economy *[which makes a lot of sense to economists, VB]* and the excessively closed, and fragmented world of cultures ? ... The fundamental matter is not seizing power, but to recreate society, to invent politics anew, to avoid the blind conflict between open markets and closed communities,, to overcome the breaking down of societies where the distance increases between the included and the excluded, those in and those out.

Professor Castells himself underlines preeminence of social morphology over social action and points to the material basis of Information Technology which supports the phenomenon of under which "the power of flows takes precedence over the flows of power".

I would like to finish discussion of Silicon Valley by agreeing that it might be indeed displays the patterns of a living creature (Malone, 1985):

> ... the Valley is more than just another business enclave. Rather, more than any industry in history, it is a self-contained, living entity. Claiming life for a bunch of buildings might seem to be anthropomorphic, but only because the analogy has never been so apt. Silicon Valley, more than any past industrial community, from the sixteenth-century Hanseatic League to twentieth-century Detroit, fulfills many of the biological requirements to be considered "alive". It has defined boundaries, is self-perpetuating and reproducing and has predictable behavior - including the instinct for self-preservation.

It might be a good example to represent suggestion by Dr. Adam (1990) to choose "for understanding human organization: whether we liken it to dead matter and the human creation of the machine, or whether we think of it as a living, self-replicating entity". At least, more conservatively, we, certainly, can view it as a firm (Brown, 2000; Kenney, 2000).

4.2 Geography Factors. Case Study #5:

Location, location, location... Belarus as the European cross-road.

> Mobile Digital Communications (MDC) regards Belarus's favorable geographic location as a more important factor than concerns about the country's current luck of prosperity.
>
> *EIU Country Report, 2nd Quarter 1999*

Introduction

MDC is the European GSM network operator. I tend to share the optimistic position of MDC and to adopt a comparison-type perspective on Belarus: externally – with Singapore, Malaysia and China; internally – with Baltic countries (Latvia, Lithuania, Estonia), Russia, Poland and Ukraine. Data from well-known sources and author's personal observations will be used for the analysis. Significant portion of the analysis is presented through the prism of the author personal view (who is Belarus citizen) projected on his intensive international business experience (flying around the globe from headquarters of various companies in Silicon Valley).

Basic Data

Land area

207,600 sq km

Population

10.18 m (1998 estimate)

Main cities
(population as on January 1996)

Minsk (capital)	1,672,000
Gomel	501,000
Mogilev	367,000
Vitebsk	356,000
Grodno	302,000
Brest	250,000 (est.)
Baranovichi	165,000 (est.)

Languages

Belarusian, Russian

Climate

Continental

Weights and measures

Metric system

Currency

Belarus rubel (BRb), introduced in 1992. BRb=100 kopeks. Average exchange rate in 1998: BRb 46295 : $1. The official, central-bank-controlled rate on April 6th 1999: BRb 239,000 : $1.

Time

Two hours ahead of GMT

Geographical location

Geographical center of Europe (see the map)

Fiscal year

Calendar year

Public holidays, 1999

January 1st (New Year), January 7th (Orthodox Christmas), March 8th (International Women's Day), May 1st (Labour Day), May 9th (Victory Day), July 3rd (Independence Day), November 7th (October Revolution Day), December 25th (Roman Christmas)

4.2.1 Historical background – business traditions of Belarus

5th – 12th century. To illustrate the point about the Belarus business traditions, I would like to present recently discovered history about my last name (if I want at all my name to be associated with something then I would choose the story, name, and actions of the ancient Belarus craft master Lasar Bogsha). Several years ago, my friends (linguists) in Belarus have pointed out to me one of their professional observations. They were positively convinced that my quite rare last name matched with a name in our country's ancient history (XII century). The individual last name was 'Bogsha' which, by solid opinion of my expert friends, would spell as 'Boksha' by now (modern Belarus language tends to be 'softer'; so more solid 'g' transforms to softer 'k'). Well, during my last visit over there, after ignoring the issue for a couple years, I finally asked these nice people to give me more details and facts, which they gladly did (Mihnevich, 1994; Jurayski, 1967; Shakyn, 1984).

History brings us down in time to the Polatsk's princess Efrosiniya (1110 – 1173). Polatsk is the most ancient city on Belarus territory and for all eastern Slavs as well (excavations have proven the existence of a settlement there as early as in the 5th century AD). The beautiful, wise and educated princess rejected marriage and lived alone in Sophia cathedral, spending her time writing and publishing books. Princess Efrosiniya Polatskaya influenced significantly cultural life in ancient Belarus. She founded and leaded the Savior-Efrosiniya convent in Polatsk. The Holy Savior Church, part of the convent, is a masterpiece of the ancient European architecture. It still stands and is considered the most precious monument of early Belarus architecture.

Figure 4.2.1 "Chase" – Belarus emblem for almost 800 years. Cross of St. Efro-siniya is on the warrior's shield.

In the 1161, the outstanding master-jeweler Lasar Bogsha created at Efrosiniya behest the famous Cross of St. Efrosiniya that she presented to The Holy Savior Church. Splendid, gem-studded six-armed golden Cross is decorated with enamel miniatures and expensive precious stones (see bottom picture). As a piece of art, the Cross is at the same level as the best samples of XII century art from Byzantine and West Europe. Of exquisite beauty, the relic survived centuries of turbulence and was the nation symbol (see top picture) for almost 800 years, until 1941. Cross mysteriously disappeared after World War II started and now assumed to be somewhere in the U.S. private collections.

The fine print is another very specific and distinguished feature of the Cross. The writing is one of the firsts of very few old Belarus business documents. It is stating date, amounts of materials used, expenses and where the Cross belongs to. The writing attracts attention because it represents the firm rules and traditions of business conduct in ancient Belarus. Both content and language specifics support it. The text still requires more detailed research and analysis, but even now, its political and historical-cultural sense is obvious. It demonstrates political independence and cultural blossoming of Polatsk county – early predecessor of Belarus, many towns and cities of which adopted Magdeburg law common among the members well-known European Hanseatic League.

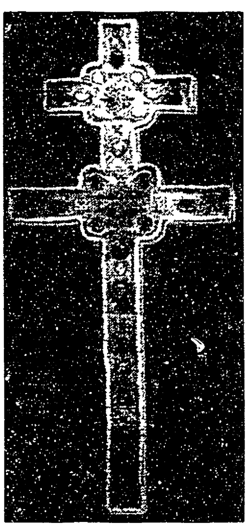


Figure 4.2.2 Cross of St. Efrosiniya. Created by Lasar Bogsha in 1161.

Whether or not I am personally related to the ancient master Bogsha might not be as important; what valuable for me is that <u>*the story represents the nation and its identity*</u>. It is symbolic that historians consider the writing on the cross as the important business document. Talented and skillful people of Belarus had always recognized a beauty and have had a strong sense of reality, being able to combine two together.

Modern times. Three of the most important events of modern Belarus history are: - World War II (during which Belarus lost an estimated 25% of its population and 80% of its infrastructure); - post-war industrialization (see figure on the left, technology level), which brought rapid urbanization and a sharp rise in living standards; - and the return to independence in the 1991, which freed the nation's spirit again. Chernobyl's nuclear disaster in 1986 with more than 70% of radioactive fallout of which deposited on Belarus territory, is devastating for the country but is the subject for separate analysis and is out of the scope of this work.

4.2.2 Political background, constitution, and institutions

Population by nationality (%), 1989 census

Belarus	77.9
Russian	13.2
Polish	4.1
Ukranian	2.9
Others	1.9
Total	100

Currently, the Republic of Belarus is a titular democracy with a substantial power vested in the presidency. The president appoints half the members of the Constitutional Court, the chairman of the National Bank of Belarus (NBB, the central bank), the state prosecutor-general, the heads of the Supreme, Economic and Constitutional courts, and the head of the Central Electoral Commission. The lower house of the National Assembly (parliament), the House of Representatives, comprises 110 members (elected in 1995). The upper house, the Senate, consists of 60 members, six of whom the president appoints directly, with the remainder elected by popular vote.

The constitution invests executive power in a government (Cabinet of Ministers) appointed and controlled by the president. The president appoints the prime minister with the consent of the House of Representatives. Local government comprises a system of councils whose members are elected by popular vote for four-year terms. The president appoints the heads of local councils and other regional administrations.

Results of the 1995 election to the Supreme Soviet

Party	Seats won	% of total vote
Communist party of Belarus	42	21.2
Agrarian Party	33	16.7
United Civic Party [a]	9	4.5
Party of People's Accord [b]	8	4.0
Belarus Social-Democratic Union (Gramada) [a]	2	1.0
Party of All-Belarus Unity and Accord [b]	2	1.0
Other parties	7	3.5
Independent deputies	95	48.1

[a]Democratic orientation. [b]Center-left orientation.

The money supply. As a result of the credit expansion policies, the rate of monetary expansion accelerated rapidly towards the end of 1998, fueling both high levels of inflation and rapid nominal currency depreciation. The monetary policy was tightened in 1999 (according to the 1st quarter data): M2 increasing by 19%, compared with 35% in the fourth quarter of 1998 and 26% in the third quarter, and M3 increasing by 21%, compared with 121% in the fourth quarter of last year. It is partly a response to the recent rapid increase in inflation and an attempt to attract IMF assistance. Despite some positive signs in the first quarter, the already high target for money supply growth in 1999 is likely to be exceeded, especially as higher than expected inflation will necessitate increased emissions in response to the need for higher minimum wages and for greater subsidies to budget-financed organizations.

Belarus government understands the dangers of hyperinflation and is likely to respond to further IMF pressure by tightening its credit policy somewhat. Over the next 12 month the country is likely to avoid hyperinflation, but will face average yearly inflation rate higher than in 1998. Belarus will continue to display signs of hidden inflation due to extensive unrecorded black-market activity, and latent inflation as suggested by continued consumer-good shortages.

Economic performance. Belarus experienced a deep recession between 1990 and 1995, including an annual decline in real output of more than 10% of GDP in all three years between 1993 and 1995. Nevertheless, the contraction proved less severe than in other former Soviet republics, because of preferential arrangements with Russia enabling Belarus to write off some of its energy bills, and because of the tight grip with which the government runs the economy. In 1996 Belarus moved out of recession with an increase in real output of 2.8% of GDP in 1996. Since then real output accelerated to 10.4% of GDP in 1997 and 8.3% of GDP in 1998. Then came Russian economic turmoil of August 1998 dragging Belarus down again.

From the macroeconomics viewpoint, I considers it as an interesting exercise to compare Belarus stabilization's efforts with the policy of Singapore, Malaysia, and in some sense with the modern policy of China. Singapore and Malaysia will be analyzed in the next chapter.

4.2.3 Development of Information Technologies in Belarus

Belarus is an attractive market for the U.S. and Western Europe because of its 10.5 million (bigger than Sweden's) population and availability of an highly educated workforce. The country always has been recognized in the former Soviet Union as the republic with the most educated population. Largely because of its skillful and capable labor, it carried the most knowledge-intensive industries such as chemical, microelectronics, optics, and mainframe computers, supplying all the Eastern Europe and far abroad.

This section represents data and experiences of my own working in semiconductor industry of Belarus in 1982-1993 (blossoming period of microelectronics worldwide) and also latest material compiled from the essay by Dr. Alexander Rzevskii (Rzevskii, 1999).

Belarus – major USSR and CIS center in computer engineering and semiconductor industry. Among all the republics of the former USSR Belarus has been always characterized by the highest concentration of industrial enterprises producing electronic computer and its components as well as advanced and relatively independent computer research and development infrastructure. A great amount of specialists engaged in development, manufacturing and maintenance of computers and computer systems have been working in various R&D centers throughout the republic.

In 1960 the production of universal medium sized computers of "Minsk" series was launched on Minsk Electronic Computer Plant named "Zavod Ordzhonikidze". In 1964 the plant developed and initiated the production of the second generation of the computers based on transistors - "Minsk-2". In the following years these systems became commercially available on a large scale – about 1200 systems of "Minsk-2" and its modifications were delivered for the national economy of the USSR. In 1968 the first samples of the most popular computer of the second generation "Minsk-32" were assembled. Universal multitask system "Minsk-32" designed for solution of research, technical, economical problems played an important role in the process of computer application to the national economy of the USSR. Practically all computing centers in the USSR were equipped with this computer. More than 3000 computers of this model were produced in total. In 1970 the group of Belarussian researchers and engineers was rewarded by the State Premium of the USSR in the field of science and engineering for the development and application of the computers of "Minsk" series. "Minsk-32" model was the first one in its class the State Quality Mark was awarded to in 1972. At the same year the Scientific Research Institute of Electronic Calculating Machines was established on the basis of design office of Minsk Electronic Computer Plant. Since 1971 the plant launched the commercial production of models of the Unified System series of computers, commonly referred to as Ryad. These computers based on third generation technology represented a major leap in the Soviet hardware capability. Like western third generation computers, the Ryad was a modular series designed to provide compatibility throughout a number of layers of users.

New stage in the evolution of computer sector in Belarus was related to the personal computers. In the middle of eighties the specialists of Scientific Research Institute of Electronic Calculating Machines in Minsk developed personal computer of Unified System US-1840. In 1986 Minsk Electronic Computer Plant has initiated large-scale production of the PC available to the general public.

The electronic stuffing of this and following models was completely based on domestic microelectronic components. For the relatively short period of time five other models were developed: US-1841 and US-1842 (the analogs of IBM PC/AT), US-1849 and US-1851 (AT-286), US-1843 (AT-386). The annual production of PCs on Minsk Electronic Computer Plant reached of 40000 units. These models became the most widely adopted domestic PCs in the USSR. Owing to the comparatively high reliability and compatibility with western standards the PCs of US series produced in Belarus expelled the least advanced competitors such as "Iskra" and "Agat" developed and assembled in Russian Federation and Ukraine.

It is worthwhile to note that a significant role in the successful competition of computer systems produced in Belarus on the All-Union market has been played by INTEGRAL Research and Production Corporation – world-class (see Figure 4.2.3), enormous in size facility; the biggest and most advanced semiconductor manufacturer in the former Soviet Union. At present time the corporation includes five plants in Minsk and four specialized design departments located in different regions of Belarus ("Isotron " in Lida, "Zapad SSD" and "Tsvetotron" in Brest, "Kamerton" in Pinsk). Under new political and economical conditions INTEGRAL made successful efforts for conversion and diversification of production. By extending and updating the microelectronic components and producing new high technology goods of its own design, INTEGRAL today is one of the largest semiconductor manufacturers on the whole territory of the former USSR and is internationally recognized.

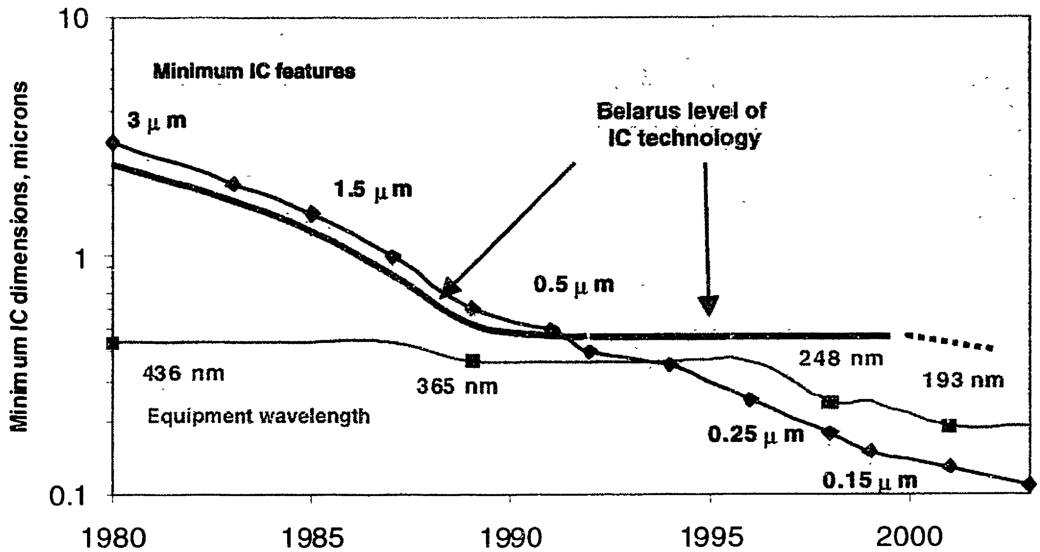


Figure 4.2.3 Progress of microelectronics worldwide reflected through the advances of microlithography. Belarus' microelectronics (Integral & KBTEM) led the technology development of the Soviet Union.

Despite the initial success of domestically made PCs due to its low cost and wide availability, for the period of Gorbachev's reforms and especially during post-Soviet years domestic PCs were gradually substituted by western designed ones. It became possible because of much emphasis has been given to forming Joint Ventures with western developers and manufacturers in computer sector. Nowadays Joint Ventures do play a major part in supplies of IT to the common market of all the former Soviet republics. A number of JVs with partners primarily from US, Japan, France and Germany as well as domestic enterprises successfully act on the computer market of Belarus with special emphasis being placed on PCs. Among JVs, the most representative are BelHard (official distributor of Hewlett-Packard Corp.), BelABM (official distributor of Fujitsu Inc.), Microsystems (dealer of Lexmark peripherals), and some others. The most large-scale domestic manufacturers of personal computers being assembled on the base of components primarily imported from the countries of South-Eastern Asia are Dainova, NTT, Computers&Peripherals, West, and some other companies.

Even today, following traditions Belarussian manufacturers of PC and peripheral devices compete in quality and innovation with the much more powerful companies from Russian Federation.

