ELECTRONIC AND TELECOMMUNICATION ENGINEERING CONCEPTS IN INDUSTRIAL PRODUCT DESIGN WITH A CASE STUDY OF CELL PHONE

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ABSTRACT

ELECTRONIC AND TELECOMMUNICATION ENGINEERING CONCEPTS IN INDUSTRIAL PRODUCT DESIGN WITH A CASE STUDY OF CELL PHONE

Industrial product design, as a field of design discipline, borrows concepts and methods from other disciplines, one of which is engineering, in order to develop its own knowledge in research and industry contexts. In the means of strengthening its place among other disciplines, a concentration on 'designerly' ways of knowing, thinking and acting should be provided. Therefore, in this study, the intersection between industrial product design field and engineering discipline is searched for revealing the engineering concepts and non-intuitive design methods within intuitive design methods used in industrial product design. Engineering design field is stated, since its being close to industrial product design, and a comparison is made between industrial product design and some engineering fields through their approach to design problems and the tools they use. Engineering design methods are stated and their advantages in design activity are revealed. This study is a part of design systems area, with formal approaches to models of design processes and knowledge. Finally, a case study of cell phones is carried out in order to prove the design approaches and the priorities of electronic and telecommunication engineering and industrial product design on a product.

ÖZET

ENDÜSTRİ ÜRÜNLERİ TASARIMI ALANINDA ELEKTRONİK VE TELEKOMİNİKASYON MÜHENDİSLİĞİ KONSEPTLERİNİN CEP TELEFONU ÖRNEĞİ İLE İRDELENMESİ

Endüstri ürünleri tasarımı, kendi disipliner bilgisini, araştırma ve endüstriyel bağlamda geliştirebilmek amacı ile, mühendisliğin de dahil olduğu pek çok disiplinin öngörü ve metotlarından faydalanır. Bu doğrultuda, diğer disiplinler arasında kendi çalışma alanı içerisindeki yerini güçlendirebilmek amacı ile, "tasarımcı yaklaşımlı", bilme, düşünme ve hareket etme eylemlerine konsantre olmalıdır. Bu çalışmada, mühendislik disiplininin içerisindeki mühendislik öngörülerinin ve sezgisel olmayan tasarım metotlarının, endüstri ürünleri tasarımı alanında kullanılan sezgisel tasarım metotları içerisindeki yerini ortaya koyabilmek amacı ile; endüstri ürünleri tasarımı alanı ve mühendislik disiplini, kesişme noktaları bağlamında araştırılmıştır. Endüstri ürünleri tasarımına olan yakınlığı sebebiyle mühendislik disiplini tercih edilmiş; bu doğrultuda, endüstri ürünleri tasarımı alanının bazı mühendislik alanları ile birlikte, tasarım problemlerine ve araçlarına yaklaşımlarının karşılaştırılması gösterilmiştir. Ayrıca, mühendislikte kullanılan tasarım metotları ve bunların tasarım aktivitesi sürecindeki avantajları da konunun daha net bir şekilde açıklanabilmesi amacı ile belirlenmiştir. Bu çalışma, tasarım sistemleri alanının bir parçasıdır ve sonuçta, tasarım sürecine ve bilgisine yönelik akılcı yaklaşımların belirlenmesini amaçlanmaktadır. Sonuç olarak; elektronik ve telekominikasyon mühendislik disiplininin ve endüstri ürünleri tasarımı alanının tasarım yaklaşımları ve öncelikleri, endüstriyel bir ürün olan cep telefonu örneği üzerinde irdelenmiştir.

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CHAPTER 1

INTRODUCTION

Design occurs when humans abstractize objects of nature and concretize the resulting ideas and visions in their minds. The relationship between humans and nature differs from the relationship between animals and nature, since humans define and use nature (materials and resources) for their prosperity instead of the simple and direct help derived from nature in animals' life. In Paleolithic ages, physical needs of human beings caused them to sharpen the edges of stones in order to kill the animals and feed themselves, and psychological needs of human beings have caused them to carve figures on stones, paint the caves, etc. This bi-dimensional structure of needs appears to be the key to understanding the epistemological structure of *design*.

From dictionaries it can be learnt that the word "design" has various meanings, ranging from conceiving a plan in the mind to making a drawing or pattern of something to be made or built. This study focuses on design in the more limited sense of "designing material products". For that purpose, design is defined in this study as "o conceive the idea for some artefact or system and/or to express the idea in an embodiable form "(Roozenburg and Eekels 1995: 53 quoted Archer 1971: 1-2)".

The term design began to be used in the language in the fifteenth century, with the aim of revealing the departure of design from "doing". After the Industrial Revolution in the eighteenth century, division of labor, mechanization, standardization, rationalization became the features of the new world. These developments encouraging new demands and changing demands encouraging new developments, all helped the new world evolve faster. Humans developed technology to meet the needs they have perceived for themselves, not for the universal needs over which the nature rules. Gaston Bachelard, the French philosopher, stated that "'obtaining the more than the enough' has stronger warning on souls as humans are not the creatures of needs, but they are the creatures of desire" "(Basalla 1996: 18)". This desire has brought about today's artificial world, which includes three times more variety than the organic world does. This incredible amount of objects can only be produced by the human mind that longs, dreams, and desires.

A lot of specializations have been developed that verify the desires of humans today, one of which is the profession of industrial designer that emerged in the twentieth century as another feature of the division of labor and specialization characteristic of large-scale modern industry. Industrial design is concerned with determining the qualities (materials, construction, mechanism, shape, color, surface finishes and decoration) of objects, which are reproduced in quantity by industrial processes, and their relationship to people and the environment. The industrial designer is responsible for these aspects of products and their impact on society and nature.

Industrial design is the most widely used term for the professional design of objects intended for mass production. However, it is not always used correctly since many industrial designers may work on products for craft manufacture and in related fields such as exhibition or interior design. In order to make a clear distinction in this study, the syntagm "industrial product design" will be employed. This field includes the design of 2 and 3-dimensional forms with transportation, furniture, home-office (accessories like clock, pencil, etc.), high-tech (Dvd player, monitor, computer, cell phone, medical machines etc.), lightening, fashion (accessories like umbrella, wristwatch, etc.), toys and games, food, packaging, gift/promotion, sports, medical and other functions and related production techniques (metal lightening, wooden furniture, etc.) in the respective sectors.

1.1. Description of the Problem

Designing an industrial product in the field of mobile communications is a multidisciplinary activity as functional, psychological, technological and economical criteria are all involved. The industrial product designer, acting through these criteria and fulfilling the design function, also acts as a team synthesist that builds a communication bridge between other professions like engineering, sociology, marketing etc. This structure is born out of the demands of the modern world. Within the many specializations that have been developed, needs of the modern world like airplanes, fast trains, or spaceships have caused to bring these specializations together and determine the respective professionals act in teams towards the common purpose. At this point industrial product design has become one of the most important strategic elements of competitive advantage in industrial context.

Because of dealing with a lot of criteria, the industrial product design field can be stretched to other fields easily, and other fields can be welcomed in industrial product design field easily, which easily gives birth to conflicts in developing industrial product design knowledge. Cross then states that design should be taken as a discipline in itself. In this study, industrial product design is going to be taken as a field of design discipline that accumulates and develops its own design knowledge. Understood in this way, industrial product design might create and strengthen its place among other overlapping fields and disciplines.

In our particular case, the design project presented here proposes a step further in understanding the functionality of the object in question. The element of innovation is represented by the projection function included in the cellular telephone. The main problem resulting from this innovation is not only a matter of design itself, but also related to the real needs of the users. In order to identify all potential problems deriving from the innovation, the author has undertaken a series of guided interviews which showed the potential implications. Most of the inputs from the interviews indicate that the increase in weight and dimensions would represent important disadvantages. On the other hand, interviews showed that the insertion of a projection device would enlarge the possibility of development in the field. Particularly, the possibility of accessing television channels at TV set parameters in the future attracts potential users. Another serious need indicated by the interviewed is related to the possibility of displaying in reasonably large format digitalized information in, for instance, PowerPoint-style presentations. In order to offer such a capability, the designer must develop a project based particularly on the inputs coming from the users.

1.2. Aims of the Study

Design priorities change according to different products. Although only cell phones are mentioned in this study, there is the aim of giving at least an idea about determining the design and telecommunication and electronic engineering priorities according to the product, depending on the big variety of the telecommunication area.

Consequently, the central aim of this study is to determine the ways in which a particular change can be induced in the perception, initiation and execution of cell phone design. The research explained here is therefore focused on developing a new understanding of the role that a cell phone can play in our lives. The *inputs* placed in this research derive basically from the perception of the cell phone as an indispensable asset in our contemporary world. However, this research pushes the limits of this understanding by turning the attention toward the potential role of the cell phone not only exclusively as a communication tool and media works producer, but also as a high quality projector of images, thus enlarging the *sharing* function of the phone. The social effects of this step can be tremendous since currently, most designs in the field presuppose that *sharing* is done as an after-downloading action. The concept proposed here aims at inserting *sharing* through the projection capability in the actual process of video and audio recording with the same device that is used for doing regular telephone calls together with all the other common functions of a cell phone.

Of course, this research, like any other, cannot aim at taking control of the life of the product-output after the design activity is completed. Many modifications would occur after the product enters the life of actual users and many other opportunities can open consequently. A series of interviews undertaken with potential users revealed that, in any case, innovation continues to be welcomed in the field. The role of the research proposed here is then ultimately that of *initiating change*. Its aim is therefore not that of revolutionizing cell phone design in itself, but that of introducing new possibilities which in turn would stimulate a novel set of desires and needs within the field. The relevance of this project for interdisciplinary approaches in design is particularly central in this study.

1.3. The Structure of the Thesis and Methods of Research and Design

This study is structured in four parts throughout the considered problem and the aims mentioned above.

Chapter 1 introduction and aim of the study and the structure

Chapter 2 consists of two parts comprising design and industrial product design. This chapter is conceived as to give a general understanding of design, industrial design, engineering design and industrial product. Then the design criteria in industrial product design and the intersecting engineering criteria are indicated, as these are the criteria (priorities) in certain products that usher the field of industrial product design into the fields of telecommunication engineering.

In Chapter 3, The becoming of mobile phone the development of the related concept is explained. A particular stress is placed on the functional expects of the design.

In the 4.th Chapter, the proposed design formula for a Projection Mobile Phone tandem is explained. Naturally, this chapter represents the core of this thesiss. In it the basic details of the Focus Mobile Projection Phone (Focus MPP) design are descirибed with a focus on the functionalexpects in the lightof the information gaint trought interactive research with potential users

In this study, documentary reading and critical research methods are used, and for providing a better explanation of the subjects, related cell phone examples are given. In *input/output* language, the study undertaken here passed through the following basic stages:

I. Stating aims
II. Literature searching and analysis
III. Interviewing potential users
IV. First brainstorming
V. Investigating user behaviour
VI. Second brainstorming
VII. Mental boundary shifting
VIII. Functional innovation
IX. Re-interviewing potential users
X. Analysis of interconnected decision areas (AIDA)
XI. Final output

The stages enumerated above indicate the entire structure of the process through which this study passed in order to reach the final output. It is obvious that the contact with the potential users has played an important role in extracting the preliminary input information needed for starting the research. While the specialized literature provides the basic input of academic information, the path toward the output and, therefore, final result of this study is strongly dependent on the input placed in by potential users through their opinions, suggestions and reactions to innovation. The stage of mental boundary shifting follows two crucial stages of brainstorming as they are inter-related. The mental boundary means here the reluctance of users to go beyond particular patterns of cell phone usages. The functional innovation stage brings in the novel contributions to cell phone design as proposed in this study and is followed naturally by another contact with potential users. This contact by re-interviewing potential users is of particular importance in this case since the possibility of having at hand the final product, i.e. the cell phone itself, does not exist.

The AIDA stage aims at identifying and evaluating the sub-solutions required for accomplishing the central aim of the research. Since the social effects of the desing project proposed here are of particular importance, the psychological, social and ultimately technical complex of alternative solutions resulting from preliminary researches need special attention. Corroborating all this potentially useful information as to serve the final implementation of innovation is therefore the essence of the AIDA stage.

In what concerns the *method of design*, the author has chosen Matchett's Fundamental Desing Method (FDM) with a particular importance given to the usage of a checklist. The interviews with the potential users were conceived as to meet the steps indicated in the respective checklist. In short, FDM presupposes the following 'routines' "(Jones 1992: 184)":

1. Studying the design situation;
2. Identifying preliminary needs to be satisfied by the design;
3. Identifying the Primary Functional Need (the need that is demanded first of all and without wich meeting all the other needs would be senseless);
4. Completion of a preliminary design to meet both primary and secondary needs;
5. Reviewing the functional effectiveness of the preliminary design;
6. Reviewing the material and work content in producing the design (not applicable in this case);
7. Reviewing the component quality in detail.

