# RESEARCH, DEVELOPMENT AND MANUFACTURING POTENTIAL OF THE GENERAL AVIATION AIRCRAFT INDUSTRY IN THE CZECH REPUBLIC


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# ABSTRACT

The Czech aircraft industry was influenced by several negative factors at the end of the eighties. The collapse of the Eastern European market, the world recession in air transport and a consequent reduction in output of aircraft were signs of the deep crisis. Conversely, the removal of trade barriers between eastern and western Europe [Ref. 20] offered new opportunities to this industry. This dissertation examines the potential of the Czech aircraft industry to respond to this new challenge.

The historical development of the Czech aircraft industry is presented and its evolution explored. The present day structure of the industry is discussed in detail and this discussion provides the basis for a subsequent evaluation of the marketing potential there.

The ability of the industry to respond to its marketing opportunities is then examined in terms of a development and production cost analysis. This analysis is contrasted with the current economics of aircraft production in the West.

Configuration studies of a four-seater light aircraft formed a logical focus for market research and development cost studies. In particular, the configuration and design specifications of an aircraft designated TP41 are presented as an example of the type of aircraft currently targeted by the Czech aircraft industry.

Through this research know-how data have been collected in the University of Glasgow Eastern European database. Unique knowledge of the development and manufacturing potential of the general aviation aircraft industry in the Czech Republic, together with its research capabilities, gives the Department of Aerospace Engineering unlimited opportunities to establish novel consultancy and research activities using the know-how database presented in this dissertation.

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# CHAPTER ONE

# A BRIEF OUTLINE OF THE RESEARCH

## 1.1 Introduction

The Aeronautical industry of the Czech Republic started its development shortly after the end of the First World War, when the new independent Czechoslovakia was founded. It gradually became one of the leading industries of the country and sport aircraft in particular were well known all around the world before the Second World War.

The technical orientation of the aeronautical industry between the First and Second World Wars was similar to the state political orientation. It was in very close contact with the democratic states of Western Europe. During the Second World War although the industry was under the control of the Germans, some Czech aircraft designs were prepared in secret looking forward to the post war period.

Not until shortly after the Second World War, was traditional co-operation with democratic Europe resumed. Since post war Czechoslovakia became a part of the Eastern Block countries, the country's aeronautical industry was forced to start close co-operation with the Soviet Block countries, particularly with the then Soviet Union. This included the licensed production of Soviet aircraft. Gradually the industry started to produce aircraft of their own design. First they were sailplanes followed by sport powered aircraft, military jet trainers and regional airliners. The industry was profiting from its many years of international experience, supported by the well developed educational system in aeronautical science. Experience from the Second World War also contributed to the rapid expansion of the industry.

After the "velvet" revolution in 1989, the relationship between the country's political situation and the aeronautical industry was again visible. When the country emerged in 1990 as an independent nation, it turned, as it had traditionally done, to the democratic world for help and advice. The reaction to this request was rather mixed: on one hand the new country's political and economic development in the direction of professional and economic partnership was welcomed, and on the other hand cautious as it had the potential to be a high quality competitor in the future. The internal development of Czechoslovakia led to the dividing of the state to two smaller countries, the Czech Republic and Slovakia. This had, however, only a slightly adverse impact on the aeronautical industry because its major activities were situated in Bohemia and Moravia, the two main regions of the Czech Republic.

The political and economic realities of the first half of the nineties brought the Czech aeronautical industry into a difficult period in its development. In the early nineties the industry faced the task of integrating itself into international manufacturing structures. When the unexpected collapse of the Council for Mutual Economic Assistance (CMEA), also known as the COMECON market, in the early nineties, when about 90% of the whole aircraft production was exported, the industry was not yet ready to compete in the world wide market environment, and there has consequently been a considerable drop in the aircraft industry's production and employment over the last five years. The long ongoing world-wide recession in aviation has also contributed to the current complicated situation. The industry and state clearly had to react. This has been a demanding and difficult process because drastic changes in management structure are required, as are modifications of equipment and practically all existing aircraft types in order to meet the different standards and requirements of new customers. The field principally affected has been that of avionic systems and propulsion units. This process has been accompanied by the changes in manufacturing and airworthiness certification procedures' necessary for successful marketing and sales of new aircraft.

In recent years the country's aircraft production has formed into three main programs consisting of the military training complex, commuter airliners and sport and utility aircraft. Some of these have been manufactured in massive serial productions.

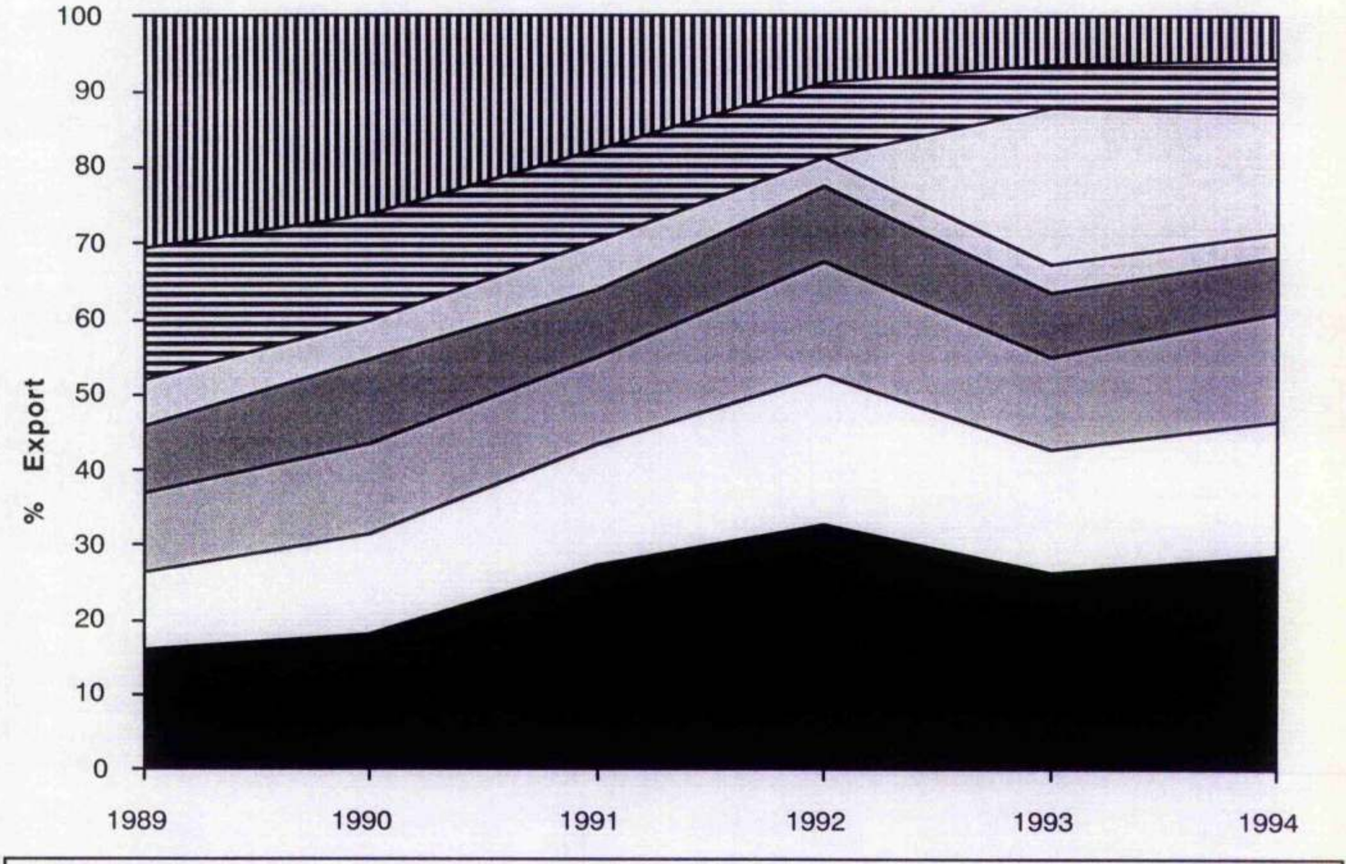



**Fig 1.1:** Change in the territorial structure of exports of the Czech Republic from 1989 to 1994, Ref. [13].

Where:

FRG = Federal Republic of Germany.

EU = European Union.

DME = Developed countries with market economy.

DC = Developing countries.

SR = Slovak Republic.

Other = other countries with non-market economy (except member countries of former CMEA).

CMEA = countries of former CMEA.

USSR countries of former USSR.

During the period covered by this research the Czech aeronautical industry has developed into a very complex community of companies deriving from the restructuring of the former centralised state industry. By detailed technical economic analysis of the current activities and development in the Czech aircraft industry, research establishments and operational environment, it was finally proposed to design a new light sport touring aircraft based on requirements found from market research in both Eastern and Western countries. Design consideration for reducing aircraft life cycle costs and energy consumption represents an important part of this research.

