Optical technology and network requirements

By B. CATANIA[1]

Innovations in telecommunications networks cannot be made without due consideration to the time and resources needed to introduce them throughout the whole territory served. Optical technologies are no exception and therefore an effort must be made to choose the right ones to be consistent with a rational network evolution and effectiveness of the investments.
In addition to the technologies of the basic components (fibres, sources, detectors, integrated circuits, etc.) suitable network architectures and service palimpsests must be carefully considered for the new generation of integrated broadband communication (IBC), the nervous system of the forthcoming 'information society' in Europe.
The paper presents some considerations on markets related to IBC and the relative position of Europe in them.

Large-systems planners, such as those involved in telecommunications, have to perform a quite difficult exercise of imagining how to navigate through waves of various lengths and intensities despite the intrinsic limitations of the ship they are supposed to be guiding.

I should like to try and sketch a few of these time waves, even if they would appear with different phases in different countries, more precisely with a delay of several years in less developed countries with respect to the more advanced ones.

For the purpose of my talk I refer to four families of such waves: the first one connected with social evolution (or, if you wish, with socioeconomic evolution), the second one with service evolution, the third one with network evolution and the fourth one with technology evolution; thus ranging from the slower ones (those mostly connected with habits of people) up to the fastest one, which is technology.

The most important aspect of social evolution, concerning telecommunications, seems the advent of the so-called 'information society' (figure 1), which follows the agriculture- and the industry-based societies and implies that most of the active population will deal with information instead of either food or all sorts of artefacts. Forecasts for the U.S.A. are such that, by the year 2000, 94 % of the active population will be employed in the tertiary sector, the remaining 6 % being equally split among industry and agriculture. Some forecasts assume that about one fourth of the population engaged in the tertiary sector will work at home. If this is true, telecommunication network planners have to give increasing consideration to residential customers, towards

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whom may be diverted a considerable amount of traffic now requested by enterprises. At the same time, suitable products—encompassing features of both the consumer and the professional sectors— should be provided by industry, having in mind the home environment and its more demanding cost/quality ratio.

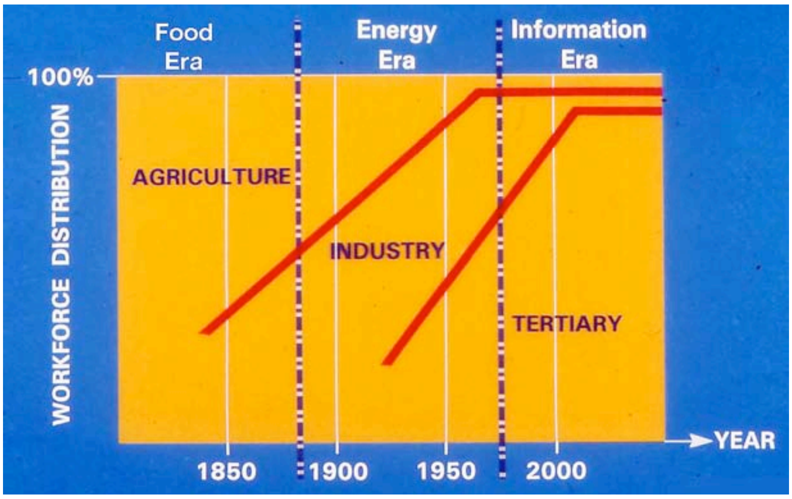

FIGURE 1. Workforce distribution change from year 1800 to 2000 and above.

More advanced forecasters also predict that even a good part of the tertiary sector may become substantially robotized, thus leaving the majority of the active population engaged with more creative jobs or, more precisely (figure 2), with activities involving knowledge transformation. Such residential customers of the home of the future have been referred to by Alvin Toffler as 'prosumers' i. e. as producers and consumers of information: they will therefore need a bidirectional infoduct from the telecommunication network. It may be of interest to network operators that information transfer (from and to the home) may also take place during the night, whenever real-time exchange is not mandatory (examples are exchanges of software packages or of video programmes, electronic mail, newspapers or even magazines and distant checks of home equipment).

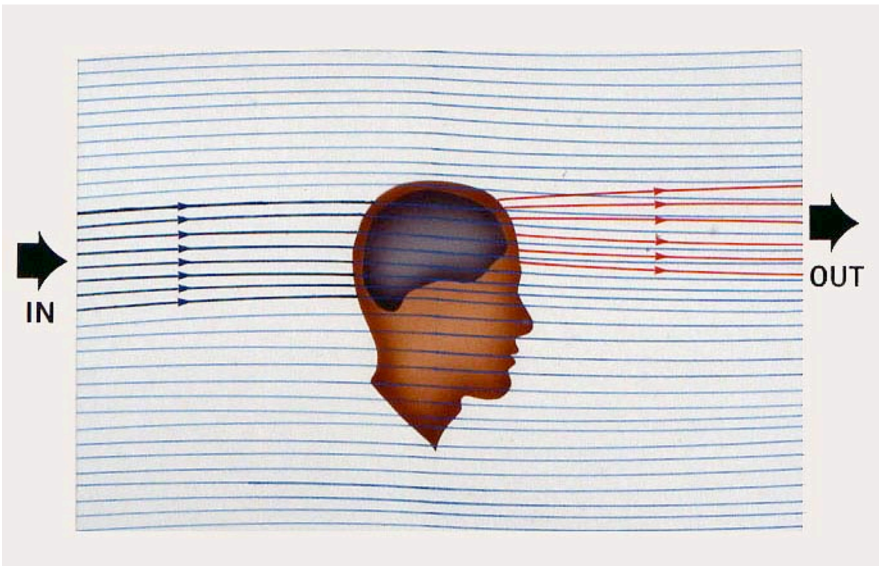

FIGURE 2. Knowledge transformation in the Information Era.

Lower night tariffs and, more generally, lower costs of deferred service delivery may be sufficiently attractive to alleviate the peak-period congestion of the network.