To the tentative checklist presented above, this author has added intermediary compulsory steps presupposing the consultation of potential users after each step. The idea is that the final outcome of the design process will be the result of a close cooperation between the designer and the user. That is to draw maximum of benefits from the possibilities offered by technology according to the real needs of the market, plus the advancement of novel needs that the general market does not display yet.

CHAPTER 2

DESIGN, PRODUCT DESIGN, INDUSTRIAL DESIGN, ENGINEERING DESIGN AND INDUSTRIAL PRODUCT DESIGN

2.1. Design

The design phenomenon is as old as the human being itself. We were designers long before we knew about it, before we could form words to talk about it, and before we could spell it. The design phenomenon is, in its broadest sense, probably as diverse and multi-faceted as there are people on earth. Everyone is, has at some occasion been, or will in a near future become, a designer; a person who identifies a need or problem, analyzes the problem, and finds a solution to that problem. Anyone who attempts to transform an existing situation into a desired new situation performs an activity we call design "(Simon, 1969)".

The term *design* and its abbreviations are used in all kinds of senses in literature and everyday language. The purpose of this thesis is not to finally define the term, a task that seems as impossible as inappropriate. Literature abounds with definitions of design. "(Hubka and Eder 1996)" list 21 definitions from various engineering related areas. General definitions of the activity are found, such as "a goal-directed problem-solving activity" "(Archer, 1965)" and the "professional service of creating and developing concepts and specifications that optimize the function, value and appearance of products and systems for the mutual benefit of both user and consumer" "(Ulrich and Eppinger, 1995)". Seen from an engineering design perspective, design may be described as containing the activities of problem solving, product synthesis, product development, and product planning "(Andreasen, 1991a)". Included in these activities is the "process of establishing which of several alternative ways (and with what tools) things could be done, which of these are most promising, and how to implement that choice, with continual reviews, additions and corrections to the work" "(Hubka and Eder, 1996)".

But design is not only the process of *designing*; the finding a solution to a problem. Design also denotes the outcome of such processes, the *design*; the created object, system, or service. A complementary definition used to denote the designed object is thus needed. Andreasen and Mortensen (1996) define the design objects as "the result of a design process". A design may be everything from a pattern on a textile, through a clothes-hanger, office furniture, a flattening iron, an automobile, to a train tunnel, or an airport inflight control system. It can include any additional systems or services for the selling, servicing or manufacturing of such products or systems. It could even be the laws governing the sales of such systems. There are many types of design found in product development. A discussion of some of the terms, which are in focus in this work, and how they relate to each other, may be in order.

2.2. Product Design

'Product design' is a useful, yet difficult-to-define term. Interpretations abound, ranging from the creation of textile, glass, and ceramic handicraft, to the form-giving activities of the industrial designer, and the engineering activities during product development. In the area of product design, where products implies mainly 'consumer products' that an individual can buy in a store, product design can be described according to the following: "*the activities involving the design of products, including the activities of engineering design and industrial design*" "(ENDREA, 2001a)".

The field of product design is thus broad and the activities involved therein are many, including engineering design as well as industrial design. Product design thus includes the activities needed for the development of a product, which in turn can be defined as: "*a system, object or service made to satisfy the needs of a customer*" "(ENDREA, 2001a)". In this thesis, the focus is on discrete, physical, and industrially manufactured objects. This implies that a product needs telecommunication and electronic engineering knowledge and skill for its realization.Thus, e.g., an object of handicraft, a book, an internet service, or jet aircraft fuel, are not considered 'products' as the term is used here.

2.3. Industrial Design

Industrial design includes the areas normally treated by industrial designers or persons with similar competence, e.g., aesthetics, semantics, appeal, graphics, product and corporate identity, ergonomics, and visual form conceptualization. A definition proposed by the Swedish Engineering Science Academy reads: "the formulation of properties primarily concerning the usefulness and appearance of products" "(IVA, 1988)". "(Monö 1997)" explains industrial design as "the creation of the gestalt of useful products intended for mass production, with the aim of adapting them to Man and his environment". The definition of industrial design used in this thesis scopes the meanings cited above, but aims at being slightly more specific: "*design with particular emphasis on the relation between product and man, e.g., semiotic, ergonomic and aesthetic aspects of the product*" "(ENDREA, 2001a)".

2.4. Engineering Design

Popularly, engineering design is what engineering designers 'normally' do. Professionals within this field can be trained engineers of different disciplines, or other individuals working mainly with engineering aspects of product design. Such aspects may be, e.g., machine elements, solid mechanics, strength of materials, aerodynamics, fluid dynamics, hydraulics, electronics engineering, telecommunications engineering, software engineering, systems engineering, quality engineering, industrial economics, and human factors engineering. Here, engineering design is defined as follows: "*design with particular emphasis on the technical aspects of a product, including both analytical and synthetic activities*" "(ENDREA 2001a)".

Naturally, it is very difficult, and hardly worthwhile, to try to define what activities belong to the domain of industrial design or engineering design, respectively. A gifted industrial designer working in product development may very well partly work with issues of engineering character, which in other situations may be carried out by an engineering designer, and vice versa.

2.5. Industrial Product Design

Through many movements in art and culture in the twentieth century, design has come to be regarded as the professional occupation of bringing humanity to dehumanized and impersonal mass-produced items. Industrial design is concerned with all the human aspects of machine-made products and their relationship to people and the environment. The designer is responsible for these products and their impact on society and nature.

The term "designer" is too general since it includes architects, engineers, stage, and fashion designers, and the like. Industrial Design is the most widely used term for the professional design of objects intended for mass production. The term is not always used correctly since many industrial designers may work on products for craft manufacture and in related fields such as exhibition or interior design. In order to make a clear distinction, since such distinctions are the very subject of this study, the term “industrial product design” is going to be used.

2.6. Main Characteristics of Industrial Product Design

There are four main characteristics in industrial product design that are: quality, quantity, identity, and method. Quality gives the value, quantity means the mass production, identity gives the name, and the method produces the design. These characteristics are set up in order according to priorities of the product, but they should be all included and dissolved in the industrial product itself.

As mentioned before, industrial designers deal with a lot of criteria. While dealing with these criteria, they design the product with an eye to quality, quantity, identity, and the method.Figure (2.1 –2.2)

Figure 2.1 Basic Model of Change

(Source: Bayazıt 1994: 55)

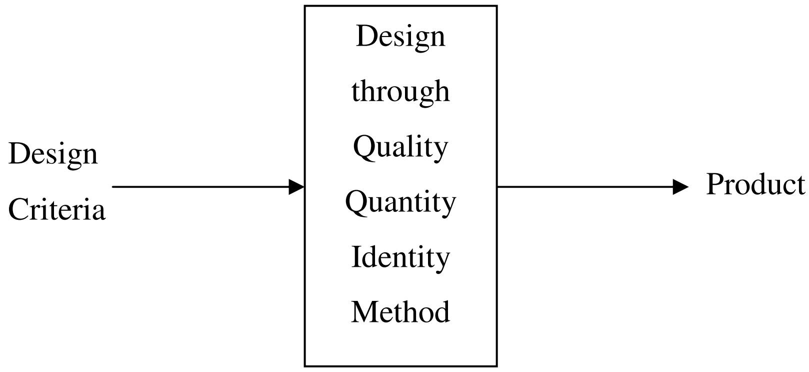

Figure 2.2 Design through Quality, Quantity, Identity, Method

2.7. Design Criteria in Industrial Product Design

Industrial product design carries a bunch of criteria such as being responsible to society, culture, environment, economy etc. "(Mehmet Asatekin 1997:39-43)" systematically classifies these criteria with a holistic approach to industrial product.

Functional Criteria	:Physiological Criteria, Environmental Criteria, Communicational Criteria
Psychological Criteria	:Perceptional Criteria Socio - Cultural Criteria, Sensitive Quality (Criteria), Explanatorily Criteria
Technological Criteria	:Material Criteria, Production Criteria
Economic Criteria	:At the Consumers' Level, At the Producers' Level, At Macro-Level

The intersecting criteria of engineering and industrial design in a product are:

Functional Criteria	:Physiological Criteria, Environmental Criteria
Technological Criteria	:Material Criteria, Production Criteria
Economical Criteria	:At the Producers' Level, At Macro-Level

Engineering fields such as human-factors engineering, materials engineering, mechanical engineering, industrial engineering, process engineering, manufacturing engineering, design engineering, product design engineering deal with the criteria given above, and participate in design of the industrial product. Engineering Designers are responsible for applying various techniques and scientific principles to the development and analysis of basic functional features of systems, devices, etc.

Process Engineers are responsible for the type of design that restricted to the design of components, tools, equipment, etc. "(Dhillon 1985: 226)" (Items for mass production systems). Human-Factors Engineers are responsible for ergonomics of the product to the user and the environment. Electronic and Telecommunication Engineers are responsible for developing electronic companenets and mechanisms vital to the design of a product. Computer-Aided engineering and analysis are also done to determine failure and stress levels of specific products

Manufacturing Engineers are responsible for determining if designs can be produced. Their expertise also involves rapid prototyping and assembly documentation of products. Product Design Engineers are responsible for the design of discrete, physical products "(Roozenburg and Eekels 1995: 53)". They are associated with specifically those items that are ultimately to be sold to consumers. Industrial Engineers are involved with the work environment and how the better can be improved for better productivity. They design, install, and improve systems that integrate people, technology, materials, and information.

Materials Engineers study the structure, properties and processing of materials used in products. The materials study done by these engineers is important to the performance of the product. In the lack of these criteria, with which engineers too are engaged, the designs cannot come into existence as a product sold in the markets of the modern world. Since this is the purpose of the industrial product design and the significance of it among the other design fields, engineering can be considered as one of the closest disciplines to the industrial product design field.

2.8. Definition of Electronics and Telecommunications Engineering

The term engineering applied to the profession in which a knowledge of the mathematical and natural sciences, gained by study, experience, and practice, is applied to the efficient use of the materials and forces of nature "(Encyclopedia Britannica Article)".

Materials and forces of nature are converted to products, processes, systems etc. in order to suffice the needs of human beings. While doing this, engineers use engineering knowledge that is derived from studying, experiencing and practicing the knowledge of the sciences and mathematics. The application of engineering knowledge provides analysis and synthesis. Synthesis of experience and analysis of materials and forces of the nature is included that the engineer acts like an artist (designer) as well as a scientist in the expansion of the engineering knowledge.

Because of these characteristics, engineering is the most important feature of industrial product design in the means of bringing design to an end product that is sold in the market. The priority of using engineering knowledge might change according to the product that is going to be designed. However, more or less it is still involved in designing activity.

Electronic Engineering

Electronic engineering deals with the research, design, integration, and application of circuits and devices used in the transmission and processing of information. Information is now generated, transmitted, received, and stored electronically on a scale unprecedented in history, and there is every indication that the explosive rate of growth in this field will continue unabated.

Electronic engineers design circuits to perform specific tasks, such as amplifying electronic signals, adding binary numbers, and demodulating radio signals to recover the information they carry. Circuits are also used to generate waveforms useful for synchronization and timing, as in television, and for correcting errors in digital information, as in telecommunication engineering. Prior to the 1960s, circuits consisted of separate electronic devices-resistors, capacitors, inductors, and vacuum tubes-assembled on a chassis and connected by wires to form a bulky package. Since then, there has been a revolutionary trend toward integrating electronic devices on a single tiny chip of silicon or some other semi conductive material. The complex task of manufacturing these chips uses the most advanced techonology, including computers, electron-beam lithography, micro-manipulators, ion-beam implantation, and ultra clean environments. Much of the research in electronics is directed toward creating even smaller chips, faster switching of components, and three-dimensional integrated circuits.

Telecommunications and Telecommunications Engineering

Telecommunications Engineering deals with the research, devices and systems which, transmit electronic or optical signals across long distances. Telecommunications enables people around the world to contact one another, to access information instantly, and to communicate from remote areas. Telecommunications usually involves a sender of information and one or more recipients linked by a technology, such as a telephone system, that transmits information from one place to another. Telecommunications enables people to send and receive personal messages across town, between countries, and to and from outer space. It also provides the key medium for delivering news, data, information, and entertainment.

Telecommunications devices convert different types of information, such as sound and video, into electronic or optical signals. Electronic signals typically travel along a medium such as copper wire or are carried over the air as radio waves. Optical signals typically travel along a medium such as strands of glass fibers. When a signal reaches its destination, the device on the receiving end converts the signal back into an understandable message, such as sound over a telephone, moving images on a television, or words and pictures on a computer screen.

Telecommunications messages can be sent in a variety of ways and by a wide range of devices. The messages can be sent from one sender to a single receiver (point-to-point) or from one sender to many receivers (point-to-multipoint). Personal communications, such as a telephone conversation between two people or a facsimile (fax) message (Facsimile Transmission), usually involve point-to-point transmission. Point-to-multipoint telecommunications, often called broadcasts, provide the basis for commercial radio and television programming.