## 1.2 Cost Analysis And Design Case Study

An important part of a new design case study is the development and production cost analysis. If an aircraft designer designs an aircraft that meets it's performance goals, but is expensive or pollutes the environment by using intolerable amounts of energy, then the designer is not really completing the job. According to Ref. [11], the aircraft designer has more influence over items like the cost of an aircraft, the amount of energy it will use and its pollution characteristics than any other single individual.

The conceptual and early preliminary design stage of a new project offer the opportunity to analyse these items. What the designer can not do, the manager can and it is decisions on future project program organisation and management which will effect the man hours required per unit as the work force becomes more accustomed to the work in hand.As described in the previous section, a design case study of two seater aircraft was performed in this dissertation, comprising of the data found from market research in the Czech Republic, Germany and also world wide assessment of the general aviation market. It was disclosed that manufacturers see a steadily ageing trainer/tourer fleet around the world and believe that, provided they can survive the tough times at present, the market simply must come back. Most of the manufacturers are still waiting for a recovery. Low development cost, and low maintenance and operating costs for new aircraft will be vital.

Production of sport-touring aircraft in the Czech Republic designed to FAR 23 airworthiness requirements, is old. The aircraft have 10-15% less performance than similar aircraft flying in the west. Modifications of existing aircraft to improve performance would be only a one sided approach to the complex design problem. The research work presented in this dissertation discloses the technical reasons for starting development on a new sport-touring aircraft, when taking into account the existing political and economic climate in the Czech Republic.

The indications are that the sport touring aircraft industry will be de-regulated soon in the USA. The FAA has already relaxed certification requirements for aircraft under 1220kg for maximum take-off weight and engine with maximum 200HP. This means that a new category for home built sport recreational aircraft will be allowed. The reason for this shift to a recreational category in the USA is to keep the cost of production down and to avoid the large product liability problem which also adds to the cost. It will be difficult for western manufacturers to compete in the light operational sport touring market with a fully certified design. However Czech production man power costs on average is five times lower than in the west, and this fact could allow Czech manufacturers to compete with western designed kit aircraft which can be prototype tested and sold very quickly and cheaply.

## 1.3 Framework Of The Dissertation

The previous section commented on the importance of preliminary design case studies, when determining the first and foremost important question of whether the new aircraft project should start. As a result, in recent years, aircraft development and design research group at the University of Glasgow, has been involved collecting data regarding changes to the technical environment in the Czech Republic, particularly in the field of light aircraft aviation, with the view to assess the suitability for a new two seater aircraft project.

A number of business missions to the country over the last five years have been performed and recorded in the departmental reports file. Some of the results from these missions have been presented at internationally recognised conferences Ref. [20].

The core of the research work which is presented in this dissertation is the design case study and development cost of a new two seater light aircraft in the Czech Republic. The country's short history of civil aviation is discussed in Chapter 2. In addition, the economic and political changes after the "velvet" revolution in 1989 are also described.

The main civil aeronautical manufacturing companies representing the past and current civil aviation in the country are described in Chapter 3. The chapter contains two main sections. The first and larger of these sections has descriptions of the main civil aeronautical companies and their current manufacturing programs. Besides these main companies, a number of small/medium enterprises and organisations were also investigated and are described in the second section.

In Chapter 4, data obtained from the market research overview is analysed in detail and is compared with data available from Germany and world-wide in general. After briefly introducing and assessing the Czech market, the chapter is divided to typical market sectors in which these sectors are analysed are discussed. The last part of the chapter is dedicated to the German market and world-wide overview analysis.

Design of general aviation aircraft has typically been conservative. Improvement in design methodology and manufacturing techniques allows significant reduction in aircraft weight and manufacturing man hours. This fact supported the philosophy that statistical data for two seater aircraft could now be used for conceptional design phase of a new four seater general aviation aircraft. To justify this, the data of the CESNA 172 has been included for comparison purposes.

The results from Chapter 4 are summarised in the first section of Chapter 5, and are further used for aircraft development and production cost analysis which covers the majority of the chapter, where also design consideration for reduced aircraft life cycle cost is discussed. Conceptual design data for four seater general aviation aircraft based on market research and development cost analysis are generated and discussed, in Chapter 6. Technical data obtained from the design analysis is shown in summarised tables and graphs.

The final chapter reviews the topics which have been motivated by this research and suggests areas that are worthy of further examination.

## 1.4 Nomenclature

| | |
|---|---|
| A | AMPER weight of aircraft (58% of empty weight) |
| D | Development support cost |
| E | Total engineering man-hours (cumulative) |
| $E_D$ | Airfame engineering man-hours (development) |
| EH | Airframe engineering man-hours |
| $E_P$ | Airframe engineering man-hours (production) |
| $E_h$ | Airframe engineering man-hour cost |
| F | Flight test operation cost |
| L | Total manufacturing labour man-hours (cumulative) |
| $L_D$ | Manufacturing labour man-hours (development) |
| $L_P$ | Manufacturing labour man-hours (production) |
| M | Manufacturing material and equipment cost |
| MA | Engine and avionics cost |
| $M_D$ | Manufacturing materials & equipment cost (development) |
| MH | Manufacturing man-hours |
| $M_P$ | Manufacturing materials & equipment cost (production) |
| $M_h$ | Manufacturing man-hour cost |
| Q | Number of aircraft produced (cumulative) |
| $Q_D$ | Number of prototype aircraft produced |
| $Q_P$ | Number of production aircraft |
| QC | Quality control man-hours |
| $QC_D$ | Quality control man-hours (development) |
| $QC_P$ | Quality control man-hours (production) |
| R | Aircraft monthly production rate |
| $R_D$ | Aircraft monthly production rate (development) |
| $R_P$ | Aircraft monthly production rate (production) |
| S | Maximum speed level at optimum altitude |

| | |
|---|---|
| T | Total tooling man-hours |
| $T_D$ | Tooling man-hours (development) |
| TH | Tooling man-hours |
| $T_P$ | Tooling man-hours (production) |
| $T_h$ | Tooling man-hour cost |

## 1.5 Acronyms and Abbreviations

| | |
|---|---|
| AMPR | Characteristic aircraft empty weight (58% of aircraft empty weight) |
| APU | Auxiliary Power Unit |
| CAA | Civil Aviation Authority |
| CK | Czech currency (Czech crown) |
| CMEA | Council for Mutual Assistance |
| CTU | Czech Technical University in Prague |
| CZ | Czech Republic |
| DASA | Daimler-Benz Aerospace |
| DC | Development Countries |
| DME | Developed Countries with Market Economy |
| EU | European Union |
| FAR 23 | US Airworthiness Standards |
| FAA | US Federal Aviation Administration |
| FL | Flight level |
| FRG | Federal Republic of Germany |
| GA | General Aviation Aircraft |
| GBP | Great Britain Pound |
| ICAP | International Centre for the Application of Pesticides |

| | |
|---|---|
| IF | Inflation Factor |
| IFR | Instrument Flight Rules |
| JAR23 | Joint Airworthiness Requirements |
| LCC | Life cycle cost |
| MOD | Ministry of Defence |
| VTOL | Vertical take-off and landing |
| SR | Slovak Republic |
| STOL | Short take-off and landing |
| ULV | Ultra low volume |
| VFR | Visual Flight Rules |
| VUT | Technical University of Brno |

# CHAPTER TWO

# A SHORT HISTORY OF CZECH CIVIL AVIATION

## 2.1 Introduction

It is not far from the truth, to say that Czech Aviation has as long a history as any in the world.

At first, flying was primaily a hobby for a few enthusiasts and the results of these activities were exploited for different purposes, like air shows and demonstrations, civil and military applications, also design activities and later industry development. In this chapter a brief history of the Czech civil aviation is presented as a result of research through Ref. [1-9].

## 2.2 Before the First World War

The first records of aviation in the country are from the 1870's. Since it was thought that flying would be possible only for machines lighter than air, in 1875 a project for controllable airships was launched by Dr. O. Vanek, the founder of the Czech Aeronautical Society. Among the first members of the Society were Ing. G. Finger, author of many theoretical studies, who in 1910 obtained the patent for one type of aircraft propulsion - for a propeller in a cylinder, F. Stepanek, a mechanic, who in the second half of the 1890's, performed the first of many experiments with unpowered aircraft of his own design and construction. At the same time J. Hirch, an army officer, performed the first experiments with ornithopters, and later experimented with man-powered aircraft. Also J. Homola, received in 1907 a patent for the construction of ornithopters. Neither, however, got further than the stage of flying models.

