Structural Change of the Semiconductor Industry from 1957 to 2007

In-Stat Conference, Phoenix, 1991

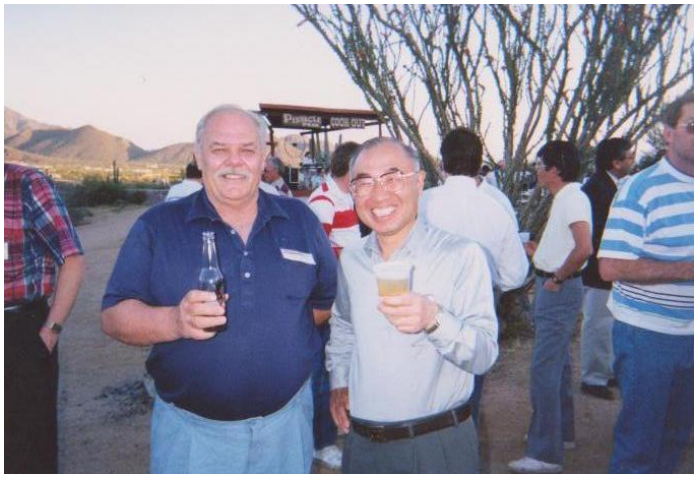
Invited Speech

In 1980's, Dataquest Conference was the largest international conference in the field of semiconductor, but in 1990s, In-Stat Conference gradually became a major conference after Dataquest. Jack Veedle, the founder of In-Stat, had previously been with Motorola, and was very popular because of his excellent build and open-hearted personality. I learned from an ex-Motorola person that Jack first came up with the idea of B/B ratio, or book to bill ratio, and used it internally. SIA published the B/B ratio as an industry wide index, for sometime, and it was well known among semiconductor community.

Soon after the year of 1991 started, I received an invitation from Jack to talk on the subject of Makimoto's Wave. It was not so long since David Manners first wrote about my idea and named it Makimoto's Wave on the Electronics Weekly, UK, in January, 1991. I was surprised to learn that the new concept was getting attention in US so quickly nevertheless the Internet was not so common. I accepted the invitation with such pleasant surprise.

I first came up with the idea of cyclical phenomena of semiconductor industry in 1987. Sometime later, I had an interview about my idea with David Manners, a technical writer in UK.. He was very much interested in the idea, and wrote a big article with the name of Makimoto's Wave in 1991. So, the invitation from Jack was the first opportunity for me to talk about my finding with my own words.

Please see Exhibit IV "Implications of Makimoto's Wave" for more details.



Jack Veedle (left)

STRUCTURAL CHANGE OF THE SEMICONDUCTOR INDUSTRY FROM 1957 TO 2007

In-Stat Conference
May 6, 1991

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HITACHI

This was my first talk on the subject of Makimoto's Wave, which first appeared on the Electronics Weekly, UK, in January of 1991. The name was given by David Manners.

SEMICONDUCTOR EVOLUTION

Various aspects to trace the Evolution

- *Technological aspect*
- *Business aspect*
- *Psychological aspect*

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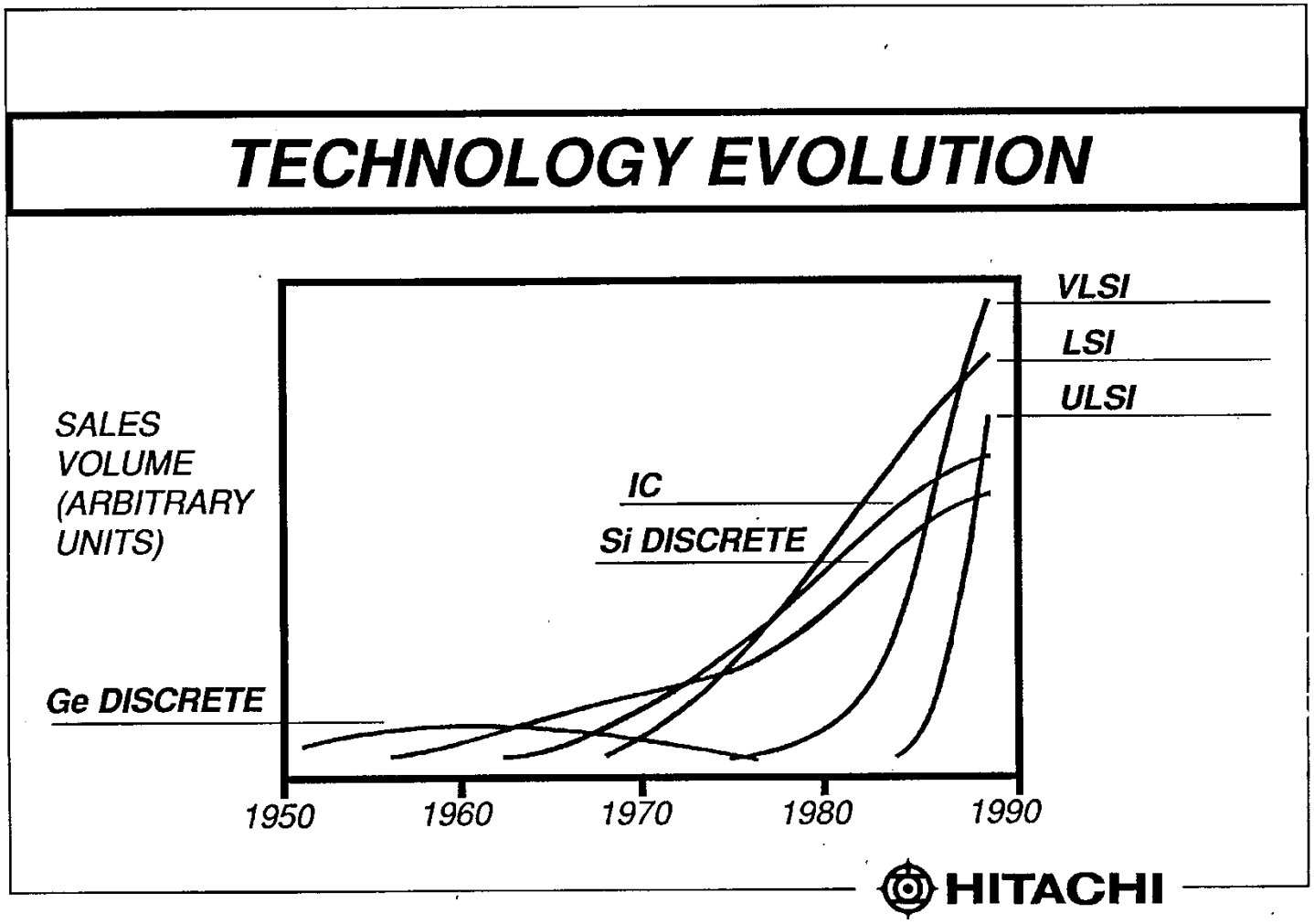
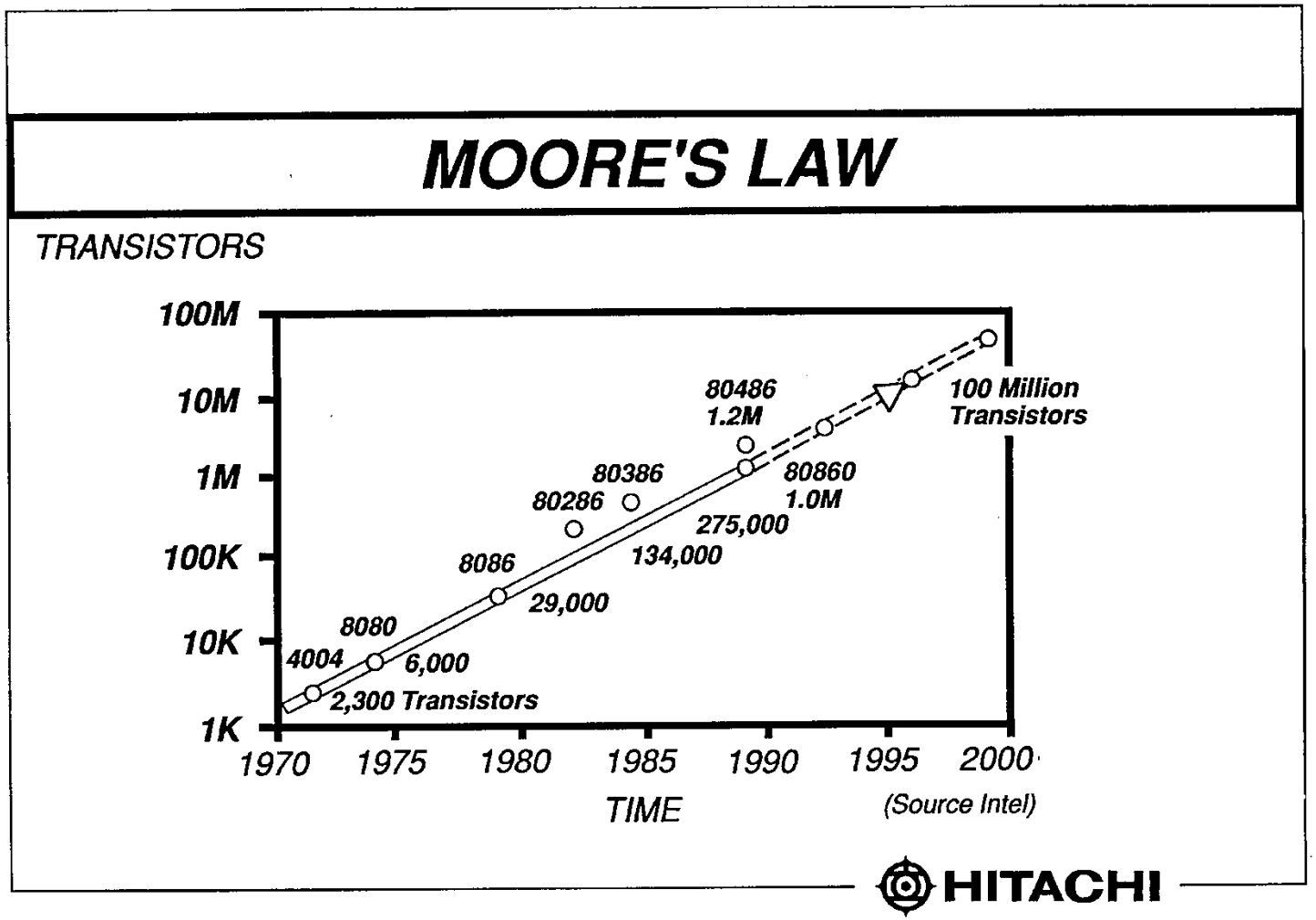
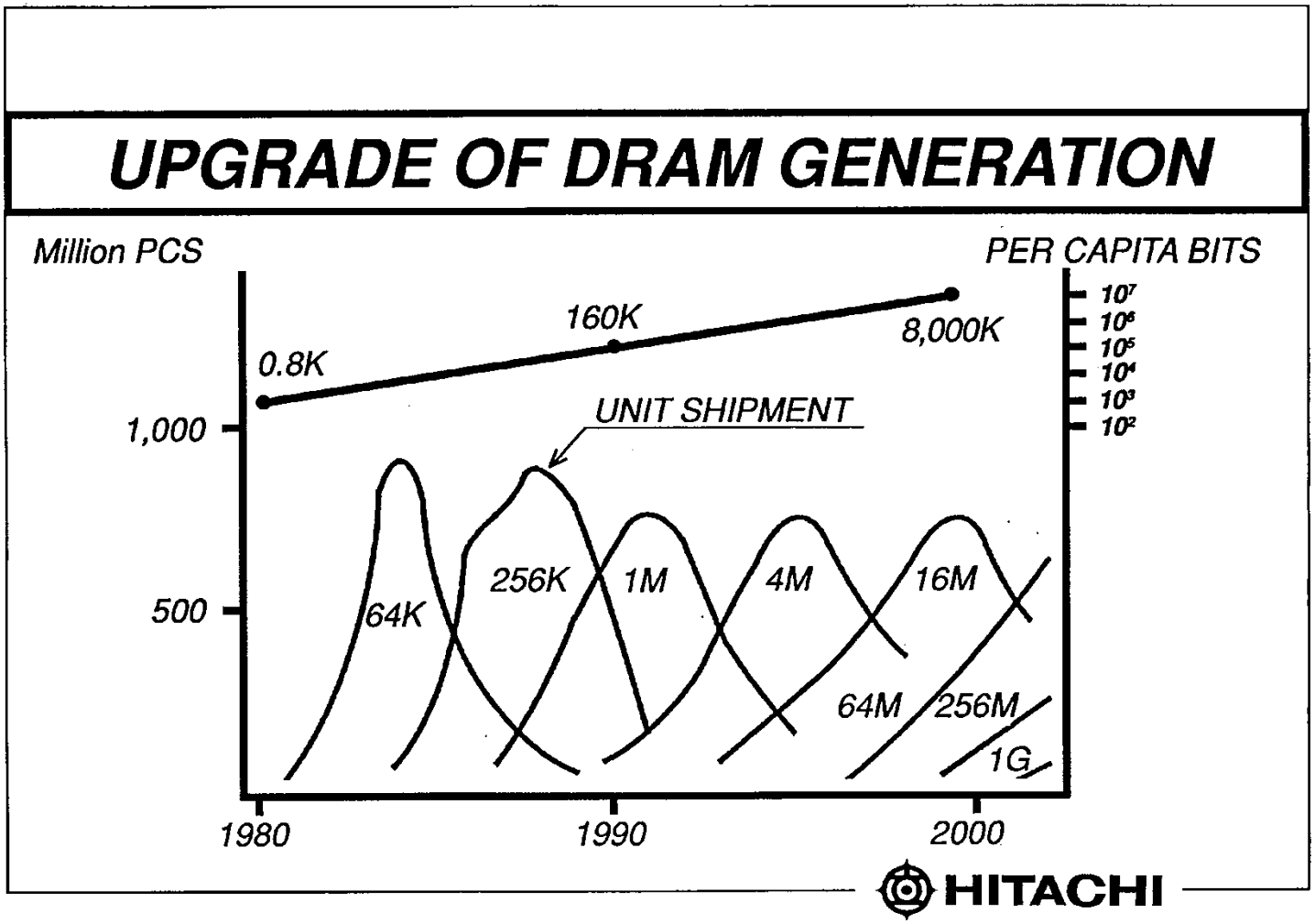