Computer science and engineering education in Belarus. The academic education in Belarus is traditionally oriented to provide a broad-based technical education. According to a press-release of

Ministry of Statistics and Analysis of Republic of Belarus the total amount of undergraduate students in the institutes of higher education by the beginning of 1999/2000 academic year was about 228 000 and among them more than 50 000 students of technical specialties (the population of Belarus is currently about 10 millions). Such a tendency when the amount of students getting technical education averages 20-25% of the total number of undergraduate students is a characteristic of a five recent years. However, in the middle of eighties and in the beginning of nineties the percentage of the graduate students with technical education was even higher, because of significant increase of the number of applicants for economics specialties in the recent years. Among nearly 12 500 student graduating every year from higher education institutes throughout the country more than 700 individuals receive M.S. degree in computer science, about 1000 have M.S diplomas in mathematics and applied mathematics.

Computer networks and Internet projects in Belarus. A great number of global networks and information centers differing in organization and technically operates today on the territory of republics of CIS including Belarus. The most advanced and large network is BELPAK – official provider of the Ministry of Communications of Belarus, which possesses a national character status. This network operates using X.25 protocol, has powerful technical support and offers a wide spectrum of universal service. BELPAK is oriented mainly to state organizations, large industrial enterprises and commercial companies. All the other networks use communication channels and basic service of BELPAK network for access to information resources outside Belarus. Among the other networks the most developed are the following ones.

BASNET – the official network of the National Academy of Sciences of Belarus offers e-mail service and access to international networks.

UNIBEL – the nonprofit network combines the leading scientific and educational organizations of Belarus. The main purpose of the network is to provide nonprofit social organization with the access to world community of Internet networks.

Sprint – the international commercial network with quite wide spectrum of services. This network has wide spread and well-organized structure on the territory of republics of CIS. The network is oriented to the state organizations, banks and large commercial companies.

EUNet/Relcom – the international commercial network offering e-mail and teleconference services, access to Internet and Usenet, etc. The network is quite popular on the territory of CIS, as well as in Belarus, because it is oriented basically to middle class of enterprises and commercial organizations, although scientific and educational organizations use its service successfully.

The popularity of this network is based primarily on the comparatively low prices and quite acceptable level of service.

Solam Teleport – the powerful commercial network provides access to networks supporting protocol X.25 and to Internet. The network has developed capabilities to interact with different information environments and to offer service of access to information resources in "on-line" mode.

GlasNet – the international public nonprofit network offering mainly e-mail service. Only one small communicational center with limited amount of users operates in Belarus.

BASNET and UNIBEL networks provide a wide spectrum of services and support protocols that meets to requirements of the scientific and education system in Belarus as well as corresponds to the accepted world standards.

Summary.

I conclude that:

1. Belarus deserves (and needs) attention of serious investors.
2. The conclusion above is based on country's historically rich business traditions and recent (20^{th} century) exceptional track record:
   - in the technologies of the 4^{th} and 5^{th} economic waves: advanced microelectronics, optics, heavy vehicles, chemical industry, mainframe computers
   - ability to handle (and abandon with dignity) nuclear weapons
   - country was one of the founders of the United Nations
3. Modern Belarus commercial market with educated and skilled population of more than 10 million people is in its initial stage of development.

Vos' yak cyaper perada mnou	The place arise in front of me
Ystae kytochak toi pryigoja.	In beauty and reality.
Kryinichki vyzen'kae loja	With narrow creek
I elka y paryi z xvainou	Besides the trees,
Abnyaushyis' cesna nad vadou	Which hug each other being freeze ...
Yak maladyiya y chas kaxannya	Like groom and bride
Y aposhni vechar rasstavannya.	Before the leave for longer journey ...
Yakub Kolas, *New Land, 1927*	*Translated by V.Boksha from Belarus language*

4.3 Geography Factors. Case Study # 6: From Operating Country Like a Clock to Mode of Partnership ?

Status, dynamics, potential and limitations of the US Venture Capital model implementation in Singapore and Malaysia[1].

As soon as we know what needs to be done – it will be done

***Wong Ann Chai**, Singapore Ministry of Defence*
Executive Program,
MIT Sloan Fellows, Class'2000

Introduction

I believe that the main title of the chapter is applicable <u>both</u> to Singapore and Malaysia. While, obviously, with different speed and from different conditions, they are impressive performers able to think fresh and to re-construct themselves.

Overall goal of this chapter is not so much to crunch numbers (which are as impressive) but rather to build my personal **vehicle** for future work (possibly, including Singapore, Malaysia, and my country, Belarus, at some point as well) with strong **pointers** of structural understanding and potential to extend and deepen them as we go.

I consider Venture Capital partnerships as another specific example of true work together and "shared best practices" (which has been discussed in regard to Silicon Valley, Chapter 4.1) inferred by the development of Information Technology. I this chapter I am trying to understand:

- are these "shared best practices" transferable ?
- who is able to adapt them ?

I am fascinated with the elegance and overall efficiency of the maturing US Venture Capital model. However, I strongly agree that it is not clear "the extent to which the U.S. model of venture capital investment will be transferred into foreign markets" (Gompers, Lerner, 1999). I wanted to understand better the opportunities and limitations for VC business in Singapore and Malaysia, partly, because of my personal familiarity with the area from business traveling and extensive work with Singapore high-tech industry (and its spin-offs) as my customers, in particular, Tech Semiconductor and Chartered Semiconductor.

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[1] This chapter is largely based on: *Boksha, V.V. May 2000. Final Project. Course: Venture Capital and Private Equity. Professosr Joshua Lerner and Felda Hadymon. Harvard Business School. Cambridge, MA*

Among other things, I was looking into overall economics weather in Singapore and Malaysia and positions of the key personalities who define with sometime vigorous determination the local political climate (Lee Kwan Yew – Singapore's founder, Dr. Mahathir – Prime Minister of Malaysia), which certainly influences initiatives in VC business landscape.

4.3.1 SINGAPORE: VC Industry Background

In successfully establishing itself as a regional financial hub, Singapore has also promoted the growth of the local venture capital industry. The expansion of the venture capital sector over the past decade has encouraged many foreign venture funds to establish their base in the country. Singapore has been chosen by many venture capitalists as a regional base to seek potential investments, resulting in an explosion of new funds. Significantly, all of the new funds raised have a regional investment focus.

With the surge of new capital, Singapore's venture capital pool grew to S$5.6 billion by year end 1996 and to S$6.4 billion at June 1997 (The Guide to VC in Asia, 1998/99). The country's venture capital pool is the third largest in Asia, following Japan and Hong Kong.

The government's promotion of venture capital in Singapore has played a significant role in the industry's growth. The Economic Development Board (EDB) of Singapore established its own EDB Venture Capital Fund in 1985 for direct investments in start-ups and young companies, as well as other local and overseas venture capital funds. The National Science and Technology Board's September 1997 announcement of a second ($150 million) TDF fund added further government support to the area. Additionally, the government introduced various fiscal incentives to promote the formation of venture capital funds and investments in technology-intensive projects. The Singapore Venture Capital Association was initiated in 1993 to contribute to the development of the industry.

Fund Raising In 1996, new funds raised slowed from 1995s torrid pace. Singapore-based funds raised S$1.0 billion in 1996, down from S$1.5 billion in 1995. These new funds further boosted the venture capital pool at year end 1996 to S$5.6 billion, up from S$4.5 billion in 1995.

Corporations (51 %), banks (24%) and government agencies (13%) proved the major contributors to the venture capital pool. In contrast to elsewhere in Asia, the majority of capital was sourced outside of Singapore from other Asian (39%) and non-Asian (32%) countries. The proportion of funds raised from local sources remained the same at 30% in 1996.

Investment In contrast to new funds raised, new investments rose dramatically to S$645 million in 1996 versus S$340 million in 1995. Total portfolio investment increased to S$2.1 billion versus S$1.6 billion in 1996. Close to 40% of the funds were invested in computer- and electronics-related ventures. The proportion of capital invested in Singapore-based companies remained at 15% in 1996 compared to 70% of the total funds going outside of Singapore. The amount spent in other Asian countries represents a further increase from a comparable figure of 62% for 1996. In 1996-98 expansion stage financing remained the dominant category, equaling 44% of total investment, followed by mezzanine financing at 25% and start-ups close behind at 23% of total investment.

Regulatory Framework Tax and financial incentives are available in Singapore to encourage the development of the venture capital industry:

- *Venture capital incentive for corporate and individual investors.* This incentive allows deduction of any loss arising from the sale of shares in an approved venture company or from its liquidation, against the investor's other income. The deduction is allowed up to 100% of the equity invested.
- *Section 13H incentive for venture capital funds.* A tax relief period of up to 10 years is granted for gains arising from the divestment of approved portfolio holdings, dividend income from approved foreign portfolio companies, and interest income from approved foreign convertible loan stock.
- *Pioneer service incentive for venture capital fund management.* A tax relief period of up to 10 years is allowed for management fees and performance bonuses received from an approved venture capital fund.
- *INTECH scheme.* This scheme provides financial support for venture capital professionals undergoing on-the-job training and attending courses directly related to the venture capital investment process.

Exits Apart from the Stock Exchange of Singapore (SES), a second market, known as the Stock Exchange of Singapore Dealing and Automated Quotation Market (SESDAQ), allows small and medium-size companies with growth potential access to the capital market. Established in 1986, SESDAQ has less stringent listing requirements than the SES.

4.3.2 Singapore: How Did It Happen Before

Sharply logical, passionate, and famous analysis of Singapore's development by Professor Krugman, perhaps, impressed me the most through my vast reading on the country over the years. Somewhat negative tone of Krugman might not be fully justified, however, if we recall well-known Alexander Gerschenkron's "Economic Backwardness in Historical Perspective"; he resolves paradox of capital-intensity for countries abound in cheap labor and concludes that it pays to substitute capital for labor to undertake industrialization. Solely because of the lack of time I do not refer here in any details to these two outstanding works. However, I will look further in the chapter into what Paul Krugman had to say on Malaysia.

In more recent and excellent review of Singapore, Manuel Castells (same as Krugman) starts from the use to be controversial Harvard's Yuan Tsao graduation work. The analysis on sources of growth in Singapore for the 1965-84 period shows the input of capital to be the main contributing factor, with labor input also having a positive effect, while total factor productivity had a negligible contribution.

The critical factor was the massive inflow of capital, from two main sources: (a) direct foreign investment, which oscillated between 10 and 20 percent of GDP, during the 1970s; and (b) an exceptional rate of growth of gross national savings which reached 42 percent of GDP in the mid-1980s, the highest savings rate in the world. For the overall period 1966-85, gross national savings represented over 74 percent of total gross domestic capital formation. Much of it was generated by the public sector (46 percent), mainly through the Central Provident Fund, a government-controlled social security scheme designed to impose savings on the population. The government invested most, but not all, of these savings, much of it in social and physical infrastructure, some in public corporations (over 500 public companies in Singapore in the 1980s). Government also invested abroad, in stocks, and real estate, to decrease the vulnerability of government revenues vis-a-vis the cycles of Singapore's economy. Additionally, about one-quarter of total government revenue was kept in a government development fund to stabilize the economy, and allow for strategic government expenditures. This reserve provided the government with a substantial instrument to ensure monetary stability and to control inflation.

The Singapore government decided from the moment of its independence, in 1965, that its impoverished, tiny territory could prosper only by offering itself as an export platform to multinational corporations. The central factor in Singapore's development process was the role of government to provide the necessary incentives to attract foreign capital, and to reach out to investors through the creation of an Economic Development Board (EDB), which did strategic planning on the future direction of the international economy. Among critical factors attracting investment to Singapore, mainly in manufacturing in the first stage, were:

- a favorable business environment, including low labor costs
- social peace
- an educated labor force largely English-speaking
- business-friendly social and environmental legislation
- excellent transportation and communications infrastructure
- a supply of industrial land, fully equipped, including the possibility of "turn-key" factories built by the government
- an advantageous inflation differential
- stable fiscal policy
- and political stability

The Singapore government was essential in making industrial diversification possible, as well as in upgrading the technical level of production operations performed in Singapore, enhancing the value of Singapore's products over time. Singapore shifted gradually from traditional services (regional trade) to manufacturing (mainly electronics assembly), then to advanced services (offshore finance, communications, business services). It moved from low-skill assembly manufacturing to advanced manufacturing products and processes, including R&D and wafer fabrication in microelectronics; and from an economy dominated by maritime trade and petroleum refining to a highly diversified industrial structure, including machinery, electronics, transport equipment, producer services, and international finance. The government was largely responsible for this upgrading by:

- creating the technological and educational infrastructure (including some of the best telecommunications and air transportation infrastructure in the world)
- providing the real estate, the information systems, and the loosely regulated environment in which new, international business services could prosper
- upgrading labor through a series of bold measures, including a deliberate, sharp increase of wages in 1979-82 to squeeze out companies looking for unskilled, cheap labor after Singapore's had passed the survival stage

Efficient government management and political stability, ensured through ruthless domination and social integration mechanisms, gave the multinationals reason to believe Singapore was the safest haven in a troubled world. The material prosperity helped to pacify the social and inter-ethnic unrest that characterized Singapore in the 1950s and early 1960s.

In the 1990s, when middle-skilled manufacturing product lines, such as computer disk drives, started to move out of Singapore, toward lower-cost production sites in South-East Asia, the government launched a major effort to anchor microelectronics production in Singapore, to make sure that the manufacturing contribution to GDP would not fall below 25 percent, coherent with its strategic conviction that manufacturing matters to the wealth of the country. It aimed at high-value manufacturing - that is, R&D and wafer production of advanced chips. Since the Singapore government was now rich, it invested by itself in micro-electronics production. Government-owned Chartered Semiconductor Manufacturing built two plants in Singapore, for a total investment of US$ 1.1 billion, and was planning, in 1996, to build four more plants.

Furthermore, the fast growth of economies in the region, particularly of Thailand, Malaysia, and Indonesia, helped Singapore to become one of the hubs of the global economy. It was not only growing fast, but transforming the quality of its growth (effectively addressing Krugman's concern on low productivity) as companies around the world chose Singapore as their preferred base of operation for management and investment in the midst of the most dynamic economic region in the planet.

Towering Figure of Senior Minister Lee [SM Lee]

(Biography)

Born Singapore, 16 September 1923

Educated

1929-35 Telok Kurau English School
1936-39 Raffles Institution
1940-41 Raffles College
1946-49 Fitzwilliam, Cambridge University, England, Double First with star for distinction (1969 Honorary Fellow).
1946-50 Middle Temple, Barrister-at-Law (1969 Honorary Bencher).

Family

1950 Married Kwa Geok Choo, educated Methodist Girls' School, Raffles College, Cambridge University, Middle Temple, Barrister-at-Law.
Two sons.
One daughter.

Activities

1950-59 Practised as lawyer and was honorary legal adviser to many trade unions.
1954 Founder member and Secretary-General of People's Action Party (PAP).
1955 First elected for Tanjong Pagar. Has continuously represented Tanjong Pagar ever since.
1959 Became Prime Minister. Continued as Prime Minister after PAP won General Elections in 1963, 1968, 1972, 1976, 1980, 1984 and 1988,
1990-96 Resigned as Prime Minister. Appointed Senior Minister by PM Goh Chok Tong after 1991 General Elections.

Lee Kwan Yew, while no longer Prime Minister, continues to influence Singapore's political culture and institutions. Castells's opinions quoted in this section are as interesting as open for disputes:

> He [SM Lee] succeeded in inventing a society out of nowhere, and making it the historical proof of the superiority of "Asian values," a project probably dreamed in his Oxford years, as a nationalist without a nation. In fact, he rediscovered Victorian England, with its cult of moral virtues, its obsession with cleanliness, its abhorrence of the undeserving poor, its belief in education, and in the natural superiority of the few highly educated. He added a high-tech twist, actually funding studies to establish a scientific basis for the biological superiority of certain groups. Not on a racial basis, but on a class basis. His beliefs directly shaped Singapore's policies.

The whole of Singapore is based on the simple principle of survival of the fittest. The ultimate goal of state policies is to enable Singapore to survive, and win, against the implacable competition of the global economy, in an interdependent world, by means of technology, social engineering, cultural cohesiveness, self-selection of the human stock, and ruthless political determination. I will allow myself last long quote of Castells, which captures closely Singapore dynamics but (perhaps, because of his own background of former Marxist) suddenly brings on picture happily forgotten (at least by some) Lenin:

> The PAP implemented this [SM Lee's] project, and continues to do so, in accordance with the principles of Leninisin that Lee Kwan Yew knew, and appreciated, in his resistance years as a labor lawyer in the anti-colonialist movement. And, indeed, it is probably the only true Leninist project that has survived, outlasting its original matrix. Singapore represents the merger of the revolutionary state with the developmental state in the building of legitimacy, in its control of society, and in its maneuvering in the economy. It may also prefigure a successful model for the twenty-first century: a model that is being sought, consciously, by the Chinese Communist state, pursuing the developmental goals of a nationalist project.
>
> ... Because it is fully integrated in the global economy, its currency is convertible, it is a leading financial center, it is fully open/ to multinational corporations, and still the state keeps considerable control over the economy and over wild fluctuations in the financial markets. ... it is the people's self-inflicted withdrawal and censorship, rather than brute force, which rule Singapore. ... I do not know of any state or society in the world that comes even close to Singapore's experience. <u>It may prefigure a future model of human civilization</u>, exactly what Lee Kwan Yew wanted. If so, an in-depth study of Singapore as a laboratory for one possible social future for the twenty-first century becomes an essential task. I propose to build a Futurology Center in Singapore, and concentrate there the best futurologists in the world, for them to try to make sense of the experience. I wish them eternal happıness in the Lion City - a city-state which still baffles (and fascinates) me.