Coming now to the second family of waves, that of telecommunication service evolution, I may recall this very impressive slide (figure 3), redrawn from an original one produced by the European telecommunications and professional electronics industry, showing the increasing variety of services from the mere telegraph service of more than a hundred years ago to the several dozens (but the CEPT has a list of a few hundreds) of the forthcoming years. Now that narrowband integrated service digital network (ISDN) is definitely taking off, perhaps the fundamental questions about new services are related to broadband services.

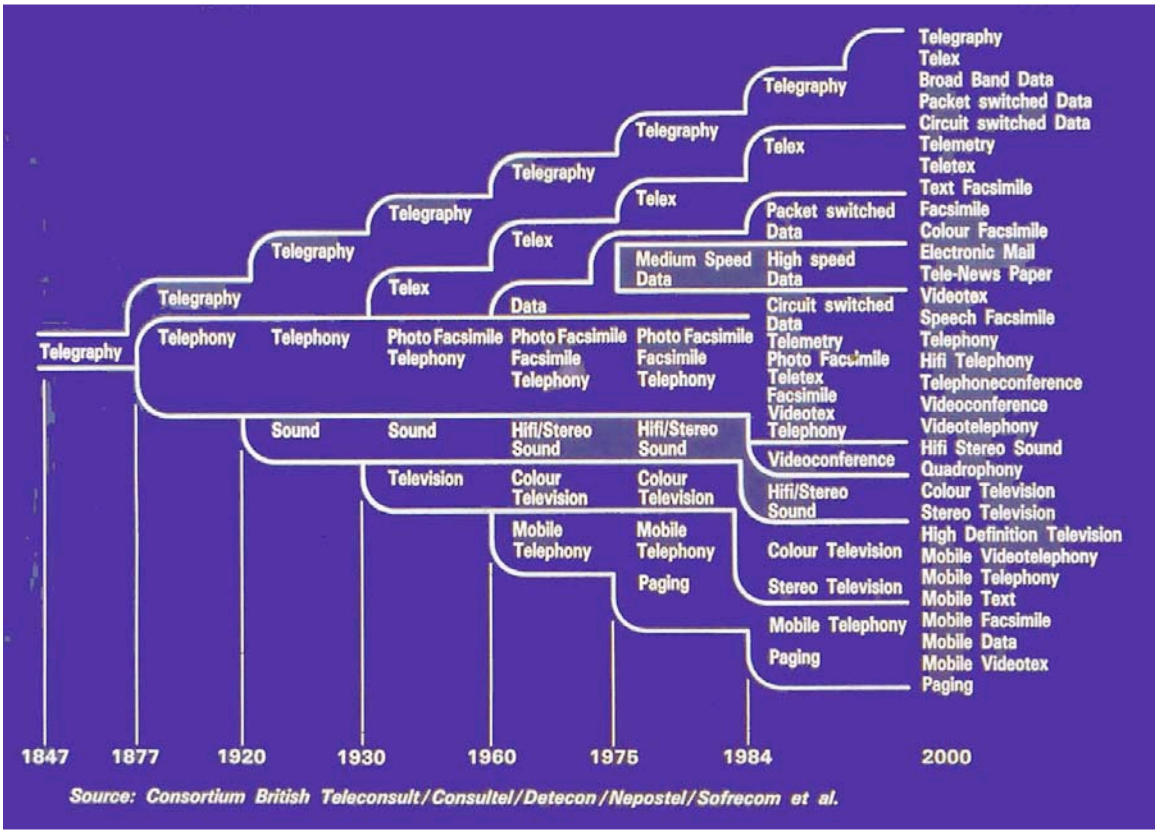

FIGURE 3. Expansion of telecommunications service from 1847 to the year 2000.
(Source: Consortium British Teleconsult/Consultel/Detecon/Nepostel/Sofrecom *et al.)*

We tried to obtain some answers a few years ago by testing customers' tastes at the Milan Fair, through an experimental arrangement comprising two main studios and 30 terminals spread over various stands of the exhibition. A computer program was set up to record the number of times each service was requested by visitors, assuming that the figures thus obtained would give indications about users' preferences. Table 1 summarizes the results.

TABLE 1. EXPERIMENTAL RESULTS OF THE MILAN FAIR
(Requests of the different services (average daily connections *ca.* 3000).)

	TV natn.	TV int'l.	Meteosat	diffusive programmes	interactive programmes	RAI TV studio	video commun.
total No.	7861	6548	1553	5702	485	2419	6031
percentage	25.7	21.4	5.1	18.6	1.6	7.9	19.7

Over 30 000 records were obtained in about 10 days and, as expected, broadcast movies, news and other television programmes gained the majority of preferences. However, contrary to expectations, video communication largely superseded interactive video-library-type requests and was nearly equivalent in interest to broadcast programmes and to non-interactive video-library programmes.

Most of the users of video-communication services were young people; they were not asking for any help from the studio staff and they were naturally using cameras and monitors, organizing tele-meetings with other young people in another location, much as if they were conversing at the same site.

This, of course, does not definitely prove that two-way full-motion TV service is a potential winner; however, it reminds us (especially those of us who are not young any more) that the future we are building is not for us, but for our descendants. More precisely, an effort should be made to imagine what these young people will demand when they reach our age, which may not be exactly what they are demanding now (on somebody else's budget). Anyhow, there is no doubt that their ability to operate keyboards and all sorts of electronic gadgets, as well as their ease of making friends all over the world, may play in favour of success of two-way video-communication services.

Let us now have a look at network evolution.

Experience has shown (figure 4) that each significantly new network structure (as, for example, the well-established IDN or the emergent narrowband ISDN or the future broadband ISDN) after having taken one or two years for field trials involving a few thousand subscribers (which is 0.01 % of 20 million subscribers) requires about five years to gather the first 1 % of the customers, mostly made of subscribers from the large business sector, who can afford the initially high tariffs of services and high prices of the equipments; in addition to that, they are more ready to test innovative techniques to take advantage against competitors.