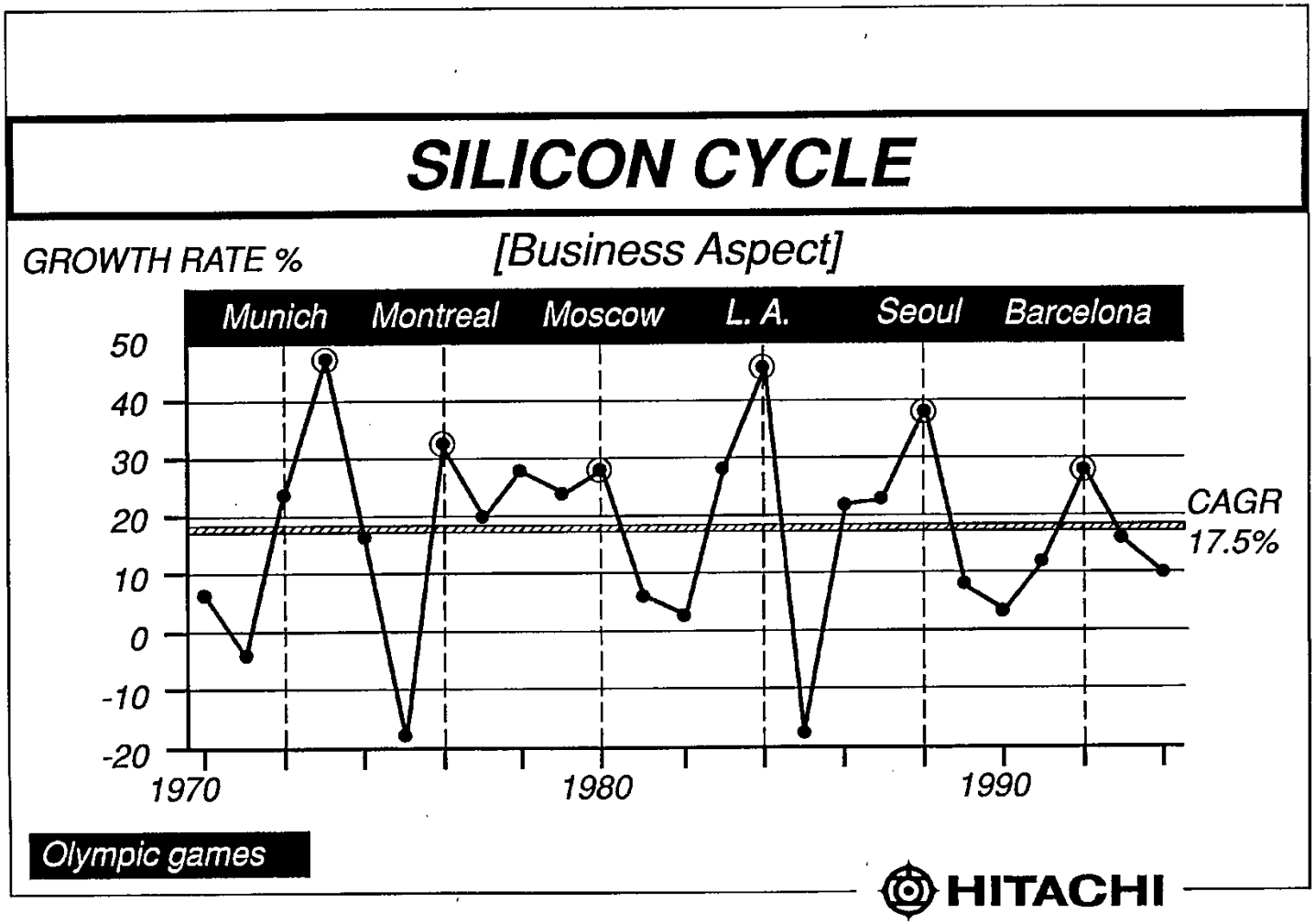
In the semiconductor industry, new technology appears every seven years. Starting from Ge transistor, the newest entry is ULSI. It is usual that a new technology wave always takes over a previous technology wave.



The figure shows the trend of integration density from 1970 to 2000. In 1990, the number of transistor was about 1 Million, but it was expected that in 2000, it would become 100 Million. Looking back from today, 2018, it was still a tiny device.



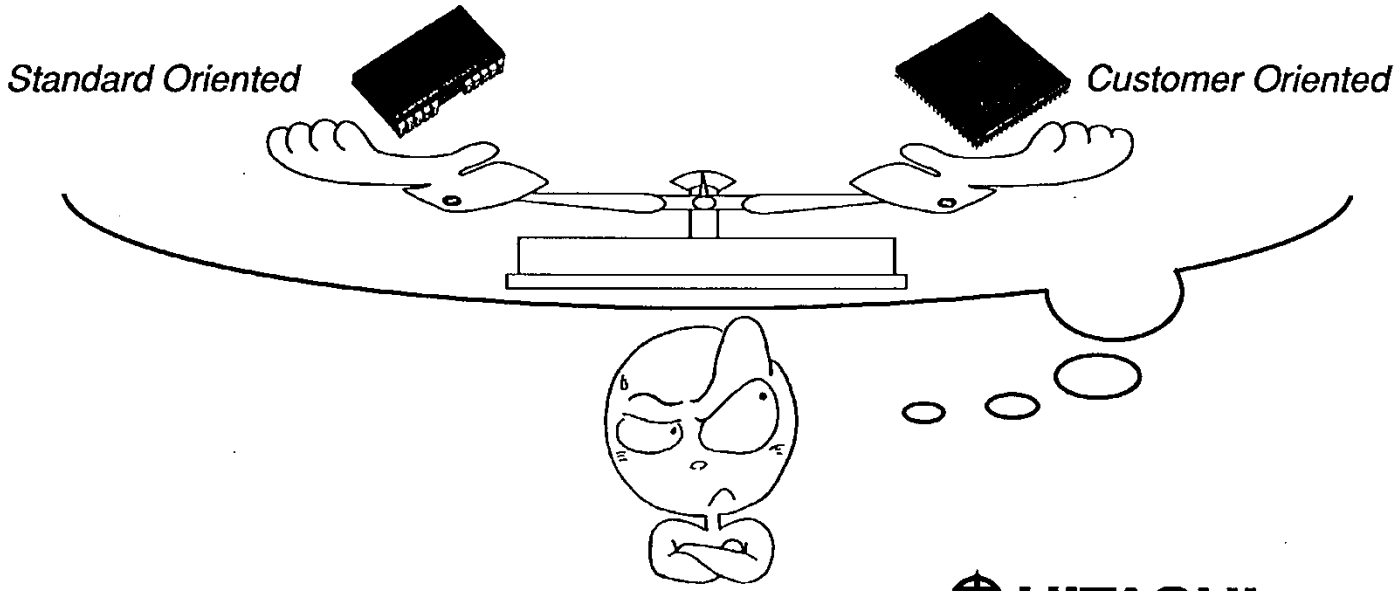
The figure shows the generation change of DRAM, starting from 64K to 1G bit. Each generation has mountain like shape, but each mountain has its unique shape.



Silicon cycle is shown here. At the time of this speech, it was believed that the peak of the cycle coincides with the year of Olympic because of the strong demand in the consumer sector, such as TVs. It was almost true until 1992 (Barcelona Olympic). However, 1996 and 2008 proved to be the worst years of semiconductor, and the “Olympic theory” disappeared.

CUSTOM OR STANDARD

(Psychological Aspect,
Another way of looking at the S. C. Industry)



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"Custom or Standard" is a new way of looking at the semiconductor industry; a serious question for the management. If custom oriented, the business will stabilize, but the efficiency will be lost. If standard oriented, the efficiency will be improved, but the stability will be lost because of heavy competition. This is the never ending question in the semiconductor industry.