CHAPTER 3

THE BECOMING OF MOBILE PHONE

3.1 Introduction to Phone

"Mr. Watson, come here. I want to see you."
"(A.G. Bell (SIT-126 & IC-122))"

On March10, 1876, Alexander Graham Bell first transmitted speech electrically with an order to his assistant Thomas A. Watson. Since then, the telephone - or rather the telephone system - has revolutionized the way we live, socialize and do business, but its ultimate potential was less than apparent to 19th century society.

In fact, the technology was so radical that even the president of WesternUnion, William Orton, had difficulty understanding telephone's extraordinary possibility. When he was approached with the option of buying Bell's patents for $100,000, he turned down the opportunity to monopolize the entire electric communication industry with the omment, "What use could this company make of an electric toy." "(SIT_16)".

To understand this lack of forecasting or unwise bureaucratic caution, one has to understand that at the time the telegraph dominated the communications industry. In 1876, 214,000 miles of telegraph wires carried over 31,703,181 messages delivered through 8,500 telegraph offices. "(SIT-18)" Since the telegraph system already had a fifty year lead over the telephone system, William Orton could not see that telephony could combine the immediacy of the telegraph, the potential for two-way person-to-person communication and the psychological advantage of a human voice instead of cryptic dots and dashes.

While social acceptance of the telephone has become practically universal in slightly over a century since its invention, 19th century society took at least a decade to fully understand the invention and implement a useful system for the new technology. In 1876, Bell, a third generation speech specialist with a deaf wife and mother, was busy working on a multiplexing device for the telegraph system - allowing simultaneous messages to be sent over the same line at different frequencies, now called frequency division multiplexing. This was the initial "harmonic telegraph" that gave Bell the idea to explore the “speaking” telegraph. Elisha Gray was also exploring harmonic multiplexing technology, but he continued to apply his research to the telegraph system and could not make the mental leap to an entirely new system of communication. Since Bell approached telecommunications as an outsider, he was able to move beyond the limitations of the current telegraph system, the downfall of practical telegraph men like Orton or Elisha Gray (who might have beat Bell's telephone patents by a year if he had seen its commercial value). “(SIT 147)”

Bell and his backers had to invent uses for the telephone and get the message across to the public. According to Bell's series of experimental prototype telephones, it took Bell about six months to design a two-way conversation model. Early telephone advertisements show how the master uses a private line to communicate with the servants, whether in the home or the factory.

Of course, the servants could now contact the master directly, a significant social equalizer. “(SIT-120)” In the mid to late 1870's, the public telephone demonstrations that Bell took on the road – to raise public awareness, finance his work and appease his backers – presented the telephone as a broadcasting system, i.e. a radio-concept of telephony. Watson would read the news from a nearby city or for large venues, professional musician and singers would entertain audiences hundreds of miles away, over the telegraph lines. (Music was easier to transmit because it was louder and could be significantly distorted while remaining recognizable.) The telephone was often confused with the telegraph in the mind of the public, and like the telegraph before it, the phone system had to create traffic of communication that had not existed before.

If many people were confused about the telephone’s possibilities, Bell himself quickly formulated a prophetic vision of a telephone system. He always saved the end of his demonstrations to speak about the future of the telephone and spoke of a central office system that would link up various phones through a “switch.” On March 25, 1978, he wrote in a letter to his British investors, “It is conceivable that cables of telephone wires could be laid underground, or overhead, communicating by branch wires with private dwellings, country houses, shops, manufactories, etc., uniting them through a main cable with a central office where the wires could be connected as desired, establishing direct communications between any two places in the city. Not only so, but I believe in the future wires will unite the head office of the Telephone Company in different cities, and a man in one part of the country may communicate by word of mouth with another in a different place.” “(SIT-22)” While he may have been correct in the long run, the first phones that were installed were "private lines" that connected only two telephones. Bell established commercial telephone service in1877. By June30, 1887 there were 230 phones installed; in July, there were 750; and in August there were 1,300. "(SIT-23)" Within ten years, 167,000 phones would create a disorganized maze of overhead wires in cities across the northeast. The early adopters of the telephone were mostly businessmen who could afford to pay for the rather expensive service. They were also the ones most likely to have been using the telegraph and switched to the new, easier to use telephone (which did not require a trained operator). Although domestic rates for leasing a phone were approximately half those of businesses, ($20 versus $40 a year) they were still too expensive for working class families. "(SIT-27)"

The switching system, signal boosters and multiplexing of simultaneous calls over the same wire were adapted from the telegraph system and made the growth of the telephone system feasible. Gardiner Hubbard, Bell's influential backer and father-in-law who later became head of AT&T, sold the rights to establish local telephone networks for Bell Telephone Co. in the UnitedStates. The first switchboard went into commercial service in 1878 with 21 subscribers in New Haven Connecticut, and in the 1880's they sprouted up across the country. However, these local switchboards would not be linked into a transcontinental system until 1914. Long distance telephone service began in 1881 between Boston and Salem and the system grew slowly after that: "(IC-129)" 1884 New York-Boston, 1892 New York-Chicago, 1893 Boston-Chicago New York-Cincinnati, 1895 Chicago-Nashville, 1896 Kansas City-Omaha New York-St. Louis, 1897 New York-Charleston New York-Minneapolis New York-Norfolk, VA 1898 New York-Kansas City (SIT-161)

3.2. Invention of the Technology

Bell's telephone was based on technology he was developing for the telegraph. Instead of a having a switch like a telegraph key which simply interrupts an electronic circuit, the telephone sends electric signals whose current responds to the air pressure of the original sound – in this case, the human voice. Once the voice passes into the transmitter, it changes into variable electric current. This modulated current travels through copper wires to the receiver. There, it drives an electromagnet which makes a diaphragm vibrate, reproducing the original sounds. While it is hard to appreciate this leap in technology from the telegraph, the telephone required the simultaneous invention of the microphone (transmitter), signal amplifiers and speaker (receiver).

Bell was obviously not the only inventor patenting new technological breakthroughs that had telephone applications. Thomas Edison provided two of the most important breakthroughs in early telephone technology. He developed the frist commercially practical transmitter and receiver. Edison had already invented multiplexing for the telegraph in 1874 that allowed two messages to be sent in opposite directions on the same line.

Bell's telephone could only carry a signal a very short distance, 20 miles at most, so variable resistance transmitters that would amplify the original signal had to be developed. In 1877, Edison - financially backed by Western Union intent on breaking the Bell Telephone Co. monopoly by developing a phone not covered by Bell's patents - invented the first carbon microphone that modulated an existing current instead of producing a varying current. The carbon microphone could produce louder, cleaner signals. Bell tried to contest the patents but failed. That same year, Edison invented the loud-speaking receiver, a diaphragm driven by an electromagnet that could transmit voices more clearly. Though Bell failed attempts to contest Edison's patents, a compromise was reached that was to repeat itself in subsequent years. These technological improvements were bought out and incorporated by the Bell Telephone Co. "(IC-124-5)"

Signal boosters to amplify fading signals as they traveled through the copper wires made long distance telephone calls feasible. A Belgian engineer, F van Rysselberghe, developed the anti-interference "choke" in 1882. Multiplexing technology developed for the telegraph was modified for the telephone. By the turn of the century, 17 calls could be handled simultaneously on one copper wire. This alleviated the need for individual copper phone lines between each subscriber. One cable could handle the long distance calls of a local network. Multiplexing helped to thin out the growing web of overhead wires that were becoming a public nuisance in American cities.

AT&T, incorporated in 1885, leased their phones to homes and offices to maintain ownership and control over the technology, which they continued to do until their break up in 1984. They initially made their money solely on rental fees for the equipment, but soon implemented a message rate for subscribers when AT&T almost went bankrupt.

AT&T's success was actually based on a patent monopoly. Endless legal battles were waged during the early years, especially with Western Union (which was eventually bought out by AT&T).Other inventors were quick to dispute Bell's telephone patents. Elisha Gray filed his telephone patent hours after Bell but did not think his invention was important enough to contest at the time. He quickly grew to regret his decision and subsequently lost a ten year legal battle. "(HT 235)" In any case, Gray's phone only transmitted sounds -not voices - through a weaker diaphragm. "(IC-124)" Philipp Reis, a German inventor, had constructed a variable resistance transmitter in 1860, but he had failed to understand its telephony value. On Long Island, Antonio Meucci had filed a patent for a telephone in 1871, but it was simply an acoustic phone, like cups on a string. "(IC-124)"

3.3. Invention of the System

The concept of the switchboard became prevalent in the 1880's, and as the system grew exponentially, the way calls were routed had to become increasingly automated. At first, there was no dial pad, no electronic switches, no signaling system. The caller would crank a handle on the phone to call the local switchboard operator who would connect the caller to the other party. If the call was long distance, the operator would have to contact another operator over an external line, then perhaps another, until the desired party was reached.

In the first year of service, the signaling system underwent a radical transformation. The first telephones did not have bells to signal an incoming call. Subscribers would have to shout in the mouthpiece or thump on it with a pencil, frequently breaking the diaphragm. J.C. Watson developed the "thumper", then the "magneto-generator" which drove a "magneto-bell." The problem was that this bell would ring indiscriminantly each subscriber's phone in the system whenever a call was placed. The pressing need for an individual signaling system became quickly apparent and was solved within the first year of service. "(HC 19-20)"

The operator could easily listen in to any conversation, so the personal nature of their service made the operator the town message center. That is, at least until there were too many telephone subscribers to be handled efficiently by operators. The first telephone operators were undertrained, unsupervised telegraph boys but were soon replaced by young women who proved to be more pleasant, reliable and submissive. “(HC 51-81)”

The ever increasing number of callers soon transformed the profession. By 1946, nearly a quarter-million young women were employed by AT&T, but their numbers would soon dwindle due to the implimentation of automatic call switching. Almon Stowger in 1889 invented the automatic switch to connect two parties without the aid of an operator. An undertaker in Kansas City, Stowger suspected that local operators were routing the calls to his rivals, so he wanted to cut the women out of the calling process. The rotary dial - which routes a call via a set of switches activated by a series of pulse signals - was developed in 1900 but was not installed on a large scale until 1914 in Newark, New Jersey. In 1921, Omaha, Nebraska opened the first all-automatic exchange. By 1926, only 20 percent of the system used the rotary dial and automatic switches. “(SIT-272)” Ironically, because other countries were slower to install their telephone systems, they were able to install automatic switchboards earlier than AT&T. Direct dial long distance took a little longer to develop. The first computerized switchboard was put into commercial service in 1976, and by 1982, half of all calls were switched electronically. The electronic switchboards used tones to route calls. This was the origin of touch tone keypad. “(IC-138)”

At the turn of the century, when Bell's 17 year patent protection ran out, around 6000 independent phone companies sprang up. These local switchboards would connect a few hundred households but could not be linked to a national system. AT&T would refuse to link these companies into their network monopoly and would buy them out when they were on the verge of bankruptcy. “(IC-127)”

AT&T, bought out in 1907 by New York Bankers like JP Morgan, had effectively overwhelmed the independent telephone companies and had over 7 million phones in their telephone system. By 1930, there were 20 million subscribers. As technology improved and the system became immense, calling costs went down. In 1927, a three minute call from New York to London cost $75, took at least eight operators and fourteen minutes to effect the connection. In 1945, the same call would cost $12 and take only 90 seconds to effectuate, due to improvements in technology. “(IC-124 and SIT-319)” This trend has been ongoing and now long distance calls cost a tiny fraction of what it once did.

Many people were rather concerned about AT&T's monopoly. AT&T agreed to Federal Communication Commission regulation in 1956 in exchange for maintaining the status quo and promising not to enter the emerging computer industry. The AT&T monopoly lasted until a ten year lawsuit to break up the telecommunication giant was settled in 1984. AT&T persuaded the courts to let it get out of the local phone service industry in favor of joining the deregulated long distance competition, where it believed the real money was. AT&T got out of the local phones service and seven "baby" bells were formed. The dissolution of AT&T also meant that people could now own their telephones and freely hook up peripheral devices such as faxes and modems.

3.4. Technological Innovation

The phone system installed before the 20th century used twisted copper wires, called a loaded system. The cost of installing copper wires took up one fourth of all of AT&T's budget in the late 19th century. Copper wires absorb a large amount of electrical energy produced by the transmitter, which distorts the original quality. Gradual improvement arrived that increased the quality of service and calling capacity. Radio telephone links created the first long distance service between England and the U.S. in 1927. Another major improvement was coaxial cables in the 1940's that reduced interference and increased calling capacity for the ever expanding telephone system. Microwave stations in the 1950 (based on radar technology) could carry almost 20,000 phone conversations. These are still used to this day though mostly for broadcasting television signals. Telecommunication satellites for transcontinental service were soon added. In 1965, the first, named Early Bird , could carry 250 calls simultaneously. By 1976, the dozen or so newer communication satellites could handle 30,000 calls each.