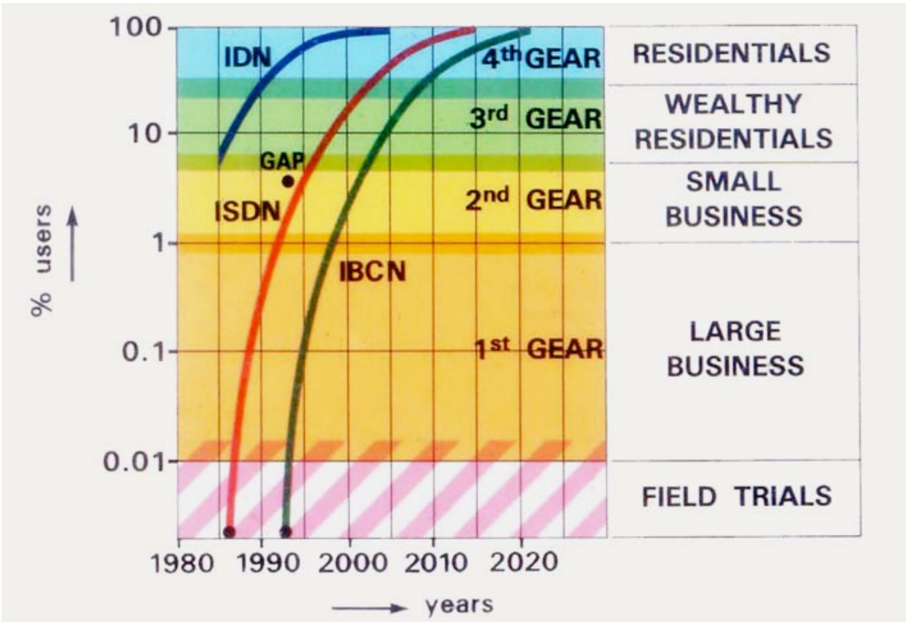

FIGURE 4. The four gears of the integrated broadband communication (IBC) evolution.

Small and medium business subscribers are added in the next five years, bringing the total penetration to a respectable figure of around 8 %; then, in the following 6-7 years, another customer band, that of more wealthy residents, pushes the total penetration to around 20%. In the final phase, lasting perhaps more than 15 years, saturation is achieved and the new network can be deemed to have become as ubiquitous as the former telephone network.

The whole process takes therefore around three decades, i.e. more than one generation of customers. This confirms that the network planner (probably in his forties or fifties) has to design the network with due consideration to the tastes, so to say, of his sons and daughters.

Another consideration that is evident in this graph is that, if we examine the picture of the entire telecommunication system of a nation at a certain epoch, say between 1995 and 2000, we see occurring at the same time the completion of the IDN (particularly the disappearance of electromechanical switching in favour of digital switching in telephone networks), a fast growing narrowband ISDN (jumping from 3 % to 15 % in the quinquennium) and the inception of broadband ISDN (or integrated broadband communications network (IBCN) as it is called in the Research on Advanced Communications for Europe (RACE) programme). The figures are, of course, indicative, but at any time in the network evolution we may see the coexistence of three, or perhaps four, technologies of different ages if, as postulated here, we are to assist in the birth of a new technology every 10 years or less, as it will be shown later.

The four phases shown in this diagram resemble, in a way, the four gears of an automobile. This is more evident from table 2, where the overall number of lines, and the number of lines installed per year, are evaluated for each phase, assuming that the European market (and also in the U.S.A. after the AT&T divestiture) is made up of components of about 20 million lines each, either per average operating company or per average manufacturer (as lifelong sales of a generation of switching equipments). One can see that the first gear raises the speed to 35000 lines per year, the second to 250 000 lines per year, the third to half a million lines per year and the fourth to one million lines per year. Concurrently, relevant reductions in price apply (initially on a halving per decade basis), and these reductions, in turn, facilitate the entry of the next customer band.

THE DEPLOYMENT OF IBCN

Phase	Duration (years)	Final size %	Final size no. of lines (1)	Penetration speed (no. of lines/year (1))	Final Price
0 - Field trials	1-2	0.01	2.000	–	P_0
1 - Large business	5	1	200.000	~ 35.000	$P_0/4$ (2)
2 - Small business	5	8	1.6 million	~ 250.000	$P_0/7$ (2)
3 - Wealthy residents	6-7	20	4 million	~ 500.000	$P_0/10$ (2)
4 - Residents	15	100	20 million	~ 1.000.000	$P_0/16$ (2) ↓ $P_0/40$ (3)

note (1): Assuming a potential market of 20 million lines (or subscribers) either per average European Country or per average European Manufacturer.

note (2): Assuming price reduction with quantity following the "halving/decade" law.

note (3): Applying further price reduction due to production robotization.

TABLE 2. THE DEPLOYMENT OF IBCN.

As a consequence of the above, it may be remarked that along all four phases there will be plenty of potential customers residing in less densely populated areas not reached by IBCN, as this will evolve in a leopard skin way, from small geographical spots with high concentration of large-business subscribers. This is one of the reasons why satellite communications have to be considered as efficiently anticipating the terrestrial network and therefore should be an integral part of the network planners' strategy.

Another consideration is that the broadband network planning should necessarily take into account the future needs of residential customers, resisting the pessimistic argument that they will not show up until 10 years after the start. An IBC system designed for business customers only will not be capable of reaching the full penetration speed, just as a car designed with only the first two gears. As with cars, it might even be advisable to add a fifth gear to improve further the economy of the system and also to cope with technical obsolescence.

Concerning the fastest wave, that involving technology evolution, let me borrow another interesting slide (figure 5), this time from J. M. Connell and Irving Dorros, showing the lifetime of successive generations of switching equipments (not to be confused with actual lifetime of individual switching equipments). It can be seen that the commercial life of successive generations has been constantly halved, as a result of the advent of new so-called ‘killer’ technologies; if that speed is to continue unchanged, we might mathematically find a’ commercial lifetime equal to zero by the year 2000.