The first powered aircraft was built and exhibited in 1910 in Prague, by V. Urbanek. The engine, however, also of his own construction, had low power and this was why the aircraft was unable to fly. In 1904, L. Ocenasek obtained the patent for the design of a rotary aircraft engine. This was received abroad with interest. Ocenasek also built a powered aircraft in 1910 based on the Bleriot XII design. In this case too, it was not possible to "teach" the aircraft to fly, and finally the aircraft was destroyed by fire whilst undergoing testing in 1911.

Jan Kaspar, an engineer from the Czech town of Pardubice and his cousin Emil Cihak represented the second generation of Czech aviators. Kaspar started with his own aircraft design but later used only the Bleriot IX and XI aircraft, which he modified and re-built after continuously damaging them during his trials. This is probably the reason why by the end of his career he had become a skilful aircraft mechanic and constructor. Mr. J. Kaspar had several significant achievements: he performed the first flight in the country, first publicly announced flight, the first solo cross-country; flight (Pardubice - Praha), and the first cross-country flight with passengers (Melnik - Praha).

In the course of their careers, Kaspar and Cihak made more than fifty publicly announced flights between 1910 - 1914. These activities proved to be very important for the propagation of aviation in the country and lifted the moral of the politically depressed nation at that time.

Kaspar ended his aviation career in 1913. Cihak continued his activities with his brother, with whom he built, in 1910, a monoplane with an Anzani engine. This aircraft was damaged during flight trials and so they bought in Paris an old monoplane Saulnier which was also destroyed during the trial flights. Before the First World War the Cihak brothers built eleven aircraft of which the most successful was the monoplane "Rapid", in which, in 1913, they made many public flights.

In 1914 Cihak concentrated on aircraft with specified mission flight characteristics, mainly to compete in the international Schicht prize competition. Cihak took part in the competition in which he was the only Czech with an aircraft of his own construction. It proved to be difficult for him to compete with competitors backed by professional companies and consequently he was not successful in the race. The aviation trials of the Cihak brothers are marked by many aircraft accidents and repairs as well as by the building of new aircraft.

Another member of the second generation of Czech aviation pioneers was the engineer, Jan Cermak. His first aviation experience was gained in the 1890's when he experienced flying as a passenger in balloons. In 1910 with S. Bloudek, a student, and the mechanic Potucek, he started the construction of a top wing, braced cantilever monoplane. The first flight of the aircraft was in the same year in the town of Plzen, which, after Pardubice, was the second centre of Czech aviation activities at the time. The following year Cermak, together with Bloudek started, in Vienna, the production of the biplane called Libella and later Libella II. In July 1911, Cermak became the first Czech holder of an international flying licence, and with his aircraft Libella II he later in 1911 performed demonstration flights in Croatia, Serbia, Bulgaria, and Hungary.

F Simunek from Prague built in 1910 his own aircraft based on the Bleriot aircraft design. He tried using different types of engines, on the aircraft but it was destroyed during trials before taking off. Simunek moved to Plzen where he continued his trials with a new aircraft. Some of the trials were successful and later he displayed the aircraft publicly in Prague and Plzen.

In 1911 K Tucek from Plzen learned the art of flying at the Bleriot school in Pau, France. Upon his return home he started the construction of his own monoplane which he had later tried to fly at Plzen aerodrome.

Early Czech aviation history is also marked by some very good pilots, notably R Holeka who learned to fly in 1911 with the Austrian Military Corps in Wiener Neustadt. B Laglerova was the first female

Czech pilot; she was a graduate of Grad's Pilot School in Berlin. Holeka became a test pilot in 1912. In 1917 he went on to teach in the newly established independent state of Czechoslovakia. Holeka was also the founder of the first Czechoslovak post war organised civil and military aviation. Laglerova demonstrated her flying, first in Czechoslovakia and later in Germany and America. Both Laglerova and Holeka were involved mostly in flying, rather than in aircraft design construction which was the common sign of the first and second generation of Czech aviation pioneers.

To complete the picture it must also be remarked that German pilots and constructors working in Czech towns contributed to the country's aviation history. I Etrich had experimented since 1898 with models of gliders. His first powered aircraft was the Taube. It was a successful aircraft, later produced by many firms and also manufactured under licence by the company Rumpler in Berlin. Ing. O. Hieronymus, a German engineer and chief designer of the car firm Laurin and Klement, in Mlada Boleslav, designed and manufactured in 1909 'Hiero', the first successful water cooled aviation engine. Hieronymus also built Wright's biplane in 1910 to be used with skis. Later in 1910 this aircraft was used to demonstrate Laurin and Klement's aviation engine.

## 2.3 Between the First and Second World War

The beginning of the First World War brought to an end the activities of most of the first Czech aviation pioneers. The majority of the aircraft were confiscated during the war and piloting was forbidden unless the pilots joined the army and continued flying as military personnel. After the First World War the newly established independent country started to build up a new airforce. There were many different types of aircraft, aviation equipment and spare parts in existence but these materials were soon too old for the expanding new airforce and the Ministry of Defence started to look around for replacements and modernisation.

For the MOD there were a number of options for modernising the airforce. It could be achieved by importing equipment, mainly from France, or by purchasing domestic equipment which was produced either by newly established aircraft factories or in the new aircraft departments established by already well established companies. Importantly it was national production that MOD chose to modernise the army. As the airforce equipment was gradually upgraded, the older outdated aircraft, most of which were in working order, were allocated to the newly established national Czech Aviation Club. This club represented Czechoslovak sport aviation internationally and was recognised by FAI. Later the organisation changed its name to the Aeroclub of the Czechoslovakian Republic, which organised and looked after all aeroclubs in the country.

In the middle twenties the "Masaryk Flying League" was established. Named after the first president of Czechoslovakia T G Masaryk, it had the objective of popularising aviation in general and on a very broad base, by raising financial awareness, organising popular lectures, demonstration flying and by providing cheap flying lessons throughout the country.

Between the First and Second World War, the most popular type of flying was gliding, which was less expensive than powered flying. Just before the Second World War, in the mid thirties, when it was evident that Hitler's army would invade the country, more state money was put toward powered flying in order to train young pilots. Also new aircraft were manufactured and bought by the state for the aeroclubs for training. These new highly trained pilots did not have the opportunity to defend their country, but later in the war these pilots gained very high reputation in air fights against the Germans in France and Great Britain.

After the German invasion of Czechoslovakia most of the country's aircraft were again confiscated and aviation firms were reorganised to serve the German Army in producing more powerful machines ready to be used in combat. A lot of people were forced to work in the aircraft industry during the Second World War and aircraft were produced in massive numbers. This was the main reason why at the end of the war all aircraft companies were affected by a rapid decline in man power. In this rather chaotic situation some aeronautical engineers recognised the need for keeping and expanding experience gained from the war aircraft production. This was mainly the experience of massive serial production, new design and production technologies not known to the Czechs before the war. Additionally experience in the use of new materials, new norms and standards, were seen as features not to be lost.

## 2.4 From the end of the Second World War to 1990

Production of German aircraft and their modifications were the main programs of most aircraft companies immediately after the end of the war. The war ended in May 1945: in September of the same year in Zlin, the aircraft manufacturers Moravan rolled out and flight tested their first post war aircraft glider, Z-24 "Krajanek". At this time most of the aeroclubs were full of all types of post war aircraft and flying them was relatively easy. In the fifties, well before these aircraft ended their life cycle, the Czechoslovakian Ministry of Industry decided to encourage aircraft companies to develop new types of aeroclub aircraft which would be available after the older war aircraft ended their operational life. This decision contributed to the fact that the most famous sport/touring aircraft in the world were developed in Czechoslovakia before the late sixties.

In the fifties the main Czechoslovak aeronautical companies were integrated into an industrial group named Aero to achieve higher efficiency in design, production and marketing. The group was controlled from headquarters located in Prague-Letnany. In the seventies and eighties the group consisted of sixteen companies with a work force of more than 30,000 employees. All research, development, production and business activities were directly controlled by the headquarters. Ministry attitude to civil aviation changed in the seventies, when it was proposed to develop types of aircraft that would be suitable for all Eastern Block countries, particularly for the then Soviet Union. Design and production of specified aircraft were allocated to selected companies causing market forces and competition to disappear. In 1985, there was a discussion in the national aviation magazine, Letectví a Kosmonautika, on "what next". This article pointed to the very bad situation in the Czechoslovakian sport aircraft industry and even suggested that the state should buy new aircraft from abroad to supply the needs of the aeroclubs. This situation was not easily understandable for many aviation experts in the country, who knew that in the last sixty years 180 different types made up the country's 10 000 sport aircraft.