STRUCTURAL CHANGE AND EVOLUTION TO DATE

HITACHI

1947-57	ERA OF R & D

MAIN EVENT

1947	INVENTION OF TRANSISTOR
1950	Ge JUNCTION TRANSISTOR DEVELOPED
1954	SILICON TRANSISTOR
1957	MESA TRANSISTOR

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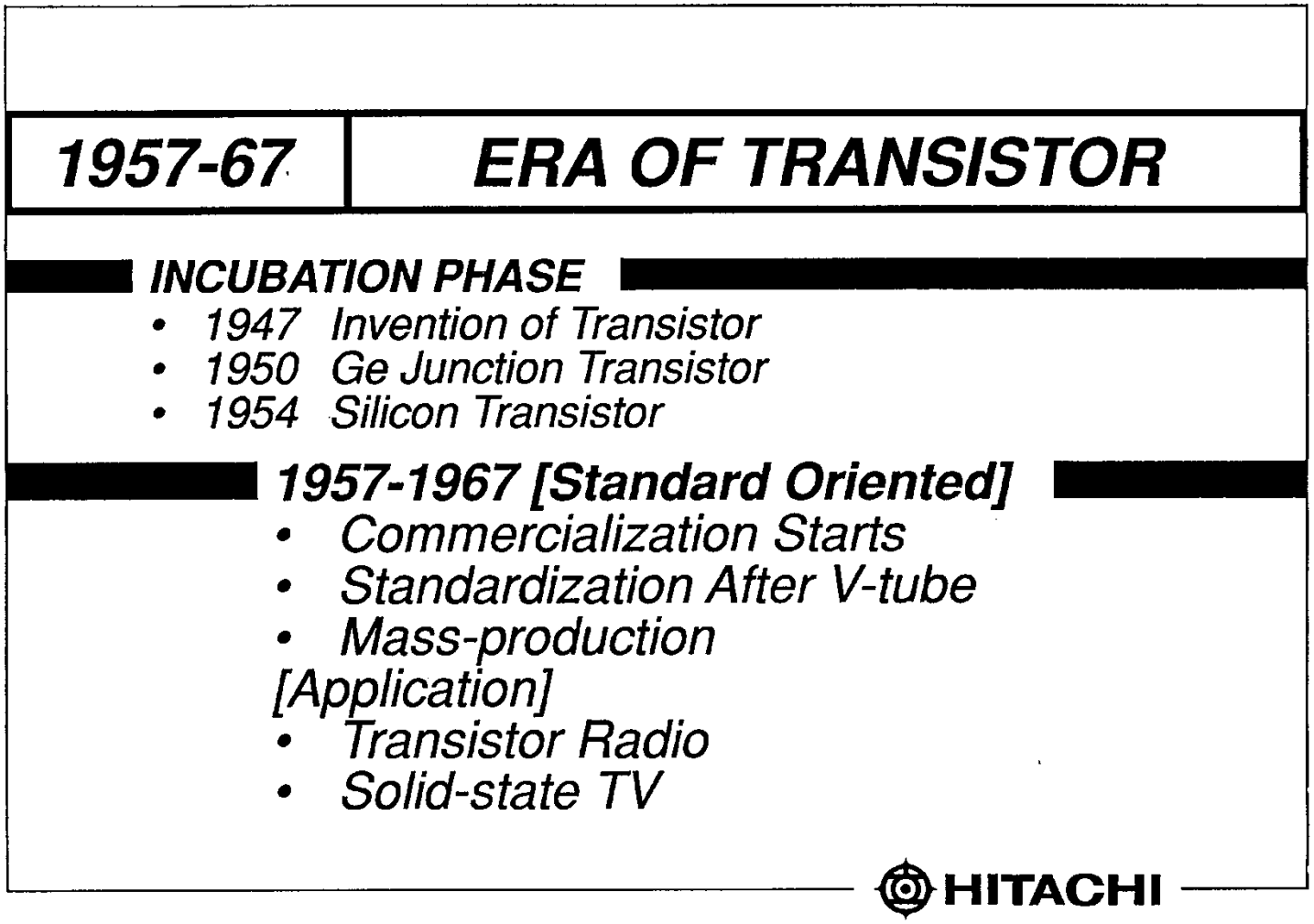
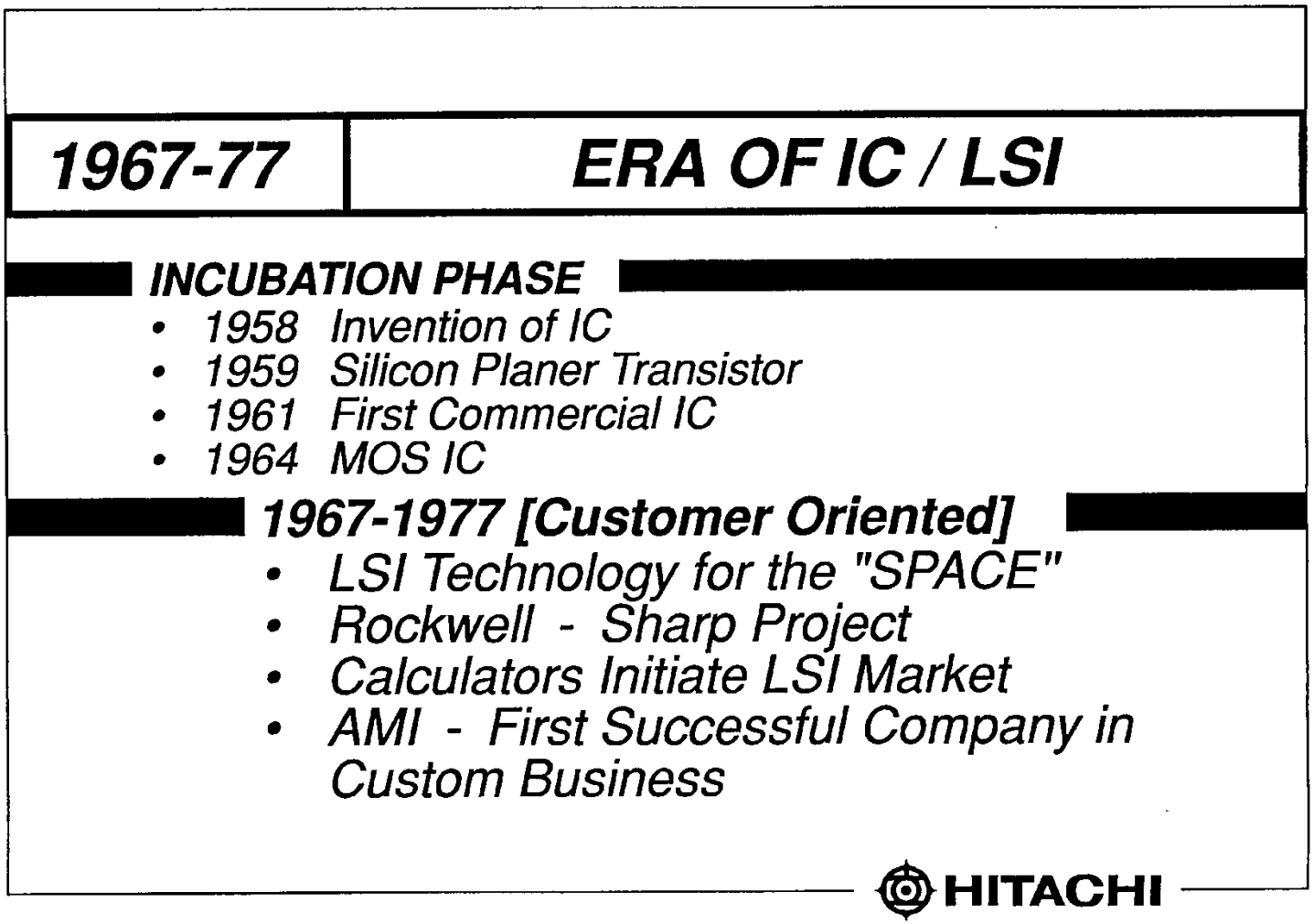
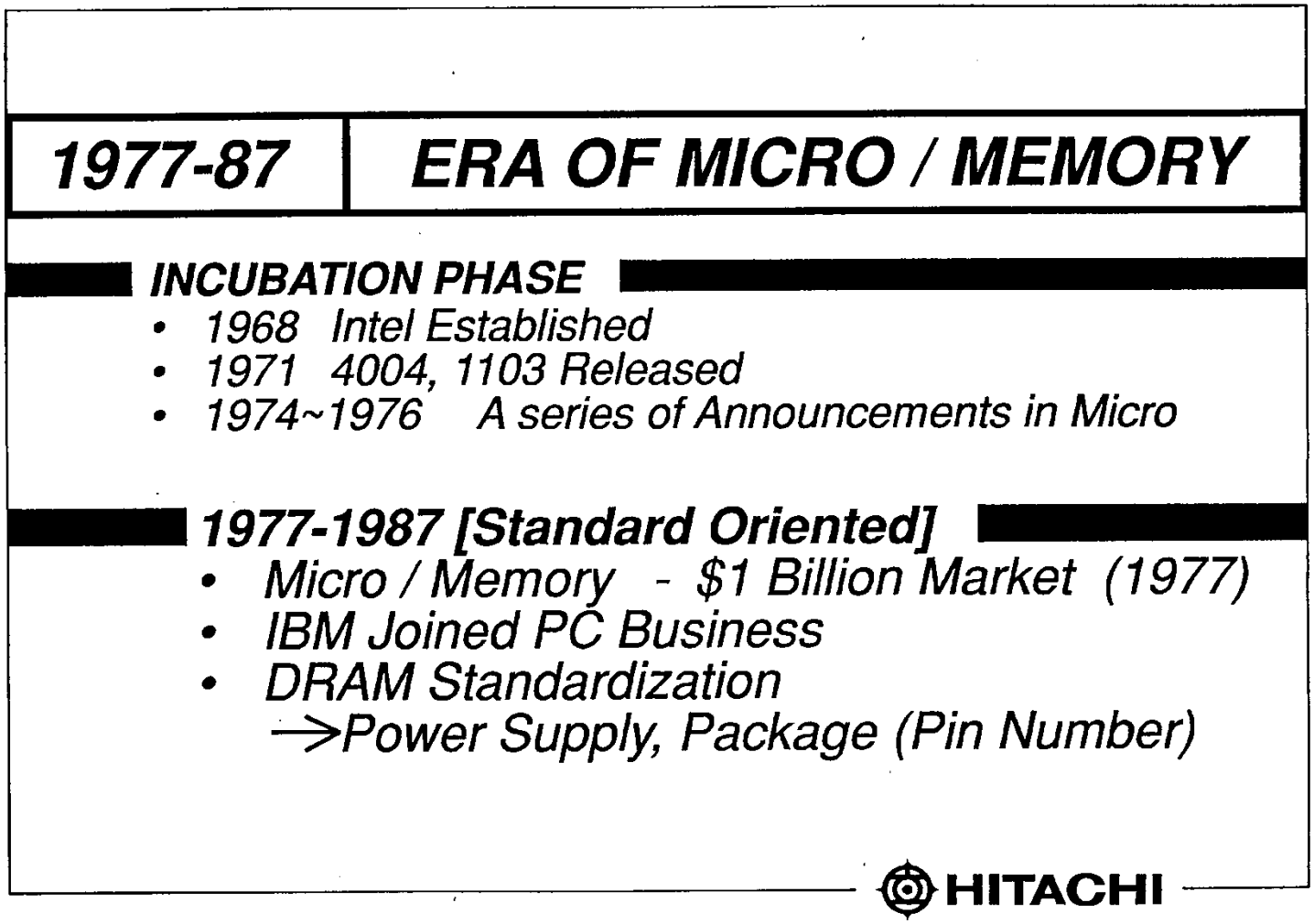
The first decade since the invention of transistor in 1947 can be categorized as “Era of R&D”, since the industry was not yet to make noticeable outcome.
In this decade, major developments were completed for producing various types of transistors.