Mr.Lee himself tirelessly continues to explain his position and actions. After the recent speech in Hong Kong he was asked (Business Times, 1999):

> **Question:** *Would you say that the most important/relevant form of government is the benevolent dictator? That is, to benefit all of us, the average pe :on in any form of society, truly the best form of government is that of a benevolent dictator, do you agree with that?*
>
> **Answer:** You are putting that proposition and asking me to agree with it? ... I am 76 years old, I have been through it all. I have been through this argument umpteen times. I don't know if you know my background; I was educated in a British colony, I went to a British law school, I studied the British Constitution, I passed my examination in British Constitutional law, and I am not unfamiliar with democratic practices, especially in the British parliamentary system. I have also, since the 1960s, seen how British and French-style Constitutions given to Asian, African and Caribbean countries have sadly gone into disarray or abandoned and given way to one-party states and dictatorships, and coups and counter-coups. There is almost no Constitution that the British, French, Belgians or Dutch have bequeathed that has worked because there are certain sets of pre-conditions that are necessary. I don't want to go into a long dissertation because I have had this argument umpteen times with many academics.
>
> When I was a student in Cambridge law school I had a professor of constitutional law who was secretary to the British Cabinet during the war. ...[He taught that] there must be some basic agreement on the major points of policy so when the Labour Party and the Conservative Party were at odds, it wasn't over whether there should be welfare, but what kind of welfare. And he also added that if the difference was so great as that between the Conservative Party and the British Communist Party, then the parliamentary system is not workable.

Now I therefore have in the recesses of my memory certain reference points, that you need certain pre-conditions, you need an educated people who know what is in their interests. But when you have people voting by symbols, do they really know what they are voting for? They were voting for symbols or icons. If you ask me why I have done what I have done in Singapore, it's because I owe the people of Singapore a responsibility to make sure that they could live decently and have a decent future for their children. Need I be a dictator? No. I won the votes each time.

4.3.3 Singapore: Latest Changes

Government support helps to cultivate entrepreneurs. The authorities are carefully, methodically changing the way things are done in the city-state. They have liberalized finance and telecoms in an effort to bring in more business. They have revamped education curriculums to encourage more creativity among students. They have pumped money into the arts and greatly loosened the limits on censorship, hoping to make Singapore a more attractive place for affluent and talented people to live. And they have taken measures to encourage entrepreneurs—loosening bankruptcy laws, wooing venture capitalists and promoting stock options.

Much of this is driven by economic necessity. Singapore's leaders realize that if local businesses are to grow outside their stable, predictable home market, they will need people who can think outside the box—faster-moving, more risk-taking leaders than they have now. "I like the analogy to the famous 'Beijing Spring,'" says Jek Kian Jin, a prominent Singaporean investor based in Silicon Valley. "The New Economy wake-up call is shaking Singapore's complacency that the old ways will persist." But the government is uncertain where these changes will take the country.

The Prime Minister of Singapore Mr GOH Chok Tong

(Biography)

Born on 20 May 1941, Mr Goh Chok Tong received his secondary school education at Raffles Institution, Singapore's oldest school. He studied Economics at the University of Singapore where he graduated with First Class Honours.

Mr Goh joined the Administrative Service of the Singapore Government in 1964 where he served in the Economic Planning Unit. Two years later, he was awarded a fellowship for postgraduate studies in Development Economics at Williams College, Massachusetts, USA. After receiving his Masters degree, he returned to Singapore to work in the Ministry of Finance.

In 1969, he joined the national shipping company, Neptune Orient Lines, as the Planning and Projects Manager. He rose to Managing Director of the company in 1973 and remained in this position for four years. Mr Goh was elected in December 1976 as the Member of Parliament for Marine Parade Constituency. Nine months later, he was appointed Senior Minister of State for Finance. Between 1979 and 1981, Mr Goh was the Minister for Trade and Industry. In January 1981, he was concurrently the Minister for Health. Six months later, he relinquished the portfolio of Trade and Industry to take on the appointment of Second Minister for Defence in addition to being Health Minister. In 1982, Mr Goh became Minister for Defence, a post he held until 1991. In 1985, he was appointed First Deputy Prime Minister.

On 28 November 1990, Mr Goh succeeded Mr Lee Kuan Yew as the Prime Minister of Singapore.

In the ruling People's Action Party, Mr Goh has served in the Central Executive Committee since 1979. He was Second Assistant Secretary-General (1979-1984), Assistant Secretary-General (1984-1992). From 1992 to date, he is the Secretary-General of the Party.

Mr Goh is Chairman of the People's Association, a statutory board promoting racial harmony, social cohesion, community services and grassroots activities. He is also a permanent member of the Presidential Council for Minority Rights, chaired by the Chief Justice of Singapore.

Mr Goh is married to Tan Choo Leng. She is a lawyer. They have two children - twin son and daughter. For recreation, Mr Goh enjoys golf and tennis.

Position of Prime Minister Goh If Singapore is to compete effectively in the wider world it will have to wean the industries, companies and even the people it has so painstakingly nurtured in what is arguably the world's most successful social engineering program. This means the business, political and cultural components of society are about to be transformed so profoundly that even Mr Goh is unsure how they will evolve (Business Times Survey: Singapore, 2000):

Question: *And this [latest changes] will have a dramatic impact on Singapore? How do you view that?*

Answer: With mixed feelings. One is that we have no choice. This is becoming a smaller and smaller world and, if Singapore is to survive into the future in this new economy, new world, it has got to embrace the cultures of the world from various places and influences. And there are positive elements there. The negative part will be that we will become less and less Singaporean in its indigenous sense/ and in fact, as a matter of policy, we have decided that for our own sustained prosperity in the future, we must become more cosmopolitan.

One thing Singapore hasn't done is truly privatize the raft of government-linked businesses that account for around a third of the local stockmarket's capitalization—though Prime Minister Goh Chok Tong said in mid-March that authorities are investigating ways to do so. Nor has it dropped its efforts to suck up talent by offering high-paid, secure civil-service jobs.

Conference: "Singapore TechVenture 2000 - Making the Connection", (March 8-10, 2000). The National Science and Technology Board (NSTB) was organizing the event. Deputy Prime Minister Tony Tan and California Governor Gray Davis were giving keynote speeches at the conference, which aims to encourage high-technology business partnerships. Key players in the high-tech industry, such as Creative Technology's Sim Wong Hoo and Wuthelam Holding's chairman Koh Boon Hwee, are among the other Singaporean panelists.

Singapore-linked venture capital luminaries such as Vertex's Lee Kheng Nam, Venture TDF's Thomas Ng and Walden International's Lip-bu Tan (the Malaysian-born Tan was raised in Singapore) were also present.

The event was targeted at the US venture community including venture capitalists, investment bankers, analysts and technopreneurs keen to set up base in Singapore to penetrate the Asian market. More than 200 participants from the venture community have been invited to attend this by invitation only event. More than 20 Singapore high-tech companies, including a number based in the Valley, were giving presentations on their capabilities. NSTB chairman Teo Ming Kian said: "This is an excellent opportunity for some of Singapore's most promising companies to demonstrate their capabilities to the US marketplace."

The most notable on the list of start-ups included online financial supermarket dollarDEX.com, Go-Events.com, Hello Technology and next generation telecom Pinnz. Four of the attending Singapore start-ups, ThirdVoice, InnoMedia, PrivateExpress and Kris Informatics, are now based in Silicon Valley.

The goal of all this? Forging partnerships and making and attracting investment. Besides DFJ, the TIF has made 20 other investments since its launch six months ago. Out of the 21 funds, eight are in partnership with US- based venture capital groups, including Sequioia Capital, Doll Capital, Global Catalyst Partners, Crystal Internet, Tim Draper Ventures, JH Whitney, Origin Partners, Warburg Pincus and Walden International. More funding Tan expects the TIF to be fully invested by June this year and is now pondering a follow-up. "When we launched the TIF, we were uncertain as to how it would be received by venture capitalists. But the results and the number of VCs which we have attracted to Singapore since then, show that its launch has really been very timely," he says. "We will review within a few months whether we need to have a second fund or some other initiative, which will continue the momentum which we have achieved so far."

Tan also announced that Singapore will be setting up a new California office called Connect@sg. This new office will house representatives of the NSTB, Contact Singapore, the Infocommunications and Development Authority of Singapore and the Singapore American Business Association.

After thanking to Mr. Tony Tan for boosting his fundraising efforts, DFJ Founder and Managing Director Tim Draper announced that his firm would be starting offices in both Hong Kong and Singapore. While the new fund will be run out of Silicon Valley, his partners in Asia would be free to adopt their own investing strategy. David Williams, former Internet chief at Merrill Lynch Asia, is heading DFJ's Asian efforts.

According to Mr. Draper, the cycle of Internet innovation and investment opportunities in Asia had just begun. He said the ePlanet Fund will look for investments in several types of companies:

- "Silicon Valley knock-offs," like startups replicating Internet models that worked in the U.S.
- Franchising with Silicon Valley successes by "sniffing arcund incubators."
- New wireless innovations, an area that is moving faster in Asia than the U.S.

While common venture capital wisdom holds that VCs should only invest locally -- within a half-hour drive is considered a good measure - Mr. Draper says DFJ wants to be "local everywhere."

The firm has established affiliate funds throughout the U.S. to expand its investment portfolio beyond Silicon Valley. "Some extraordinary companies have started in very remote areas," he said. "It's very competitive in Silicon Valley for a venture capitalist. The market for VC may be moving [beyond the area]."

SM Lee Embraces the New Economy The highlight of the conference was the evening keynote by Lee Kuan Yew. In his speech, Lee says that Asia needs to learn from the US' success in shifting towards an Internet-based economy:

> The US economy has been experiencing sustained growth with low inflation. This sterling performance is founded on enterprise and productivity gains brought about by rapid advances in IT and globalization, and has been described as the New Economy Asia now needs to embrace the New Economy to enjoy the kind of productivity gains the US has achieved. Failure to do so will mean an inability to compete in the global marketplace, and consequently slow growth.
>
> Asia has a track record of being able to re-engineer itself. They are young societies willing and able to embrace the New Economy.

The elder statesman also urged young Singaporeans to give up the rules of the old economy and embrace the opportunities that they will have in the new one. He, who created the system, first as Prime minister and then in his current capacity is enough a visionary to see it is unsustainable. He explained that, unlike Japan, Singapore did not have "that same irreversible attachment" to the blueprint by which it was built. So the authorities are hustling to change it. The problem facing young Singaporeans is the mindset:

> For us, the change in mindset means the abandonment of rules, which have served us well for 30-plus years. The revolution [Internet]is real, and is going to transform the way we do business, the way we buy and sell, the way the world is. That's the reason why I wanted to come to Silicon Valley, meet the operators, and get a sense of what was in the offing

4.3.4 MALAYSIA: VC Industry Background

Following a large increase in 1995, Malaysian venture capital plateaued in 1996. Only a small increase in its venture capital pool was reported. The country's venture capital industry had grown rapidly since the Malaysian government allocated M$115 million for venture capital financing in 1991; the capital pool rocketed from M$54 million in 1991 to M$1.1 billion by year end 1995. The Government provided funds to finance high technology-based small- and medium-sized industries involved in research and development, commercialization and product development.

The Malaysian government has also sponsored the establishment of two venture capital companies: Malaysian Technology Development Corp. Scln. Bhd. (MTDC) and Perbaclanan Usahawan Nasional Bhd (PUNB). The former invests primarily in new technology-based companies and facilitates commercial opportunities for research and technology. The latter, on the other hand, provides venture financing and other value-added services to potential Burniputra or ethnic Malay entrepreneurs. The government has also launched a venture capital program to create a pool of middle-class Burniputra entrepreneurs as well as increasing the number of small and medium-scale industry investments.

Malaysia's venture capital industry was formally set up in 1984 with the establishment of Malaysian Ventures Scln Bhd by Singapore's South East Asia Venture Investment (SEAVI). But the industry's development was slow with no new entrants until 1989 when Southern Bank Bhd established its own venture capital arm, S.B.Venture Capital Corp. Scln. Bhd. By the end of 1996, 22 venture capital funds were operating in Malaysia, more than half of them partnering with foreign investors. Meanwhile, the Malaysian Venture Capital Association was set up in 1995.

Fund Raising After 1995 high of M$578 million, new venture capital fund raising plunged to M$22 million, its lowest point in five years. Overall, the total venture capital pool remained stable at M$ 1.1 billion, the same figure for 1995. Corporations and government agencies collectively contributed 78% of the total funds. As in previous years,the majority (66%) of capital was sourced domestically with 15% coming from Non-Asian sources.

Investment Annual investment made by the country's venture capital groups decreased to M$146 million in 1996 from previous year' s M$186 million. However the venture capital firms' total investment portfolio increased to M$628 million, representing a 29% increase over 1995s figure.

Local companies accounted for 92% of total disbursements with other Asian companies taking the balance. Industrial products (24%), electron ics-related (19%), and other manufacturing (16%)

were the leading recipients of funds disbursed. Invested capital focused mainly on companies at start-up (39%), expansion (21 %) and mezzanine (20%) stages.

Regulatory Framework A venture capital company is defined as a Malaysian incorporated company which is involved in high-risk ventures or engaged "in a new technology product or activity that would promote or enhance the economic or technological development of Malaysia."

Certain venture capital companies approved by the Ministry of Finance are eligible for the following favorable treatment:

- the expenses of a venture capital firm not deducted in any year, because of an insufficient aggregate income, can be carried forward to the following year of assessment;
- losses incurred by a venture capital company arising from the disposal of shares in a portfolio company or the liquidation of a portfolio company, can be deducted against the aggregate income or total income of the venture capital company;
- gains from the disposal of shares in a portfolio company will be exempted from tax for a period of three years after the date on which the portfolio company is listed on the Kuala Lumpur Stock Exchange;
- limited deduction of up to 25% of certain expenses, otherwise not deductible under current revenue practice,is permitted;and
- dividends paid out of tax exempt gains from the disposal of shares are exempted from tax in the hands of shareholders.

Exits The new OTC market, the Malaysian Exchange of Securities Dealing and Automated Quotation (MESDAQ), was expected to be launched in early 1998. The listing criteria would be less stringent than that of the Kuala Lumpur Stock Exchange. Companies with minimum paid-up capital of M$2 million and particular focus on technology-related areas would be eligible for a listing on the new stock exchange.

One of the Malaysian funds, Commerce Asset Ventures, comments that, there is a general lack of awareness and misconception of the role and advantages of venture capital financing. In 1995, Malaysian Venture Capital Association was set up with the main purpose to promote and develop the venture capital industry. This "natural" a country's internal skepticism to a US-model was dramatically twisted by the special reaction of Malaysia to the 97/98 Asian crisis. I feel it is important to look into this response more in detail, mainly to realize that the country, surely, has exceptional capability to innovate and follow common sense.

4.3.5 Malaysia During the 1997/98 Asia Crises

On 1 September 1998, Malaysia became the first Asian country affected by the economic crisis to announce the new track of imposing foreign exchange controls in a bold attempt to lay the ground for a recovery program. Until recently capital controls were a taboo subject. With its action, Malaysia broke the policy taboo, whilst only a week earlier Paul Krugman broke the intellectual taboo by advocating that Asian countries to adopt exchange controls.

The Malaysian move involved measures to regulate the international trade in its local currency and regulate movements of foreign exchange aimed at reducing the country's exposure to financial speculators and the growing global financial turmoil.

The main features of the new Malaysian policy package included:

- The official fixing of the ringgit at 3.80 to the US dollar
- Measures relating to the local stock market, including the closure of secondary markets so that trade can be done only via the Kuala Lumpur Stock Exchange (this is to prevent speculation or manipulation from outside the country)
- Measures to reduce and eliminate the international trade in ringgit, by bringing back to the country ringgit-denominated financial assets such as cash and savings deposits via the non-recognition or non-acceptance of such assets in the country after a one-month dateline.
- Measures imposing conditions on the operations and transfers of funds in external accounts.

Instead of fixing the exchange rate through a Currency Board system (where money supply and domestic interest rates are determined by the foreign reserves and inflows and outflows of funds), Malaysia has chosen the route of controlling the flows of ringgit and foreign exchange. The advantage of this approach is that it allows the government greater degrees of freedom to determine domestic policy, particularly in influencing domestic interest rates. It was able to reduce interest rates without being overly constrained by the reaction of the market and by fears of the ringgit falling. Since the introduction of the measures, interest rates have fallen by about four to five percentage points. This has eased the debt servicing burden of businesses and consumers (especially house buyers), and the financial position of banks. The decision to make ringgit that is held abroad invalid after one month encouraged an inflow of ringgit to return to the country. It will also dryed up the sources of ringgit held abroad that speculators can borrow to manipulate the ringgit, for example by "selling short."

Dr.Mahathir stated that the Malaysian measures were a last resort. "We had asked the international agencies to regulate currency trading but they did not care, so we ourselves have to regulate our own currency. If the international community agrees to regulate currency trading and limit the range of currency fluctuations and enables countries to grow again, then we can return to the floating exchange rate system. But now we can see the damage this system has done throughout the world. It has destroyed the hard work of countries to cater to the interests of speculators as if their interests are so important that millions of people must suffer. This is regressive."

Dato' Seri Dr. Mahathir bin Mohamad (biography)

became the fourth Prime Minister of Malaysia on 16 July 1981

Born on 20 December 1925 in Alor Setar, the capital of the State of Kedah, Dr. Mahathir did his early and secondary education in his home town. In 1947, he gained admission into the King Edward VII College of Medicine in Singapore. Upon graduation, he joined the Malaysian government service as a Medical Officer. He left in 1957 to set up his own practice in Alor Setar.