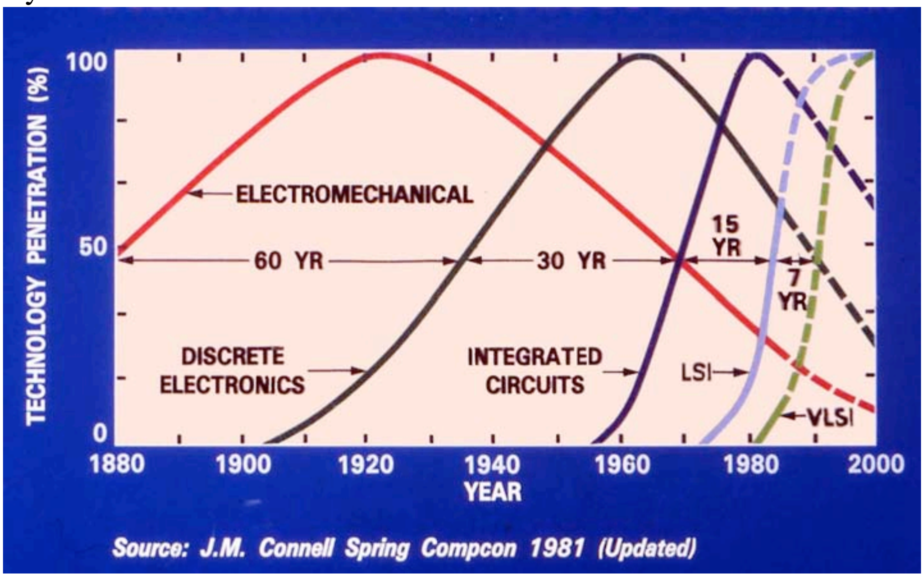

FIGURE 5. Component technology evolution. (After J. M. Connell, Spring Compcon 1981 (updated)).

Apart from that ‘boutade’, we can say that the actual operating life of the equipments will be more and more independent of their intrinsic reliability, as they may be put out of service — even if they are still performing to specifications — whenever new technologies provide either more revenues or reduced maintenance costs or would economically justify their substitution.

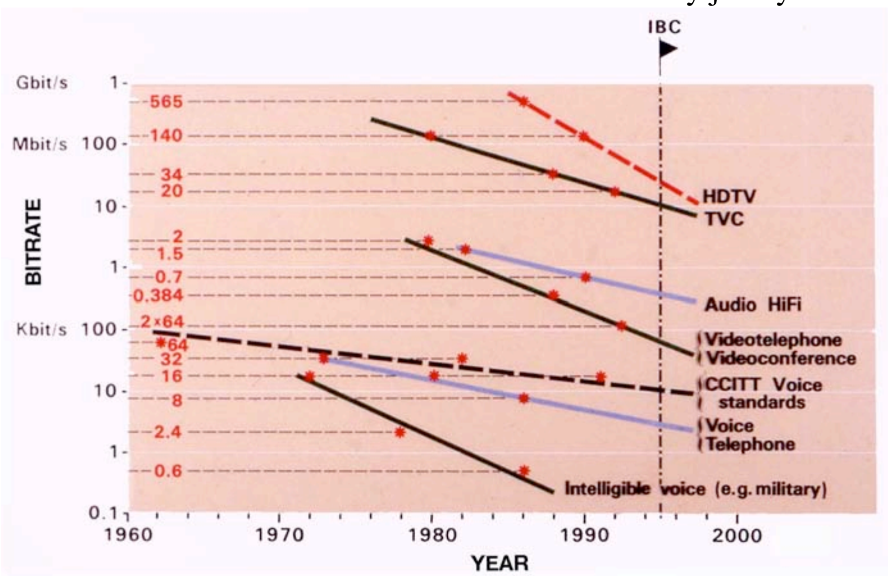

FIGURE 6. Progress in coding technologies.

Another interesting example is that of coding technologies (figure 6): the progress made in about 20 years of history of this quite young but very powerful technology shows that both audio and video coding bit rates have been constantly reduced by a factor of 5-10 times per decade, with international standards (e.g. Comité Consultatif International Télégraphique et Téléphonique (CCITT)) generally following the first laboratory demonstrations after about 10 years. This means that over the 30 or more years of penetration of a new network, such as ISDN or broadband ISDN, bit rates may be reduced, in theory, by orders of magnitude, thus upsetting any rigidly conceived, channel-based architecture of the network.

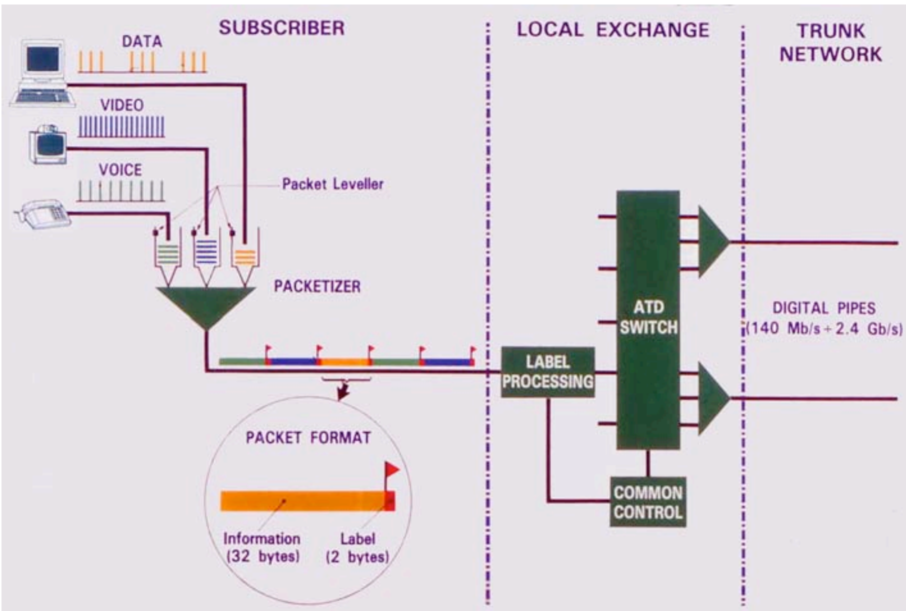

FIGURE 7. The Asynchronous Time Division (ATD) or Asynchronous Transfer Mode (ATM) concept.