## 2.5 Between 1990 and 1996

The political relaxation in Europe in the first half of the nineties was accompanied by some features which complicated the situation in most aircraft companies. These were principally the reduction of armament production, the decline of civil air transport, the overall economic recession, the loss of the Eastern Bloc market and unsuitable management structures, together with a change in the domestic economic environment. All manufacturers had to find new customers and this required the improvement and updating of all aircraft types in order to satisfy the different needs and requirements of potential new customers. The result of these changes was a very high insolvency, particularly of companies in the aeronautical industry. The number of employees in all state owned companies was reduced by 25%. In November 1990 the government of the Czech Republic approved the transformation of the Aero corporation into the joint-stock company Aero. The company is still fully owned by the state, and in 1993 was renamed Aero Holding. The new company has a major stake in eight companies with more than 7500 employees. Its main fields of activity are research, development, production, assembly, sales, operation, repair and maintenance of aircraft, aircraft components and equipment. The company is also responsible for Aero Holding's international co-operation programs. The restructuring process started with a very important role being played by the major Czech banks which at the same time were the major creditors of the Aero Holding company. The financial restructuring ensured the creditors peace of mind with their participation in former subsidiaries of the Aero Holding Company. Indirectly through the majority participation by Aero Holding, state influence is retained in companies that are involved in production of strategic importance to the state. It resulted in the exchange of bank loans for a total of 55.5% of shares of the companies participating in the military training program. The remaining 45.5% is still in the hands of Aero Holding. The remaining companies still fully owned by Aero Holding are offered to domestic or foreign investment partners for taking Aero Holding stake. The financial restructuring is followed step by step by a operational restructure which should result in the development of new long term reliable business relations with new customers from around the world. A lot of consultative work has been done by western firms specialising in management training, strategic planning management, marketing styles and product support. Already major changes can be seen in the field of cross-boarder co-operation programs. Several "East-West" projects are in different stages of development.

Czech aeronautical industry production can be divided into two main areas, with an annual turnover of about 147 million of GBP (1994). Of the total turnover, 75% is represented by military production, the remaining 25% by civil production.

In 1994 the structure of production was as follows: complete aircraft units 86%, aircraft engines 5% and avionics and other equipment 7% of the total turnover.

Complete aircraft units turnover is represented by the production of military training aircraft (83%), regional commuter aircraft (14%) and sport and general aviation aircraft (3%).

The decline in aeronautical production within the period since 1987 can be seen in the Fig 2.1 below:

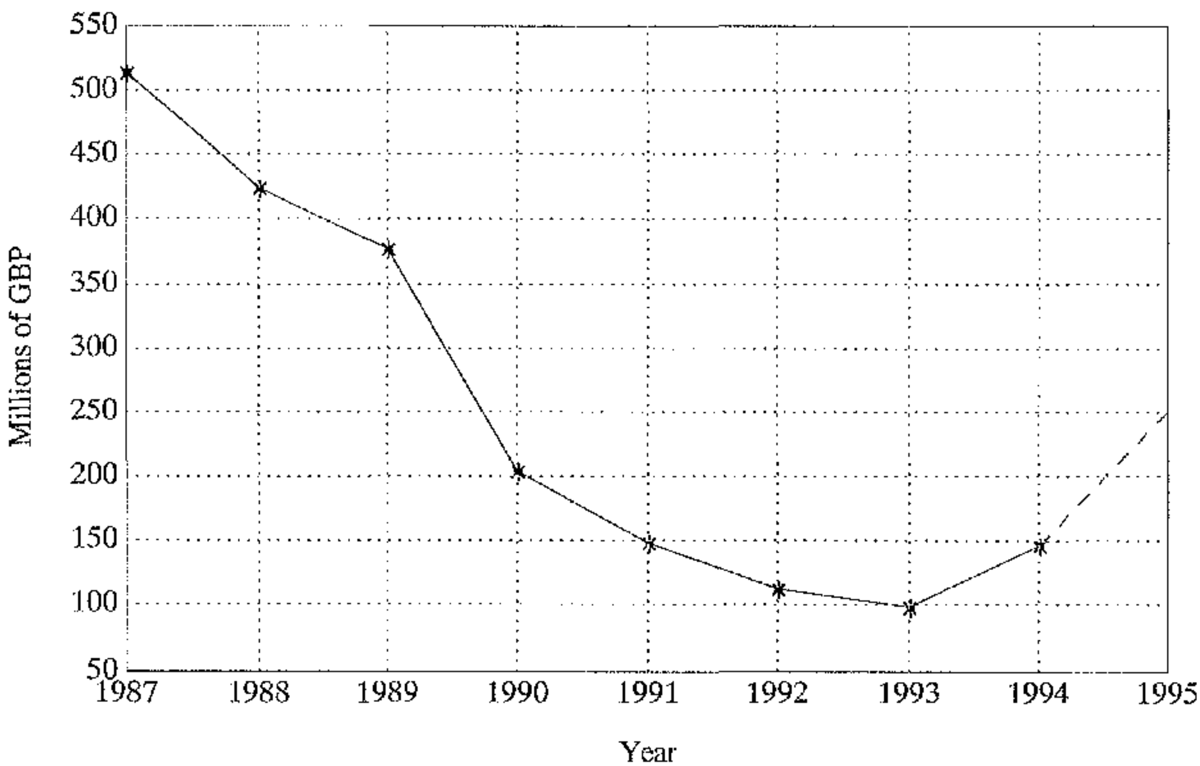



**Fig 2.1:** Czech Aviation Industry Turnover.

The total turnover represents about 0.5% share total of the European Community Aerospace industry turnover, which was approximately 35 billion GBP in 1994. The highest share of European Community sales turnover by the Czech Aviation industry was achieved in 1987 when the share was approximately 1.5%.

After 1990, three main companies became independent from Aero Holding, these being Jihlavan, Moravan and Mesit.

Jihlavan was the first company to become independent from Aero Holdings. The company was involved in the manufacture of hydraulic systems, but now concentrates mainly on non-aeronautical engineering productions.

Moravan Otrokovice is still involved in designing and manufacturing sport powered aircraft as well as agricultural aircraft and pilot ejection seats. The company is now also designing and manufacturing non-aeronautical engineering products.

Mesit, was previously involved in the production of avionics, radio communication and radio navigation systems and engine control systems, but now concentrate mainly on non-aeronautical electro-engineering products.

In Table 2.1 there can be seen an overview of all companies operating in 1995 under Aero Holding. The geographic positions of the companies is shown in Fig 2.2.

| | Company | Established | No. Employees | Turnover Mill GBP | Main Activities | Remarks |
|---|---|---|---|---|---|---|
| 1 | Aero Vodochody | 1953 | 2350 | 125 | Design and mnfct Military Jet Training Aircraft | A currently successful company (chapt 3.3) |
| 2 | Let | 1936 | 2050 | 22 | Design and mnfct Regional Turbo Prop Commuters All Metal Gliders | Needs investment, partner, and management restructuring (chapt 3.7) |
| 3 | Letov | 1918 | 1200 | 3.5 | Design and mnfct Aircraft Components and Simulators Ultralight Aircraft | Successful with international co-operation programs (chapt 3.2) |
| 4 | Walter Motorlet | 1911 | 1200 | 6.5 | Aircraft Engines Design and mnfct Jet, Turboprop and Piston | Company with a long and successful tradition, needs management restructuring and investment partners |
| 5 | Technometra Radotin | 1922 | 300 | 1.2 | Design and mnfct Undercarriage, hydraulic and control systems for military aircraft | Current production of engineering products for customer requirements |
| 6 | Teset Semily | 1946 | 350 | 0.2 | Design and mnfct Undercarriage for civil aircraft | Current production of engineering products for customer requirements |
| 7 | Research & Test Aviation Institute | 1922 | 370 | 2.6 | Business activities Research and Testing | Joint venture with Hamilton Standard |
| 8 | Cenkovske Strojirny | 1871 | - | 0.3 | Design and mnfct Aircraft interiors | Proposed for liquidation |