Dr. Mahathir has been active in politics since 1945. He has been a member of the United Malays National Organisation (UMNO) since its inception in 1946. He was first elected as a Member of Parliament following the General Elections in1964. However, he lost his seat in the subsequent General Election in 1969. Owing to his keen interest in the country's education, he was appointed Chairman of the first Higher Education Council in 1968, Member of the Higher Education Advisory Council in 1972, Member of the University Court and University of Malaya Council, and Chairman of the National University Council in 1974. In 1973, Dr. Mahathir was appointed a Senator. He relinquished this post in order to contest in `the 1974 General Elections where he was returned unopposed. Following the elections, Dr. Mahathir was appointed the Minister of Education. In 1976, Dr. Mahathir was made Deputy Prime Minister in addition to his Education portfolio. In a Cabinet reshuffle two years later, he relinquished the Education portfolio for that of Trade and Industry. As Minister of Trade and Industry, he led several investment promotion missions overseas.

Dr. Mahathir was elected as one of the three Vice Presidents of UMNO in 1975. In1978, he won the Deputy President seat and in 1981, he was appointed President of the party. He was returned unopposed as President in 1984. In the 1987 party elections, Dr. Mahathir defeated his challenger to retain the Presidency and in 1990 and 1993, he was again returned unopposed as party President. Under his leadership, the ruling party Barisan Nasional (National Front) won landslide victories in the 1982, 1986, 1990, 1995 and 1999 General Elections.

Dr. Mahathir is married to a doctor, Datin Seri Dr. Siti Hasmah bt Mohd Ali, and they have seven children Marina, Mirzan, Melinda, Mokhzani, Mukhriz, Maizura, and Mazhar and ten grandchildren.

Some analysts (+IMF), especially those related to investment funds that depend on free capital movements to make speculative or investment gains, have been quite critical. One London-based analyst said Malaysia was now suffering from an "IQ crisis" as the measures were the stupidest action possible.

However there were many bouquets as well. Business groups, consumer groups and trade unions in the country supported the measures and the local stock market went up. Foreign investors in the country, through the International Chamber of Commerce, also expressed support.

The Financial Times, which represents an independent and conservative opinion within the financial establishment, gave guarded support, stating that there was an argument for temporary capital controls in time of crisis. An editorial noted that some economists argued that controls on short-term capital should be a standard part of policy for emerging markets to avoid destabilizing capital inflows and outflows that were at the heart of the Asian crisis.

On the academic level, the taboo was broken in August 1998 when the MIT economist Paul Krugman advocated that Asian governments should re-impose capital controls as the only way out of their crisis.

> In short, Asia is stuck: its economies are dead in the water, but trying to do anything major to get them moving risks provoking another wave of capital; flight and a worse crisis. In effect, the region's economic policy has become hostage to skittish investors.

Krugman pointed out some problems posed by exchange controls in practice, such as abuse by traders and distortions, so that economists think these controls work badly. "But when you face the kind of disaster now occurring in Asia, the question has to be: badly compared to what?" Asking why China hasn't been so badly hit as its neighbors, Krugman answered that China

> has been able to cut, not raise, interest rates in this crisis, despite maintaining a fixed exchange rate; and the reason it is able to do that is that it has an inconvertible currency, a.k.a. exchange controls. Those controls are often evaded, and they are a source of lots of corruption, but they still give China a degree of policy leeway that the rest of Asia desperately wishes it had.

According to a report in the New Straits Times, Krugman in a seminar address in Singapore in August 1998 said that Asian economies were reaching the end of the road and it was time to "do something radical", including implementing foreign exchange controls since pressures on the Asian economies were too high. At the initial stage of the Asian crisis he thought the affected counties were following the right strategy, "but in the last few months I began to wonder whether Asia is on the right track. ...Why did I become a radical? I didn't want to be. But we are in a trap."

After the announcement of the Malaysian measures, Krugman published an open letter to the Malaysian Prime Minister stating that he fervently hoped the dramatic policy move pays off. He however warned that these controls are risky with no guarantee for success.

> Sept. 1, 1998
>
> AN OPEN LETTER TO PRIME MINISTER MAHATHIR
>
> Dear Dr. Mahathir:
>
> I was as surprised as anyone when you announced sweeping new currency controls yesterday, and am still unclear about some of the details. However, since my recent Fortune article did suggest that temporary currency controls are part of the solution for Asia, I cannot deny some responsibility for your policy turn. Let me therefore say that, like yourself, and of course the people of Malaysia, I fervently hope that this dramatic policy move pays off.
>
> The imposition of currency controls is, of course, a risky step, with no guarantees of success. It is, as many people have pointed out, a stopgap measure. There is no shame in that: some gaps desperately need to be stopped. For the new policy to succeed, however, the freedom of action achieved by your willingness to defy orthodoxy must be well used. Let me therefore suggest four guiding principles in the no doubt very stressful months to come.

First, the actual implementation of controls should aim to disrupt ordinary business as little as possible. The devil can be in the details - that is, even a conceptually sound policy can founder if the rules are poorly conceived. The initial announcement of the plan seems to indicate, for example, that Malaysians travelling abroad will be restricted to carrying unreasonably small quantities of currency; this will need to be fixed, as will any other failings that become apparent on further study or through experience.

Second, no matter how well currency controls are executed, the distortions they impose on the economy are serious, and tend to get worse over time. That is why these controls must be regarded as temporary measures, designed to win breathing room for an economic recovery, not as a permanent secession of Malaysia from the international capital market. It would be a good idea to state now a planned date for the removal of controls - at most three years from now, perhaps less - with the strong possibility of early parole as the economy recovers.

Third, experience suggests that currency controls do most damage when they are used to defend an over-valued currency, and thereby inexorably evolve from a temporary defense against speculation into a permanent system of trade protection. Malaysia does not need a strong ringgit - on the contrary, it needs a highly competitive real exchange rate in order to increase exports.

Finally, controls must serve as an aid to reform, not an alternative. The purpose of currency controls is to allow adoption of more expansionary monetary and fiscal policies, and hence to promote a recovery of the real economy. Such a recovery will, if all goes well, reduce the problems of insolvency in the corporate sector and non-performing loans in the banking system. However, it will by no means eliminate these problems; the breathing room given by controls should be used to accelerate, not slow, the pace of financial cleanup.

Remember, above all, that the point of this policy departure should be purely and simply to buy space for economic growth. It should not be used in an attempt to prove points about the soundness of the pre-crisis economy, or about the wickedness of hedge funds, or anything else. If Malaysia truly does succeed in achieving a recovery, that will be lesson enough for the rest of us.

Sincerely,

Paul Krugman

Singapore's Senior Minister Lee, is well known because of the clarity of his economic vision. Before the Asian crisis, according to Mr. Lee (The Strait Times, 1998), East Asian countries were encouraged by multilateral groups and developed nations to open up their capital accounts - but such liberalization should have been calibrated to match the sophistication of each country banking supervision systems and laws. Such multilateral bodies as World Trade Organization (WTO), International Monetary Fund (IMF), and World Bank, plus the Group of Seven (G-7), all urged Asian countries to liberalize their financial systems. Speaking from the perspective of the affected nations, Mr.Lee noted:

- Thailand liberalized foreign exchange controls from 1990 and set up the Bangkok International Banking Facility
- Indonesia opened its capital account in 1970 – but its corporations and banks began tapping international capital markets in the 1990s. It had no system for monitoring short-term foreign debt.
- Korea liberalized its capital account when joining the Organization for Economic Cooperation and Development (OECD) in 1996.

The governments of these countries were trying simultaneously to control two incompatible economic targets: exchange rates and interest rates. The pegging of currencies to the US dollar led domestic companies to believe that there was no currency exchange risk in borrowing overseas at low interest rates. Hence, they borrowed short-term, in foreign currency, for long-term projects, and did not hedge their currency exposure. Had they carried on in the old way and financed their investments using their own savings, there would not have been such disaster, according to Mr.Lee.

Commenting on the sociopolitical side, Mr.Lee noted that it was not realistic for the US and the West to push for rapid political changes, or expect corruption to be weeded out immediately. Rapid changes in some countries had resulted in serious social upheaval, which destroyed the economic infrastructure and pushed these countries deeper into poverty. It was wrong to assume that one-man-one-vote democracy would solve all the countries' problems, he said.

The Senior Minister Lee concluded that there were two options for afflicted countries to find their way out of the crisis. They could follow the IMF prescriptions, as Thailand and South Korea were doing. Or they could close the capital account, like Malaysia. There are usually good aspects about each model, he added, saying that countries should not be fixed rigidly on the idea that one model could provide all answers. Countries in the rest of Asia that were in trouble, as well as Russia *[and Belarus, VB]* and Latin America, were watching closely the efficacy of these options.

Malaysia is the most controversial and notorious for its "own way" and debates with financial community. Its goal was to attain fully-developed nation status by the year 2020. The currency crisis, which became a financial crisis and a region-wide recession, put this goal in jeopardy. According to Malaysia's leadership, as there were no single formula for Asian success before 1997, there has no been only right model for dealing with the crisis. Dr. Mahathir says that each country has to devise "its own winning formula". To date, Malaysia has certainly not been shy about going its own way. During the early part of the currency crisis, Malaysia adopted the text-book prescription. Public expenditure was slashed and monetary policy tightened to contain the exchange rate depreciation. But in January 1998, the country began to seek its own strategies and launched its major initiative, the National Economic Recovery Plan, by middle of the year. Debt restructuring began under the several government agencies, most notable: asset management arm, Danaharta, whose role was to take non-performing loans of banks, and Danamodal, whose job was to recapitalize them. As a result, Malaysia reserves went up by US$90 m; the current balance for 1998 improved to a surplus of RM 34 bn from a deficit RM 14 bn in 1997. The work of Danaharta and Danamodal is under the supervision from J.P.Morgan, Salomon Smith Barney (economic advisers to the government) and Goldman Sachs. In the February last year Malaysia eased its tough capital controls in a bid to woo back serious long-term investors.

According to the Financial Times (1999), Dr. Mahathir was not, as many thought, simply being recalcitrant. Indonesia's attempts to pull through led its economically divided races to turn on each other, and Dr.Mahathir feared similar rips in Malaysia's racial fabric, which is woven of the same material. He put social stability above tough reforms, and Malaysians backed him. Zeti Akhtar Aziz, deputy central bank governor, said imposing capital controls enabled the economy to begin recovering before it hit bottom, so that social dislocation, unemployment and the cost of recovery were not as extensive as in neighboring countries.

Summary

VC is a business, only more so ...

***Victor Boksha**, 1999/2000 analysis*

Seriously, I think so, as it is stated in the epigraph, after spending time to look into structures and operation of various VC partnerships. Harvard Business School VC Club Web page states a similar thing differently: "it is too much fun ... working with highly motivated and intelligent people and the latest ideas..."

Singapore:

Assuming that Singapore finalizes implementation of minimum necessary conditions for healthy operation of VC-type partnerships (mainly legal and financial reforms), it seems to me that:

1. Country's leadership genuinely recognizes the need and willing to study hard the best practices in this area available (I was assessing practices of Silicon Valley in that regard)
2. I clearly see consistency in country's leadership building: I've referred to SM Lee and PM Goh in the paper. Next wave of leaders is obviously coming: for example, the brightest of my classmates at Sloan are from Singapore
3. The country certainly appreciates and is perfecting in the "crafting strategy" including:
   - get into process with corrections as we go
   - **growing** right people (massive number of young people are studying in the best schools abroad)
   - executing precisely on decisions
4. I see the similarity of Singapore and Silicon Valley in the rear ability to re-design and re-focus itself

Malaysia:

1. The country strikes me with its impressive consistency and stability
2. There is the issue of succession; to address it country eventually need to find adequate replacement of undeniable brilliance, drive and independence of Dr. Mahathir's thinking
3. What keeps me extremely optimistic is the country's clear ability to innovate and follow sense rather than non-sense (I was recalling quite fresh, and still ongoing "risky" experiment with capital controls during the Asian crisis).

Bottom Line: I feel good about the future of the VC business both in Singapore and Malaysia. Effectiveness, relative simplicity, and undeniable elegance of venture capital partnerships, surely, is and will be even more appreciated over there.

5. Discussion: Ultimate Impact of Computing Technology => Space & Time Transformation

space being an order of co-existences
as time is an order of successions...
Gottfried W. Leibniz, correspondence with Clark, 1715-16

Without an intention to go into it at the beginning, I found that the fundamental space-time considerations (to which I was initially referring in the Chapter 1) are really powerful foundations from which it is easy to approach, for example, business and management applications. Furthermore, with the coming new generation of Computing Technologies, really complex temporality-linked categories of quantum mechanics (such as influence of observation system and interactions without any direct cause or signal used mostly by experts now) might well be a common knowledge, same as PC. Phenomenon of time compression might appear quite real if we refer to the problem, which, for example, for a while is bothering me (and many other managers in Silicon Valley): how do you retain people and plan serious projects with average employment time at one place is less than three years ? It might be the case that, instead of confronting the logic of new temporality, it is useful to recognize that things are *really* moving faster and that time is *really* compressed in such localities as Silicon Valley.

To finish analysis of the physical clustering at appropriate localities and to integrate discussions from previous chapters I will transfer to considerations of the role of cities.

5.1 Morphogenesis of a City-Shell

Certainly cities are carrying infrastructural consequences of technology development. I found it is helpful to think about cities genesis as something, which is evolving toward the multiple functionalities of the UNIX shell with many wonderful qualities of the later. These two supporting points might well be supplemented by the last couple of paragraphs of the discussion on Silicon Valley (Chapter 4.1) about morphogenesis of a leaving creature. Self-replicating and self-preservation properties of a cluster such as a city might explain its self-sustaining importance.

A city's military role is largely responsible for its emergence as major economic and political unit. In many cases city fortress started from seigniorial castle (Weber, 1927):

> The construction of military castles is very old, doubtlessly older than the war chariot and the military use of the horse. ... Wherever a castle existed, artisans came in or were brought in to satisfy the needs of the seigniorial household and of the warriors; the purchasing power of a military court and the

protection which it guarantees always attracted merchants and, furthermore, the lord himself was always interested in attracting these classes since they put him in a position to procure money revenues, either by taxing trade and crafts or by participating in them through capital advances, or by conducting trade on his own account, or even by monopolizing it.

Two kinds of regulations were critical to cities' growth and their dominant role in the latest technology development: 1. initially, governance of "urban local market with its exchange between agricultural and non-agricultural producers and local traders", which is counterpart to "exchangeless" economy of other settlements; and 2. urban's real estate law, which made so big difference for the Occidental medieval city. Notes Max Weber:

> Urban landed property was always alienable without restriction, inheritable, unencumbered with feudal obligations or obligated only to fixed rent payments, while peasant land was always restricted in multiple ways by rights reserved to the village, the manor, or both. Eventually, the urban citizenry usurped the right to dissolve the bonds of seigniorial domination; this was the great – in fact, the *revolutionary* – innovation. After that in the cities the status differences disappeared – at least insofar as they signified a differentiation between "free" and "unfree" men.

When concentration of population is big enough then highly dynamic and cumulative (or auto-catalytic) nature of technology development is enhanced by recombination processes. I will illustrate it here by two examples related to writing: printing of first Bible by Gutenberg in A.D. 1455 vs. Newton (Apple Computers) & PalmPilot (U.S.Robotics) story. Why did printing spread explosively in medieval Europe after Gutenberg printed his Bible in A.D. 1455, but not after the unknown master printed the Phaistos disk in 1700 B.C. (6.5 inches in diameter, covered with 245 signs or letters, and found on the island of Crete) ? The explanation is partly that medieval European printers were able to combine six technological advances (most of that were unavailable to the maker of the Phaistos disk): paper, movable type, metallurgy, presses, inks, and scripts. While Apple's Newton and GO Corporation of Mr.Kaplan (famous through his book and cases of Harvard Business School) were too early (by ~10 years) for existing technology, PalmPilot's success is indisputable. The simplicity of its design and ability to easily synchronize with a PC account for at least 50% of the success; another half was contributed by "hard-core" technology factors. Among them are: memory & LCD pricing; advances in operational systems and architecture; IC chip size and performance.

Professor Castells identifies clusters of scientific/technical knowledge, institutions, firms, and skilled labor as the furnaces of innovation in the Information Age. He is certain *[may be too certain on my taste, VB]* that they do not need to reproduce the cultural, spatial, institutional and industrial patterns of Silicon Valley, or for that matter, of other American centers of technological innovation, such as Southern California, Boston, Seattle, or Austin. He states:

> Our most striking discovery is that the largest, old-metropolitan areas of the industrialized world are the main centers of innovation and production in information technology outside the United States. In Europe, Paris-Sud constitutes the largest concentration of high- technology production and research; and London's M4 corridor is still Britain's preeminent electronics site, in historical continuity with ordnance factories working for the Crown since the nineteenth century. ... Tokyo-Yokohama continues to be the technological core of the Japanese information technology industry. ... Moscow-Zelenograd and St.Petersburg were and are the centers of Soviet and Russian technological knowledge production *[certainly I would include cluster of Minsk, Belarus capitals, which was at least as powerful in the areas of microelectronics and optics, VB]* .... Hsinchu is in fact a satellite of Taipei; Daeduck never played a significant role vis-a-vis Seoul-Inchon; ... and Beijing and Shanghai are, and will be, the core of Chinese technological development. And so are Mexico City in Mexico, Sao Paulo-Campinas in Brazil, and Buenos Aires in Argentina.

Castells reduces city-based advanced services including finance, insurance, real estate, consulting, legal services, advertising, design, marketing, public relations, security, information gathering, and management of information systems, but also R&D and scientific innovation (which are at the core of all economic processes, be it in manufacturing, agriculture, energy, or services of different kinds) to knowledge generation and information flows. Being effective in that regard, megacities are connected externally to global networks and to segments of their own countries, while internally disconnecting local populations that are either functionally unnecessary or socially disruptive. Overall, Manuel Castells defines that "the informational city is not a form but a process. ... A process by which centers of production and consumption of advanced services are connected in a global network."

Dr.Adam echoes the "process" idea in a similar fashion referring (at the level of mental models) to city of London which "represents an enormous growth of order and information. London could not have evolved except as the result of vast movements towards **disorder** in the world outside it."