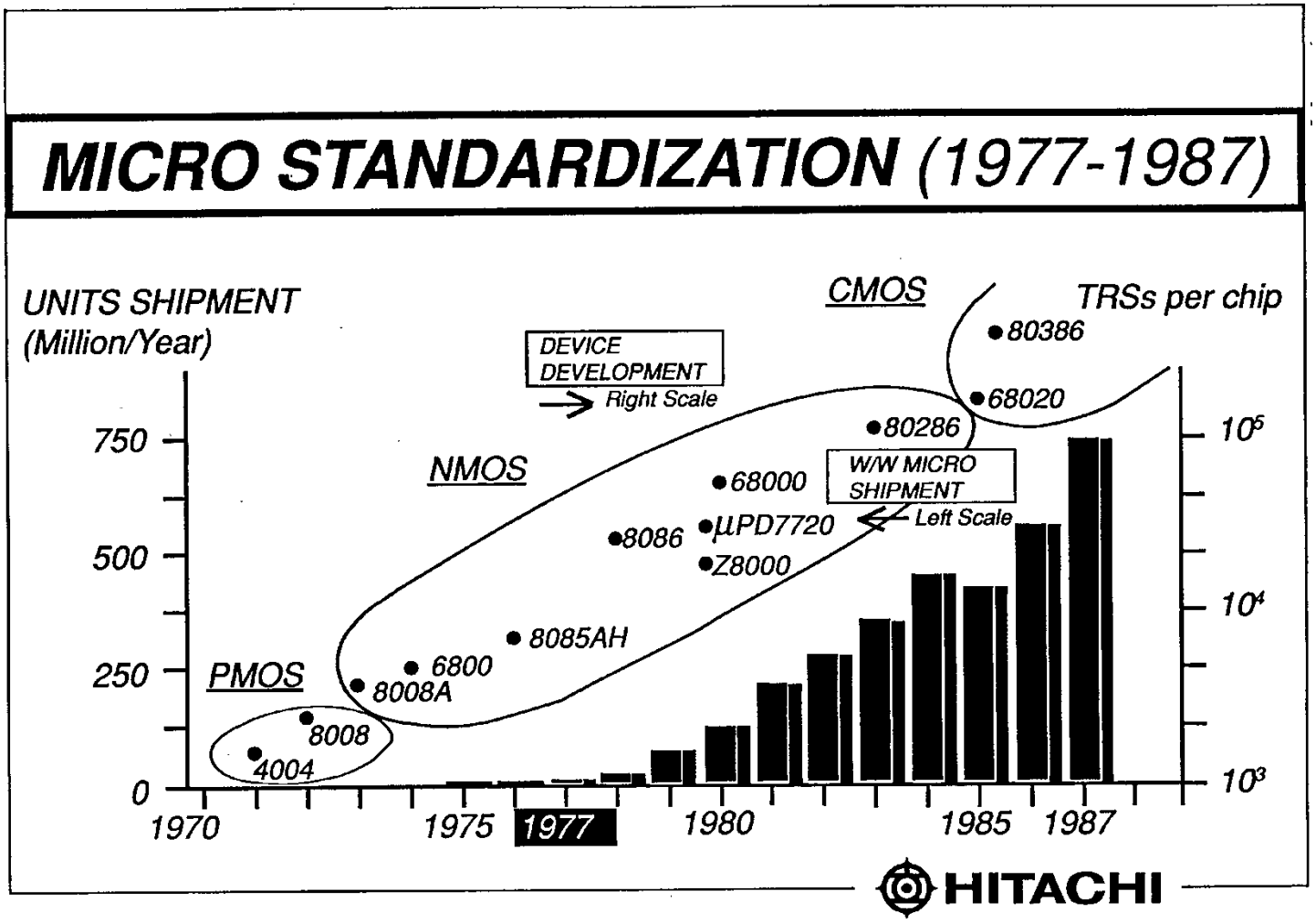
After 10 years of incubation period after the invention of transistor, the commercialization finally started since circa 1957. Transistors were standardized, after vacuum tubes, and they were mutually replaceable. This was the “standard oriented” decade. There was a big demand from transistor radios and solid-state TVs.



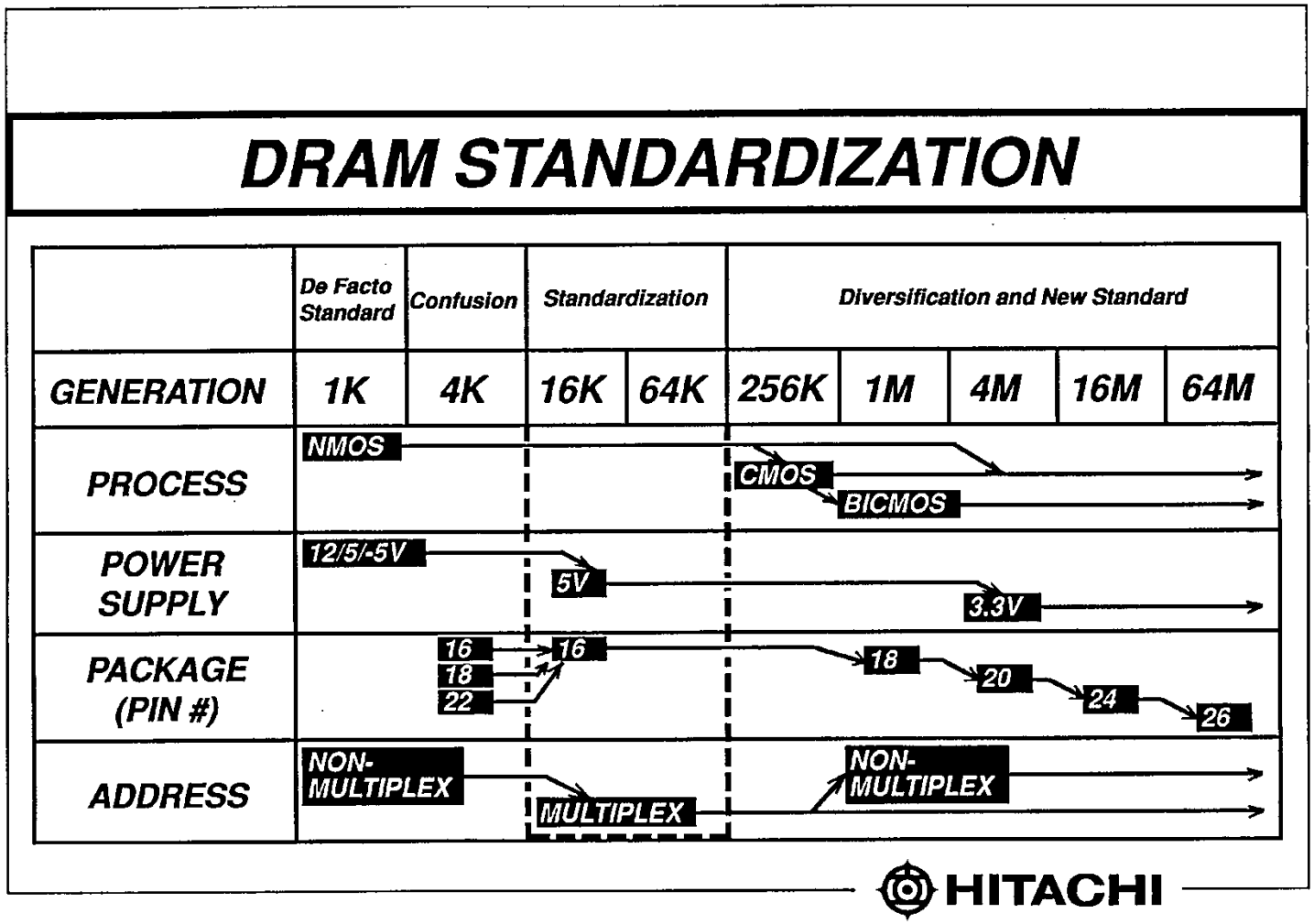
The decade from 1967 to 1977 can be called the “Era of IC/LSI”. Following the invention of IC in 1958, planer technology was developed, and bipolar and MOS devices were produced. LSI business started since circa 1967 for space application followed by the calculator application which was led by Sharp. AMI was the first successful company in the custom LSI business.



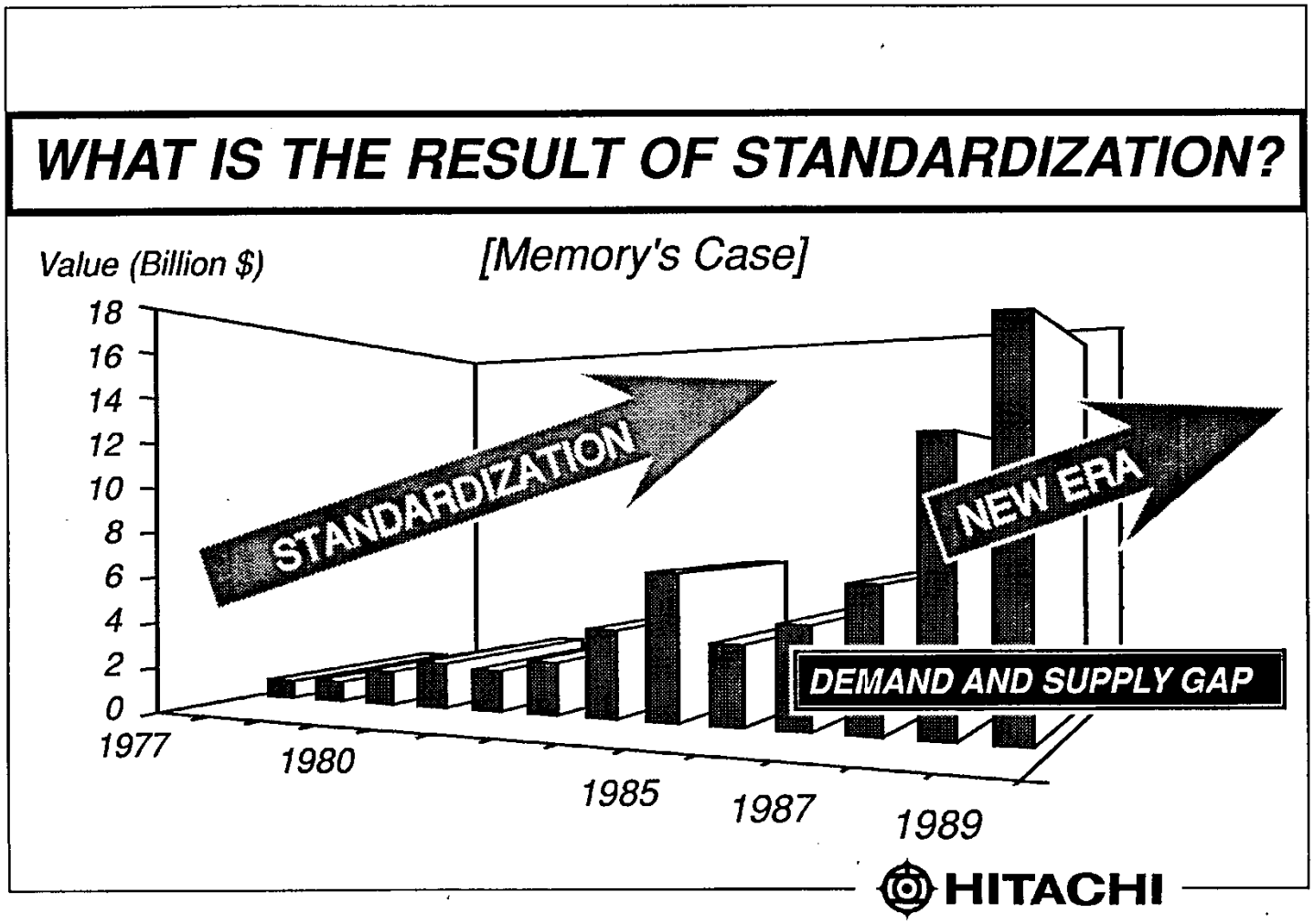
Intel was established in 1968, and 4bit microprocessor was introduced to the market in 1971. This trend was followed by many companies. After incubation period, in 1977, market volume of memories and microprocessors reached 1B$, and it was the start of “Standard Oriented” era. IBM participated in the PC business and standardization of memory was promoted.