Digital transmission, i.e. the binary language of computers, was introduced in 1962. In the old analog system, the electronic signal in the wire looks like the sound waves in the air, which was Bell's great breakthrough. In digital system information about the sound wave - not a representation of it - is sent over the wire. Information about the amplitude of the speech is sampled thousands of times a second, so that it can be reconstructed at the other end. The system didn't really come into its own until the 1980's.

In 1970 Corning Glass developed the first fiber optics cable, which uses laser light traveling through glass instead of electrons traveling through copper. Laser light can be modulated at tremendous rates, making possible a very high speed of transmission and an information capacity 125,000 times that of a comparable copper wire. "(ME 77)". In the last 20 years five different generations of fiber optics systems were implemented, and industries wrote off billions of dollars invested in microwave towers and copper cables.

By 1980, it was being used everywhere, on almost every intercity route and on many local runs. "(IC -138)" The Achilles heel in this new system-often billed as the information superhighway-is the old copper cables that still lead into the vast majority of American homes. The only ones that take advantage of digital transmission at this point are companies that can afford to pay for the installation of expensive high-bandwidth phone lines and high speed switching systems.

Estimates for rewiring every household in the U.S. with fiber optic cables has been estimated at $100-325 billion. In New Jersey alone, this effort requires the replacement of 56.3 million mile of copper. "(IC 158-9)" This has created a strong interest in developing technology for old lines, in the form of digital service, fiber optics and signal compression. I.S.D.N - short for Integrated Service Digital Networks - promise to make the entire phone system digital. The local network is analog due to low capacity copper wires, but signal compression technology might just make I.S.D.N. a possibility without rewiring every home with fiber optics.

The eight NYNEX employees I spoke to recently had never have heard of I.S.D.N., so it would be foolish to speculate just when this service might be available.

3.5. Evolution of the cell phone

3.5.1. Mobile Telephone History

This article describes how mobile telephones, for decades a near dormant technology, became the dynamic and perhaps most important communication tool of our lives. Commercial mobile telephony began in 1946. The cellular radio concept was published in 1947. But only since 1995 have mobiles become low cost, rich in features, and used world wide. We first examine mobile telephony's early and bulky beginnings.

Next, the long journey to analog cellular followed. Finally, full digital working, exemplified by GSM and now CDMA, providing services and features that make the mobile indispensable and ubiquitous. We'll see how early mobile telephony battled the same problems of today: government regulation, scarce spectrum, and hardware limitations. How Scandinavian, Japanese, and United States groups independently crafted their own radio-telephone solutions. The relatively recent, spectacular success of today's mobile telephone could hardly be guessed by its age. But its history reveals why this technology took so long to mature. And the present shows us that it was worth the wait.

Public mobile telephone history begins in the 1940s after World War II. Although primitive mobile telephones existed before the War, these were specially converted two way radios used by government or industry, with calls patched manually into the landline telephone network. Many New York City fireboats and tugboats had such radiotelephones in the 1930s. These were private services. For this article, though, a mobile telephone is a wireless device which connects to the public switched telephone network and is offered to the general public by a common carrier or public utility. Further, for the most part, mobile history is not just a study of the telephone, the handset itself, but a look at the wireless system it is connected to.

After World War II badly neglected civilian communication needs could finally be addressed. Many cities lay in ruin; their infrastructures need years of reconstruction. Post, Telephone and Telegraph administrations, the PTTs, and private telephone companies concentrated on providing landline telephones and services first, but some mobile radio research and development still went on. Americans lead this low priority movement for three reasons. The United States was physically intact after the war, Bell Telephone Laboratories had a large group of radio engineers and scientists to use, and the Motorola corporation had grown significantly during World War II. Consumer demand, research facilities, and manufacturing capability all existed for U.S. mobile telephony. But was that enough? And what kind of mobile system would be created?

On July 28, 1945 a cellular radio or small zone system was first described in print. The head of the United State's Federal Communications Commission, the FCC, outlined a two way radio service in the 460 MHz band to the *Saturday Evening Post*. Commissioner J.K. Jett had just been briefed by AT&T personnel. They talked to him about possibilities for American wireless communications after World War II. Deceptively titled "Phone Me by Air", Jett's *Post* interview didn't suggest connecting mobile radios to the landline telephone system. But he did describe frequency reuse within a small geographical area, the main element of cellular radio. Millions of users, he said, could use the same channels across the country. Low powered transmitters using high band radio frequencies would keep signals in nearby cities from interfering with each other. Despite Jett's initial enthusiasm, the F.C.C. never allocated the spectrum needed for this service. Still, radio engineers were thinking of cellular, even if they couldn't build such a scheme just yet.

A year after that landmark article, the first American commercial mobile radio-telephone service began. On June 17, 1946 in Saint Louis, Missouri, AT&T and one of its regional telephone companies, Southwestern Bell, began operating MTS, or Mobile Telephone Service."(Peterson, A.C., Jr. Vehicle Radiotelephony Becomes a Bell System Practice. *Bell Laboratories Record,* 137, April, 1947)" Motorola built the radios and the Bell System installed them. MTS was modeled after conventional dispatch radio. A centrally located antenna transmitted to mobiles moving across a wide area. The mobiles, all of them car based radio-telephones, transmitted to several receivers situated around the city. The traffic from the receivers and to the transmitter went through a central telephone office. MTS used six channels in the 150 MHz band with 60 kHz wide channel spacing. Unexpected interference between channels soon forced the Bell System to use only three channels. Waiting lists developed immediately in every one of the twenty five cities MTS was introduced.

3.5.2 Cellular telephone systems first discussed

In December, 1947 Bell Laboratories' D.H. Ring, with help from W.R. Young, articulated a true cellular radio system for mobile telephony in an internal company memorandum. Young said later that all the cellular radio elements were known: a network of small geographical areas called cells, a base station transmitter in each, cell traffic controlled by a central switch, frequencies reused by different cells and so on. He stated from1947 Bell teams "had faith that the means for administering and connecting to many small cells would evolve by the time they were needed." "(Roessner, D., et al. *The Role of NSF's Support of Engineering in Enabling Technological Innovation: Phase II, Chapter 4: The Cell Phone. Final report to the National Science Foundation.* Arlington, Virginia: SRI International, 89, 1998. *citing* Ring, D.H., "Mobile Telephony

- Wide Area Coverage," Bell Laboratories Technical Memorandum, December 11, 1947)". "(Online:http://www.sri.com/policy/stp/techin2/chp4.html)"

But more mobile telephones were always needed. Then, in 1947, and for decades after. Better technology would help, but more spectrum, more channels, were essential to developing a high capacity mobile telephone service.

3.5.3 Conventional mobile telephony

In 1947 the Bell System asked the F.C.C. for more frequencies. The Commission allocated a few more channels in 1949, but they also did something unexpected. They gave half of those frequency allocations to other companies wanting to sell mobile telephone service. These firms were called Radio Common Carriers or R.C.C.s. The F.C.C. thus created wireless competition for the Bell System while allowing capacity to increase only slightly. These small businessmen, however, advanced early mobile telephony further and faster than AT&T. As proof of their competitiveness, the R.C.C.s serviced 80,000 mobile units by 1978, twice as many as AT&T. This growth began with an excellent start, the introduction of automatic dialing in 1948.

On March 1, 1948 the first fully automatic radiotelephone service began operating in Richmond, Indiana, eliminating the operator to place most calls. "(McDonald, R. Dial Direct: Automatic Radiotelephone System. *IRE Transactions on Vehicle Communications* 80 July,1958)" T&T by comparison didn't provide automatic dialing until 1964. Most systems, though, R.C.C.s included, still operated manually until the late1960s. While these small, independent wireless companies could provide service to a few dozen customers at a time, they did not have the money or the resources to research, design, and then build a high capacity mobile telephone system.

On July 1, 1948 the Bell System unveiled the transistor, a joint invention of Bell Laboratories scientists William Shockley, John Bardeen, and Walter Brattain. It would revolutionize every aspect of the telephone industry and all of communications. Fragile and bulky vacuum tubes would eventually be replaced by transistors. Compact, low cost, rugged radios could now be speculated about. Vacuum tubes, though, would dominate the radio and telephone industry for another twenty years.

Outside of the United States mobile telephony developments came slowly. Most governments or PTTs did not allow the public radiotelephones. There were exceptions. In 1949 the Dutch National radiotelephone network inaugurated the world's first nation-wide public radiotelephone system. And in 1951 the Swedish Telecommunications Administration's Sture Lauhrén and Ragnar Berglund designed a novel automatic mobile telephone system called the MTA. This scheme began with a Stockholm trial and soon encompassed the city and its surrounding area. A similar system was soon set up in Gothenburg, although both networks did not become fully operational until 1956. As with all car mounted radio telephones, the equipment was huge and required much power. The transmitter and receiver were mounted in the boot or trunk, while the dial and handset went inside the cab. A car's headlights dimmed while a customer transmitted. On the other side of the planet, an electronics giant was gaining life.

In 1952 Japan regained its independence., seven years after World War II ended. Nippon Telephone and Telegraph became privatized, its research division strengthened and various government sponsored laboratories escalated radio and telephone studies. Although private radiotelephones were not allowed, consumer demand for commercial radio and television broadcasting sets would come about quickly, and the Japanese soon looked to making this equipment for export. Quality control pioneer Edwards Deming had been lecturing Japanese industry leaders since 1950. He stressed quality first, something American manufacturers were not receptive to. The Japanese took Deming's advice quite seriously. Japanese cameras, cars, and electronics became so good over the next thirty years that other countries were forced to rethink and often retool entire industries.

In 1953 the Bell System's Kenneth Bullington wrote "Frequency Economy in Mobile Radio Bands." "(Buliton, K. Frequency Economy in Mobile Radio Bands. *Bell System Technical Journal*. Volume 32: 42 et. seq. January,1953)."This dull sounding paper appeared in the *Bell System Technical Journal*, circulated around the world. For perhaps the first time in a publicly distributed paper, the 21 page article hinted at, although obliquely, cellular radio principles. Three years later the Bell System began providing manual radio-telephone service at 450 MHz, a new frequency band assigned to relieve overcrowding on their lower frequency band. This system also filled to capacity wherever it was introduced.

In July, 1958 Jack Kilby invented the integrated circuit at Texas Instruments in Dallas, Texas. A toothpick size piece of geranium contained his complete electrical circuit or IC. It used no soldered connections and consequently was reliable and stable. He also showed how resistors, capacitors, diodes, and transistors could co-exist on a single block of semiconductor and that they could all be made of this same material. As Texas Instruments itself puts it, “The roots of almost every electronic device we take for granted today can be traced back to Dallas more than 40 years ago.”

In 1958 the innovative Richmond Radiotelephone Company improved their automatic dialing system. They added new features to it, including direct mobile to mobile communications. Other independent telephone companies and Radio Common Carriers made similar, incremental advances to mobile-telephony throughout the 1950s and 1960s. In this same year the Bell System petitioned the F.C.C. to grant 75 MHz of spectrum to radio-telephones in the 800 MHz band. Despite the Bell System’s forward thinking proposal, the F.C.C. ignored their request for ten years.

During the late 1950s little cellular radio research and development was accomplished. Without enough spectrum to make it economically feasible, a high capacity cellular system could not be built in the United States. Still, two important papers by Bell System employees were published in 1960. They appeared in the *Institute of Radio Engineers Transactions on Vehicle Communications.* The articles discussed handoffs, in particular, that process of transferring a call from one cell to the next, with different frequencies used in adjacent cells. This was the first time the entire cellular system concept was outlined in print to a worldwide readership.

In 1961 Ericsson subsidiary Svenska Radio Aktiebolaget, or SRA, reorganized to concentrate on building radio systems. This forerunner of Ericsson Radio Systems was already selling paging and land mobile or dispatch radio equipment throughout Europe. SRA would go on to become a central part of Ericsson, helping create their wireless consumer business.

In 1964 the Bell System introduced Improved Mobile Telephone Service or IMTS, a replacement to their badly aging Mobile Telephone System. “(Douglas, V.A. The MJ Mobile Radio Telephone System. *Bell Laboratories Record,* 383, December,1964).”wit IMTS people didn’t have to press a button to talk. Conversations went back and forth just like a regular telephone. IMTS finally permitted direct dialing, automatic channel selection, and reduced bandwidth from between 25 and 30 kHz. Some regional telephone companies like Pacific Bell, owned by AT&T, took nearly twenty years to replace their old MTS systems. Again, although demand was great, there were not enough channels to accommodate more users.

Other countries in the mid 1960s were also replacing their first mobile telephone systems. The Swedish Telecommunication Administration began replacing their MTA system with MTB. Ragnar Berglund developed this new system and, thanks to the transistor, made possible smaller phones which required less power and were therefore less expensive. MTB was available to the public from 1965. Like MTA, the MTB soon ran out of capacity with 660 customers served. "(Olle Gerdes, citing *Dædalus 1991, The Yearbook of the National Museum of Science and Technology.* Stockholm)".