**Table 2.1:** 1994 Aero Holding Companies

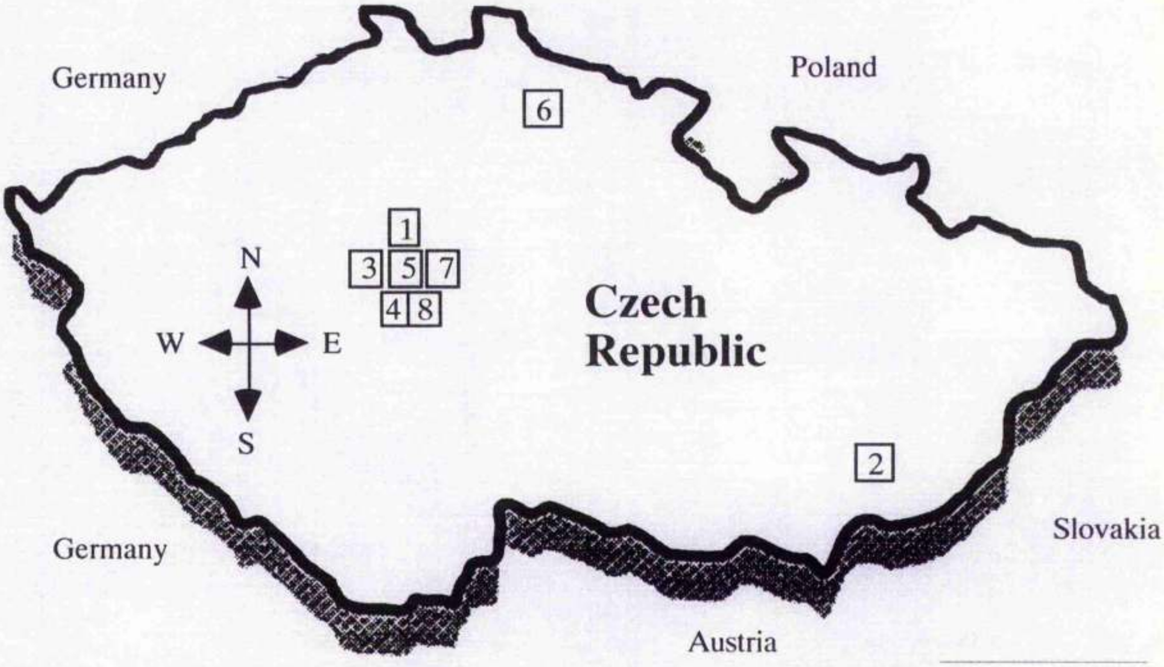



**Fig 2.2:** Geographic positions of Aero Holding companies in 1995.

Since 1990 a dozen small to medium private companies, specialising mainly in the production of ultralight and sport aircraft, their equipment, components, accessories and other products for recreational flying, have been founded. Most of them are headed by experienced engineers, or former employees of big state owned aeronautical factories. In addition some small aircraft companies have been established; these offer both development design and special technology services for the aeronautical industry. Yearly turnover of these small to medium enterprises is estimated at 15-20% of the major aeronautical industry's yearly turnover.

In 1994 the first signs of improvement in the industry's situation appeared. Deals, involving co-operation with Airbus, Pilatus, General Electric, Hamilton Standard, Northrop-Grumman, Boeing, Eurocopter, Triplex Loyd and others were struck. Such co-operation will rapidly improve management restructuring and certification procedures in design and manufacturing of the companies involved.

# CHAPTER THREE

# PROFILE OF THE MOST INFLUENTIAL AERONAUTICAL COMPANIES

## 3.1 Introduction

The aviation industry and its companies have been for the quarter of a century of their existence, in the top league of the Czechoslovak, Czech, and indeed European engineering industry. Its products are well known to many users around the world. Despite the current world recession in aircraft production and all the related problems, which are affecting the industry, the government and the banks continue to seek the optimum solution. The following chapter discusses the main companies, those companies designing and manufacturing aircraft, which had and still have an effect on the whole industry.

### 3.2 Letov

Letov, established in Prague in 1918, was the first aviation company in the country. At first the company was involved in aircraft manufacturing and repair and served the Ministry of Defence; later Letov designed and manufactured. In the early twenties, Ing A Smolik, the chief company designer, devised a high wing aircraft, S-8, which was specially designed to break the national speed record. The prototype aircraft in cruise configuration was flown at 300 km/hr, and had a strong effect on country sport flying development. This led to a second type of aircraft being produced by the company. This was the S-10, a copy of the German aircraft Hansa-Brandenburg B1. More than fifty of these aircraft were produced and used by the aeroclubs. In 1925, Ing. Smolik designed a new aircraft for pilot training. This was the biplane S-18 with a Walter NZ-60 engine. This aircraft was later modified to S-118, S-218, designed for more powerful engines. The entire family of aircraft comprised more than one hundred units.

One of the best company designs before the Second World War was a light, high wing aircraft for sport flying, S-39, powered by a Walter Polaris engine, and its modifications S-139, S-239 with engines, Pobjoy R and Walter Minor 4 respectively. Forty three were manufactured in total. During the Second World War, the company was producing various types of German designed aircraft.

After the war the company manufactured the aircraft, Praga E-114D and E-114M. The beginning of the fifties saw the aerobatic glider, LF-107 "Lunak", of which eighty were manufactured. During the same period two prototypes of the two seater school glider, LF-109 "Pionyr" were built and tested. Serial production was later transferred to the aircraft companies Let and Orlican.

Letov also took part in a national competition organised by MOD in 1947 to develop a new military trainer. They entered the competition with their aircraft Praga E-112 powered by Walter Minor 4-III. They lost the competition to Moravan's Z-26 "Trener" which became famous world-wide.

At various points in its history the company also helped to build amateur projects. In the second half of the sixties it built the motor glider MK-1 "Kocour" followed by the well known SK-1 "Trempik" designed by Ing. J. Simunek and Ing. J. Kamaryt.

Current fields of activity include:
Development, production, assembly, maintenance, repairs, marketing and sales of flight simulators, checking and diagnostic equipment including spare part production and deliveries.

Production of flight simulator hydraulic motion systems according to the customer's requirements.

Production of air frames, wings, and external fuel tanks.

Development, production, marketing and sales of LK-2 and LK-3 ultralight aircraft.

Ultralight Aircraft Flight School LETOV AIR.

Manufacturing co-operation with several domestic and foreign companies, among others with: Eurocopter Deutschland Donauwörth

(Germany) - emergency exit doors for Airbus A-321; Pilatus (Switzerland) - airframes of PC-6 Turbo Porter.

### 3.3 Aero

Aero was established in 1919 in Prague-Vysocany as one of the first aircraft manufacturers in the new independent state. It started with the licensed production of Hansa-Brandenburg B1, powered by a Mercedes (174kW) engine, and the more powerful versions with Hiero (169kW) engine, and BMW IIIa (136kW) engine. These aircraft had the trade marks A-1, A-14, A-15, and A-26 respectively. Most of them were made for the army and then later released for aeroclub use. Another aircraft made by Aero, before the Second World War, was the reconnaissance biplane A-12, powered by the Maybach engine. Later, when released by the army these aircraft were also used by aeroclubs for sport flying.

Even though the main production of the company was of military aircraft, they also produced typical sport/touring aircraft. Before the Second World War, they built the light biplane Aero A-34 "Kos", powered by Walter Vega (62kW), and its modifications, A-136 powered by Walter Venus (88kW), and A-34J powered by Walter Junior (77kW). In 1934 the company built two special mission aircraft, Aero A-200 powered by Walter Bora (147kW) engine. These aircraft were designed for an international “Challenge” competition.

Before the Second World War the company gained a reputation as one of the most important European manufacturers of civil and military aircraft. During the occupation of the country 1939-1944, the company designed and manufactured the school biplane Bucker Bu-131D. This aircraft was still produced after the war under the trade mark C-4 powered by the original engine Hirth and later C-104 powered by Walter Minor 4-III (77kW) engines. The majority of these aircraft were after the war extensively used by aeroclubs. Another aircraft produced by the company during the war was the trainer Siebel Si-204D, after the war trade marked as C-3. The company was nationalised just after the end of the war. In 1953 Aero moved to new facilities built at Vodochody, near Prague, and this new factory continues the tradition of the major aircraft manufacturer in Eastern Europe.

The first company-designed post war civil aircraft was the world famous Aero Ae-45. This aircraft stayed in production in different versions until 1961. These robust, low cost operational aircraft were popular on four continents. Some of them are still flying today. Since 1953 serial production of aircraft has been transferred to the newly built aircraft company, Let.

Current fields of activity are:
Development, production, assembly, maintenance, service, repairs, marketing and sales of several modifications of Aero L-39 and L-59 training and light attack aircraft including spare parts production and delivery.

Aircraft overhauls.

Production of aircraft parts - co-operation for domestic as well as foreign customers (including Boeing and Airbus).

Development of the light multi-role combat and training aircraft Aero L-159.

Development of the multi-purpose business aircraft Aero Ae-270.

Working in co-operation for development and production with Elbit (Israel), Flight Vision (USA) and other foreign and domestic manufacturers.

### 3.4 Avia

This company was established in 1919 in Prague-Cakovice with the objective of building and repairing aircraft. The newly designed aircraft were marked BH, this title was taken from the names of the aircraft's designers, Benes and Hajan. At first they designed the BH-2, a low wing monoplane, but this was never completed. Later they designed the BH-5, powered with Anzani or Walter NZ-60 engines.