In this respect (figure 7) the asynchronous time division or asynchronous transfer mode (ATM) technique may ensure a much higher flexibility, because it instantaneously profits from the different statistics and bit rates of voice, video and data signals by constructing both at the transmit and at the receiving subscriber ends a single stream of labelled packets, where all the various signals are put together. In this way, individual signal channels are substituted by individual packets in a single channel, which we may call an 'infoduct' or 'digital pipe'. Switches and transmission lines in this network may only need to be designed for the maximum speed, ignoring the nature of transmitted signals.

Unfortunately this technique implies a quasi-complete upset of the network architecture. In addition, there will be resistance from the operators to preserve their huge investments in the first-generation ISDN and from those who think that the statistics of video signals is such that it would not give rise to definite advantages using ATM and therefore envisage hybrid techniques.

We thus see that life is made difficult for network planners by the dizzy progress of technology. In fact, technologists continue to throw new marvellous toys on the floor, before system planners have formulated rules to play with the previous toys.

Therefore, either no games can be played, or new technology is to be rejected or delayed for some time, or a new, very difficult game with continuously variable rules has to be played.

In devising the future broadband communication system for the European Community —called IBC— we first set a deadline for the completion of the preparatory stage and the first introduction of commercial services: the year 1995. We then did an exercise, to be reviewed annually, to see which ingredients we could pick up for the IBC of 1995, putting together all the crystal balls of technologists and discarding anything which did not seem to have passed the blue-sky research stage by 1995. Despite that, it appeared that there were vast possibilities of choice, even not taking into account additional, unexpected achievements, which may occur during the five years of the preparatory phase.

It is also to be pointed out (figure 8) that a distinctive feature of the IBC concept was to consider the whole system from the service providers up to the end users, including their respective specialized private or public networks converging to a central structure called the IBC network (IBCN).

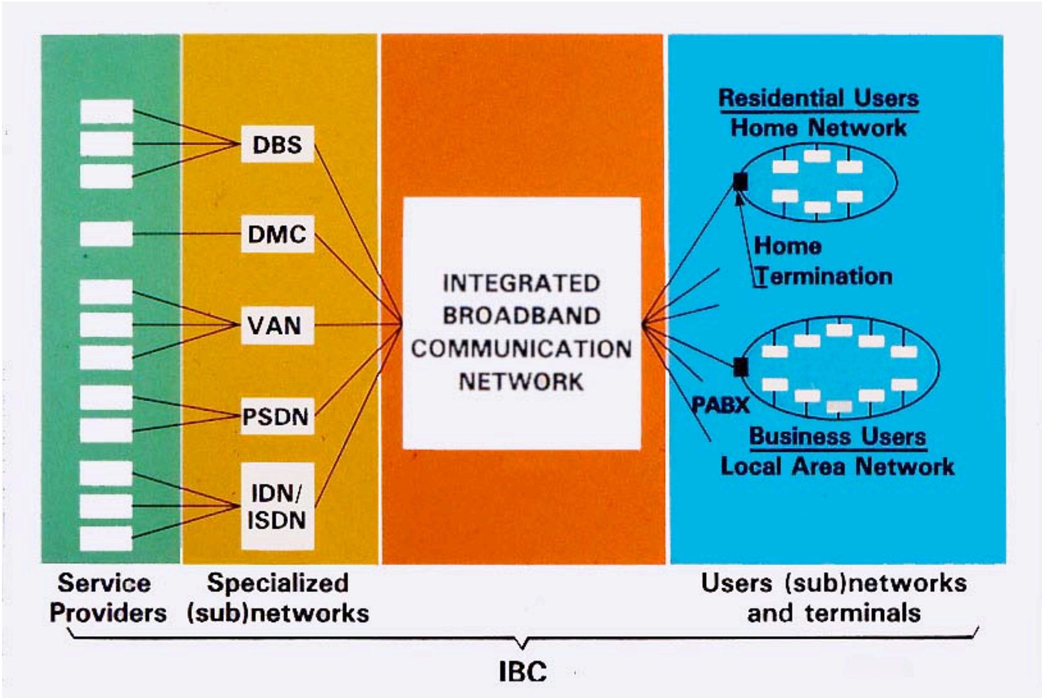

FIGURE 8. The IBC structure.

In addition to that, from the preceding analysis, we were convinced that markets connected with IBC were not only those of computers and communications (the famous computers and communications (C&C) convergence outlined by Mr Kobayashi of NEC), but also of consumer electronics (therefore at least another C) and of the relevant component sector (a fourth C) feeding the other three (figure 9). At CSELT we have analysed all four markets at two years distance (1985 and 1987) to assess the competitive position of Europe.

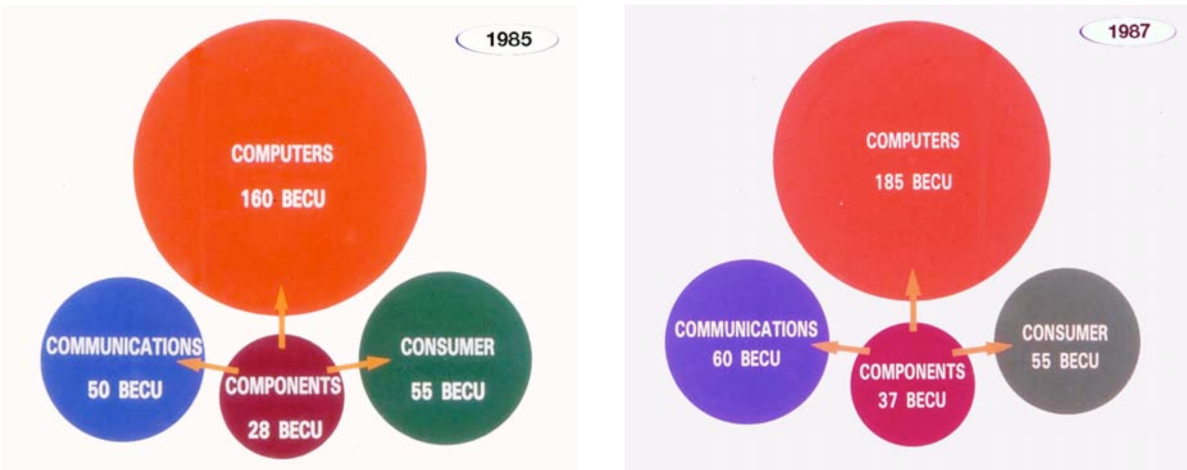

FIGURE 9. The four IBC related world markets in 1985 and 1987.