In 1967 Nokia was formed by consolidating two companies: the Finnish Rubber Works and the Finnish Cable Works. Nokia expanded Finnish Cable Works electronics division to include semi-conductor research. These early 1970s studies helped Nokia develop digital landline telephone switches. Also helping the Finns was a free market for telecom equipment, an open economic climate which promoted creativity and competitiveness. Unlike most European countries, Finland's PT&T was not required to buy equipment from a Finnish company. And other telephone companies existed in the country, any of whom could decide on their own which supplier they would buy from. Nokia's later cellular development was greatly enhanced by this free market background and their early research.

In 1967 Televerket, now Telenor, began operating a public mobile telephone system known as the OLT. It was a manual system using the 160 MHz band. It, too, ran out of capacity soon after introduction. A few years later an additional system was introduced in the 450 MHz band in southern Norway.

By the late 1960s it is certain that every major telecommunications company and manufacturer knew about the cellular radio idea. In 1967, for example, NT&T may have begun research for a nationwide cellular system at 900 MHz for Japan. "(Ikegami, F. Mobile Radio Communications in Japan. *IEEE Transactions On Communications,* 744. Vol. Com-20 No. 4, August, 1972)". But, how to make it work technically and economically? There was no way to evolve the existing radiotelephone infrastructure to cellular. New base station radio equipment and new customer mobiles were needed. Instead of a single, central antenna site with one fairly simple transceiver, several to dozens of cell sites would be required, each needing its own transceiver, all of them interconnected to each other, with a network switch to manage the traffic, and software to make everything work. The cost would be enormous.

The Federal Communications Commission in the United States in 1968 reconsidered the Bell System's ten year old request for more frequencies. They made a tentative decision in 1970 to grant them, asked AT&T to comment, and received the system's technical response in December, 1971. The Bell System submitted a frequency-reuse cellular radio scheme. Their proposal was based on the patent Amos E. Joel, Jr. and Bell Telephone Laboratories filed on December 21, 1970 for a mobile communication system. Six long years passed before the F.C.C. allowed AT&T to start a trial.

Besides bureaucratic sloth, this delay was also caused by lawsuits and objections from radio common carriers, independent telephone companies, and their suppliers. All three groups feared the Bell System would dominate cellular radio if private companies weren't allowed to compete equally. They wanted the F.C.C. to design open market rules, and they fought constantly in court and in administrative hearings to make sure they had equal access. And although its rollout was delayed, the Bell System was already working with cellular radio, in a small but ingenious way.

3.5.4. The first commercial cellular radio system

In January, 1969 the Bell System made commercial cellular radio operational for the first time by employing frequency reuse in a small zone system.Using public pay phones. Passengers on what was called the *Metroliner* train service running between New York City and Washington, D.C. found they could make telephone calls while moving at more than 160 kilometers per hour. Six channels in the 450 MHz band were used again and again in nine zones along the 225 mile route. A computerized control center in Philadelphia, Pennsylvania, managed the system. Thus, the first cell phone was a payphone! As Paul described it in the *Bell Laboratories' Record* article on the project, "The system is unique. It is the first practical integrated system to use the radio-zone concept within the Bell System in order to achieve optimum use of a limited number of radio-frequency channels." "(Olle Gerdes, citing *Dædalus 1991, The Yearbook of the National Museum of Science and Technology.* Stockholm)".

Around 1969 the first all transistor mobile telephones appeared from a large manufacturer. The tube era for radio telephones was ending. Motorola's 'Mark 12' was an IMTS telephone designed to work in the 450Mhz band. This transistor rig was still big and bulky and mounted in a vehicle. The first commercial portable radiotelephones in the United States also appeared at this time. In 1969 or 1970 SCM Melabs, owned by

Smith Corona, produced an attaché phone, a complete MTS telephone built into a briefcase. Almost immediately Canyon Communications and Livermore Data came out with their attaché phones. These were all MTS even though IMTS had been introduced in 1964. Only small firms made these units. Harris, Motorola, and GE never did. All these phones were essentially made by hand. (Geoff Fors Personal correspondence)

In November, 1971 Intel introduced the first commercial microprocessor, the 4004, a miniature computer on a silicon chip. The original contained 2,300 transistors and did 60,000 operations a second. Today's microprocessors can contain 5.5 million transistors, performing hundreds of millions of calculations each second. Intel's 4004 was designed originally for a desktop calculator, but microprocessors were soon improved on and eventually put into all kinds of electronics, including telephone switches and cell phones. That integration could have come sooner for one telecom group.

During the late 1960s and early 1970s the Nordic Mobile Telephone group was planning a Scandinavian wide mobile telephone network. Their 1970 report concluded the microelectronics needed to build an analog cellular network would not be available until 1980. The group decided therefore that instead of using new technology, they'd design a conventional, manual mobile telephone system. It started in Örebro, Sweden in 1971. It required 400 operators to serve just 19,800 subscribers. MTD shut down in 1987, eclipsed, of course, by an automated cellular radio system made possible by microprocessor technology.

On October 17, 1973, Motorola filed a patent for its own cellular radio system. (US Patent Number 3,906,166, granted September16,1975). Although Motorola had supplied the Bell System with radiotelephones for decades, AT&T was now considered a threat, not a friend. Motorola's main business was dispatch radio systems for taxi companies, utility fleets, police departments, and so on. If cellular was successful then dispatch customers might move in whole or in part to the new service. So Motorola needed a cellular offering to compete with AT&T. A rivalry developed between the two companies to field working equipment. In 1973, after completing Motorola's first prototype cellular telephone and its base station, Dr. Martin Cooper called his competitors at Bell Labs. Ferranti says "Cooper couldn't resist demonstrating in a very practical manner who had won." "(Ferranti, M. Father of Cell Phone Eyes a Revolution. IDG News Service, New York Bureau,14:31, October 12,1999)". What Cooper's team invented was the first handheld cell phone. But not the cell phone itself. That had already been done on the *Metroliner* train. Motorola's successful field work caused the American magazine *Popular Science in* July, 1973 to picture the portable phone on their cover. The accompany article said that with F.C.C. approval New York city could have a Motorola cellular system operating by 1976. No approval came.

On May 1, 1974 the F.C.C. approved an additional 115 megahertz of spectrum for future mobile telephone use. Cellular loomed ahead, although no one knew when F.C.C. approval will permit its commercial rollout. American business radio and radio-telephone manufacturers begin planning for the future. The demand was certainly there. In 1976 only 545 customers in New York City had Bell System mobiles, with 3,700 customers on the waiting list. In the United States overall, 44,000 Bell subscribers had AT&T mobiles but 20,000 people were on five to ten year waiting lists. Demand always existed but the spectrum to accommodate them did not.

In1975 the F.C.C. let the Bell System begin a trial. It wasn't until March, 1977, though, that the F.C.C. approved AT&T's request to actually operate their cellular system. A new wireless industry was developing in America and the F.C.C. sought to control every aspect. They'd decide the number of wireless carriers in each market, the companies allowed to operate, standards for the equipment, frequency assignments, channel spacing, and on and on. "(http://www.fcc.gov/Bureaus/OGC/Reports/cellr.txt)".

Suffering less bureaucratic trouble, Japanese and Scandinavian manufacturers diligently worked on trialing first commercial analog cellular systems. The NMT group ran a satisfactory trial in Stockholm in late 1977 through early 1978. Nippon Telephone and Telegraph probably started field tests in Tokyo as early as 1975. "(Ito, Sadao and Yasushi Matsuzaka. 800 MHz Band Land Mobile Telephone System - Overall View. *IEEE Transactions on Vehicular Technology.* 205, Volume VT-27, No. 4, November 1978., as reprinted from Nippon Telegraph and Telephone's *The Review of the Electrical Communication Laboratories*, Vol. 25, nos 11–12, November-December,1977.(English and Japanese))"

NTT produced the first cellular systems for Japan, using all Japanese equipment. The Japanese also contributed important studies to cellular research. Y. Okumura's 1968 "Field Strength and its Variability in VHF and UHF Land Mobile Service," is an often cited, pioneering work. But Japan's greatest contribution to cellular radio was quality control. American industry and those who emulated its practices, in the final analysis, favored quantity over quality. The Japanese insisted on both.

In the mid to late 1970s, Japan's goal to produce electronic goods without defects forced manufacturers around the globe to ask themselves if they could compete. Self-examination was a wrenching but necessary process that for many companies would go on for years. Before completing the turn to better quality shipping dates would be missed, production quotas lost, profits reduced. It was all very necessary; assembly line production of mobiles by the millions could not have happened with the one at a time techniques of producing conventional mobile telephones.

In January, 1978 Andy Affrunti Sr. warned Motorola management that the biggest threat to their company was quality competition from the Japanese. He asked his bosses, "Do we have a quality organizational structure that could meet this Japanese competition and achieve zero defects?" As if to highlight the issue, the next week Affruniti found factory workers beating on warped metal housings with a board and mallet to make them true, and, to make a deadline, radios deliberately shipped with a missing part. Motorola immediately began institutional changes toward quality control. "(Affrunti, Andy. *A Personal Journey: 50 Years at Motorola*. (132–133). Motorola University Press, Rolling Meadows, Illinois, 1994)"

3.5.5. First generation analog cellular systems

In May, 1978 The Bahrain Telephone Company (Batelco) began operating the first commercial cellular telephone system. The simple two cell scheme had 250 subscribers, operated on 20 channels in the 400 Mhz band, and used all Matsushita (Panasonic) equipment. "(Gibson, Stephen W., *Cellular Mobile Radiotelephones*. Englewood Cliff, Prentice Hall, 141, 1987)". Cable and Wireless, now Global Crossing, installed the equipment for Batelco.

In July, 1978 Advanced Mobile Phone Service or AMPS began operating near two American cities. The first area was around AT&T Labs in Newark, New Jersey, and the second place was near Chicago, Illinois. Ten cells covering 21,000 square miles made up the Chicago system. Oki Electric provided the mobile terminals. This first equipment test started with 90 Bell System employees acting as customers. After six months, on December 20th, 1978, a market trial began with paying subscribers who leased the car mounted telephones. This was called the service test. The system used the newly allocated 800 MHz band. "(Blecher, F. Advanced Mobile Phone Service. *IEEE*

Transactions on Vehicle Communications, Vol. VT-29, No. 2, May, 1980)".Although the Bell System bought an additional 1,000 mobile phones from Oki for the lease phase, it placed orders from Motorola and E.F. Johnson for the remainder of the 2,100 radios. Fewer busy signals for mobile phones. "(*Business Week*, Industrial Edition, Number 2546: 60B, August 7, 1978)". This early network, using large scale integrated circuits throughout, a dedicated computer and switching system, custom made mobile telephones and antennas, proved a large cellular system could work.

In 1979 INMARSAT was born, an international group fostering and coordinating satellite telephony. Originally developed for ships at sea, INMARSAT's charter later extended to telephone calls made on land and from aircraft. MARISAT or Marine Satellite was the first mobile communications satellite service, beginning in 1976. Both satellite groups sought to make more dependable radio-telephone traffic which had previously gone over High Frequency or shortwave radio links. Shipboard satellite customers first talked with an international operator who then manually patched their call into the landline telephone system. Echo and reverberation problems were common in these days, an operator might need 6 to 9 call setups for 1 call. "(http://www.privateline.com/Snyder/TSPS_history_recollections.htm)" Let's return now to terrestrial radio-telephony.

Worldwide commercial cellular deployment blossomed in the late 1970s and then continued into the early 1980s. An 88 cell system in the challenging cityscape of Tokyo began in December, 1979, using Matsushita and NEC equipment. The first North commercial American system began on August, 1981 in Mexico City. It was a one cell system. The world's first Nordic Mobile Telephone network started on September 1, 1981 in Saudi Arabia. It used 20 cells and operated at 450 Mhz. The next month, starting on October 1, 1981, and opening in stages until March, 1982, Sweden, Norway, Denmark, and Finland, began operating a Scandinavian wide NMT network. It also operated at 450 Mhz, and used three Ericsson switches. The first multi-national cellular system, the NMT450 had 600 cells and offered roaming, an important first. As the Scandinavians operated the most advanced cellular system in the world, rollout of cellular radio in America was stopped again by government bureaucracy.

New regulations and AT&T's impending breakup caused American cellular to be delayed once again. The Federal Communication Commission in 1981 required the Bell System regional operating companies, such as Bell Atlantic, to have competition in every cellular market. The F.C.C. thought this would provide better service and keep rates low. In reality prices between the wireline and non-wireline carriers were always about the same, and service no better between the two. Rules governing this state imposed duopoly were many: Applications to operate in each city were required and a lengthy licensing award process needed to be followed.

On March 25, 1980, Richard Anderson, general manager for Hewlet Packard's Data Division, shocked American chip producers by saying that his company would henceforth buy most of its chips from Japan. After inspecting 300,000 standard memory chips, what we now call RAM, HP discovered the American chips had a failure rate six times greater than the worst Japanese manufacturer. American firms were not alone in needing to retool. Ericsson admits it took years for them to compete in producing mobile phones. Let's skip ahead five years to make this point.