Since 1923 Benes-Hajan monoplane aircraft have been successful at most flying competitions around Europe. Many types of sport aircraft were developed by this company and many pilots made their names using them. Their success persuaded the company to produce military aircraft as well. This decision was to affect national civil aerobatic flying in the future. Under MOD direct intervention the company designed the biplane BH-21 bomber which stayed in production for over nine years in which time 139 units were produced. Later the BH-21 called Avia B-21 became an influential aircraft in the Czechoslovak aerobatic school. The aircraft was modified for use with stronger engines. The trade marked B-122, for example, was powered by Walter Castrol (191kW) and BA-122 was powered by the stronger Avia RK-17 (261kW). These aircraft flown by Czechoslovakian aerobatic pilots were successfully demonstrated in France, Yugoslavia, Romania, Spain, Portugal and also during the Olympic Games in Berlin in 1936.

After the Second World War, the company built their last sport aircraft, a high wing two seater AV-36 "Bojar", powered by Walter Mikron III (48kW) and its modified versions with more powerful engines AV-136 and AV-236. This type of aircraft was also exhibited at the Paris airshow in 1946. After the fifties the company stopped production of civil aircraft and produced only military aircraft. In the seventies aircraft production stopped completely. Only the propeller design and development department survived into the nineties, when a joint venture with Hamilton-Standart propeller manufacturers was established.

### 3.5 CKD

The aircraft division in CKD company was established in Prague in 1930 with the objective of taking over aircraft production from Avia. Benes and Hajan, originally Avia's aircraft designers, began to work for CKD Praga. Their first manufactured aircraft was an elementary trainer biplane BH-39 powered by Walter NZ-620. Later the same aircraft was modified for different engines and in total one hundred and thirty nine units were manufactured.

For sport flying use both Benes and Hajan designed an aircraft BH-111 which was based on the successful Avia BH-11. The BH-111 aircraft was specially designed for the 1932 Challenge competition.

These new aircraft were powered by either de Havilland Gipsy III or Walter Junior engines.

In 1933 a new aircraft chief designer, Jan Slechta was appointed to the aircraft department and in 1934 a new aircraft project with the trade mark E-46 was developed. It was a light wooden, top wing, side by side two seater aircraft powered by Aeronca (26kW). This aircraft was finally modified, changed to a closed cockpit with a Czech engine Praga B (29kW); for trade it was re-named "Air Baby" E-114. This aircraft proved to be commercially successful and also popular with aeroclubs even after the war. Altogether nearly two hundred units were manufactured and some of them exported to aeroclubs in France, Romania, Iran and Great Britain where production under license was also set up. Successful as it was, the "Air Baby" was still modified several times to achieve even better performance.

During the occupation of the country 1936-45, the aircraft produced there and used in aeroclubs were of German design, for example Focke-Wulf FW-44 "Stieglitz" and Siebel Si-204D. After the war the company returned to production of the E-114 "Air Baby". The concept of the aircraft was still attractive and with a number of new modifications was still commercially viable. So some post war "Air Baby" aircraft had towing mechanisms for gliders and some of the aircraft had a Walter Mikron III (48kW) engine. In total more than one hundred E-114 and modified versions of it were produced after the war.

The last company aircraft was designed by Ing. Slechta. This was the E-112, powered by a Walter Minor 4-III engine. The aircraft was specially designed to meet MOD specifications for a new trainer. In the same competition in 1947 was the Z-26 "Trener" from the Zlin aircraft manufacturer, Moravan. The "Trener" proved to be closer to the MOD specification and the Praga E-112 project lost the contest and did not go into serial production. Aircraft production in CKD ended in 1947.

### 3.6 Orlican

When Benes left CKD Prague in 1935, he established in Chocen together with a businessman Mraz, a new aircraft company named Benes-Mraz, later known as Orlican. Before he returned to his original aircraft design layout, Benes designed a side-by-side two-seater with braced high wing and a mechanism that allowed the wings to fold along the fuselage. The aircraft was powered by Walter Mikron II (48kW) engine and trade marked Be-60 "Bestiola". Twenty three of them were produced, mainly for the MOD and aeroclubs.

Almost simultaneously with Be-60, Benes designed an aircraft with his traditional layout: low wing, tandem two-seater powered by Walter Minor 4 (70kW) engines. It was a relatively simple aircraft trade marked Be-50 "Beta-Minor". In total forty three were produced exclusively for civilian use in aeroclubs.

The Be-50 was later modified according to the engine used. First it was Be-150 "Beat-Junior", powered by a Walter Junior (85kW) engine and then Be-250 powered by a Walter Major (96kW) engine. In late 1936 a new version of the Be-50 was released with a closed cockpit. This aircraft was trade marked Be-51 "Beta Minor" and its modified versions were Be-51A, Be-51B, and Be-51C. The basic type of aircraft was also redesigned as a two-seater aerobatic trainer. It was trade marked Be-52 "Beta Major" powered by a Walter Major (96kW) engine. Later this aircraft was modified to the single seater versions Be-56 and Be-252 powered by a Walter Scolar (132kW) engine.

Later Benes designed a new type of aircraft which developed into the whole family of Be-500 aircraft. He began with the single-seaters, Be-501 and Be-502 "Bibi", especially designed for the competition "douze heures d'Angers" in France, where the aircraft won in their categories in 1936. Two-seater Be-550 "Bibi", an elegant low winger developed from a single-seater was powered by a Walter Micron II. It was exhibited at the Paris airshow. Its last version, which represents the top of Benes's achievements in design was the Be-555 "Super Bibi" powered by a Walter Minor 4 (62kW) engine. This came just before the occupation by the Germans in 1936, when further production of the "Super Bibi" was aborted. During the occupation Benes left the company and Mraz was forced to work for the Germans on special military projects. During the war the only sport aircraft produced by the company was the two-seater glider DFS "Kranich II", known after the war as VT-52 "Jerab". These gliders were widely used after the war especially for elementary flying, and formed an important part of the hardware of aeroclubs before the new post war glider types arrived.

In 1941 a new branch of the company was established in Slovakia. The chief designer was the young engineer Z. Rublic, one of the close associates of Benes. Only one type of aircraft was made by this branch of the company, the touring, low wing, "Zobor I" based on the

Be-555 "Super Bibi". Ten of these aircraft were made in Slovakia. Experience gained with this aircraft and also with the company Benes-Mraz before the war, allowed Rublic to design his first post war aircraft, M-1A "Sokol". It was an elegant, wooden two-seater, low wing design with retractable undercarriage, powered by a Walter Minor 4-III (77kW) engine and was first flown in March 1946. In 1947 the aircraft was modified to be used with a Toma 4 engine and this aircraft was trade-marked M-1B. Both aircraft, however, never got beyond than the prototype stage. Serial production of Sokol was trade-marked M-1C. This was a three-seater with a modified wing platform to the original aircraft powered by a Walter Minor 4-III. The aircraft was first flown in 1947. Sokol was an aerodynamically well designed aircraft, which operated in many countries around the world. Altogether three hundred units were produced, of which more than half were sold to foreign customers. Rublic's idea was that the Sokol type of aircraft should develop further in post war time and all new aircraft derivatives should take advantage of the very good aerodynamic and performance characteristics of the original aircraft.

The company produced two prototypes in 1948: the M-2 "Skaut", a three-seater with a fixed undercarriage and powered by a Praga D (55kW) engine and the four-seater M-3 "Bonzo" with a retractable tricycle type undercarriage powered by a Walter Minor 6-III (118kW). Both aircraft failed to make it to serial production.

In the late forties Sokol was redesigned for an all metal structure. The aircraft was trade marked XLD-40 "Mir". The first test flight was in 1950 and the main feature was a new "V" tail. It was a three-seater, however, and not a very good design. The development work was suspended for three years and then the aircraft was modified again. Now with a "classic" tail and four seats, it was trade marked XL-40 "Meta-Sokol". The first flight was in 1956 in Chocen. By this time the design office together with Rublic had already been relocated in Prague. The proof serial production was run in Orlican, between 1957 and 1958 and the aircraft was powered by a Walter Minor 4-III engine with V-401E propeller. Standard serial production aircraft were powered by the popular Czech engine M-332 with a new propeller V-410. Altogether one hundred and six L-40 "Meta-Sokol" were manufactured. The last aircraft was produced in 1959. Meta-Sokol was a successful aircraft breaking many national and international records. It was the last powered aircraft developed and manufactured in Orlican. In 1959 Orlican also stopped production of the L-60 "Brigadyr" aircraft, originally designed in Aero by their chief aircraft designer O. Nemec. Brigadyr was a high wing tail-dragger aircraft, powered by an M-208B (162kW) engine. The first prototype was flown in Chocen in 1953. Between 1953 and 1959 two hundred and fifty aircraft were produced in Orlican, many of them exported to 15 different countries. Both the Brigadyr, now with a new type of engine AI-14RA (191kW), and the Meta-Sokol are still used today by individuals and aeroclubs in the country.