Before I discuss temporal consequences of IT (inferred mostly through city-type infrastructure by technology development and space transformation) it would be appropriate to touch on the role of government and military needs in this process.

5.2 Government & Military Role in Polity and Technology Development. Limits

According to Dr. Diamond (1999), horses, usage of which originated ~4000 B.C. in steppes of modern south Russia, were the first and so far longest (until the World War I) "technology vehicle" invented (mostly for military purposes). They were essential military ingredient behind the westward expansion of speakers of Indo-European languages from Ukraine (these languages eventually replaced all earlier western European languages except Basque). Around 1800 B.C. horse-drawn battle chariots revolutionized warfare in the Near East, the Mediterranean region, and China. Then saddles stirrups were invented with which Huns and other steppes people terrorized the Roman Empire and its successor states, culminating in the Mongol conquests of much of Asia and Russia in the 13th and 14th centuries A.D.

It is technology, in the form of weapons and transport (recently enhanced through communications by vast information branch of technology), provides the direct means by which certain people extended their realms and conquered other people. While initially it might be true that invention was "mother of necessity" and many or most inventions were driven by curiosity or by "a love of tinkering", since approximately middle of 19th century governments and military were dominant in this process. By Diamond's opinion, for example, car's era came in because of the World War I, when military concluded that it really did need trucks. After that intensive postwar lobbying by truck manufacturers and armies finally convinced the public of its own needs.

From such perspective, I consider investment and policy decisions made (not always necessarily a bad ones), for example, by the US Government as the major driving force behind the reinforcing loop influencing the US long-term GDP growth. In my opinion, GDP growth is determined by the variety of positive feedback loops (which are highly aggregated) on the left side of the Figure II, which I am replicating from the Introduction.

It would be interesting to consider in this regard a couple more recent examples. Briefly about military-driven computer evolution: it was the American military during the WWII willing to spend enormous sums on developing (successfully) machines to calculate at high speed the position of fast moving aircraft overhead and of fast-moving enemy ships.

> In 1937 Alan Turing (Britain) conceived the idea of Universal Machine to execute any describable algorithm. It was used in Colossus (1943) to decipher German codes. Before that in 1930s Konrad Zuse (Germany) developed Z-computers which were used in WWII by the German aircraft industry.
>
> More recent example is related to semiconductor industry and one of its critical technologies: microlithography. One of the most serious candidates for urgently needed next generation of products is Extreme Ultraviolet Lithography to which I referred in the Chapter 3.1. It is amazing how early (since 1985) US Government started to invest into it and was doing it consistently until major commercial giants (Intel, AMD, Motorola) took over (Hawryrluk et al., 1997-1). Then Europe and Japan rapidly started to conceive their own programs.

While government and military-related activities boosted production (GDP growth), they did not destroy the US industrial infrastructure in neither one of the major wars of 20th century. It simply re-inforced output and positively influenced technology (see the Figure II).

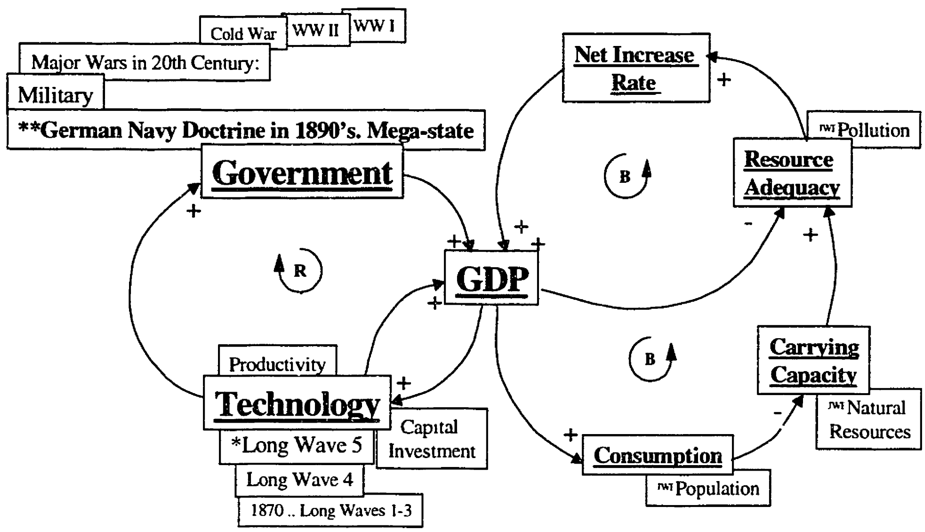

Figure II Identification of the Feedback Structure of Growth and Limits to Growth

* adopted from "The Economist", February 20, 1999, p.20
** see P.Drucker, Post-Capitalist Society, p.127-128
JWF adopted from J.F.Forrester "World Dynamics"

Technology itself has major impact on productivity, capital investments and, closing the loop, on military. There are powerful re-enforcing loops within technology group itself, which is represented on the Figure II by separation into Economic Long Waves (LW). These economy waves were and are driven by critical and dominant at the time technologies: LW1 (1785-1845): by water power, textiles, iron; LW2 (1845-1890): by steam, rail, steel; LW3 (1900-1950): by electricity, chemicals, internal-combustion engine; LW4 (1950-1990): by petrochemicals, electronics, aviation; LW5 (1990-2020?): by digital networks, software, new media, semiconductors, fibre optics, genetics. Among the easy identifiable positive feed back loops within technology group are: "steel – electricity", "internal-combustion engine – electronics"; "electronics-software, semiconductors & digital networks" (The Economist, 1999c). From such point of view the recent Asia's 1997/98 crisis might be considered as a part of the Global Long Wave behavior pattern.

The "progress" is not coming cheap. Two aggregated balancing loops (right part of the picture above) may lead to a collapse scenario in case when the "Carrying Capacity" (Natural Resources) will be driven to exhaustion. Internal feedback loops for each of three aggregated variables are somewhat self-explanatory and are well-described in the "World Dynamics" by J.W. Forrester (1971) and in consequent literature.

Role of government and military needs is undeniable in Silicon Valley's set-up and development of its initial structure. Professor Saxenian in her 1985 paper "Genesis of Silicon Valley" heavily underlines military component. By one count (The Economist, 1997), in the period 1958 – 1974 the Pentagon paid for $1 billion worth of semiconductor research. The government contributed significantly into the Internet as well. The Valley got direct help from officials in the Netcsape & Co. vs. Microsoft case.

Overall, Professor Castells captured the phenomenon perfectly; I haven't seen yet such clear and consistent description of the latest technology development. So, I will let him speak:

> ...<u>the entrepreneurial model of the Information Technology Revolution seems to be overshadowed by ideology</u>. The role of the state is generally acknowledged as decisive in Japan, where large corporations were guided and supported by MITI for a long time. A similar story can be told about South Korea and Taiwan, although in latter case multinationals played a greater role. India's and China's strong technological bases are directly related to their military-industrial complex, under state funding and guidance. But it was also the case for much of the British and French electronics industries, centered on telecommunications and defense, until the 1980s. ...
>
> Even in the US it is a well-known fact that military contracts and Defense Department technological initiatives played decisive roles in the formative stage of the Information Technology Revolution, that is between the 1940s and the 1960s. Even the major source of electronic discovery, Bell Laboratories, in fact played the role of a national laboratory: its parent company (AT&T) enjoyed a government enforced monopoly of telecommunications; a significant part of its research funds came from the US Government; and AT&T was in fact forced by the Government from 1956, in return for its monopoly on public telecommunications, to diffuse technological discoveries in the public domain. MIT, Harvard, Stanford, Berkeley, UCLA, Chicago, Johns Hopkins, and national weapons laboratories such as Livermore, Los Alamos, Sandia, and Lincoln, worked with and for Defense Department agencies on programs that led to fundamental breakthroughs, from the 1940s computers to optoelectronics and artificial intelligence technologies of the 1980s "Star Wars" programs. DARPA, the extraordinarily innovative Defense Department Research Agency, played in the US a role not too different from that of MITI in Japan's technological development, including the design and initial funding of the Internet.
>
> Genetic engineering spun off from major research universities, hospitals, and health research institutes, largely funded and sponsored by government money. Thus, the state, not the innovative entrepreneur in his garage, both in America and throughout the world, was the initiator of the Information Technology Revolution.

However, since the early 1970s, technological innovation has been essentially market driven. *... It is indeed by this interface between macro-research programs and large markets developed by the state, on the one hand, and decentralized innovation stimulated by a culture of technological creativity and role models of fast personal success, on the other hand, that new information technologies came to blossom.*

Technology development came to the point (in just last decades) that war-making possesses astonishingly different temporality; the "professional/instanteneous/clean" socio-military strategy dramatically changed its perception by citizens of the most developed countries. Absence of direct participation for majority of population means "disappearance of war from the lifecycle" and "fundamental discontinuity in the human experience" (Castells, 1999).

5.3 Rhythmicity Broken by Microlithography: Re-definition of Space and Transformation of Time

It does not matter if you will miss your plane or lose your job
The coffee brews on its own schedule, and you wait
A.J.Weigert, Sociology of Everyday Life

Unlike in most classical social theories, Professor Castells assumes the domination of time by space. He proposes the hypothesis that space organizes and shapes time in our network society. The dominant trend is that space is structuring temporality in different, frequently contradictory logics; for example, it dissolves time by disordering the sequence of events and making them simultaneous

I certainly see the iron logic behind the concept above and would like to extend on this point. I would emphasize that the time transformation dynamics (described previously in this thesis and referred to below) are based on material micro-spatial technological advancements – microlithography. I would suggest therefore that **the underlying *material* reason for IT/space-inferred Castells-type time transformation and consequent social arrhythmia is** not being too broadly defined and somewhat fuzzy macro-space of flows but rather **ultra-densification of space implemented in the technology of microlithography.**

There is indeed a pattern of discontinuity of fundamental significance inferred by the information technology revolution (dismissing all the hype and ideological manipulation" [Castells, 1999] around it). It is at least as major a historical event as was the eighteen-century Industrial Revolution, inducing major disturbances (with consequent **disorder**) into the basics of economy, society, and culture.

New "time regime" is linked to the development of communication technologies. Capturing this, recent research in physics and biology seems to converge with social sciences in adopting a contextual notion of human time, which is not only consistent with the cosmology of some leading contemporary physicists but also with that of Eastern mysticism and mythological cosmologies, be they contemporary or ancient ones. "...modern science beginning to converge with the rest of the world's cosmologies ..." (Adam, 1990).

To better understand what I am trying to say it might be helpful to take another look into Castells-Adam views on temporality, specifically on ***rhythmicity***; I hope that extended quotes below will help to understand the issue better and bring us to the central point of the discussion.

> **Professor Castells (1999):** **Biological rhythms**, be it individual, related to the species, or even cosmic, are essential in human life. People and societies ignore them at their peril. For millennia human rhythmicity was constructed in close relationship to the rhythms of nature, generally with little bargaining power against hostile natural forces, so that it **seemed reasonable to go with the flow**, and to model the lifecycle in accordance with a society where most babies would die as infants, where women's reproductive power had to be used early, where youth was ephemeral, where growing elderly was such a privilege that it brought with it the respect due to a unique source of experience and wisdom, and where plagues would periodically wipe out a sizable share of the population. In the developed world, the industrial revolution, the constitution of medical science, the triumph of Reason, and the affirmation of social fights has **altered this pattern in the last two centuries**, prolonging life, overcoming illness, regulating births, alleviating death, calling into question the biological determination of roles in society, and constructing the lifecycle around social categories, among which education, working time, career patterns, and the right to retirement became paramount. However, although the principle of a sequential life shifted from **being bio-social** to **becoming socio-biological**.

> **Dr.Adam (1990):** Rhythmicity is a universal phenomenon. Scientists conceptualize atoms as probability waves, molecules as vibrating structures, and organisms as symphonies. Living beings, they suggest, are permeated by rhythmic cycles which range from the very fast chemical and neuron oscillations, via the slower ones of heartbeat, respiration, menstruation, and reproduction to the very long range ones of climatic changes. Their activity and rest alternations, their cyclical exchanges and transformations, and their seasonal and diurnal sensitivity form nature's silent pulse. Some of this rhythmicity constitutes the organism's unique identity; some relates to its life cycle; some binds the organism to the rhythms of the universe; and some functions as a physiological clock by which living beings 'tell' cosmic time.

Barbara Adam emphasizes the urgent need to re-conceptualize Newtonian- and thermodynamic-based time considerations with the latest research results of 20^{th} century, particularly in quantum physics and modern biology. In that regard rhythmicity is in the center of Dr. Adam's attention: "... rhythmicity, which entails cycles, structure, and processes with variation, would therefore be a more useful key concept for social theory than reversible time." Rhythms and irreversible processes must be understood together since, on their own, neither could account for that which is expressed by the idea of time.

> Notion on irreversibility of time is related to thermodynamics. One of the prominent 20th century physicists, Nobel laureate Ilya Prigogine, suggests that irreversibility is an aspect of the physical world; that it is fundamental to all of nature (Prigogine, Stengers, 1984):
>
> > ...we discovered symmetry breaking processes on all levels, from elementary particles up to biology and ecology. ...Irreversibility is the mechanism that brings order out of chaos.

Discussing the new organization of life from being bio-social to becoming socio-biological, Castells finally arrives to the new concept of temporality and proposes "the hypothesis that the network society is characterized by the **breaking down of *rhythmicity***, either biological or social, associated with the notion of a lifecycle":

> This linear, irreversible, measurable, predictable time is being shattered in the network society, in a movement of extraordinary historical significance... it is the mixing of tenses ... not cyclical but random. I argue that this is happening now not only because capitalism strives to free itself from all constraints. ...Neither is it sufficient to refer to the cultural and social revolts against clock time, since they have characterized the history of the last century without actually reversing its domination, indeed furthering its logic by including clock time distribution of life in the social contract. Capital's freedom from time and culture's escape from the clock are decisively facilitated by new information technologies, and embedded in the structure of the network society.
>
> ...the mixing of times in the media, within the same channel of communication and at the choice of viewer/interactor, creates a temporal collage ... with no beginning, no end, no sequence ... Multimedia hypertext is a decisive feature of our culture, shaping the minds and memories. ... Overall effect is a non-sequential time of cultural products available from the whole realm of the human experience. If encyclopedias organized human knowledge by alphabetical order, electronic media provide access to information, expression, and perception according to the impulses of the consumer or to the decisions of the producer. By so doing, the whole ordering of meaningful events loses its internal, chronological rhythm, and becomes arranged in time sequences depending upon the social context of their utilization.

Dr.Adam writes that as members of Western industrial societies we create time as a resource, as a tool, and as an abstract exchange value; and again it overlaps with what Professor Castells has to say on the issue:

> ...Time is managed as a resource, ...it is compressed and processed. ...Today , the individual is overwhelmed by the various temporalities he has to confront. ...While technology allows us to work

less for the same amount of output, the impact of this technological fact on the actual working time and schedules is undetermined (especially in most advanced sectors of most advanced societies).

Split-second capital transactions, flex-time enterprises, variable working time, the blurring of the lifecycle, the search for eternity through the denial of death, instant wars, and the culture of virtual time, all are fundamental phenomena, characteristic of the network society that systemically mix tenses in their occurrence.

I will maintain further that transforming time we are rapidly loosing ability to manage it and Drucker's Management Revolution (see section 1.2.1 of this thesis) might need another phase or extension into Time Management Revolution. Another tools and mental models/approaches and level of technology are obviously necessary to make it happen ...this is both a challenge and, of course, an opportunity ! Perhaps, next generations of computing will be able to overcome the limitations (leading to broken rhythmicity in its current socio-biological stage) of silicon-based technology and take the humans to the level where society (as any truly living structure) is able to do self-repair. I hope it will allow to get the rhythmicity "back", to the stage of being manageable (which is different from the pre-industrial dominating bio-social temporality of simply "going with the flow of nature").

For now, however, people resort to language that resembles poetry when they are trying to express the nature of living forms. In a sense I was doing exactly that in this thesis work scattering epigraphs around (Belarus group "Pesnyary" [Ancient Singers] with song on poem by Yakub Kolas, Russian group "Mashina Vremeni"); it certainly helped me to maintain bigger picture, slice of which somewhat reflected on Figure I (see Introduction, p.7). Finally, I would like to present the absolute star of 1980's, group Nautulus Pompilius, the text of which is brilliant, being with that absolutely beyond any capability to be translated (however, I have tried to help an English-only speaking reader and translated couple lines of the song; please, see the next Chapter 6, Conclusions):

Sphere of Khaki's Color

(by Vyacheslav Butusov, group Nautilus Pompilius)

был бесцветным был безупречно чистым
был прозрачным стал абсолютно белым
видно кто-то решил что зима и покрыл меня мелом

был бы белым но все же был бы чистым
пусть холодным но все же с ясным взором
но кто-то решил что война и покрыл меня черным

я вижу цвет но я здесь не был
я слышу цвет я чувствую цвет
я знать не хочу всех тех кто уже красит небо

я вижу песню вдали но я слышу лишь
марш марш левой
марш марш правой

я не видел толпы страшней
чем толпа цвета хаки

был бы черным да пусть хоть самим чертом
но кто-то главный кто вечно рвет в атаку
приказал наступать на лето и втоптал меня в хаки

я вижу дым но я здесь не был
я слышу дым я чувствую гарь
я знать не хочу ту тварь
что спалит это небо

я вижу песню вдали но я слышу лишь
марш марш левой
марш марш правой
я не видел картины дурней
чем шар цвета хаки

5.4 New Ordinateur

Time coincidence of temporality disturbances with the coming new generation of Computing Technologies is striking for me. Very briefly I would like to refer to few of them which appeared within last year and powerfully pretend to have future technical and market potential.