In 1987 Panasonic took over an Ericsson plant in Kumla, Sweden, 120 miles east of Stockholm to produce a handset for the Nordic Mobile Telephone network. Meurling and Jeans explain: "Panasonic brought in altogether new standards of quality. They sent their inspection engineers over, who took out their little magnifying glasses and studied, say displays. And when they saw some dust, they asked that the unit should be dismantled and that dust-free elements should be used instead. Einar Dahlin, one of the original small development team in Lund, had to reach a specific agreement on how many specks of dust were permitted." "(Meurling, John and Richard Jeans. *The Ugly Duckling: Mobile phones from Ericsson*. Stockholm, Ericsson Radio Systems AB, 46, 1997)". Let's go back now to the early 1980s, when telecom changed forever.

On August 24, 1982, after seven years of wrangling with the American federal Justice Department, American Telephone and Telegraph was split apart, succumbing to government pressure from without and a carefully thought up plan from within. The Bell System, serving 80% of the American population, and custodian of Bell Laboratories, was broken apart. Complete divestiture took place on January, 1, 1984. After the breakup new companies, products, and services appeared immediately in all fields of American telecom, as a fresh, competitive spirit swept the country. The AT&T divestiture caused nations around the world to reconsider their state owned and operated telephone companies, with a view toward fostering competition in their own countries.

Europe saw cellular service introduced in 1981, when the Nordic Mobile Telephone System or NMT450 began operating in Denmark, Sweden, Finland, and Norway in the 450 MHz range. It was the first multinational cellular system. In 1985 Great Britain started using the Total Access Communications System or TACS at 900

MHz. Later, the West German C-Netz, the French Radiocom 2000, and the Italian RTMI/RTMS helped make up Europe's nine incompatible analog radio telephone systems. All services used analog for sending voice, signaling was done with a variety of tones and data bursts. Handoffs were based on measuring signal strength except C-Netz which measured the round trip delay. Early C-Netz phones, most made by Nokia, also used magnetic stripe cards to access a customer's information, a predecessor to the SIM cards of GSM/PCS phones. All of these mobiles were car phones.

On October 12, 1983 the regional Bell operating company Ameritech began the first United States commercial cellular service in Chicago, Illinois. This was AMPS, or Advanced Mobile Phone Service. United States cellular developed from this AT&T model, along with Motorola's system known as Dyna-TAC, first introduced commercially in Baltimore and Washington D.C.. AMPS or Dyna-Tac, often both, were soon installed and operating within three years in each of the ninety largest markets in America. "(Gibson, Stephen W., *Cellular Mobile Radiotelephones.* Englewood Cliff, Prentice Hall, 19–22, 1987)".

Cellular's popularity in the United States was unexpectedly strong. Estimates say there were 340,213 customers in 1985, 681,825 by 1986, and 1,300,855 by 1987. "(http://ctia.org/research_statistics/index.cfm/AID/10030)" Conventional mobile telephones by comparison served less than 100,000 subscribers before cellular began. This 100% growth each year attracted overseas equipment makers. Ericsson supplied switches and eventually base station equipment, while companies like Nokia sold handsets. AMPS systems were sold throughout the world. One country was especially interested in the technology, not just to use but also to develop as an industry.

In March, 1984 the government KMT or Korea Mobile Telecommunications Company was formed. On May 1, 1984 KMT began AMPs service in South Korea. They had some experience with mobile telephony; a Motorola IMTS system had been operating in Korea since the late 1960s. But cellular was new and something the Koreans thought they could participate in. They started with manufacturing. In 1984 Nokia and Tandy formed Tandy Mobira Corporation in Korea. The Finns wanted to sell AMPS phones in America. The Tandy corporation had electronics stores across the United States which could distribute those phones. By 1992 824,000 handsets had been sold under the Tandy label and 885,000 under the Nokia brand. "(Haikio, M. *Nokia: The Inside Story*. Prentice Hall, London, 160, 2001)". South Korea thus entered the mobile telephone business, taking the first step toward becoming a leader in cellular radio.

Analog cellular was also booming in Europe by the mid-1980s. The main problem was that systems worked well by themselves, but they wouldn't work together. A German customer, for example, couldn't operate their mobile in Italy. Planning began during the early 1980s to create a single European wide digital mobile service with advanced features and easy roaming. While North American groups concentrated on building out their robust but increasingly fraud plagued and featureless analog network, Europe planned for a digital future.

Why didn't America build a fully digital system earlier? The United States suffered no variety of incompatible technologies as in Europe. Only AMPS or an AMPS compatible system existed in America. Roaming agreements between operators and a common networking standard, IS-41, allowed customers to make calls from whatever city or state they were in. Little desire existed to design an all digital system when the present one was popular and working well. To keep the current phones working (and producing money for their carriers) any new system would have to accommodate them. Chances lessened for an all digital future with each analog phone sold.

3.5.6. A New Cellular Band and Systems

In the mid-1990s more wireless channels and carriers were allowed in America. The F.C.C. auctioned off new blocks of frequencies at 1900 MHz starting on December 5, 1994 and ending on January 14, 1997. A new, lucrative market opened for GSM and CDMA. Several carriers were licensed in each metropolitan area. CDMA, TDMA, and GSM proponents spread out across the United States, urging license holders to use their systems.

GSM vendors quickly tailored a system for the American 1900 MHz band. In November, 1995 American Personal Communications, eventually an affiliate of Sprint Spectrum, launched the first commercial GSM service in the US. This network operated in the Washington-Baltimore area. After just six months there were 15 more GSM 1900 networks in the United States. In perhaps a hint of things to come, Sprint PCS in 2000 replaced APC's GSM network with a CDMA system. IS-136 started shortly after these new spectrum blocks were opened. This was the successor or evolution of IS-54. It again used TDMA and offered a number of new services. AT&T Wireless was its chief proponent. It is still used in America and other countries but its use is declining. In the places it remains it is slowly being cleared out for GSM systems.

On July 1, 1995 the NTT Personal Communications Network Group and DDI Pocket Telephone Group introduced the Personal Handyphone System or PHS to Japan. Also operating at 1900 MHz, sometimes referred to as 1.9GHz, PHS is an extremely clever system, allowing the same phone used at home to also roam across a city. A cordless phone acting like a mobile. In September, 1995, Hong Kong's Hutchison Telecom turned on the world's first commercial CDMA/IS-95 system. A year later in San Diego, California, the operator NextWave PCS launched the first American IS-95 system on August 16th. The next 10 years might well be called the Triumph of CDMA.

3.5.7. The Rise of GSM

Europeans saw things differently. No existing telephone system could accommodate their different cellular systems. They decided instead to create a new technology in a new radio band. Cellular radio but fully digital, the new service would incorporate the best thinking of the time. No backward compatibility with existing systems. They patterned their new wireless standard after landline requirements for ISDN, hoping to make a wireless counterpart to it. The new service was called GSM.

GSM first stood for Groupe Speciale Mobile, after the study group that created the standard. It's now known as Global System for Mobile Communications, although the "C" isn't included in the abbreviation. In 1982 twenty-six European national phone companies began developing GSM. This Conference of European Postal and Telecommunications Administrations or CEPT, planned a uniform, European wide cellular system around 900 MHz. A rare triumph of European unity, GSM achievements became "one of the most convincing demonstrations of what cooperation throughout European industry can achieve on the global market." Planning began in earnest and continued for several years.

By the late 1980s the American wireless industry began searching for a higher capacity system. In September, 1988 the Cellular Telecommunication Industry Association published a set of User Performance Requirements, urging a new digital technology be built with 10 times the capacity of existing analog schemes. Two choices quickly emerged, one digital, one analog, but neither came close to the capacity goal. In December 1988 Japan's Ministry of Posts and Telecommunications ended NTT's monopoly on mobile phone service. Although technically adept, NTT was also monolithic and bureaucratic; it developed a good cellular system but charged too much to use it. Growth was slow. They also required customers to lease phones, not to buy them. After 1989 competition and new networks increased cellular sales. But it was not until 1994, when telecom was completely deregulated, did cellular prosper. In the late 1980s Japan was also studying the next generation of cellular. Their first generation systems were modeled after AMPS but it was unclear if their second systems would be analog or digital.

In 1989 The European Telecommunication Standards Institute or ETSI took responsibility for further developing GSM. In 1990 the first recommendations were published. The specifications were published in 1991. The United States cellular industry knew time based systems would work well but wanted a digital system of their own, a dual mode technology that could keep existing analog phones working. In January, 1989 the Telecommunication Industry Association selected a time based or TDMA approach to North American digital cellular radio. The Cellular Telecommunication Industry Association also endorsed the TIA's pick, although it did not contain the 10 time capacity gain it asked for the year before. The CTIA hoped that over time capacity gains would increase. The TIA next wrote a standard for this new digital system, soon to be called IS-54. It was unofficially called D-AMPS or Digital AMPS. After publishing the standard manufacturers would know how to build for the system. Few suspected the technology to get the most gain was already being developed.

On November 3, 1989 in San Diego, California, Qualcomm successfully demonstrated a prototype CDMA cellular system to a group of 250 network operators and suppliers from around the world. Three months later they repeated this demonstration in New York City. Code Division Multiple Access had come to mobile telephony. It came out too late to be considered as the digital choice for new North American cellular networks. Over the next few years, however, it would come into the American market and show the wireless industry that CDMA, in one form or another, would eventually replace time division systems.

3.5.8. The Mid 1990's: Fundamental Change

On August 15, 1996, Nokia introduced the Communicator, a GSM mobile phone and handheld computer. It had a QWERTY keyboard and built in word processing and calendar programs. Besides sending and receiving faxes, the 9000 could check e-mail and access the internet in a limited way. But its effectiveness was limited since cellular networks were optimized for voice, not data.

To be a telephone an instrument must convey speech. By the mid-1990s, however, delivering quality speech was assured with every cellular radio scheme. Voice, with adjustments, was as good as it needed to be. With the speech requirement settled, data became the first interest of system designers. Voice remained the essential service for the large majority of mobile phones, but developing better and faster data networks over cellular radio became the priority. To best conduct voice cellular had always used circuit switching, just as the landline telephone network did. But data isn't efficiently conducted by circuit switching. An example is the GSM service called High Speed Circuit Switched Data or HSCSD. It needs four GSM channels to achieve, in theory, speeds between 28.8kbits and 43.2kbits a second. Actual speeds are lower. A fundamental change was needed, therefore, from circuit switching to packet switching. And the kind of packet switching needed was obvious from the start.

The internet became commercial in the mid-1990s with the advent of graphical browsers like Mosaic and then Netscape. Internet user growth rivaled cellular telephony between 1995 and 2000. The internet runs on the aptly titled Internet Protocol or IP, a packet switching technique cellular data network operators quickly chose to adopt. Today's General Packet Radio Service (GPRS), its improvement, EDGE, and short range wireless networks like Bluetooth all employ IP. All 3G systems use IP as all of us head toward "an all IP world."

By the mid 1990s the mobile became as small as practically possible. The keypad and display limited any more reduction in size. Cell phone circuitry started getting built into laptops and PDAs and instruments like the Blackberry, forcing us to rethink what a cellular telephone was. Is an SMS only device a mobile telephone or a two way pager? Handsets evolve to provide a variety of services, mostly non-voice, such as ring tones, image capturing, text messaging, gaming, and so on. While cell phone services seem limited only by the imagination, the systems they run over become fewer.

GSM and CDMA systems would continue to be installed around the world but by 2005 no new cellular radio scheme would emerge. Flarion's technology was tested extensively by the American carrier Nextel but the system was not adopted. The lone exception was China. To keep its market closed they choose a hybrid technology called TD-SCDMA, a cross between TDMA and CDMA. The history of cellular telephones from the mid-1990s, therefore, is mostly a chronicle of improvements to existing systems. The UMTS Forum was established in December, 1996. at a meeting in Zurich, Switzerland. It proposed a wideband CDMA standard known as UMTS or Universal Mobile Telecommunications System. A 5 MHz channel spacing is used with data rates of up to 2 Mbps. The Forum provided more than just an European response to Qualcomm's narrowband CDMA technology. While acknowledging that future capacity gains could only be achieved by using CDMA, the Forum provided a step by step migration plan to WDCMA for GSM, PDC, TDMA, and IS-95 operators. This evolution path was carefully planned to use most of GSM's core components.

On December 1st, 2001 Telenor Mobil trialed a UMTS system in Oslo. Commercial UMTS systems followed, with the technology now installed in different parts of the world. Rollout of UMTS tends to be slow and expensive, since the change from time division to code division requires more than software updates. Hardware changes are needed, especially at the cell site. One can't, for example, reuse existing antennas without severe performance problems. The radio spectrum is an inherently fragile, vexing medium, of course, and operators are struggling to bring data rates close to those promised. While the UMTS Forum assures us that 384 kbps is a minimum for UMTS, and only then in "high mobility situations", 300 kbps may be the working, upper limit for this technology.