We see from this figure that in 1985 the computer (or electronic data processing (EDP)) world market was at least three times as big as any of the other three. In 1987 the computer market grew by 16%, communications by 20%, consumer remained steady and components by 32 %. It is interesting to note that communications have shown the greatest growth and that they have overtaken by size the consumer market.

Please do not take these figures too seriously; it has been very difficult for us to assign the available data to the four shares shown here and, as I said before, this will be more and more difficult in the future, where the four "C" convergence will become more and more pronounced.

Let us now look in more detail at each of these markets and see the part industry plays in them.

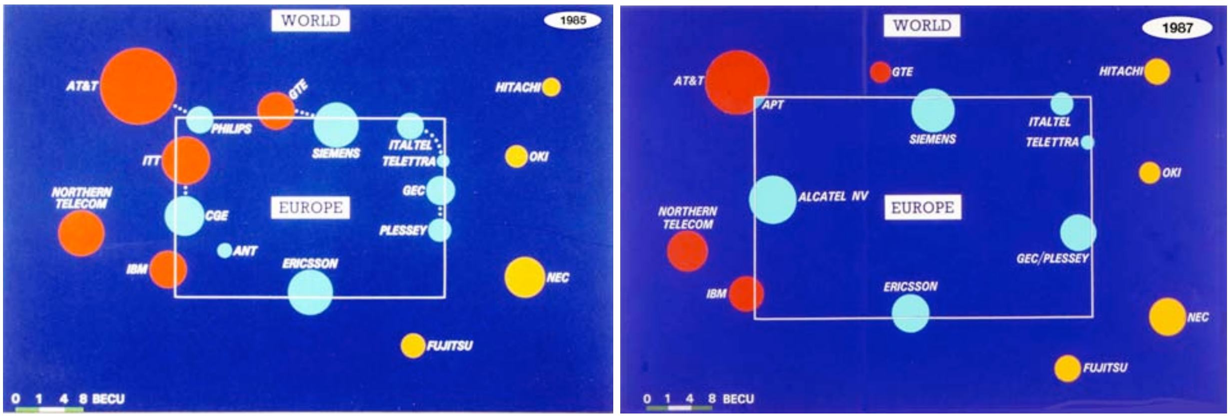

FIGURE 10. The firmament of 'telecom' manufacturers in 1985 and 1987.

Starting with the 'telecom' segment (figure 10) we can see that the European manufacturers (the blue stars of the firmament) were, in 1985, fairly well placed and that a few mergings or liaisons were, or were about to be, established with American companies. Outside the window—which relates to Europe—AT&T, Northern Telecom and NEC, in addition to IBM and Fujitsu, challenge by size the European companies, AT&T being at least three times as big as anyone else.

Two years later (right of figure 10) several interesting changes may be noticed.

1. Philips disappeared as an independent company in telecommunications and, in its place, a new company, APT, jointly owned with AT&T, was formed, which allows AT&T to show up in the European window.
2. Both GT&E and ITT sold their European activities to Siemens and to Alcatel, respectively, practically disappearing as independent entities from the telecom scenario.
3. Within Europe, the merging of GEC and Plessey was completed, whereas the merging of Italtel and Telettra failed to happen. Moreover, ANT (AEG-Telecommunications) was acquired by Bosch and switched from the telecommunication to the consumer sector.

A common remark, only noticeable to the expert eye, is that annual revenues of almost all big companies engaged in switching equipment production dropped substantially as a result of the lower cost of electronic, with respect to electromechanical lines. In this context, the substantial growth of both Fujitsu and Hitachi is to be considered as a very remarkable achievement.

In conclusion, the firmament of telecom manufacturers seems to become less crowded and more balanced in size throughout the world. However, it is to be noted that all that is viewed with the naked eye and therefore stars below a certain size are not seen; perhaps, by using a telescope, we may discover that the very many little stars that would be seen may constitute a very significant fraction of the whole firmament.

The situation of EDP manufacturers (figure 11) *is* dominated by the giant IBM and by the strong position of American companies in general. Their indentations into the European market largely superseded the capabilities of the local companies, with the Japanese stars staying outside for the moment.

Looking at the situation two years later (right of figure 11 we may note the completion of the merging of Burroughs and Sperry into a bigger company, UNISYS, which appears to have joined DEC, NEC and Fujitsu as the first group of after-runners of IBM.

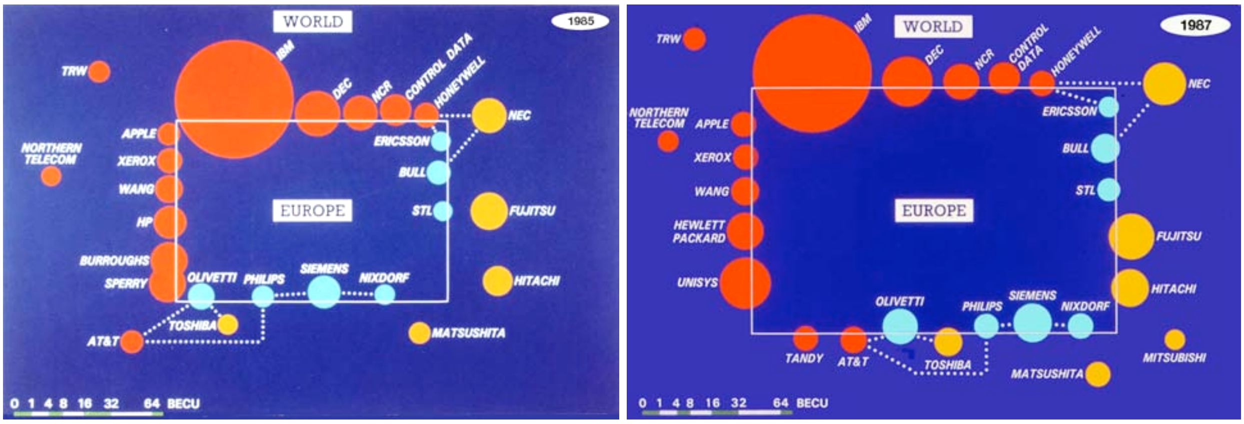

FIGURE 11. The firmament of EDP manufacturers in 1985 and 1987.