Since 1950 Orlican's activities have focused on the design and production of sailplanes in what became the only product of the company in the sixties. First in 1950 it was a sailplane LG-125 "Sohaj 2", originally designed by Moravan, and later modified to LG-425 "Sohaj 3". Then in 1954 Orlican started production of LF-109 "Pionyr", originally designed and manufactured by Let aircraft company. Since the beginning of the sixties, Orlican became a major manufacturer of club sailplanes in the country. In 1961 the company produced a single-seater of all wooden construction to FAI specification, a standard class sailplane VT-16 "Orlik", designed by J. Matejcka. After eighty aircraft were produced the company modified the aircraft which was trade marked VT-116 "Orlik II" and this aircraft stayed in production until 1963. In total, two hundred and twenty Orlik II sailplanes were made and in the mid eighties and they still formed an important base for gliding clubs in the country. The aircraft did not achieve any world records but helped the country's best sailplane pilots to keep up with the world wide top class gliding community.

In the second half of the sixties it was inevitable that the quality of design and development of sailplanes in the country was declining in comparison with the situation before the war. This trend applied in the case of Orlican as well. Orlican's last attempt to gain credibility was a sailplane designed in Orlican in 1970 by T. Walla. This, WK-1, was modified a number of times until the final model trade-marked VSO-10 "Gradient" was completed. This aircraft combined all available production technologies, from wood and metal to fibreglass. A version of VSO-10 with a fixed undercarriage won, the first two places in club class in the European Gliding Championship in 1979. Since the VSO-10 no new sailplanes have been designed in Orlican. In 1995 the company was bought by a German investor. The company's aviation division current field of activity is manufacturing fibre glass sailplanes Discus CS and Janus CS under license.

## 3.7 Let

The company was established in the town of Kunovice in the mid thirties as a branch of Avia Prague. At first, the company handled the maintenance of military aircraft. The first civil aircraft manufactured here was a Moravan design, sport aircraft Z-22 "Junak", powered by a Praga D engine. One hundred and seventy units of the aircraft were produced between 1945 and 1951. Another Moravan design manufactured in Let was the sailplane trainer Z-124 "Galanka". LF-109 "Pionyr" was a two seater sailplane designed by Letov's designer V. Stros and manufactured by Let in large series, representing over two hundred units. In 1950 the company expanded and built a new site in the same region. In the so called "new factory" the Russian Jak-11 was first manufactured under license. In 1955 the company started to manufacture the Aero Prague designed aircraft, four seater all metal, Ae-45 powered by two Walter Minor 4-III engines. This aircraft was later modified for use with other engines and proved to be very successful.

The first aircraft to be designed and manufactured from 1957-66 in the company was the twin engine, five-seater Aerotaxi L-200 "Morava". This was designed by L. Smrcek, the company's chief designer. This aircraft was later modified for use with different engines and propellers, and trade marked L-200A and L-200D. A number of these aircraft are still operated by aeroclubs and individuals in the country and world wide. The same design team, in Let aircraft company designed one of the country's largest aircraft, L-410, L-420 and L-610. These are turboprop commuter transport aircraft with nineteen and forty seats respectively.

In the second half of the fifties the Let company started production of the L-13 "Blanik" tandem two-seater, all metal, sailplane originally designed by the Aeronautical Research Institute in Prague. It was a very successful sailplane production: 2649 aircraft were made and exported to forty countries.

Current fields of activity are:

Development, production, assembly, maintenance, service, repairs, marketing and sales of L-410 commuters, L-610 regional airliners, L-23 training and club gliders and L-33 world class gliders including spare parts production and deliveries.

Production of parts for aircraft power units.

Charter air transport.

Delivery of technical documentation for repairs of all aircraft types produced by the comany.

Manufacturing co-operation agreement with ACT Great Britain and ACT Austria.

### 3.8 Moravan

This company, based in Zlin-Otrokovice, has been involved in the design and manufacture of sport aircraft since 1933. It was established with the financial help of the shoe manufacturers Bata and began production with the sailplanes Z-I and Z-II, designed by Ing. Kryspina and Z-III and Z-IV designed by Ing. Donacek. In 1934 F. O. Mayer worked for the company as a designer, and his sailplanes were trade marked Z-V and Z-VI. The trainer sailplanes, Z-VII "Akela", Z-VIII and Z-X complete the list of sailplanes produced by the company before the war.

Powered aircraft design was from the beginning affected by the Bata's objectives. Bata wanted to produce light, simple to make and cheap aircraft that many people would be able to afford. Before the war, however, this policy resulted in the unsuccessful aircraft Z-XI, powered by Persy I engine and designed by F. O. Mayer and later the Z-IX, powered by Salmson engine and designed by J. Lonek. At the same time Lonek worked on the most successful powered aircraft produced by the company before the war, this was based on his previous constructions, L-5 and L-8 "Ginette", and was trade marked Z-XII. It was a two seater made from wood and powered by a Persy II engine. The aircraft had either an open or covered cockpit. The company produced in total more than two hundred units and sold them to eight different countries. This type of aircraft was still seen at airports at the beginning of the fifties. In 1938 Lonek left the company and Frantisek Pospisil became the new chief designer. During occupation of the country the company was forced to produce German designed aircraft at a high rate of production.

Soon after the war, the company design office modified some German aircraft for the installation of new engines and also produced aircraft to their own design. The two-seater sailplane Z-23 "Honza" and the single-seater Z-24 "Krajanek" were both important and successful.
In 1947 the new company sailplane "Sohaj" had its first trials. The aircraft was trade marked Z-25, this was followed by Z-125 "Sohaj II", Z-225 "Medak" and Z-425. In total two hundred and fifty units of the

Sohaj sailplane were made by Moravan. Other types of sailplanes designed and produced by the company after the war were the Z-124 "Galanka" and the Z-130 "Kmotr".

Moravan is well known as a manufacturer of powered sport aircraft. The first powered aircraft after the war in 1946 was the not very successful Z-22 "Junak". Later came the much better aircraft PLK-5, designed jointly by L. Marcol and the pilot L. Svab.

In 1946 the MOD called for a competition for the design and production of a new fully aerobatic military trainer. Moravan won the competition with their Zlin Z-26 "Trener". The prototype was flown first in 1947 and stayed in serial production until 1950. Later the aircraft was modified to enable the use of new materials and fulfil customers' requirements', it was then trade marked Z-126. This type of aircraft won the 1st World Aerobatic Championship in 1960 and was exported to ten countries world wide.

The aircraft was again modified to be used with a more powerful engine Walter Minor 6-III (118kW), and was then trade marked Z-226. This engine allowed even better manoeuvrability and the aircraft started winning international competitions one after the other. The entire number of Z-226s including the manufactured modified versions, was three hundred and fifty, most of which were exported to seven countries. The saga of "Trener" does not end with this model, however: the aircraft was modified further to Z-326, Z-326A, Z-526, Z-526A, Z-526AS, Z-526AF, Z-526AFS "Kratas", Z-526F, and Z-256L which was designed to FAR standards. Company experience with the Trener led to the design of a new more "universal" aircraft Z-726 which was not, however, as successful and only thirty two units were made.

In the mid sixties, the company chief designer J. Mikula designed a new type of aircraft, again universal and apparently suitable for a wide range of aeroclub use. It was a two side by side seater, all metal aircraft, Z-42. This aircraft was also modified a number of times for use with new engines and propellers. The four seater modification Z-43 was first flown in 1968. In the second half of the seventies Z-42 was modified even further. With a more powerful engine and new cabin it was trade marked Z-142.

The aircraft family of Z-42 and Z-43 was not technically successful. It became clear that for top class aerobatic flying, aeroclubs need specialised and not universal aircraft. Hence the company (with its tradition) began to look into the possibility of designing and manufacturing top class aerobatic aircraft. In 1975 a new type of aerobatic aircraft the Z-50 was first flown. The aircraft had a Lycoming AERO-540-D4BJ (194kW) engine with a three blade propeller. The aircraft proved to be very successful and later won a number of world aerobatic championships. This type of aircraft is still in production with some modifications to the original type. Unfortunately the aircraft was never made in large scale serial production and is available only to a small number of acrobatic pilots in selected aeroclubs.

The Zlin-Otrokovice aircraft manufacturer Moravan is the country's Centre for Design and Development of Advanced Sport Aircraft. It is to be hoped that such a role will continue in the future.

Current field of activity:

Development, manufacture and maintenance of sport and agricultural aircraft. In production are the trainers Zlin Z-142 powered by an M-337AK (156kW), and Zlin Z-242L powered by Lycoming AE10-360-AIB6 (149kW) engine. Also the touring Zlin Z-143L, a four-seater powered by a Lycoming 0-540-J3A5 (177kW) engine, acrobatic aircraft Zlin Z-50 LS/LX one seater powered by a Lycoming AE10-540 LIB5 (224kW) and Zlin Z-50M powered by an M-137AZ (134kW) engine. The company also produces turbo prop agriculture aircraft Z-37T and pilot ejection seats.