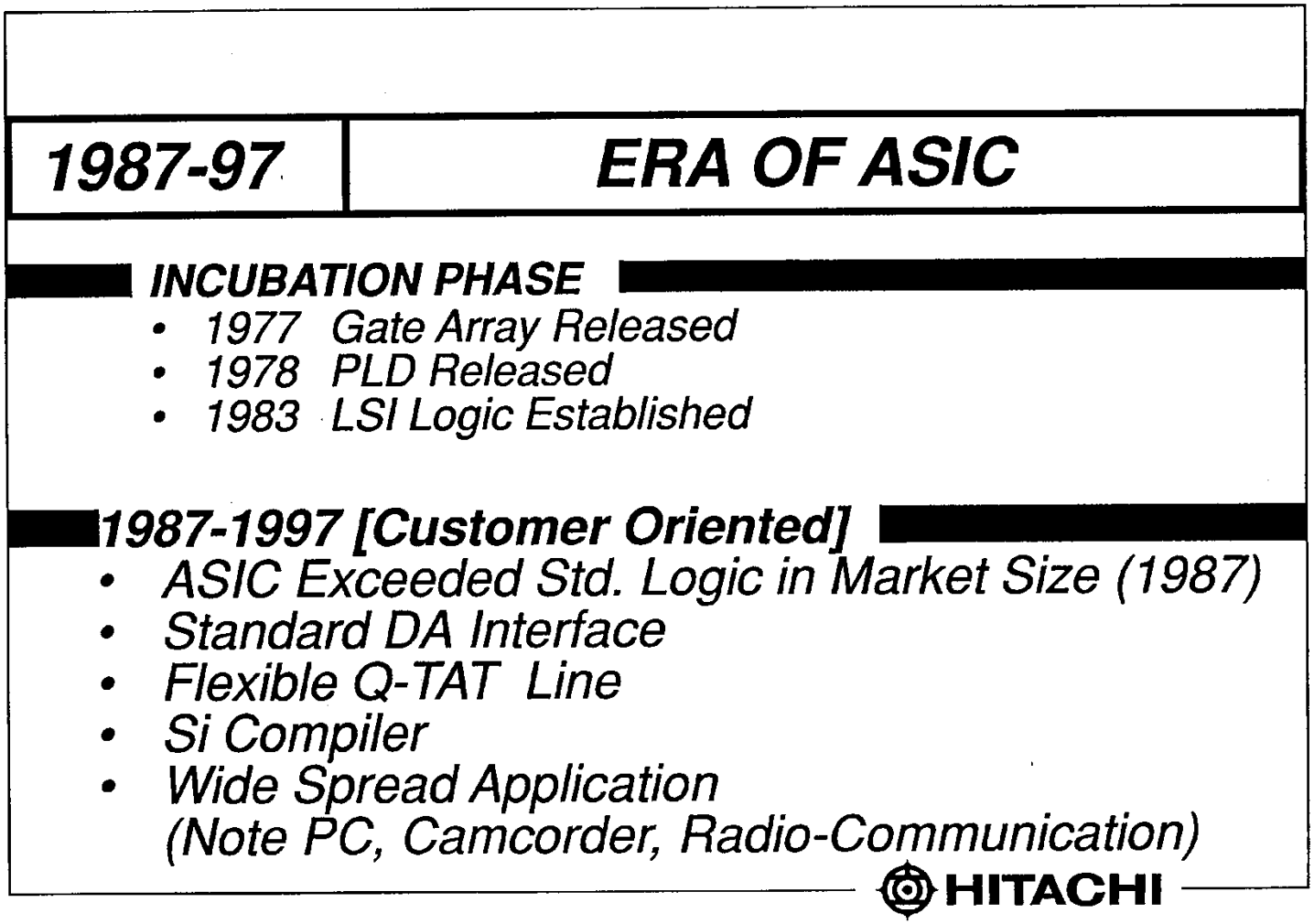
This figure show the standardization trend of microprocessors. Intel's x86 series and Motorola's 6800 series became de-fact standard in the industry. Device type started from P-MOS, then to N-MOS, and finally converged on CMOS. The trend of shipment shows that MPU output took off in circa 1977.



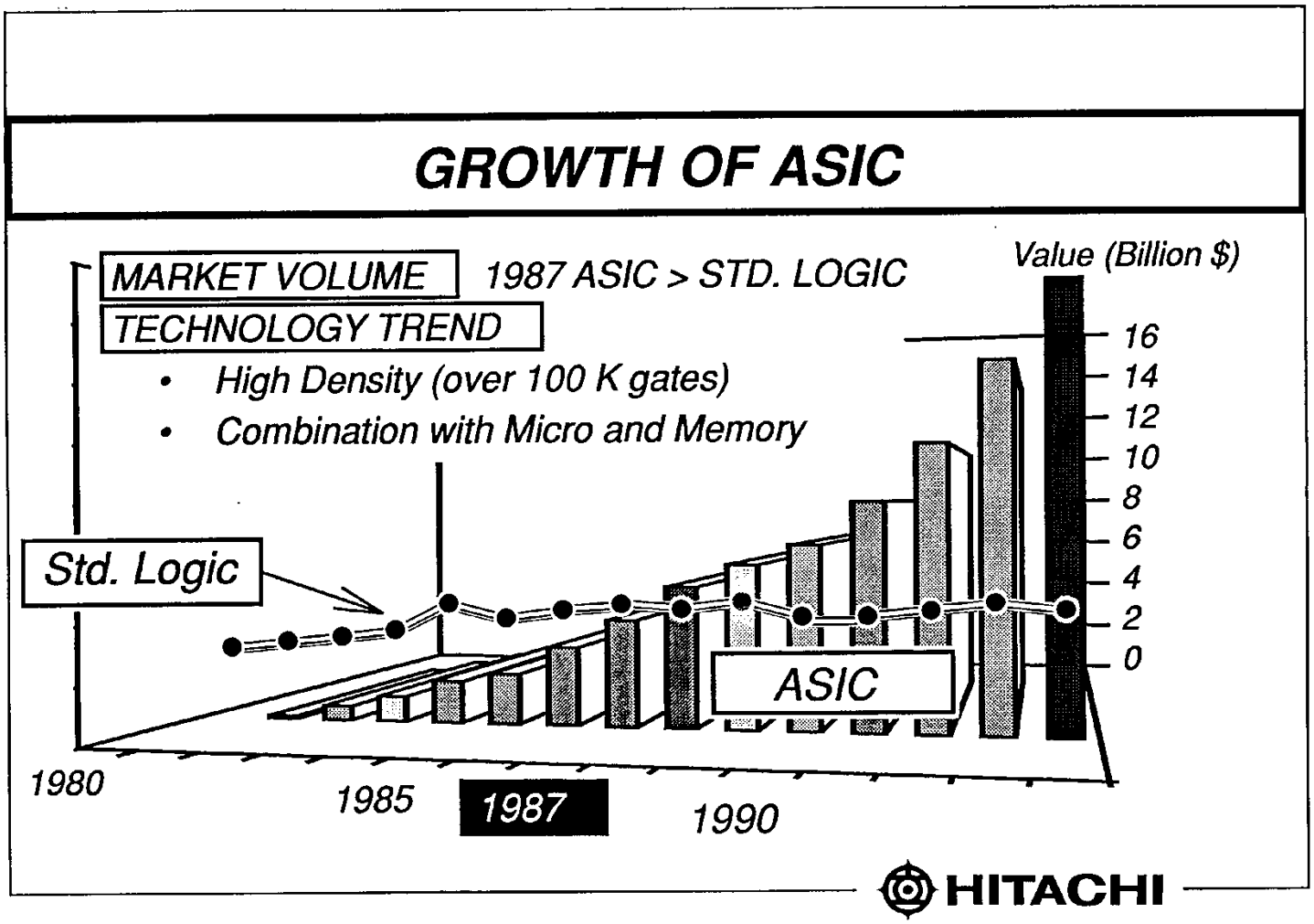
The figure show the trend of DRAM standardization for various generations. In 1K bit generation Intel's memory was the de-fact standard. 4K generation was in the confusion and different types of memories with different packaging types were introduced to the market. After 16K generation industry standard was established.



DRAM grew nicely until mid 1980s, but the market suddenly fell into the slump in 1985 due to supply-demand imbalance, and Intel withdrew from DRAM business. The imbalance was caused by the fact that “unspecified number of makers supplied standard products at the same time”. It was the warning to the management about the choice of “standard or custom”.



Gate array was introduced to the market in 1977, and LSI Logic was established in 1983. In 1987, ASIC exceeded standard logic in market size, and it was the start of ASIC era. Standard DA interface was prepared and quick TAT manufacturing line was available. ASIC business expanded to low power applications such as Note PC, camcorder, and wireless devices.



The figure compares market volume of ASIC and standard logic including TTL and CMOS. In 1987, ASIC overtook standard logic in market volume. Technology was advanced to the density of over 100 K gates, and ASIC included embedded microprocessor and memory.