In addition, this graph clearly shows a substantial growth of most of the other big companies, but notably HP, NEC, Fujitsu, Hitachi and all the Europeans; this time, however, a net penetration of the Japanese companies into Europe is shown. Also noticeable is the 'visibility' of Mitsubishi and of the new American company Tandy in this market sector.

The firmament of the 'consumer electronics' manufacturers (figure 12*)* is clearly dominated by the Japanese stars Sony, Sanyo and Matsushita, each one about 1.5 to 2 times bigger than the biggest European star, Philips, and three to four times bigger than the two biggest American stars RCA and Zenith.

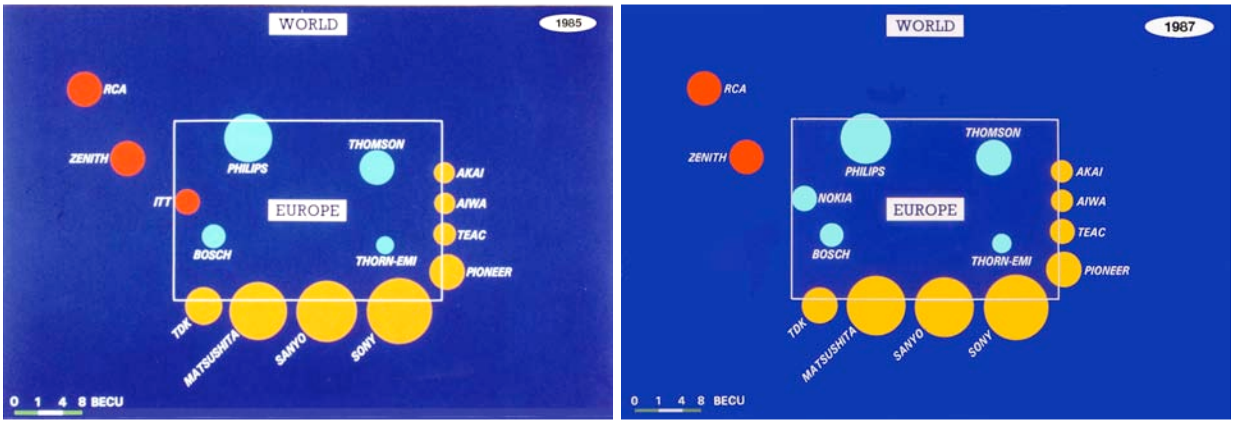

FIGURE 12. The firmament of Consumer manufacturers in 1985 and 1987.

The only noteworthy change in 1987 (right of figure 12*) is* the appearance in the European family of the Finnish Nokia, which has acquired the European subsidiary of ITT in the consumer sector. It can also be seen that the Japanese supremacy is far from being reduced.

To complete our sky scanning, let us look at the last galaxy (figure 13), that of component (mostly semiconductors) manufacturers, where the so-called 'captive production' is indicated in dots. One first remark is that in the U.S.A. there are many big companies fully *verticalized*, IBM being once again the world's biggest one. The same phenomenon appears to be largely spread both in Japan and in Europe, but for less than one third of the total sales of each company. Another remark is that this segment of the market is very crowded, because we find here most of the companies operating in the other three segments illustrated before. Two years after (right of figure 13*)* perhaps the most evident change is the very remarkable growth of National Semiconductors in the U.S.A., as well as of both Fujitsu and Hitachi in Japan. AMI disappeared from the graph, having been split into two smaller companies. On the contrary, three new Korean companies are coming up quite fast; these are Hyundai, Goldstar and Samsung. And, finally, both Philips-Signetics and Thomson-SGS-Mostek are shown as a single company, which they are, whereas another merging between Ferranti and Plessey shows up on the horizon.

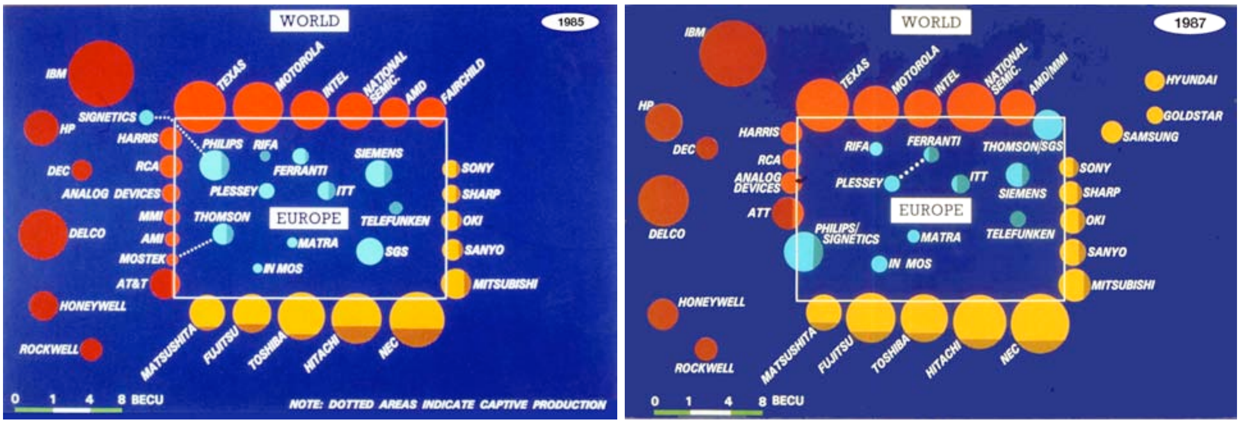

FIGURE 13. The firmament of Component manufacturers in 1985 and 1987.