Examples of the recent breakthroughs:

- Hewlett Packard/UCLA - molecular (rotazanes) based computing
- both MIT and IBM - quantum based computing (manipulating of spins of atoms)
- MIT - building DNA that controls cells in sophisticated, computer-like ways,
- instead of the simple ways currently
- Georgia Tech & University of Bordeaux (France) - combining neurons with silicon chips

People from HP/UCLA people easily imagine fantastic capabilities of new "ordinateurs":

> In an effort to create ultrafast, low-power computers, a research team has for the first time fashioned simple computing components no bigger than a single molecule. The achievement, being reported in **Science magazine**, opens a new window onto a once speculative but now increasingly probable field of molecular-scale sensors, computers and machines. The researchers, from Hewlett-Packard Co. and the University of California at Los Angeles, say their work could be a step toward computers 100 billion times as fast as today's most powerful personal computers. And they envision a world in which supercomputing power is so pervasive and inexpensive that it literally becomes an integral part of every manmade object.
>
> Over the next decade, such technology "holds the promise of vast data storage capability," said Phil Kuekes, a physicist and computer designer at Hewlett-Packard. And ultimately, he said, it could create a new class of "Fantastic Voyage"-style machines, like sensors traveling within a person's bloodstream, issuing alerts if health problems are encountered.
>
> One of the next challenges for the researchers will be to come up with a chemical process to create the ultra-thin wires—no more than several atoms across—needed to connect all the molecular switches into a complete computer circuit. In current circuitry these wires are as thin as less than one-quarter of a micron—a human hair is about 400 times as thick—but even so, they are far too thick to connect individually to the new molecular switches.
>
> The molecules themselves, called rotazanes, are synthetic compounds created by chemists at UCLA, and the switches built from them deliver "the equivalent capability to a silicon circuit I could have bought in 1970" that was the size of a fingernail, Kuekes said.
>
> Computer researchers said they believe the advance heralds the rapid acceleration of a new field known as moletronics, or molecular electronics. "This field is still in its infancy," said Mark Reed, a chemist at Yale University who is doing experimental research in molecular-scale computing. "But the results are starting to come in faster. Over the last five years we've come from an incredible idea to the point where we might be able to do something." "This is an important stepping stone, but we still have a long way to >go," said James Tour, a Rice University chemistry professor who is conducting similar molecular-scale research. "I don't want people to think that in three to five years we'll have molecular electronics, but the interesting thing about this work is that we can now see ways to scale past the limits of silicon."
>
> James Heath, a UCLA chemistry professor who is leading the research with Hewlett-Packard, described the possibility of computers 100 billion times as fast as a Pentium III microprocessor. He also suggested that it may some day be possible to replicate the power of 100 computer work stations in a space the size of a grain of salt. To illustrate the density possible at the molecular level, Tour said that a mouthful of water contains so many molecules that, if they were each represented by a sheet of paper, the stack would reach from the earth to the sun 400 million times. "A single molecular computer could conceivably have more transistors >than all of the transistors in all of the computers in the world today," he said.

Finally…

> The new social order, the network society, increasingly appears to most people as a meta-social disorder.
>
> ***Manuel Castells**, Information Age, 1999*

Joseph Shumpeter's mechanism of "creative destruction" with sharp abandonment of obsolete businesses and corresponding layoffs performed admirably for the U.S., and, with some limitations, for the UK. However, even for Germany and France (with their strong European-born socialistic roots), leaving alone Japan (with the tradition of a life-long job guarantee), introduction of a highly dynamic US model continues to meet significant resistance. From one side this is good news for the U.S.: this provides its leadership for the decades ahead. However, the world instability resulted from the explosive US economic model expansion is much more visible. In some sense it supports populist messages about the "global crisis of capitalism". Recent experiences from around the world (collapse of Thailand, South Korea and Russian economies, violent riots in Indonesia, to name a few) show that it is may not be enough any more to have a free market only. In that sense China, Singapore, and Malaysia have not collapsed (suffering, however, to different extend) during the current crisis having, maybe, the only one thing in common - strong government and being at different points on the way to free society.

To finalize, I would like to simply repeat what I had been writing in my application to MIT Sloan School of Management:

> We yet to understand in depth all these **social responsibilities issues** on the background of newest mental and ideological riots in Asia and Eastern Europe. (by Andreii Makarevich: … i neglyadya na nebo, nikogo ne lubya vya prohodite mimo samix sebya… Vyi schitaete chto ochen_ vajno schitat_. Translation: a counting is not what counts). Overall, it seems to me that slowly coming recovery will be based on reforms with respect to traditions of millenniums and current status of a society in each affected country. Equally important, I hope that we will be able to deal with consequences of all of that on business practices and learn lessons from the just passed another "economy" crisis (Asia'97/98). Finally and fundamentally, I personally would like to find the right balance for the truly *transnational* economy operations (when at 11 p.m. being in Silicon Valley, I still working with Tokyo, where local time is 4 p.m, and thinking to call Paris in 30 minutes to hire top professional before his 9 a.m. meeting) cooping with the rising *tribalism* even within the most established nations and regions.

6. Conclusions

1. Capabilities of modeling for modern microlithography and overall microelectronics have been demonstrated through the extensive examples of precisely calibrated simulations and ability to conduct integrated yield assessment. Current level of knowledge in microelectronics allows to govern IC manufacturing processes with precision unavailable before when the technology was operated in the mode of art.

2. I conclude that the semiconductor industry with its amazing development is rapidly moving through a transition period and to the status of a mature business. Consequently, I suggest **(hypothesis #1)** that **the technologically available solid-state based Integrated Circuits are becoming a commodity.** This, combined with the possible slowdown in microlithography advancements, causes doubts in the ability of current Computing/Information Technology to continue contribute at the same level into the growth of economy.

3. We have made a significant effort to explore the transition to Next Generation Lithography through the System Dynamics approach. Main concepts were developed and critical functions identified. Initial model of the transition was formulated, created and verified.

4. The economic Long Wave Game was re-designed and developed for PC version. Main code and enhancements (vs. Macintosh version) were implemented in an open TclTk development platform which allows easily modify package as needed in the future.

   Logical continuation of the present work would be to link the model of transition to Next Generation Lithography with the Long Wave Game to quantify, for example, an important aspect of macro-economic behavior: effects of economic policy in semiconductor's industry (and, consequently, effects of IT) on GDP growth.

5. **Modeling and Economic Geography** Some portion of the analysis refers to simulations and modeling approaches, both in microelectronics and economics/business/management domains. I distinguish models accepted by semiconductor industry as fairly complete from the excellence of the early modeling efforts in management and "new economic geography", which are still waiting for wider acceptance by practitioners. In a sense it reflects maturing stage of the microelectronic technology and commoditization of its products versus highly dynamic science of management and education.

   Significant geographic diversity of the presented high-technology related cases helped me to grasp (to some extend) the new concepts of differential geography (by Jeffrey Sachs) and self-organizing agglomeration economies (by Paul Krugman).

Shared best practices were identified as a significant new and common element inferred and required by Information Technology for very diverse and physically dispersed organizations to be effective. Peter Drucker's jazz combo team might be an appropriate model to refer to describing operations either maker of the most complex equipment ASML in Holland, or Silicon Valley in the US, or venture capital partnership in Singapore.

6. **Space-Time Transformation** While rapidly growing, Information Technology is still young in terms of the useful applications it offers. However, underlying silicon-based technology is in maturing stage and is already significant enough to deserve serious assessment of consequences of its macro-impact.

Building on Professor Castells considerations I note that the clarity of his "space of flows" concept may need an improvement. However, the brilliance of revealed space-time relationships is stunning with the final notion that it is space that organizes time and transforms it. I would suggest further **(hypothesis #2) that the underlying *material* reason for IT/space-inferred Castells-type time transformation and consequent social arrhythmia is** not being too broadly defined and somewhat fuzzy macro-space of flows but rather **ultra-densification of space implemented in the technology of microlithography.**

Perhaps, next generations of computing will be able to overcome the limitations (leading to broken rhythmicity in its current socio-biological stage) of silicon-based technology and take the humans to the level where society (as any truly living structure) is able to do self-repair. I hope it will allow to get the rhythmicity "back" to the stage of being **manageable** (which is different from the pre-industrial dominating bio-social temporality of simply "going with the flow of nature").

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APPENDIX A

(Chapter 3.3)

COMPREHENSIVE LIST OF VARIABLES

Economy category:

- GDP growth
- GDP
- Market expectation
- Percentage of GDP due to IT (Info Tech industries)
- Consumer spending
- Inflation
- Price of a PC
- Price of a DRAM
- Price of a Microprocessor
- Cost of a wafer
- Margin on wafer
- Cost of a Fab plant
- Price of Equipment (microlithography based equipment)
- Technology Gap ("Haves and Have nots")
- Labor cost
- Regional Capital investment (Silicon Valley)
- Semi-Conductor Industry Capital investment
- Fab Capacity
- Fab size
- Equipment throughput
- US Capital investment
- Europe Capital investment
- Japan Capital investment
- Korea/Singapore Capital investment
- Taiwan Capital investment
- Government research funding (in new technologies)
- Consortia research funding (in new technologies)

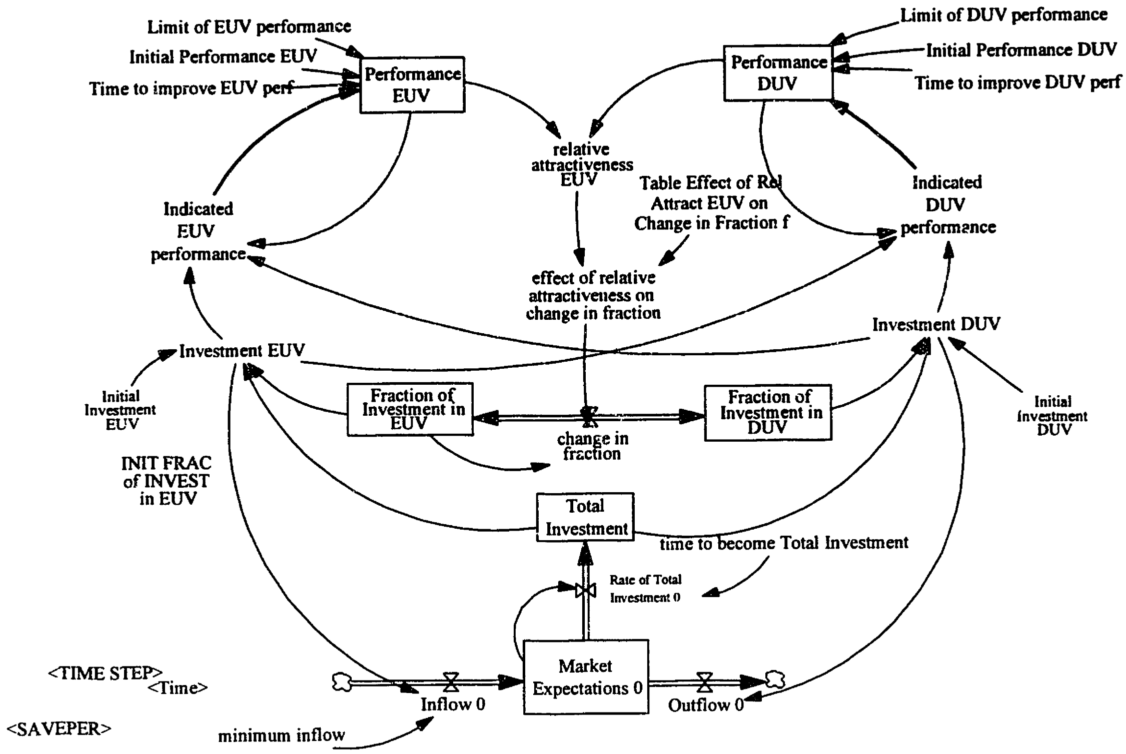
Socio-political category:

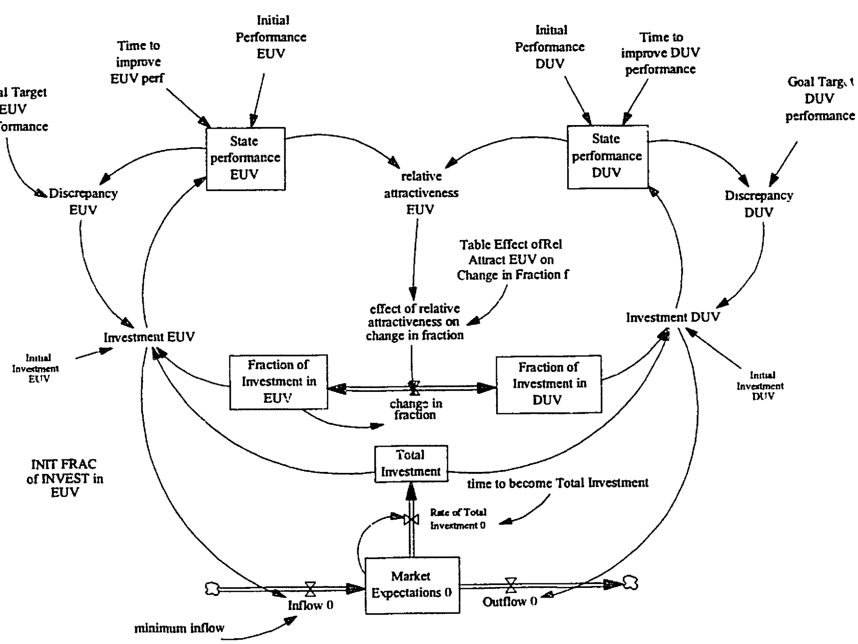
- Political stability
- Riots
- Strikes
- Asian crisis

Technology category (with a few economic):

- Critical Dimension
- Optical resolution
- Current computing based functionality
- Demand for current computing based functionality (*economic*)
- New "ordinateur"* functionality ?
- Demand for new "ordinateur" functionality (*economic*)
- Equipment complexity
- Equipment quality (robustness+reliability…)
- Undiscovered opportunities in new technologies

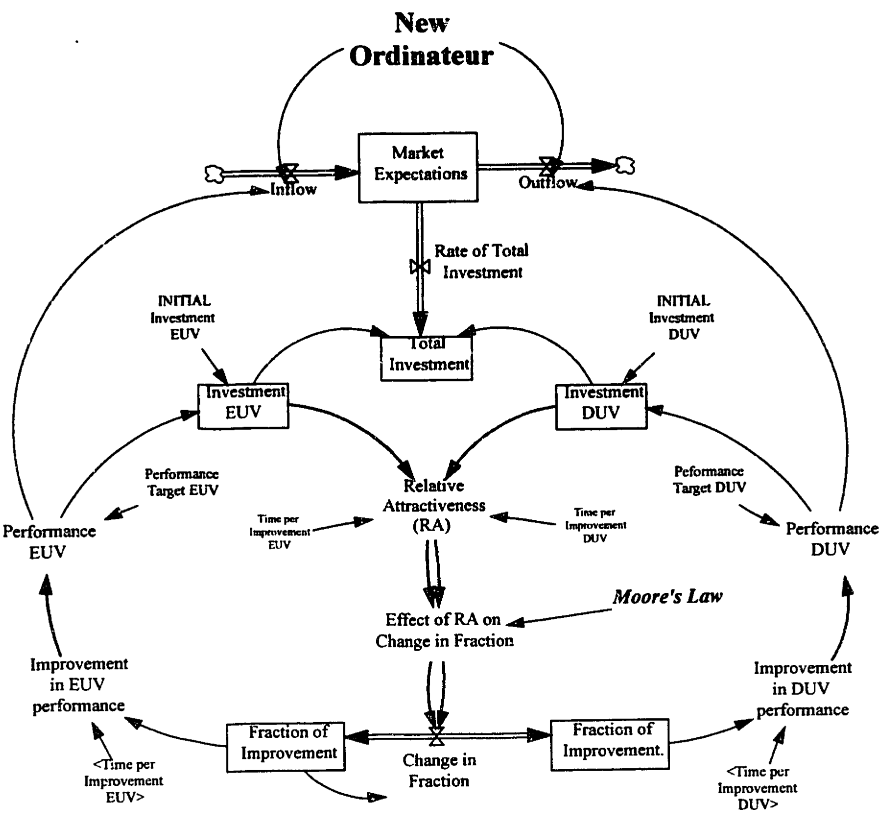
Appendix B1

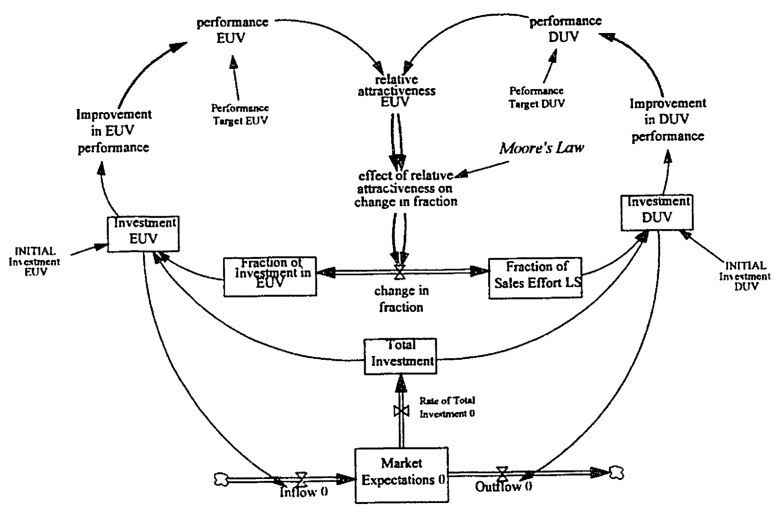




Set 1: Intermediate models

Appendix B2



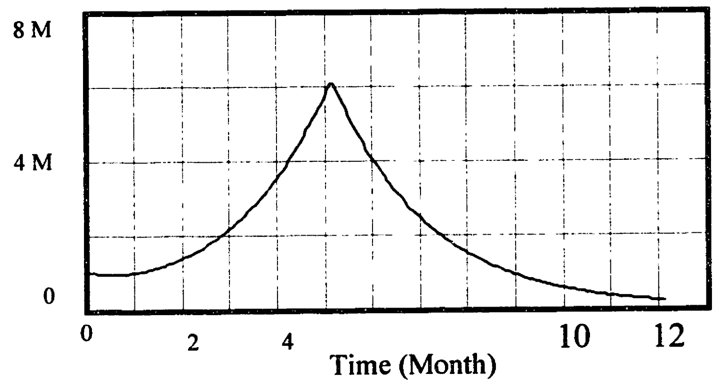


Set 2: Intermediate models.