SUMMARY OF THE HISTORY

	1947	1957	1967	1977	1987	1997	2007
GENERATION	Big Bang		Transistor	IC/LSI	Micro/ Memory	ASIC	
COMMERCIAL PRODUCTS		—	Radio TV	Calculator	PC WS	Note-PC Camcorder Radio-Communication	
KEY WORDS		R & D	Mass-Production	CAD Building Block	Architecture Software Fine Geometry	DA Q-TAT Si-Compiler	

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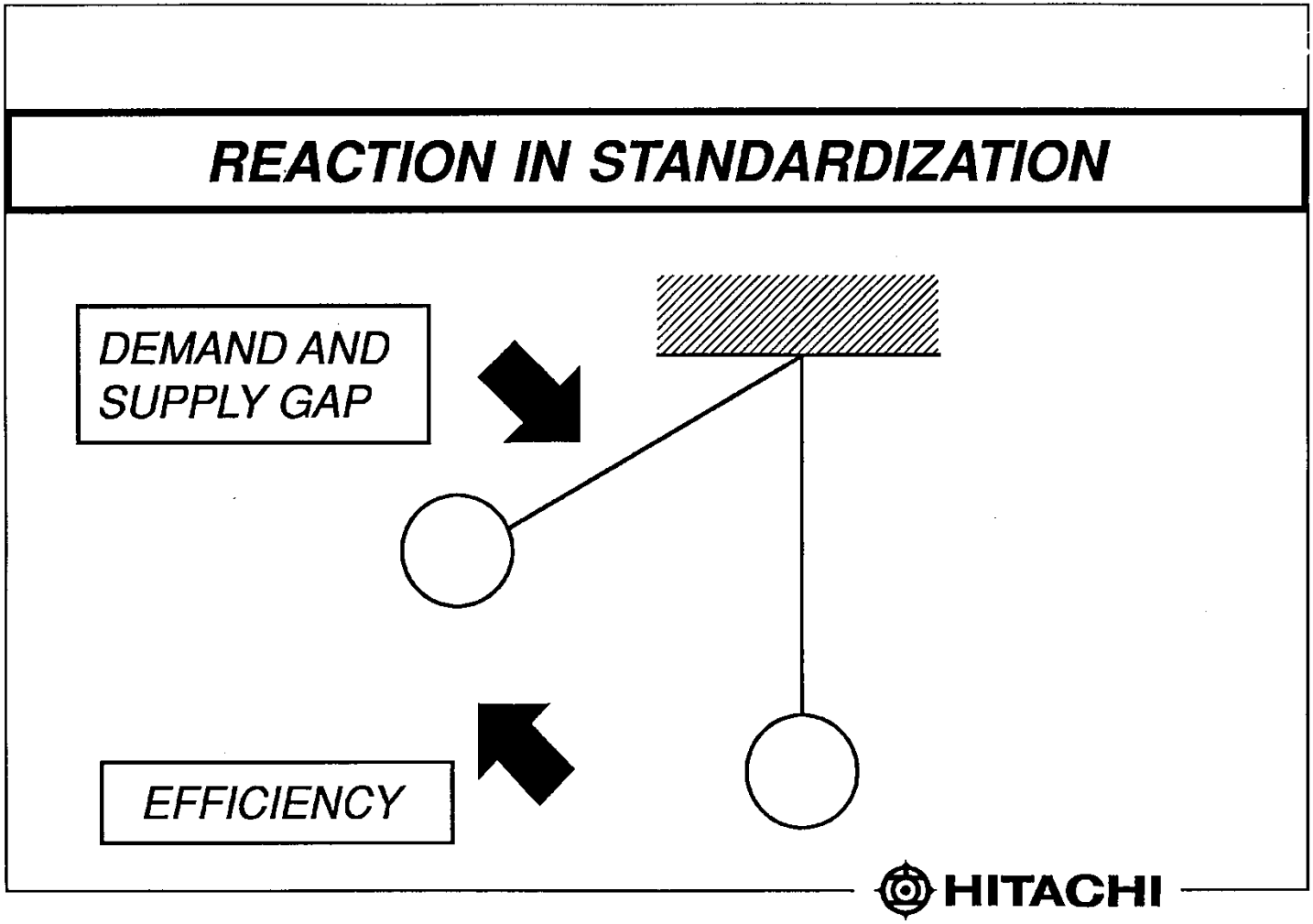
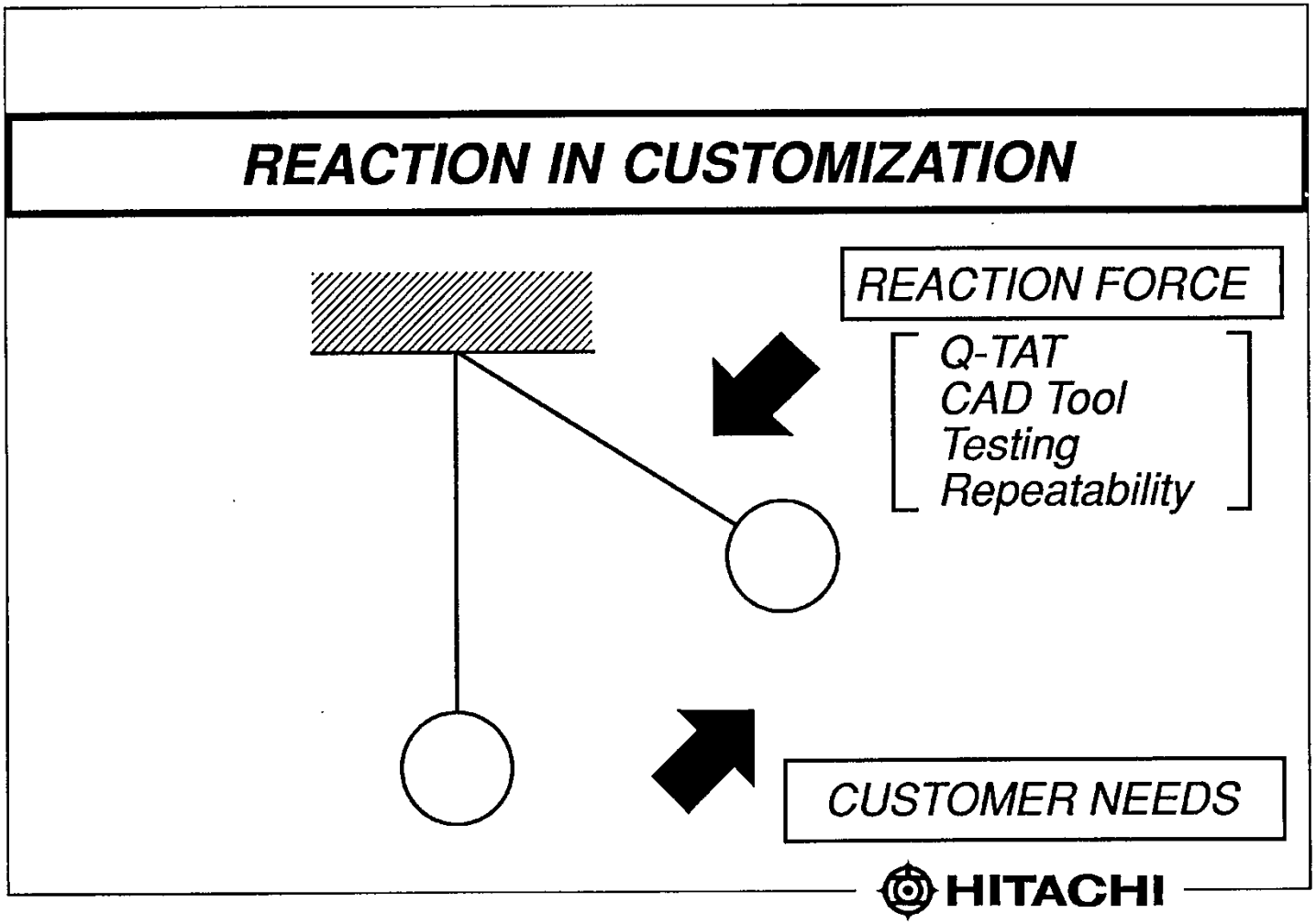
This is to summarize the history of semiconductor since the invention of transistor in 1947, with 10 year interval. The device evolution started from transistor to IC/LSI, to memory/ microprocessor, and to ASIC.
The evolution of commercial applications and major key words for technology are also shown.



In the case of standard oriented business, manufacturing efficiency is high because small number of items are produced in a big quantity. However, there are unspecified number of players with different motives which would tend to create supply-demand imbalance, and the stability of business would be lost.



In the case of custom oriented business, customer needs will be satisfied. On the other hand, quick TAT, CAD tool, and special testing will be required. Furthermore, it is not possible to produce a single product in large quantity, and the production efficiency will be low.

WHAT COMES BEYOND ASIC?