In November, 1998 the greatest mobile telephone disaster began when the Iridium project was launched. Using 66 satellites, and costing almost 5 billion US dollars, the service went bankrupt after only 16 months. The lead design firm and largest investor was Motorola. Hoping to make satellite phone service a mass market item, planning for the system began before cellular became widespread and reduced demand. Iridium gathered only 10,000 customers before it folded. Due to the high cost of handsets and services, and an inability to work indoors, satellite telephone service remains a niche market to this day.

In October 2000 Sharp produced the first integrated camera phone. It supplied them to the Japanese Operator J-Phone. The J-SH04 mobile phone let users take, send, and receive images by email."(http://sharp-world.com/corporate/info/his/h_company/2000)" The Nokia 9110 Communicator in 1998 was the first mobile to enable image transfers but the device relied on an a camera supplied by each user. At the end of 2004 it was estimated that 75% of the mobiles sold in Japan were camera phones.

The CDG or CDMA Development Group promotes narrowband CDMA. They are the equivalent to the wideband CDMA oriented UMTS Forum. During the late

1990s and early 2000s, the CDG outlined coming improvements to IS-95. They gave these system changes, unfortunately, names which look and seem alike. They even changed the name of IS-95. CDMA One is now the marketing term for IS-95A, the original CDMA scheme. CDMA One includes IS-95B which is little implemented. We can look at these evolutions by the dates they debuted.

CDMA2000 1X was first launched by SK Telecom in Korea in October, 2000. Building on an existing IS-95 network, CDMA2000 1X, doubles the voice capacity of cdmaOne networks. It delivers packet data speeds of, supposedly, 307 kbps in mobile environments. But it's doubtful this rate is maintained while the mobile is at speed or while conducting handoffs from one cell to another.

In May, 2002 SK Telecom again made another first, introducing CDMA2000 1xEV-DO service in May, 2002.(persal correspondence, Hanjoo Kim of the IITA (Korean Institute of Information Technology Assessment) July 13, 2004 This is a high speed data only service and an odd one at that. It's actually a CDMA/TDMA hybrid, and uses various modulation techniques, depending on the data rate.

On August 27, 2003, Nokia announced it completed a call using cdma2000 1xEV-DV, and that they achieved a peak data rate of 3.09 Mbps. In a San Diego, California laboratory. CDMA2000 1xEV-DV combines data and voice, something UMTS does already. The CDG claims speeds up to 3.09 Mbps. Perhaps. Both DO and DV are backward compatible with CDMA2000 1X and cdmaOne.

In April 2004 Cingular became the first carrier in North America to offer UMTS. They now cover six markets in the United States. Acceptance is slow due to limited coverage, bulky handsets, and the high cost of service. UMTS and CDMA upgrades are very expensive for the carriers. Operators around the world are now spending billions for networks that won't pay for themselves for quite sometime. The potential demand for service is certainly there, as cell phone subscriber levels attest.

In January, 2005 industry analysts Deloitte & Touche predicted mobile phone users will top 2 billion by the end of 2005. They say mobiles currently number over 1.5 billion. Many countries have over 100% penetration, as people have second phones or multiple SIM cards, one for business, another for personal use. As throughout its history, regulatory, technical, and competitive problems remain for mobile telephony. But the desire for people to communicate, and for business to cater to that need, insures an imaginative and successful future for the mobile.

3.5.9. Global System for Mobile Communication (GSM)

GSM provides recommendations, not requirements. The GSM specifications define the functions and interface requirements in detail but do not address the hardware. The reason for this is to limit the designers as little as possible but stil to make it possible for the operators to buy equipment from different suppliers.

The GSM network is divided into three major systems: the switching system (SS), the base station system (BSS), and the operation and support system (OSS). The basic GSM network elements are shown in Figure 3.1.

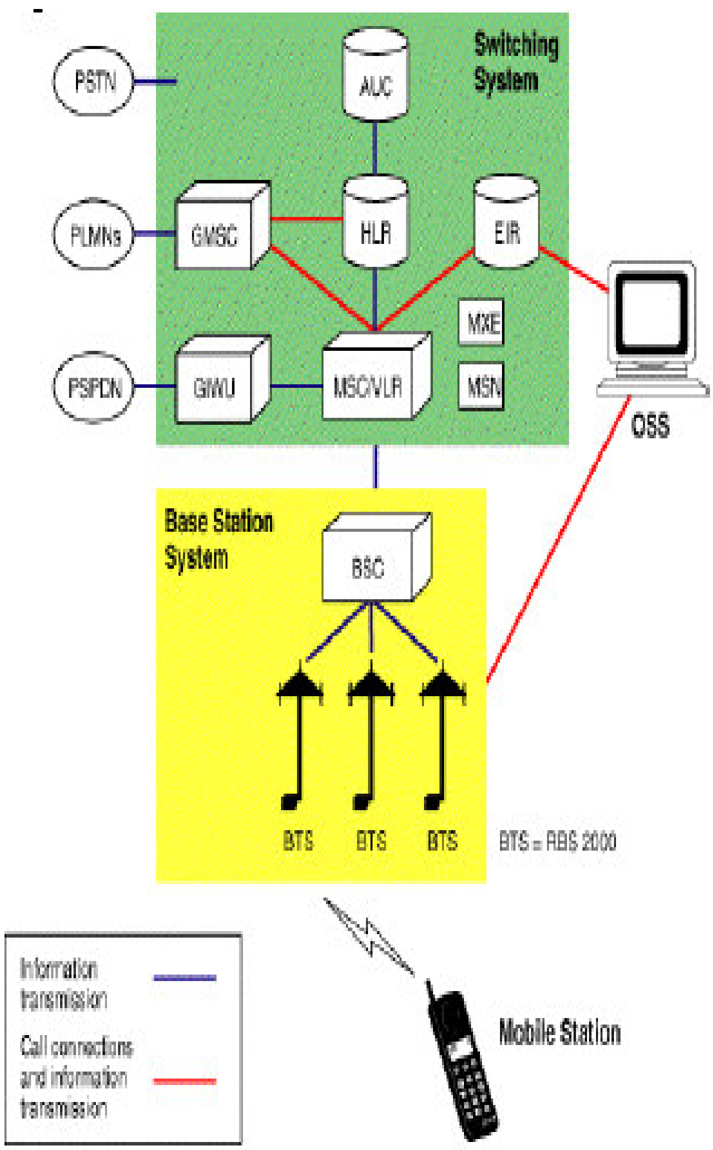

Figure 3.1 The basic GSM network elements

CHAPTER 4

THE *FOCUS* MOBILE PROJECTION PHONE (*Focus* MPP)

4.1. The Research

In undertaking this research project, the author has placed particular importance on the communication with potential users of the design. The data gathered through interviews turned out to be a major input in the research work. The aim of involving the users in research and development processes is to create meaningful and useful products. User-centric research focuses on identification and design of relevant concepts, prototype development, and usability and feasibility tests. Researchers and developers increasingly recognise the need to cross the barriers of disciplines to create products that match the future demands of users. A more multidisciplinary approach to the development process opens up to new possibilities, perspectives and methods.

The possibilities and constraints of future mobile technologies and applications are dependent on user evaluations in the context of their everyday lives. Such research considers relevance to social and cultural practices and provides a framework for cross European studies of variations in user's needs and expectations of mobile technologies and applications. Key issue in the user experience is that the research should be done continuously: Users habits, trends, competencies and levels of acceptance chances over time. Then the research and testing activities should be done following a dynamic process – not in need basis.

4.2. Results of the Interviews

The research undertaken for the completion of this study was focused on the market segment represented by the businessmen. The reasons for such an approach is that the respective segment is the most likely to express specific needs in accordance with the intended purpose of the design project proposed here. The rough results of the interview activity are displayed in the table (Table 4.1) below:

Table 4.1 Questionnaire Results

Questions	Number of respondents	Most preferred answers	Percentage of businessmen
Which is the basic need to be met by the design?	123	PC functions (windows software, ofis programs, multimedia, video camera, high resolution display Bluetooth, infrared …etc)	100
		Bigger display	90
		High band	80
Which would be a secondary need?	123	Lightness	83
		Low price	62
		High talking time	100
		Batteries Life	100
What is the main problem with the current designs of mobile phones?	123	Small memory	94
		Short talking time	100
		Small display	73
What would you like a mobile phone design to include in the near future?	123	Online video communication	97
		TV facility	81

The respondents were mostly interested in acquiring a mobile phone with full PC capabilities. The demand is obviously oriented toward a device that could combine cellular phone with laptop capabilities. Additionally, the respondents reacted positively when suggested that their mobile phone could also be used as a mobile projector once such an element is included.

The price of the new design does not seem to be a problem for businessmen. Their expectations tend to focus on the result of the technological improvements, particularly in what concerns the possibility of being as much independent as possible from classical PC/laptop. The perspective of giving projection capabilities included in cellular phones would open the door for other developments. Almost all the respondents considered TV facilities and online video communication as two of the basic needs for business in the future.

Consequently, they considered the possibility of displaying the cellular phone's information in large format on any type of surface by means of a projector as a step facilitating considerably the respective developments. Together with this, an increase in the memory capacity toward the level of a few gigabytes would also be of great use. Therefore, the design project proposed here had to meet at least partially the needs indicated by the small number of respondents to this embryonic opinion poll.

4.3. The Actual Design Proposal

First of all, we must consider what engineering is, and what type of work an engineer does. Despite of the possibility of many definitions, our definition of an engineer is this: 'A person who, based on natural and mathematical laws, uses resources in the service of human beings in the most economical way'. In other words, an engineer is a person who designs, builds, develops and maintains devices, using science and mathematics. It is generally desired for the engineer to be a creative person. In order to be a good engineer, one must know the laws of nature and understand them, and also have a good knowledge of mathematics.

Historically, Building Engineering and Mechanical Engineering have started and developed in connection with the needs in the building and machinery sectors. With the discovery of electricity, electrical engineers worked on electrical networks and distribution of city electricity. In time, electrical engineering grew into new eras of specialization and is still growing everyday. The fact that contemporary information technology together with electronic systems and devices found new areas of application, resulted in the expansion of Electric-Electronic Engineering. For instance, in the recent years, new eras like 'Micro electro mechanic', 'Compact Optics' have appeared under electric-electronical engineering. As a result of fast technological developments and their socio-economical effects, some electronical engineering eras like 'telecommunications' have eventually become more popular. The qualifications of electric-electronical engineers to be successful in their careers and have good positions in industry change in parallel with this.

Today we live in an age of information in which there is a constant and fast global technological change. This operation which started with having computers enter our lives goes on with internet and its development. The same thing goes true for mobile phones. The mobile phone which has become an indispensable need in our daily life is no longer just a device of communication but has developed into a multi-media device. Bluetooth, infrared, video camera, web e-mail have become standard qualifications. Now-a-days, not only people are in communication with each other, but also devices are in communication among themselves.

In view of this information the questionnaires indicate that mobile phone users choose the product with top qualifications and newest technology. Businessmen were chosen as the target group in the study with the questionnaire.

Top executives spend most of their daily life in trips, meetings and seminars. The presentations of these seminars or meetings are done with PPT. Why can't this data when put together become a projection device? Starting from this idea, a research has been done on projection machines concerning the pocket projection device produced by a Finnish firm called Upstream (Figure 4.2). A presupposition is made for these two products to be put together in the same form and function (as a single compact device). At the same time, the size of the telephone device is not distorted for the purpose of producing a big screen, nevertheless a big screen solution has been reached. Moreover, the Upstream project gives an idea about the advancement of the technology in this domain. It is therefore the strong belief of this author that the Upstream technology can be adapted in the near future as to make possible the development of a marketable model such as the *Focus* MPP proposed here. That is very much possible since the projection technologhy proposed by the Upstream is based on the photon-vacuum principle which goes beyond the traditional solutions on the market.

Figure 4.1 The Pocket Projection device produced by Upstream Company
(Source: WEB_2, 2006)

Photon Vacuum is a proprietary light collection and distribution technology for led-based projection. It basically overpasses the problems that have diminished the quality of projection displays to enable mobile applications. Thus, the Photon Vacuum technology practically promises to meet the requirements needed for designing highly mobile projection devices, such as a mobile phone in our case.

The current Photon Vacuum LCoS lighting engine is on prototype status. It has three Photon Vacuum collection components, one cross-dichroic prism (x-cube) and one polarization beam splitter.

The dimensions of the engine are approximately 35x45x16mm and it sports three Luxeon III leds, one for red, green and blue. The package itself is robust and is easy to protect from external shocks like dropping to the floor. The robustness factor is important for the mobile applications of the technology (Figures 4.2).