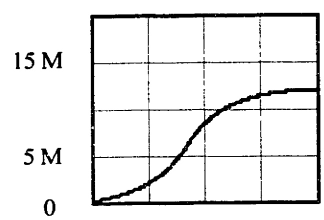
"Ordinateur" is French for computer. However, the meaning of ordinateur goes beyond computing (literally "machine that arranges things"). The idea here is that we should aim at significantly new functionality from new types of "ordinateurs" which will satisfy the market expectations.

Appendix B3

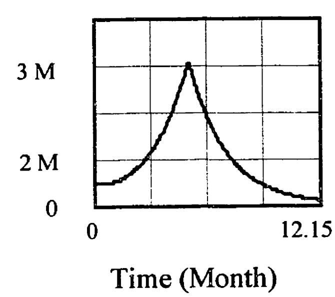
Graph for Market Expectations



Total Investment



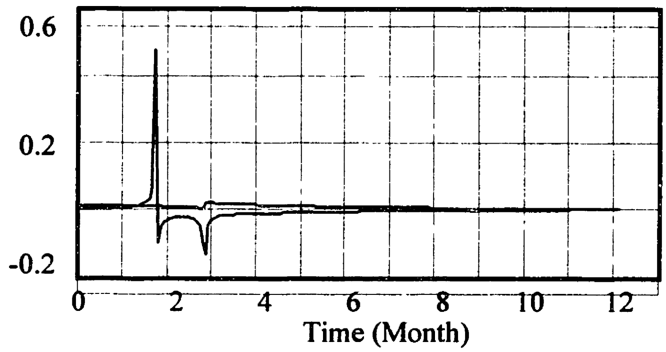
Rate of Total Investment



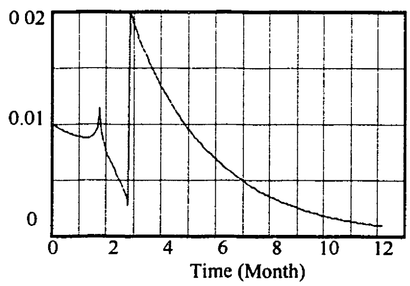
Set 3: Preliminary results from intermediate models
Possible sharp discontinuities in investment pattern;
yet to be analyzed in depth and explained

Appendix B4

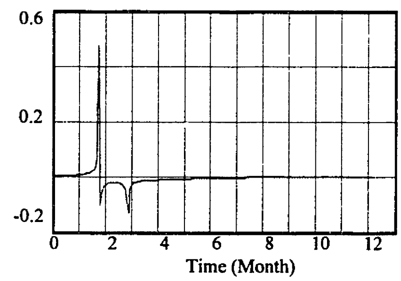
Performance Behaviour: EUV



Graph for Performance EUV

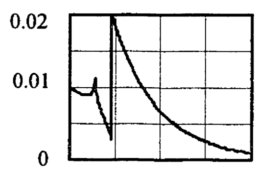


Graph for Indicated EUV performa

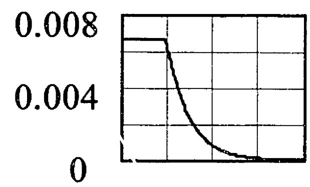


Performance EUV : current 1/nm

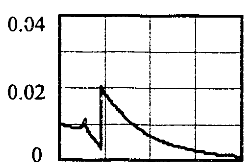
Performance EUV



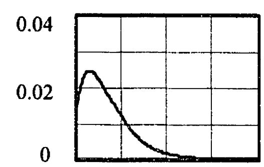
Performance DUV



IndicatedEUVperformance



IndicatedDUVperformance



Set 3 (continue): Preliminary results from intermediate models

APPENDIX C

(Chapter 3.3)

Equations of the Model

EQUATIONS for Figures B1, B2, B3:

change in PA of DUV = (DUV Attractiveness-Perceived DUV Attractiveness)/Time to perceive
~ 1/(nm*Year)
DUV Performance = 1/DUV Critical Dimension
~ 1/nm
~ DUV performance is the same as resolution, or inverse of critical \dimension.
growth trend= (-Disturbance*amplitude)*Disturbance Switch +constant trend
~ Fraction/Year
~ Growth Trend is set to zero as a default. A disturbance can be applied to \
it. Also, if we were to include market expectations feedback in the model, \
growth trend would be a function of other variables.
Perceived DUV Attractiveness = INTEG (change in PA of DUV,Initial Perceived DUV Attractiveness)
~ 1/nm
~ It takes time for DUV attractiveness to be perceived.
Initial DUV Performance = 1/Initial DUV CD
~ 1/nm
EUV CD Limit = 50
~ nm
~ The physical limit for EUV technology
Initial EUV Performance=1/Initial EUV CD
~ 1/nm
constant trend=0
~ Fraction/Year
DUV Attractiveness=DUV Performance
~ 1/nm
~ DUV attractiveness is equal to DUV performance.
Total Perceived Attractiveness = Perceived DUV Attractiveness+Perceived EUV Attractiveness
~ 1/nm
~ This variable will become the denominator of the Investment Fractions. It is not a real physical parameter.
Investment in EUV=Fraction Investment in EUV*Total Investment
~ dollars/Year
~ Investments ($/year) going to EUV technology.
EUV Performance=1/EUV Critical Dimension
~ 1/nm
~ EUV performance is the same as resolution, or inverse of critical \
dimension.
Initial Perceived DUV Attractiveness=Initial DUV Performance
~ 1/nm
Initial Perceived EUV Attractiveness=Initial EUV Performance
~ 1/nm
EUV Attractiveness=EUV Performance
~ 1/nm
~ EUV attractiveness is equal to EUV performance (simple proportionality \
relationship).
Fraction Investment in EUV=Perceived EUV Attractiveness/Total Perceived Attractiveness
~ Fraction
~ This is the fraction (between 0 and 1) of total investments that will be \
given to EUV technology.
StartTime = 0.5
~ Year
Fraction Investment in DUV=Perceived DUV Attractiveness/Total Perceived Attractiveness
~ Fraction
~ This is the fraction (between 0 and 1) of total investments that will be \

given to DUV technology.
DUV Project Effectiveness=0.05
~ Fraction/Project
~ Fractional contribution of a completed DUV project to the reduction in \
critical dimension gap. In other words, one completed DUV project will \
reduce the critical dimension gap (same as saying, it will enhance the \
performance) by this fraction.
Fractional DUV Gap reduction=Completing DUV projects*DUV Project Effectiveness
~ Fraction/Year
reducing DUV CD=Fractional DUV Gap reduction*Gap DUV CD
~ nm/Year
DUV Critical Dimension= INTEG (-reducing DUV CD,Initial DUV CD)
~ nm
~ Critcal dimension of DUV (in nanometers or nm).
Gap DUV CD=DUV Critical Dimension-DUV CD Limit
~ nm
Initial EUV CD=200
~ nm
change in PA of EUV=
(EUV Attractiveness-Perceived EUV Attractiveness)/Time to perceive
~ 1/nm/Year
EUV Critical Dimension= INTEG (-reducing EUV CD,Initial EUV CD)
~ nm
~ Critcal dimension of EUV (in nanometers or nm).
reducing EUV CD=Gap EUV CD*Fractional EUV Gap Reduction
~ nm/Year
Fractional EUV Gap Reduction = Completing EUV projects*EUV Project Effectiveness
~ Fraction/Year
EUV Project Effectiveness = 0.05
~ Fraction/Project
~ Fractional contribution of a completed EUV project to the reduction in \
critical dimension gap. In other words, one completed EUV project will \
reduce the critical dimension gap (same as saying, it will enhance the \
performance) by this fraction.
DUV CD Limit = 150
~ nm
~ The physical limit for EUV technology
Initial DUV CD = 200
~ nm
Gap EUV CD = EUV Critical Dimension-EUV CD Limit
~ nm
Completed DUV projects = INTEG (Completing DUV projects,0)
~ Projects
Normal DUV project rate = 1e-006
~ Projects/dollars
~ Normal number of DUV projects that get started per dollar.
Completing DUV projects=
"On-going DUV projects"/Time to complete DUV projects
~ Projects/Year
~ Rate at which projects in DUV are completed.
"On-going DUV projects"= INTEG (+DUV project starts-Completing DUV projects,0)
~ Projects
DUV project starts = Investment in DUV*Normal DUV project rate
~ Projects/Year
Time to complete DUV projects = 0.5
~ Year
~ Time it takes to finish a project in DUV technology.
Completing EUV projects = "On-going EUV projects"/Time to complete EUV project
~ Projects/Year
~ Rate at which projects in EUV are completed.
Time to complete EUV project=0.5
~ Year

~ Time it takes to finish a project in DEUV technology.
Investment in DUV = Fraction Investment in DUV*Total Investment
~ dollars/Year
~ Investments ($/year) going to DUV technology.
change in TI = growth trend*Total Investment
~ dollars/Year/Year
Completed EUV projects= INTEG (Completing EUV projects,0)
~ Projects
"On-going EUV projects"= INTEG (EUV projects starts-Completing EUV projects, 0)
~ Projects
Initial Total Investment=5e+007
~ dollars/Year
Normal EUV project rate=1e-006
~ Projects/dollars
~ Normal number of EUV projects that get started per dollar.
EUV projects starts = Investment in EUV*Normal EUV project rate
~ Projects/Year
Total Investment= INTEG (change in TI,Initial Total Investment)
~ dollars/Year
~ This is the total dollars per year available for both technologies.
Perceived EUV Attractiveness= INTEG (change in PA of EUV,Initial Perceived EUV Attractiveness)
~ 1/nm
~ It takes time for EUV attractiveness to be perceived.
Time to perceive=0.3
~ Year
~ Time required for technology attractiveness to be perceived.
Disturbance = PULSE(startTime, duration)
~ dimensionless
~ Disturbance will be a Pulse type function.
Disturbance Switch=0
~ dimensionless
~ Switch allowing for disturbance (if set to 1) or no disturbance (if set to \
0) to be applied to Growth Trend.
Duration = 2
~ Year
amplitude = 0.8
~ Fraction/Year