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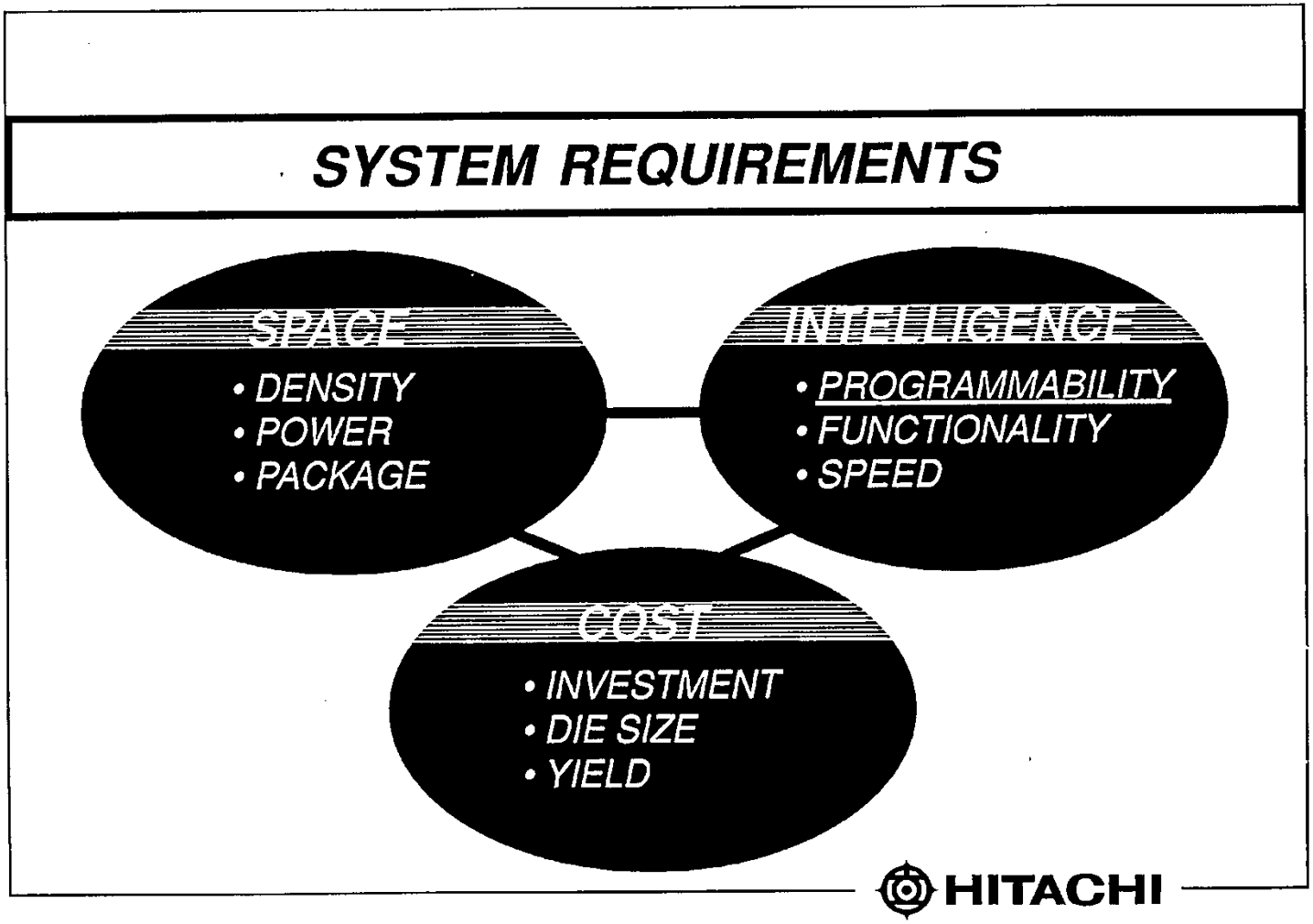
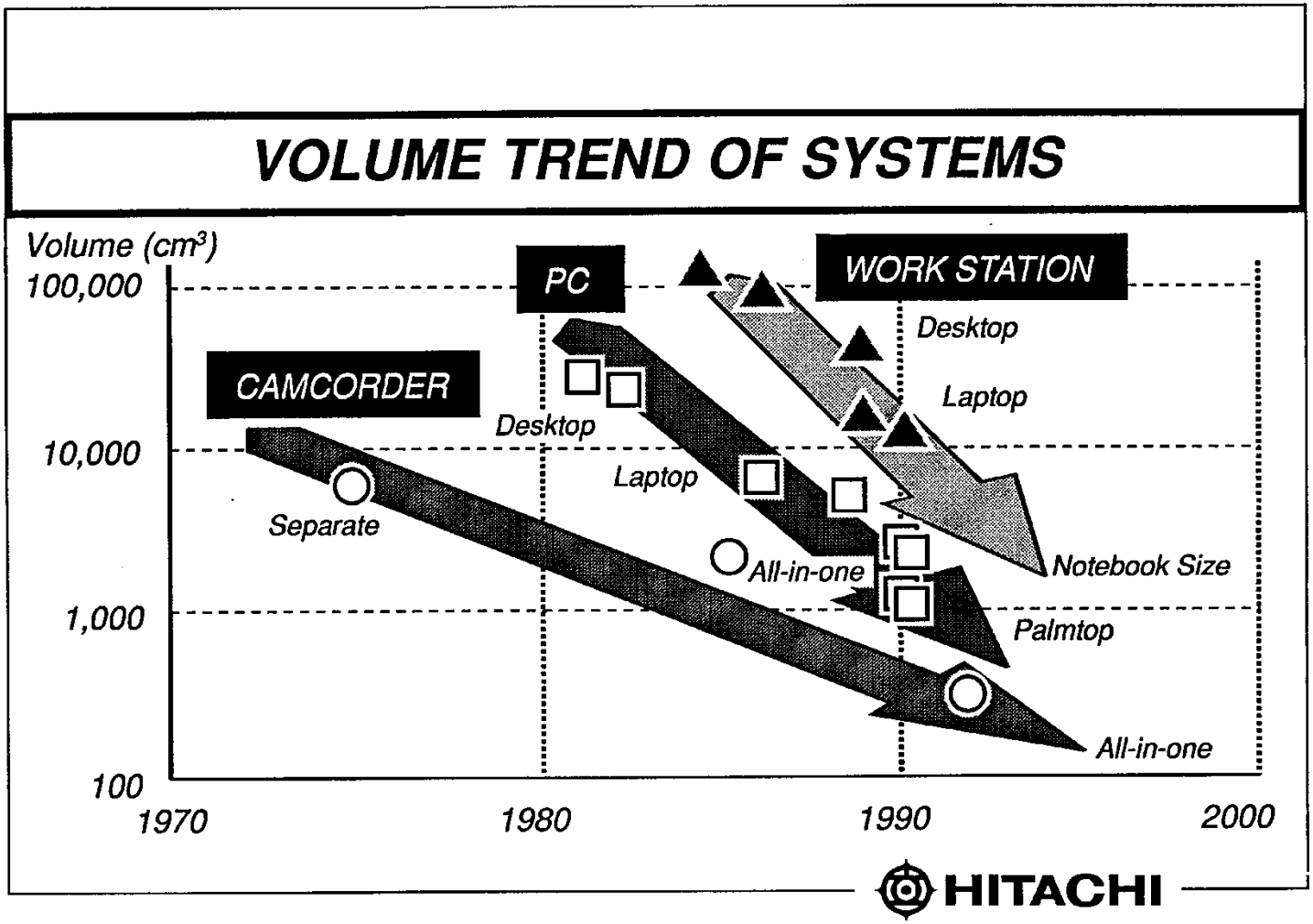
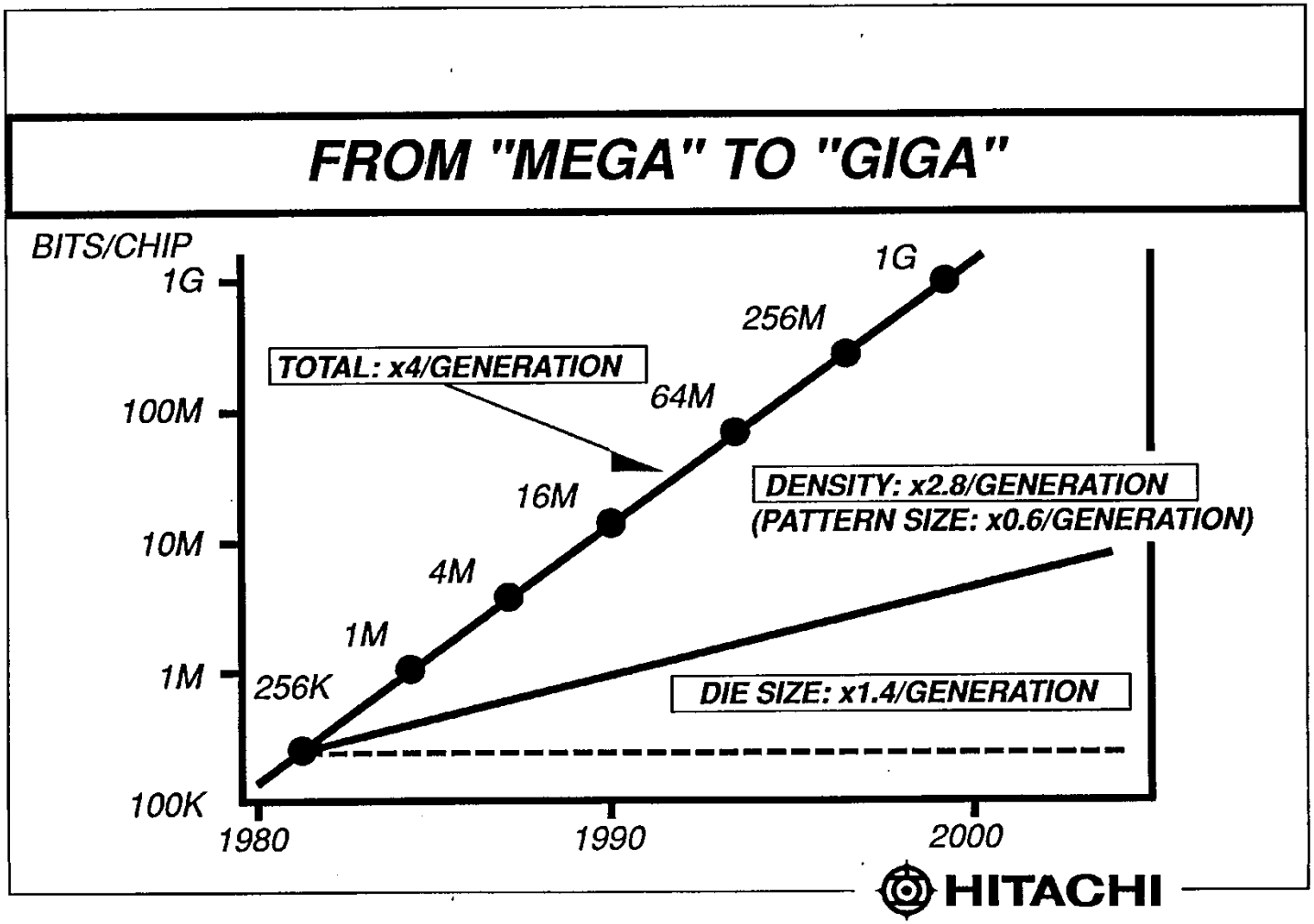


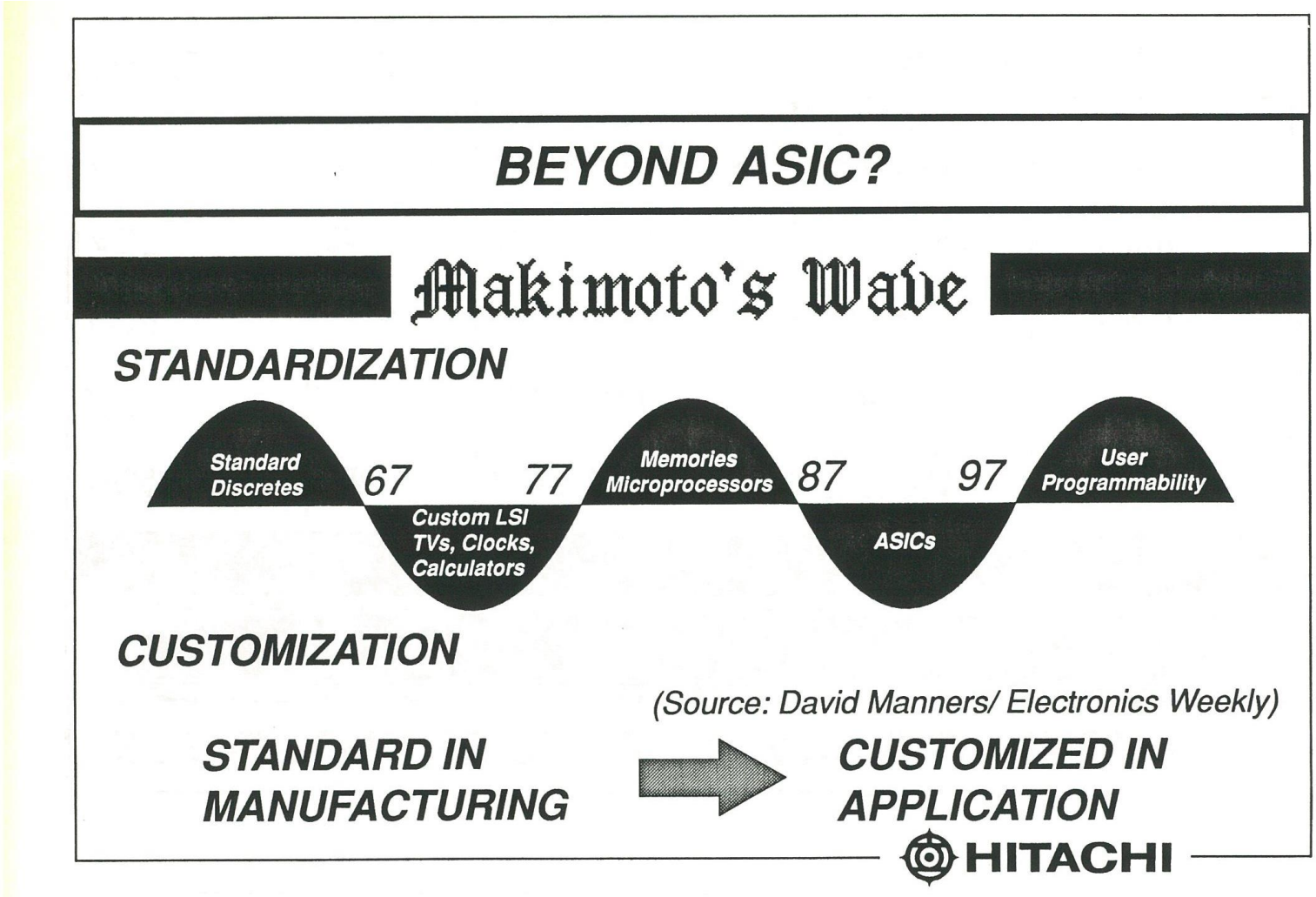
The figure shows three requirements from system side: space and power saving, low cost, and intelligence with programmability, functionality, and speed.