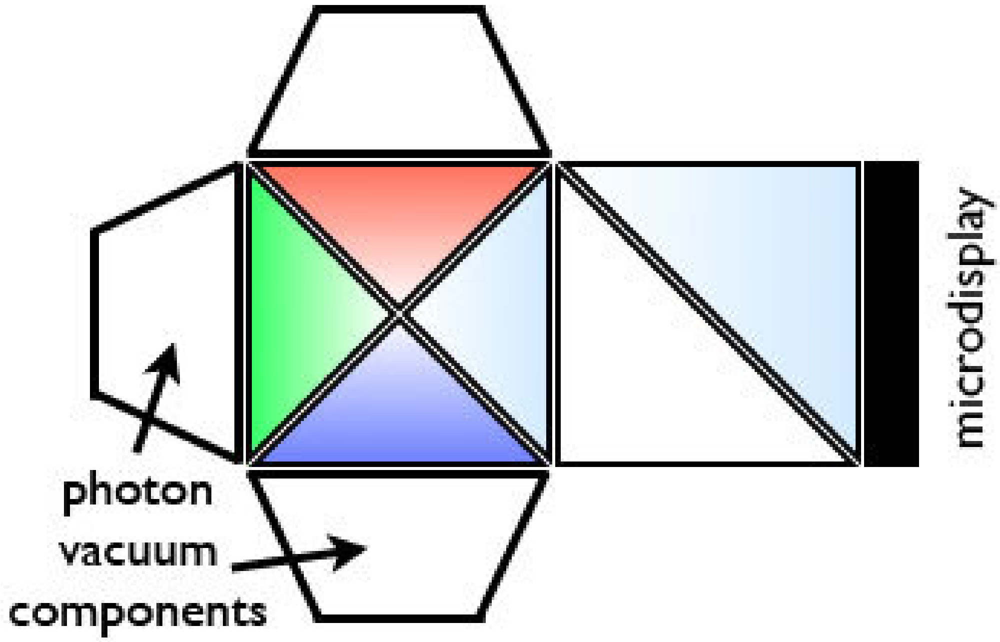

Figure 4.2 The Photon Vacuum technology

(Source: (WEB_2, 2006)

MPP, is crossing of the ever developing visual and mobile communications technology. This crossing gives an idea about the functions and operation of the new generation of mobile phones which will appear in the near future. How the industrial designer should behave in view of the developing technology is considered to be one of the problems studied in many design schools. This project points at the thought of the importance of his own reflexes against a product whose functions are not defined totally.

By paying great attention to the suggestions of the potential users interviewed for completing this project, the author has reached the conclusion that a mixture between the Upstream technology and appropriate design solutions could lead to meeting potential market expectations. The *Focus* MPP comes to fill therefore a gap. It provides the user with an up-to-date mobile phone which, at the same time, incorporates an element to facilitate the projection of any information that appears on the classical screen. It projects that information on any type of surface in any position (horizontal or vertical). It can be therefore capable of displaying photographic images, text written in computer format, or applications of any kind (e.g. Powerpoint, Excell, etc.).

Multi-functional system designs, generally are believed not to live as long as simple designs. However, inspite of this rule, designers of today and tomorrow will be expected to develop visual facets to extensively complicated designs, far from being simple. It is a fact that electronical design engineering has become very prominent in the world. MPP is a device which wants to live long. It wants to say this with its multi-functions but simple structure. Its design criteria are ultimately clear:

1- Easy use is possible with a correct ergonomic structure

2- Easy use is possible with a correct psychological perception

"Easy use, easy perception"

MPP is based on these principles and its key-buttons are big consequently. Therefore the geometry is clear and simple. MPP, compared to other mobile communication devices used in this time-frame, has many more functions although it is a simpler device of high-perception level.

The professional reaction of an industrial designer against increasing functions getting more intricate has great importance in results in respect to the user. The need for user-friendly devices is observed everyday. User-friendly is naturally obtained by facilitation of usage.

Another visual problem taken into account in MPP is the correlation built between the visual and the target user group. The body is designed to be black because the target user group is planned to be businessmen and our subjects seem to opt for such a solution.

It seems that as electronical designs facilitate human lives; this is done with the aid of industrial designers. Many discoveries in this field wait to wear their costume through a designer before it meets its user. This is a great responsibility.

This responsibility means imagining easier usage as the work gets bigger. It means imagining easier perception.

It is possible to talk about aesthetic presence on the body of an electronic device. This aesthetic presence generally embodies itself with the technological accents the body contains. On the other hand, something looking technological does not mean it has aesthetics. A combination of technology and aesthetics would be the measure for a fine medium. MPP has become a direct visual design target expressing its technology. With the effective details making up its line, the aesthetics in the final product as a whole has become the target.

4.4. Problems Encountered in Design

The main problems encountered in designing the *Focus* MPP model were related to the following:

1. Increased weight;
2. Increased dimensions;
3. Energy supply in projection mode.

It is natural that at this moment these problems appear. The technological development of human kind however gives hope that these problems will be passed over without any delay and within quite a short time frame. The Upstream project is simply just one of the opportunities offered in this sense. The increase in weight is probably the most serious of all negative aspects of the *Focus* MPP at this point. A solution to this problem cannot come but from the inventors of lighter and better microelectronics and optical engineering.

The issue of increased dimensions, although in connection with the weight problem, can receive solutions from the designers, too. For instance, the mobile telephone needs a classical display in any case. At the same time, *Focus* MPP proposes a projection device that hypothetically adds to the size of the mobile phone. However, the author of this thesis suggests that the projection device be actually built inside the structure of the phone’s screen. If the respective screen is conceived as mobile, as it can be seen in (Figure 4.3 – 4.4), *Focus* MPP can function as a projector with the insertion of a miniaturized Upstream-type projection device right in the body of the screen.

Figure 4.3 Focus MPP Projection device

Figure 4.4 Focus MPP Projection device

In what concerns the energy supply problem, this can become serious indeed if one considers the considerably bigger amount of energy necessary for the working of a light-producing device, as it is the case with the projection element. However, it must not be forgotten that this is not only the problem of mobile telephony but of most of technological development nowadays. Until this problem is somehow solved, the only solution seems to be the adaptation of a lighter power connector (charger) and the usage of the projector as plugged in most of times.

CHAPTER 5

CONCLUSIONS

The project proposed here does not attempt at revolutionizing mobile phone design over night. It however attempts at pushing a particular limit: it makes sufficiently clear that, from the point of view of the designer, a mobile phone and a projector can be united to form a very profitable total on the market, with a success that most opinions collected up to now suggest.

A very important part of this study has been that in which the author has been closely in contact with potential users. The information gathered helped at the development of a particular vision of how the project should look like. As a result, other secondary aspects of the design have been put aside and the most important place was taken by the actual challenge posed by combining the two fundamental elements: phone and projector.

The industrial product design deals with a lot of criteria, like physiological, environmental, communicational and technological criteria. It therefore borrows concepts and methods from other disciplines, and the industrial designer behaves like the team leader between other professions such as engineers, sociologists, marketers etc. in order to determine the qualities of objects produced by industry.

The industrial product design field, because of dealing with a lot of criteria, is considered by some authors as an interdisciplinary activity in research context. However, as industrial product design field can be stretched to other fields easily, and other fields can be welcomed in the field easily, interdisciplinary approach causes conflicts in developing industrial product design knowledge. Referring to Cross, industrial product design should be taken as a field of design discipline that accumulates and develops its own design knowledge. With this approach, industrial product design might create and strengthen its place among other trespassing fields and disciplines.

Designing is a multidisciplinary activity with the participation of disciplines such as design, engineering, sciences, and humanities acting toward the same purpose. Industrial product design borrows concepts and criteria from other disciplines throughout this activity. Engineering, as the subject of this study, is one of the most important features of industrial product design in the means of bringing design to an end product that is sold in the market. Industrial product design intersects with engineering criteria, given below, and deals with engineering professions related to these criteria throughout the design activity.

By revealing these criteria and comparing industrial product design with related engineering professions, human-centered aspect and synthesis approach of industrial product design, and on the contrast, material-centered aspect and analysis-synthesis approach of engineering design, which is the chosen engineering field as being close to industrial product design field, are indicated.

In this thesis,

1. Intuitive concepts and methods used in industrial product design field have been searched for in order to try to contribute to the developing of industrial product design knowledge in design discipline;

2. The advantages of interacting with potential users of the proposed design are revealed.

3. Approaches of scientists, engineers and designers to the design problems, as another advantage of observing the artifacts in order to design, are given.

5. A diversity of advantages/disadvantages is explored and the related consequences and solutions examined.

The final result of the research, the design of *Focus* MPP (Figure 5.1., 5.2., 5.3., 5.4.,) is meant to meet at least some of the expectations of people that consulted it. Future research undertaken by this author will hopefully reveal new paths toward accomplishing it and possibilities of overpassing the problems encountered in the process.

Figure 5.1. *Focus* MPP

Figure 5.2. *Focus* MPP

Figure 5.3. *Focus* MPP

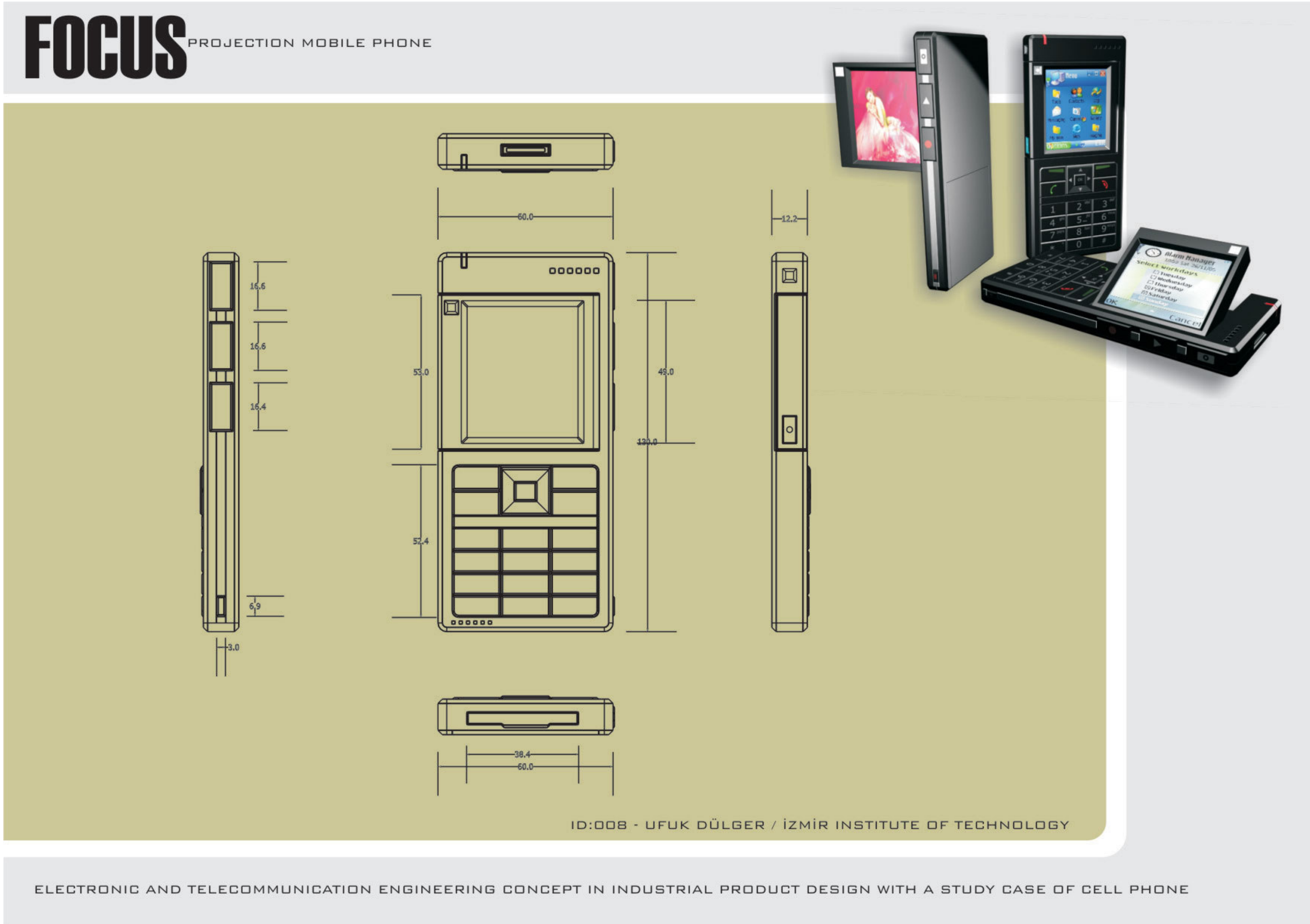

Figure 5.4. *Focus* MPP

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WEB_5 http://www.fcc.gov/Bureaus/OGC/Reports/cellr.txt

WEB_6 http://www.privateline.com/Snyder/TSPS_history_recollections.htm

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