APPENDIX D

(Chapter 3.3)

```
#          Sterman's Model of Two-Sector Economy          #
#                                                         #
#        Flight Simulator/Game: Economic Long Wave        #
#                 (version 2.0. PC-based)                 #
#                                                         #
#  Model:   Sterman, J.D. 1989. Deterministic chaos in an #
#  experimental economic system. Journal of Economic      #
#  Behavior, and Organization.                            #
#                                                         #
#  Designed and developed by Professor John D. Sterman,   #
#  Dr. Yuri V. Granik, Dr. Victor V. Boksha.              #
#                                                         #
#              MIT Sloan School of Management             #
#               November 1999 - April 2000                #
#                                                         #

################################

#Load iwidgets
package require Iwidgets


################################
#
class Curstack {

   #Static Variables
   #common _static_name ""

   #Can be set using "configure"
   #that's why it's public
   public variable maxstack 100

   #Variables
   private variable _stacklist [list]

   #-1 means empty stack
   private variable _cursor -1

   #Constructor declarations
   constructor { } {}
   #destructor {}

   #Static methods
   #proc aProc {}

   #Methods
   method empty { }

   method peek { }

   method pop { }

   method push { item }

   method back { }

   method forth { }
```

```
  method toList { } {
          return $_stacklist
  }

  method getCursor { } {
    return $_cursor
  }

  method getLength {} {
    return [llength $_stacklist]
  }
}

#--- Constructor Implementations ---

#
# Constructor implementation
#
body Curstack::constructor { } {

}

#
# Destructor implementation
#
#body Curstack::destructor {} {
#}

#--- Static Procedures Implementations ---

#
#
#
#body Curstack::aProc { } {
#}


#--- Method Implementations ---


#
#Returns item at cursor position
#
body Curstack::peek { } {
  return [lindex $_stacklist $_cursor]
}
#
#Set cursor all the way back
#
body Curstack::empty { } {
  set _cursor -1
  set _stacklist [list]
}
#
#Set cursor back
#
body Curstack::pop { } {
  if { $_cursor >= 0 } {
          incr _cursor -1
  }
  return [lindex $_stacklist $_cursor]
}

#
#Cut to [min(0, $_cursor-$maxstack]...$_cursor,
#set cursor forth, and append
#
body Curstack::push { item } {
  #Cut list to the cursor, length less than
  #maxstack
```

```
    set _stacklist [lrange $_stacklist [expr $_cursor-$maxstack] $_cursor]
    incr _cursor

    if { $_cursor >= [llength $_stacklist] } {
            set _cursor [expr [llength $_stacklist]]
    }
    lappend _stacklist $item
}

#
#Set cursor back
#If cannot go back, return empty
#string
#Cannot empty the stack! unlike pop does.
body Curstack::back { } {
    if { $_cursor > 0 } {
            incr _cursor -1
            return [lindex $_stacklist $_cursor]
    } else {
            return ""
    }
}

#
#Set cursor forth. If cannot go forth, return empty
#string
#
body Curstack::forth { } {
    if { ($_cursor < [expr [llength $_stacklist]-1] ) } {
            incr _cursor
            return [lindex $_stacklist $_cursor]
    } else {
            return ""
    }
}
#
#################################################################

#################################################################
#
class Set {

    #Static Variables
    #common _static_name ""

    #Variables
    private variable _elarr

    #Constructor declarations
    constructor { {argv "" } } {}
    #destructor {}

    #Static methods
    #proc aProc {}

    #Java interface
    #boolean add(Object o) Adds the specified element to this set if it is not already present.
    #void clear() Removes all of the elements from this set.
    #Object clone() Returns a shallow copy of this HashSet instance: the elements themselves are not cloned.
    #boolean contains(Object o) Returns true if this set contains the specified element.
    #boolean isEmpty() Returns true if this set contains no elements.
    #Iterator iterator() Returns an iterator over the elements in this set.
    #boolean remove(Object o) Removes the given element from this set if it is present.
    #int size() Returns the number of elements in this set (its cardinality).

    #Methods
    method add { el }

    method addAll { ell }
```

```
    method toList { }

    method contains { el }

    method isEmpty { }

    method remove { el }

    method clear { }

    method size { }

}

#--- Constructor Implementations ---

#
# Constructor implementation
#
body Set::constructor { {argv ""} } {
    #In case the argv is empty
    #we identify _elarr as array
    set _elarr(0) 0
    unset _elarr(0)

    #Add elements
    foreach el $argv {
            set _elarr($el) 1
    }
}

#
# Destructor implementation
#
#body Set::destructor {} {
#}

#--- Static Procedures Implementations ---

#
#
#
#body Set::aProc { } {
#}


#--- Method Implementations ---

#
#
#
body Set::add { el } {
    set _elarr($el) 1
}

#
#
#
body Set::addAll { ell } {
    #Add elements
    foreach el $ell {
            set _elarr($el) 1
    }
}

#
#
#
body Set::toList { } {
    return [array names _elarr]
```

```
}

#
#
#
body Set::contains { el } {
  if { [info exists _elarr($el)] } {
           return 1
  } else {
           return 0
  }
}

#
#
#
body Set::isEmpty { } {
  if { [$this size] } {
           return 0
  } else {
           return 1
  }
}

#
#
#
body Set::remove { el } {
  catch { unset _elarr($el) }
}
#
#
#
body Set::clear { } {
  catch { unset _elarr }
  set _elarr(0) 0
  unset _elarr(0)
}

#
#
#
body Set::size { } {
  return [llength [array names _elarr]]
}
#
################################################################


#
#Sterman's model of two sector
#economy
#
class Economy {
         private {
                  #Capital stock
                  variable _K

                  #Aquisitions by capital sector
                  variable _A

                  #Aquisitions by goods sector
                  variable _Ag

                  #Deprecation
                  variable _D

                  #Order for capital sector, backlog
                  variable _B
```

```
			#Order for goods sector, backlog
			variable _Bg

			#Backlog fraction
			variable _F

			#Production
			variable _P

			#Desired Production, P*
			variable _Ps

			#Production capacity
			variable _C

			#Model parameters

			#Capital orders: determined by subject of simulator
			variable _O

			#Goods orders: extrogenious variable
			variable _Og

			#Ed parameter tau, average life of capital
			variable _tau

			#Capital/output ratio
			variable _kco
		}
		constructor { {tau 10.0} {kco 1.0} } { }

		method initEquilibrium { K Og }

		method step { o }

  method perturbOg { og }

  method toList { }

  proc header { }

  method getVar { a } {
		return [set $a]
  }
}


#
#Set new value of Og
#
body Economy::perturbOg { year } {
  if { $year == 2 } {
		incr _Og 50
  }
}

#
#Dump to list values
#
body Economy::toList { } {
  return [list $_K $_A $_Ag $_D $_B $_Bg $_F $_P $_Ps $_C $_O $_Og $_tau $_kco]
}

#
#Dump to list
#
body Economy::header { } {
  return [list K A Ag D B Bg F P Ps C O Og tau kco]
}
```

```
#
#Calculate new values
#given value of _O
body Economy::step { o } {
        set _O $o

        #From 3 find new K
        set _K [expr $_K+$_A-$_D]

        #From 9
        set _B [expr $_B+$_O-$_A]

        #From 10
        set _Bg [expr $_Bg+$_Og-$_Ag]

        #Now update everything else
        #From 2 new value of C
        set _C [expr $_K/$_kco]

        #From 4 find D
        set _D [expr $_K/$_tau]

        #Fromm 8 find P*
        set _Ps [expr $_B+$_Bg]

        #From 1 find P
        set _P [expr ($_Ps > $_C)?($_C):($_Ps)]

        #From 7 find F
        set _F [expr $_P/$_Ps]

        #From 5,6 find A, Ag
        set _A [expr $_B*$_F]
        set _Ag [expr $_Bg*$_F]
}
#
#
#
body Economy::constructor { {tau 10.0} {kco 1.0} } {
        #Init parameters
        set _tau $tau
        set _kco $kco
}

#
#Given initial orders, calculate variables assuming
#the system is in equlibrium
#
body Economy::initEquilibrium { k og } {
        #Memorize given orders
        #Og = 450
        set _Og $og

        #Capital stock is given
        #K = 500
        set _K $k

        #Variables calculated from stationary point
        #see page 9, sterman, 1989

        #Using 4 we find D:
        #D = 500/10=50
        set _D [expr $_K/$_tau]

        #Using eq 3: in edu-m Kt+1=Kt, then
        #A = 50
        set _A $_D

        #Using 2 find C
        #C=500
```

```
set _C [expr $_K/$_kco]

#Using 9
#O=50
set _O $_A

#Using 10
#Ag = 450
set _Ag $_Og

#Assuming P* = C
#P* = 500
set _Ps $_C

#Then from 1, 7, 6, 5
#P = 500
set _P $_C
set _F 1.0
set _B $_A
set _Bg $_Ag
}
################################################################


#
#
#
class ModeWindow {

   inherit iwidgets::Dialog

        variable _rb ""

        variable _step_year 2

        variable _step_value 50

        variable _max_value 600

        variable _min_value 400

        variable _year_period 10

        method applyClbk { } {
                set s [$_rb get]
                if { $s == "step" } {
                        #Pretty amaizing piece of the code
                        #We redefine class method to our likening.
        eval body Economy::perturbOg \{ year \} \{ if \{ \$year == $_step_year \} \{ incr _Og $_step_value \} \}
                } elseif { $s == "noise" } {
        eval body Economy::perturbOg \{ year \} \{ if \{ \$year >= $_step_year \} \{ set _Og \[expr ($_max_value-
$_min_value)*rand()+$_min_value\] \} \}
                } elseif { $s == "oscil" } {
        eval body Economy::perturbOg \{ year \} \{ if \{ \$year >= $_step_year \} \{ set _Og \[expr ($_max_value-
$_min_value)*(sin((\$year-$_step_year)*6.283/$_year_period)+1.0)/2.0+$_min_value\] \} \}
                } elseif { $s == "rwalk" } {
        eval body Economy::perturbOg \{ year \} \{ if \{ \$year >= $_step_year \} \{ set _Og \[expr 2.0*$_step_value*(rand()-
0.5)+\$_Og\] \} \; if \{ \$_Og <= 0 \} \{ set _Og $_min_value \} \}
                }
        }

    constructor { {argv ""} } {
                set chst [childsite]
                set _rb [iwidgets::radiobox $chst.mode -labeltext "Orders Mode"]
                pack $_rb
                $_rb add step -text "Step"
                $_rb add noise -text "Noise"
                $_rb add oscil -text "Oscillations"
                $_rb add rwalk -text "Random Walk"
```

```
                        $_rb select step

                        delete Help
                        buttonconfigure OK -command "[code $this applyClbk]; [code $this deactivate 0]"
                        buttonconfigure Apply -command "[code $this applyClbk]"

                        set vf [frame $chst.valuef]
                        pack $vf

                        set row 0

                        set l [label $vf.incrl -text "Increase in orders"]
        set e [entry $vf.incre -textvariable [scope _step_value] -width 5]
                        grid $l -row $row
                        grid $e -column 1 -row $row
                        incr row

                        set l [label $vf.stepl -text "Year to step up"]
        set e [entry $vf.stepe -textvariable [scope _step_year] -width 5]
                        grid $l -row $row
                        grid $e -column 1 -row $row
                        incr row

                        set l [label $vf.noiseminl -text "Min value"]
        set e [entry $vf.noisemine -textvariable [scope _min_value] -width 5]
                        grid $l -row $row
                        grid $e -column 1 -row $row
                        incr row

                        set l [label $vf.noisemaxl -text "Max value"]
        set e [entry $vf.noisemaxe -textvariable [scope _max_value] -width 5]
                        grid $l -row $row
                        grid $e -column 1 -row $row
                        incr row


                        set l [label $vf.yearperiodl -text "Year period"]
        set e [entry $vf.yearperiode -textvariable [scope _year_period] -width 5]
                        grid $l -row $row
                        grid $e -column 1 -row $row
                        incr row

                eval itk_initialize $argv
                }
}

#
#
#
class FlightWindow {

   inherit iwidgets::Mainwindow

   constructor { {argv} } { }

   common MAXYEAR 72

   #
   private {
           variable _O ""

           variable _Og ""

           variable _Ps ""

           variable _P ""

           variable _K ""

           variable _F ""
```

```
            variable _year ""

            variable _economy ""

            variable _econostack [Curstack ::\#auto]

            variable _cost "?"

            variable _filechooser ""

            variable _mode_dialog ""
    }
    #
    #Called when window is closed by wm
    #
    method _exitCB {} {
            #
      # Configure the message dialog for confirmation of the exit request.
            #
      msgd configure -title "Exiting" -bitmap warning -text "Exiting Flight Simulator"
            msgd center [childsite]

            #
            # Activate the message dialog and given a positive response
            # proceed to exit the application
            #
            if {[msgd activate]} {
               ::exit
            }
    }

    method openClbk { }

    method saveClbk { }

    method stepClbk  { }

    method resetClbk { }

    method openModeClbk { }

    method setEconomy { e }

    method display { e }

    method reset { }

    method cost { e }

}
#
#
#
body FlightWindow::constructor { {argv} } {


    #Menubar
    menubar add menubutton file -text "File" -underline 0 -padx 8 -pady 2 \
            -menu "options -tearoff no -background  red; \
               command save -command \"$this saveClbk\" -label {Save...} -underline 0 -helpstr {Save experiment file} ;\
               separator sep1;\
         command exit -command  \"$this _exitCB\" -label {Exit} -underline 1 -helpstr {Exit Flight Simulator} "

    menubar add menubutton options -text "Options" -underline 0 -padx 8 -pady 2 \
            -menu "options -tearoff no -background  red; \
               command mode -command \"$this openModeClbk\" -label {Orders Mode...} -underline 0 -helpstr {Save experiment
file} ;\
               separator sep1;"
```

```
#Toolbar
toolbar add button step -text "Step" -helpstr "Step to new year" -balloonstr "Add 2 years"  -relief flat -command [code $this
stepClbk]

toolbar add button reset -text "Reset" -helpstr "Start over" -balloonstr "Start simulation over"  -relief flat -command [code $this
resetClbk]

#Canvas
set chldst [childsite]

#This frame holds the main picture
set f [frame $chldst.cf]

#Capital sector new orders
set cof [frame $f.cf -bd 2 -relief sunken]
label $cof.cosln -text "New Orders"
entry $cof.csnoe -textvariable [scope _O] -width 5
label $cof.cosl -text "Capital\nSector"
pack $cof.cosln
pack $cof.csnoe
pack $cof.cosl

#Left Canvas arrow
set fcal [frame $f.fcal -bd 2 -relief flat]
canvas $fcal.cn -width 60 -height 40 -borderwidth {-1}

#Draw an arrow
set arrowh 40
set arroww 60

$fcal.cn create polygon \
        0 [expr $arrowh/4] \
        [expr $arroww-10] [expr $arrowh/4] \
        [expr $arroww-10]  0  \
        $arroww [expr $arrowh/2] \
        [expr $arroww-10] $arrowh \
        [expr $arroww-10] [expr 3*$arrowh/4] \
        0  [expr 3*$arrowh/4] \
        -fill red

pack $fcal.cn

#Right Canvas arrow
set fcar [frame $f.fcar -bd 2 -relief flat]
canvas $fcar.cn -width 60 -height 40 -borderwidth {-1}
#Draw an arrow
$fcar.cn create polygon \
        $arroww [expr $arrowh/4] \
        10 [expr $arrowh/4] \
        10  0  \
        0 [expr $arrowh/2] \
        10 $arrowh \
        10 [expr 3*$arrowh/4] \
        $arroww  [expr 3*$arrowh/4] \
        -fill blue

pack $fcar.cn

#Goods sector new orders
set gof [frame $f.gf -bd 2 -relief sunken]
label $gof.gosln -text "New Orders"
label $gof.gsnoe -textvariable [scope _Og]
label $gof.gosl -text "Goods\nSector"
pack $gof.gosln
pack $gof.gsnoe
pack $gof.gosl

#Desired production frame
set fdp [frame $f.dp -bd 2 -relief sunken]
```

```
#Top frame
set fdpt [frame $fdp.dpt -bd 2 -relief flat]
label $fdpt.dpl -text "Desired Production" -width 30
label $fdpt.dple -textvariable [scope _Ps]
pack $fdpt.dpl $fdpt.dple

#Second top frame
set fdpt2 [frame $fdp.dpt2 -bd 2 -relief flat]
label $fdpt2.dpl -text "Backlog of\nUnfilled Orders"
pack $fdpt2.dpl

#Left frame in Desired production
set fdpl [frame $fdp.dpl -bd 2 -relief groove]
label $fdpl.cdpl -textvariable [scope _O]
label $fdpl.cdl -text "Capital Sector"
pack $fdpl.cdpl $fdpl.cdl

#Right frame in Desired production
set fdpr [frame $fdp.dpr -bd 2 -relief groove]
label $fdpr.gdpl -textvariable [scope _Og]
label $fdpr.gdl -text "Goods Sector"
pack $fdpr.gdpl $fdpr.gdl

#Pack frames in Desired production
pack $fdpt $fdpt2
pack $fdpl -side left -fill both -expand yes
pack $fdpr -side right -fill both -expand yes

#Shipments to goods
set fsgs [frame $f.sgs -bd 2 -relief flat]
label $fsgs.l -text "Shipments\nto\nGoods\nSector"
canvas $fsgs.cn -width 60 -height 40 -borderwidth {-1}
$fsgs.cn create polygon \
        0 [expr $arrowh/4] \
        [expr $arroww-10] [expr $arrowh/4] \
        [expr $arroww-10]  0 \
        $arroww [expr $arrowh/2] \
        [expr $arroww-10] $arrowh \
        [expr $arroww-10] [expr 3*$arrowh/4] \
        0  [expr 3*$arrowh/4] \
        -fill blue

pack $fsgs.cn -side left
pack $fsgs.l

#Shipments to capital
#Draw an arrow
set arrowh 40
set arroww 160

set fscs [frame $f.scs -bd 2 -relief flat]
label $fscs.l -text "Shipments\nto Capital\nSector"
canvas $fscs.cn -width 40 -height 160 -borderwidth {-1}
$fscs.cn create polygon \
        [expr $arrowh/4] $arroww \
        [expr $arrowh/4] 10 \
        0 10 \
        [expr $arrowh/2] 0  \
        $arrowh 10 \
        [expr 3*$arrowh/4] 10 \
        [expr 3*$arrowh/4] $arroww  \
        -fill red
pack $fscs.cn -side left
pack $fscs.l

#Production frame
set fpr [frame $f.pr -bd 2 -relief sunken]
label $fpr.l -text "Production"
label $fpr.le -textvariable [scope _P]
pack $fpr.l $fpr.le
```

```
    #Capital stock frame
    set fcs [frame $f.cs -bd 2 -relief sunken]
    label $fcs.l -text "Capital Stock"  -width 30
    label $fcs.le -textvariable [scope _K]
    pack $fcs.l $fcs.le -fill both -expand yes

    #Deprecation
    set arrowh 40
    set arroww 60
    set fdep [frame $f.dep -bd 2 -relief flat]
    label $fdep.l -text "Deprecation"
    canvas $fdep.cn -width 60 -height 40 -borderwidth {-1}
    $fdep.cn create polygon \
            0 [expr $arrowh/4] \
            [expr $arroww-10] [expr $arrowh/4] \
            [expr $arroww-10]  0  \
            $arroww [expr $arrowh/2] \
            [expr $arroww-10] $arrowh \
            [expr $arroww-10] [expr 3*$arrowh/4] \
            0  [expr 3*$arrowh/4] \
            -fill red

    pack $fdep.cn -side left
    pack $fdep.l

    #Year
    set fy [frame $f.y -bd 2 -relief flat]
    label $fy.l -text "Year" -font bold
    label $fy.le -textvariable [scope _year] -font bold
    pack $fy.l $fy.le -side left

    #Grid the frames
    grid $cof -row 10 -column 2 -rowspan 2
    grid $fcal -row 10 -column 3 -sticky s
    grid $fdp -row 8 -column 4 -columnspan 2  -rowspan 3
    grid $fcar -row 10 -column 8 -sticky s
    grid $gof -row 10 -column 9 -rowspan 2 -columnspan 2
    grid $fsgs -row 7 -column 8 -columnspan 5 -rowspan 2
    grid $fscs -row 6 -column 5
    grid $fpr -row 6 -column 8 -columnspan 2
    grid $fcs -row 4 -column 4 -columnspan 2
    grid $fdep -row 4 -column 8 -columnspan 2
    grid $fy -row 3 -column 4 -columnspan 2

    #grid configure $f -columns 15


    #Left main frame
    set ff [frame $chldst.ff -relief sunken -bd 2 ]
    set frscale [scale $ff.frscale -from 100 -to 0 -orient vertical -variable [scope _F] -highlightthickness {-1} -state disabled]
    label $ff.l -text "Fraction\nof\nDemand\nSatisfied"
    #Cost
    label $ff.cost -text "Cost"
    label $ff.coste -textvariable [scope _cost]

    pack $ff.l
    pack $frscale -fill both -expand yes
    pack $ff.cost $ff.coste

    #Packing main and left frames
    pack $ff -side left -fill y -expand true -padx 5 -pady 5
    pack $f -fill both -expand true -padx 5 -pady 5

    #set frscale [scale $ff.frscale -orient vertical -digits 3 -from 1.2 -resolution 0.01 -showvalue 0 -to 0.0 -variable [scope
_contscale] -command [code $this scaleClbk]]

    #Real window evaluation
    eval itk_initialize $argv
}
```

```
#
#
#
body FlightWindow::openClbk { } {
}

#
#
#
body FlightWindow::openModeClbk { } {
            if { $_mode_dialog == "" } {
                        #create mode dialog
                        set _mode_dialog [ModeWindow $this.modewin]
                        $_mode_dialog center [childsite]
                $_mode_dialog configure -title "Orders Options"
            }
            $_mode_dialog activate
}


#
#Saving to the file
#
body FlightWindow::saveClbk { } {
   if { $_filechooser == "" } {
            #create filechooser
            set _filechooser [iwidgets::fileselectiondialog ${this}.filechooser -modality application -mask "*.2se" ]
            $_filechooser center [childsite]
            $_filechooser configure -title "File Selection"
   }

   set result [$_filechooser activate]

   #OK has been hit
   if { $result == 1 } {
            set filename [$_filechooser get]
            set fd [open $filename w]
            set h [Economy::header]
            puts $fd "year $h"
            set l [$_econostack toList]
            foreach line $l {
               puts $fd $line
            }
            close $fd
   }
}

#
#Step to next year
#
body FlightWindow::stepClbk { } {

   #Grab existing economy and
   #step
   if { $_year >= $MAXYEAR } {
            set _statusVar($this) "The game is over"
            return
   }

   set _year [expr $_year+2]
   $_economy step $_O

   #Memorize economy
   set l [list $_year]
   eval lappend l [$_economy toList]
   $_econostack push $l

   #Calculate cost
   cost $_economy
```

```
    $_economy perturbOg $_year

    display $_economy
}

#
#Reset things clbk
#
body FlightWindow::resetClbk { } {
    reset
}

#
#Calculates cost of economy
#
body FlightWindow::cost { e } {
    set cost 0.0
    set el [$_econostack toList]
    for { set i 1 } { $i < [expr $_year/2] } { incr i } {
            set line [lindex $el $i]
            set p [lindex $line 9]
            set c [lindex $line 10]

            set cost [expr $cost+abs($p-$c)]
    }

    set _cost [format "%.2f" [expr double($cost)/double($_year)]]
}

#
#Reset things
#
body FlightWindow::reset { } {
    set _year 1

    $_economy initEquilibrium 500 450
    #Memorize economy
    $_econostack empty
    set l [list $_year]
    eval lappend l [$_economy toList]
    $_econostack push $l

    display $_economy
}

#
#Display economy
#
body FlightWindow::display { e } {
    set _O [expr int([$e getVar _O])]

    #set _Og [format "%.2f" [$e getVar _Og]]
    set _Og [format "%.0f" [$e getVar _Og]]

    #set _Ps [format "%.2f" [$e getVar _Ps]]
    set _Ps [format "%.0f" [$e getVar _Ps]]

    #set _P [format "%.2f" [$e getVar _P]]
    set _P [format "%.0f" [$e getVar _P]]

    #set _K [format "%.2f" [$e getVar _K]]
    set _K [format "%.0f" [$e getVar _K]]

    set _F [expr 100*[$e getVar _F]]
}


#
#Set economy
```

```
#
body FlightWindow::setEconomy { e } {
   set _economy $e
}


####################################################
#Actions are here
#Open window up
FlightWindow .mw [list -title "Flight Simulator"]
wm withdraw .
.mw center .
.mw activate

Economy ::E

.mw setEconomy ::E
.mw reset
.mw display ::E
#
####################################################
```

THESIS PROCESSING SLIP

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