We can summarize all the above in two tables. The first one (table 3), relating to 1985, where market size and production volumes are shown for the three main regions of the world plus the rest of the world (Row), and, of course, for the four market segments quoted above.

IBC RELATED MARKETS (BECU - 1985)

	N. AMERICA		W. EUROPE		JAPAN		R.O.W.		SUBTOTAL
	MKT	MFG	MKT	MFG	MKT	MFG	MKT	MFG	
TELECOM	23	24	16	18	5	6	6	2	50
	+1		+2		+1		−4		
EDP	90	103	40	28	20	24	10	5	160
	+13		−12		+4		−5		
CONSUMER	22	8	18	10	12	28	3	9	55
	−14		−8		+16		+6		
COMPONENTS	13.5	16	5.5	2.5	8	9.5	1.5	0.5	28.5
	+2.5		−3		+1.5		−1		
IBC TOTAL	148.5	151	79.5	58.5	45	67.5	20.5	16.5	293.5
	+2.5		−21		+22.5		−4		

TABLE 3.

The table shows that the telecom markets are quite well served by internal producers in each of the three main regions, with little interchange among them; their slight over-production is sold in the rest of the world. In the EDP segment North America dominates, not only in manufacturing capabilities, but also for the demand of products, which is more than twice with respect to Europe and more than four times with respect to Japan. Europe has the biggest deficit, amounting to one third of its market.

Concerning the consumer segment, Japan dominates and exports about 60% of its production, whereas North America is in the worst position with a deficit amounting to about 64% of its market; Europe follows with a deficit of 44%, whereas the rest of the world (mostly Korean companies) appears to be also quite a strong exporter.

In the component segment, both North America and Japan export 16 O/ of their production, Europe being down by more than 50 % of its internal market.

After two years (table 4) we may note the following.

IBC RELATED MARKETS (BECU - 1987)

	N. AMERICA		W. EUROPE		JAPAN		R.O.W.		SUBTOTAL
	MKT	MFG	MKT	MFG	MKT	MFG	MKT	MFG	
TELECOM	24	23.5	17.5	20	6.5	8.5	12	8	60
	−0.5		+2.5		+2		−4		
EDP	85	104	62	41	28	34	10	6	185
	+19		−21		+6		−4		
CONSUMER	22	8	18	10	12	28	3	9	55
	−14		−8		+16		+6		
COMPONENTS	13.5	16	7	3.5	9	10.5	7.5	7	37
	+2.5		−3.5		+1.5		−0.5		
IBC TOTAL	144.5	151.5	104.5	74.5	55.5	81	32.5	30	337
	+7		−30		+25.5		−2.5		

TABLE 4.

In the telecom segment a small opening of the U.S. market to European and to Japanese suppliers takes place, probably tied with AT & T's divestiture. Also noteworthy is the doubling of demand in the rest of the world, but covered with manufacturing structures grown up inside (by an impressive fourfold rate), probably through a mechanism of licensing or by subsidiaries of foreign companies, as it is very common in newly industrialized countries.

In the EDP segment, whereas the U.S. market size remains about constant, there is a growth both in Europe and in Japan by an impressive 50 % in two years. Their manufacturing system has responded quite well, through increasing their production by the same percentage, this being, however, not enough for Europe, which is smaller by 21 BECU (Billion ECU[2]), with respect to the 12 BECUs figure of 1985. Nevertheless, this was a quite positive effort made by European industry.

There is nothing to be said about the consumer segment, which shows about the same figures as two years before.

For the component segment, the only notable change is in the rest of the world in which the market demand has grown by a factor of five, promptly covered by internal facilities, for much the same reasons as illustrated above. A tendency of the components to increase their incidence on

[2] ECU is the acronym for European Currency Unit, a standard measure for not yet unified European Currency.

on the overall market size (11% in 1985, 12.5% in 1987) is also worth noting (please note that their incidence on the hardware alone is at least twice as much).

In conclusion, it appears that the overall IBC market in the three regions of the world (if we include Far East and Japan in the Asian region) tends to reach about the same size as the American one, with some lag in time, Europe needing the greatest effort to fit its market growth with internal industrial capabilities, but Asia being the biggest challenger.

RACE is therefore an appropriate name to characterize the effort that European engineers have to make to cope with our future telecommunication requirements.

Discussion

C. E. HOPPITT *(British Telecom Research Labs, Ipswich, U.K.)* Can Dr Catania comment on the relative merits to European industry of a strategy based upon leap-frogging technology and standards (as in IBCN) and an approach based upon investing EEC money in modest technology aimed at specific medium-term profitable market segments?

B. CATANIA. The main concern of the European Community (EC) in subsidizing R&D initiatives in Europe is not to distort the market, therefore to confine EC interventions within the so-called 'pre-competitive research' (much the same as does MITI in Japan). Medium-term profitable market segments must be the concern of individual company policy or of suitable Eureka projects, which are not directly supported by the EC.

D. J. SKELLERN *(Hewlett-Packard Labs, Bristol, U.K.)* In the IBC market slides the EDP market is shown as three times the size of the telecom market. Does the telecom component include revenue from services? If not, does this significantly change the overall picture?

B. CATANIA. Service revenue is included.

D. J. SKELLERN. This is very surprising indeed! I would have expected revenue from services to have led to a much larger figure.
Are we to expect a vastly smaller ratio of service-revenue : equipment costs for IBC services than for current telecom services? What factors lead to this?

B. CATANIA. I'm sorry for the misunderstanding! Slides referred to *manufacturers* of equipments (industry), not to service providers. It is not easy to predict how much bigger or smaller would be the ratio of service-revenues: hardware-investments for IBC as compared with current telecom services. It has been evaluated that hardware investments will be (in the steady-state conditions) around twice as much as those for the present telephone service. As for service revenues, I am convinced that they will be, in perspective, much higher than at present, so that the overall return of investments should be much more advantageous than the present one.