The figure shows the trend of volume for three products. The volume decreased more than one order of magnitude since the time of introduction to today.



The figure shows the trend of memory capacity from 1980 to 2000. Device dimension is decreased by 0.6 times, and density increases by 2.8 times each new generation. Since chip size increases by 1.4 times, the number of bit increases 4 times each generation. The memory capacity will reach 1G bit by 2000.



This sinusoidal figure was first introduced on the Electronics Weekly, UK, by David Manners, and was named Makimoto's Wave. The wave predicted the rise of "user programmability" after ASIC. The essence of programmability can be summarized as "standard in manufacturing but customized in application".

SEEDS FOR THE COMING STANDARDIZATION AGE

Key Word = User Programmability

Concept	Pioneer	Programmability	Technology	Year of Birth
PLA (MOS)	Altera	Logic Array	EPROM/ EEPROM	1983 -
ZTAT	Hitachi	On-chip ROM	EPROM	1984 -
LCA	Xilinx	Logic Block	SRAM	1985 -
ACTL	Actel	Gate-array	Anti-Fuse	1988 -
I-ZTAT*	Hitachi	Logic Function	EPROM/ FLASH	1991 -

* I-ZTAT : Intelligent ZTAT

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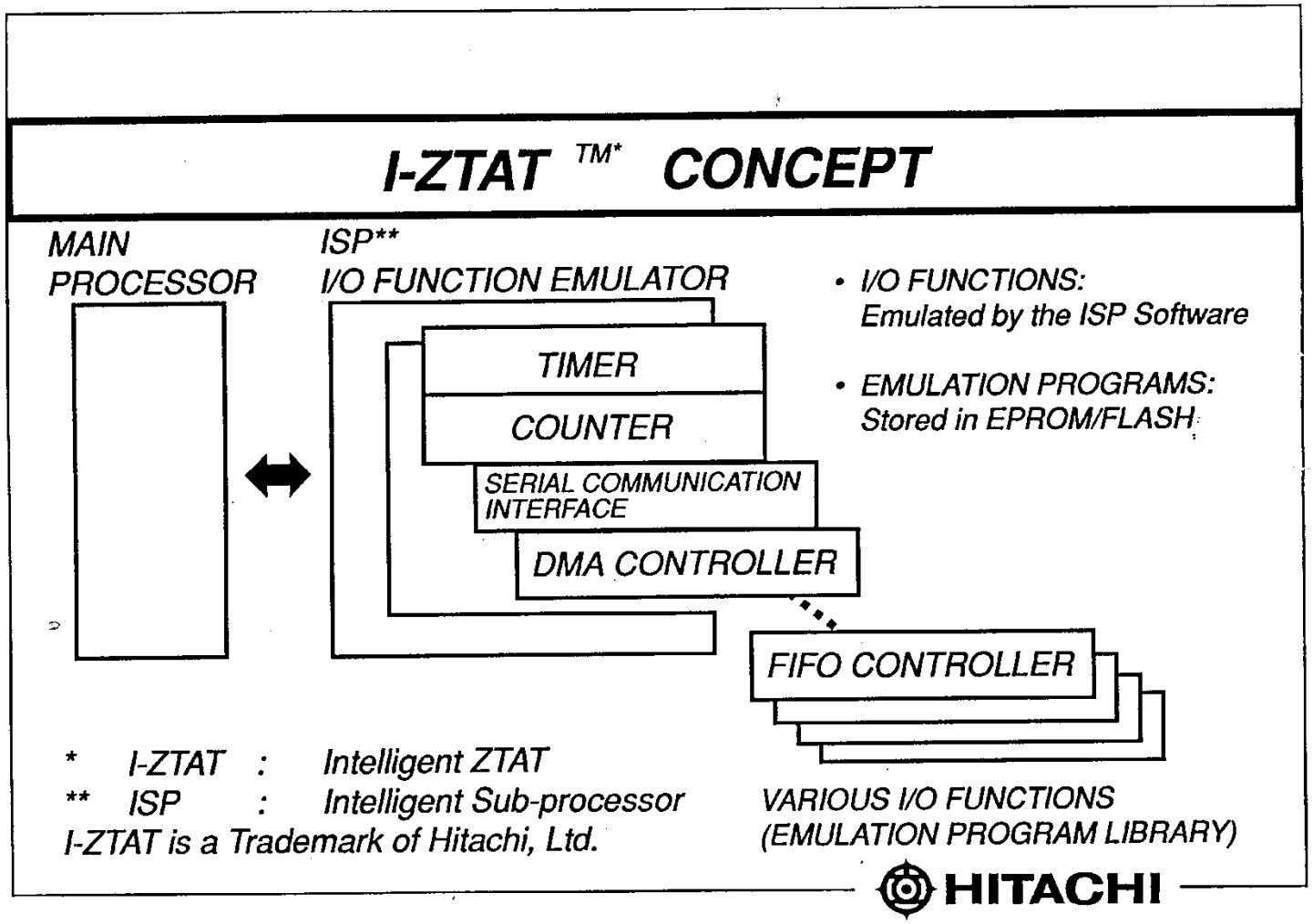
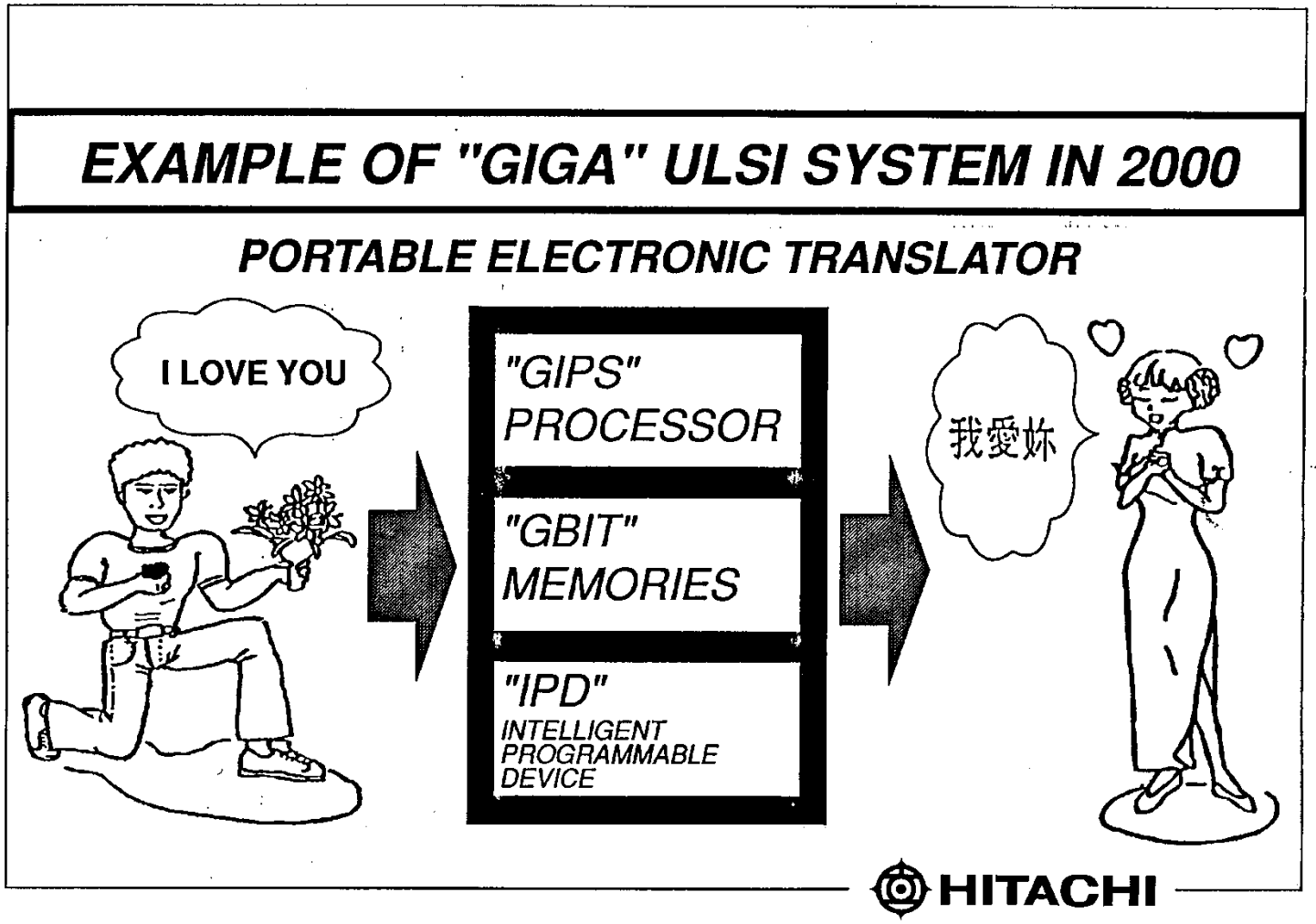
Technical seeds for the coming standard oriented age are shown. The key word is user programmability. Hitachi's field programmable MCUs, ZTAT and I-ZTAT, are introduced. Altera, Xilinx, and Actel have made great contributions for creating the big trend of field programmable gate arrays.



The figure shows a concept of Hitachi's I-ZTAT. The idea was to include a sub-processor dedicated for emulating peripheral functions which would provide versatility and flexibility. It was an innovative concept at the time which is similar to the idea of today's heterogeneous multi core architecture. The production was discontinued because of legal issue (see Exhibit II).



In 2000, GIPS processor and G bit memory would be available, and then, portable electronic translator would be realized by adding intelligent programmable device.
As of today, in 2018, this forecast was a little too optimistic. Although, there are machines like this, but they are not at the stage of free conversation.