## 3.9 Others

In the former Czechoslovakia and later in the Czech Republic there have been a number of relatively small companies and research establishments which have played an important role in the development of the aircraft industry in the country. These include the manufacturer Walter-Motorlet, established in 1911, and the Aeronautical Research Institute, both based in Prague. Walter's engines were used in most Czech made aircraft and the Institute was the organisation involved in research, development and testing for the whole industry. The Research Institute was established before the Second World War. There are aeronautical departments in universities, the first was set up in the Military Academy in Brno and later an aeronautical department was also established at the Technical University in Prague. Since 1994 the Institute of Aerospace Engineering of VUT Brno has been actively involved in teaching and research. There were, and still are, small companies involved in aeronautical engineering such as Aeron Brno, Aerotechnik, Evector, Inteco, and previously Ardea, Hodek-Kriz, Tatra-Studenka and many others, all of which have contributed to the establishment and development of the country's aeronautical industry. Since 1990 large numbers of small private companies have specialised in the design and production of ultralight aircraft and their equipment, components, accessories as well as other products for recreation flying. In 1990 the Amateur Air Association of the Czech Republic was established. This Association immediately made it one of its tasks to draw up a code of practice for the operation of ultralight aircraft within the framework of existing legistration. At the present time a new airworthiness code has been prepared by the association which establishes the operation of and design requirements for ultralight aircraft.

The newly reorganised Aeroclub of the Czech Republic has held a prominent position in the development of general aviation activities in the country since its establishment in 1914. The First World War stopped the activities of the club. Immediately after the establishment of the Czechoslovak Republic, the Czech Aviatic Club started to continue in its work. In March 1919 it was renamed as Czechoslovak Aviatic Club, which became a member of the Federation Aeronautique Internationale, (FAI). In 1990 the club was accepted as a member of FAI under the new name, Aeroclub of the Czech Republic. The newly reorganised organisation has more than 7500 members active in 106 gliding, powered flying, sky diving, paragliding and ultralight flying clubs.

# CHAPTER 4

# MARKETING STUDY

## 4.1 Introduction

Any design of a new sport-utility aircraft needs to look not only at the requirements of the domestic market, but also those of the markets of countries all over the world.

The United States has the largest general aviation market in the world. One indicator of this is the number of private pilot licenses issued annually. The U.S. global figure is approximately 30% higher than in Great Britain. In the late seventies 14000 light aircraft were sold in the U.S. But in 1990 only approximately 600 were bought. Historically, this was the lowest level of U.S. sales ever. The decline in sales, which can be observed in all developed western countries, has been influenced by rising fuel prices, product liability insurance costs, and the availability of an increasing number of good second hand aircraft.

The established US. manufacturers of light aircraft, such as Cessna, Beech, and Piper, had been, until 1995, exposed to potentially very large insurance claims as a result of US. product liability laws. Conventionally there was no time limitation on liability, which means that the longer a manufacturer has been producing aircraft, the higher the potential total liability. As a result manufacturers were having to anticipate this potential cost by including their insurance costs in the current prices of aircraft. For example, in the late eighties S105 000 was added to the price of each new Beech general aviation aircraft simply to cover Beech's insurance premium on the fleet of aircraft they had sold in previous years. Cessna and Piper ceased production of light aircraft in 1987 principally because of the costs. In 1995 the liability regulations were relaxed by a reduction of the liability time limit and Cessna, together with Piper started aircraft production again.

Second hand aircraft can affect the market everywhere in the world. Corrosion resistant materials, rugged construction and frequent regulatory checks mean that aircraft tend to remain serviceable for a considerable amount of time. This has meant that a large number of good second hand, light aircraft has accumulated since the 1950s, and this has tended to reduce the price of new aircraft, particularly those of a similar specification.

The vacuum created by the disappearance of the established manufacturers from the light singles market in the first half of the nineties has encouraged many newer, smaller operations, particularly in Europe to emerge. Also the end of the Cold War has opened new markets in the countries of the former Eastern Bloc states.

According to the CAA forecasting division, the world market for general aviation aircraft will continue to recover slowly over the next five years, growing at about 3 to 4% per annum.

## 4.2 Czech Light Aircraft Market Sectors

The market for two/four seater general aviation aircraft can be broken down as follows:

Business Transportation
Flying Training and Recreation
Surveillance/Aerial Mission Flights
Agriculture
Military

Most aircraft are designed for a particular market sector, but are in practice, multi-role. This can be either a straight forward process or a process of modification. The implications for the designer of an aircraft are that it is important not only to identify the strengths and weaknesses of an aircraft so that the most suitable market sector can be targeted, but also to identify opportunities which might arise in other sectors. The following sections deal with overall aircraft market potential and with significant trends in each of the sectors.

Currently only Zlin aircraft manufacturer Moravan are producing sport-utility aircraft designed to FAR 23. Some of these aircraft are fully aerobatic. Their technical specifications are shown in Table 4.1.

| AIRCRAFT | | ZLIN Z 142 | ZLIN Z 242L | ZLIN Z 43 | ZLIN Z 143L |
|---|---|---|---|---|---|
| | Units | | | | |
| SPAN | m | 9.16 | 9.34 | 9.76 | 10.14 |
| LENGTH | m | 7.33 | 6.94 | 7.75 | 7.6 |
| WING AREA | m2 | 13.15 | 13.86 | 14.5 | 14.8 |
| ASPECT RATIO | | 6.4 | 6.3 | 6.6 | 6.9 |
| WING SECTION | | NACA 63-4165 | | | |
| SEATS / CABIN WIDTH | no./cm | 2/114 | 2/114 | 4/114 | 4/114 |
| WEIGHT EMPTY | kg | 730 | 730 | 730 | 830 |
| T/O WEIGHT | kg | Aerobatic 970 Normal 1090 | Aerobatic 970 Normal 1090 | Normal 1350 | Normal 1350 |
| FUEL | litre | 120+100 | 230 | 230 | 230 |
| LOCATION | | wing,tip | wing | wing,tip | wing |
| LANDING GEAR | | tri | tri | tri | tri |
| POWER | hp | 210 | 200 | 210 | 235 |
| ENGINE | type | M 337 AK | Lyc.AEIO-360 | M 337 A | Lyc.0-540 |
| PROPELLER | | variable | var 3-bl | variable | var 3-bl |
| WING LOADING | kg/m2 | 73.8/82.9 | 70/78.6 | 93.1 | 91.1 |
| POWER LOADING | kg/hp | 4.62/5.19 | 4.85/5.45 | 6.43 | 5.74 |
| RATE OF CLIMB SL | ft/min | 1080/885 | 1080/850 | 690 | 855 |
| CRUISE AT FL8.0 (75%) | kts | 106 | 116 | 105 | 130 |
| MAX PERM IAS | kts | 180 | 172 | 166 | 166 |
| RANGE [NO RES] | nm | 510 | 570 | 620 | 560 |
| STRUCTURE | | alu steel | | | |
| YEAR FIRST FLIGHT | | 1978 | 1990 | 1968 | 1992 |
| STANDARD PRICE | US$ | 100 600 | 135 900 | production stopped 1995 | 148 700 |
| COPIES SOLD | ALTOGETHER MORE THAN 750 | | | | |

**Table 4.1:** Technical data for Zlin aircraft in production.

### 4.2.1. Business Transportation Overview

In 1990 the College of Aeronautics at Cranfield Institute of Technology estimated that over 80% of the world's single aircraft were used primarily for business, recreation and training. Experience of many aeroclubs in the UK suggests that business use is only a small proportion of this total.

This type of market sector did not exist in the Czech Republic before 1990. Since the political changes have occurs, there has been a growing interest in using general aviation aircraft for business transportation, even in a flying radius of less than 200km. Undeveloped road and train systems are underlying this sector of the market in the country. Similarly this happens throughout the former Eastern Block countries.

### 4.2.2 Training and Recreation Flying Overview

Aircraft designed for training are usually also used for recreational purposes. Nevertheless, aircraft specifically designed for recreational and touring purposes, possess certain desirable characteristics. This research considers the most important to be:

1. Easy, low cost maintenance.
2. Robust construction.
3. Range.
4. Cruise speed.
5. Stall characteristics.
6. Payload capability.
7. Acrobatic capability.

Currently there are not many light aircraft available that possess all these desirable characteristics in whatever degree. Most of the aircraft are old Czech made aircraft, approaching their total allowable flying hours.

Training has declined within general aviation activity since 1990, but has been recovering over the last two years. Currently in the Czech Republic there are 16 professional pilot training schools that are independent of the aeroclubs of the Czech Republic, of which there are more than a hundred, some of them running their own pilot training schools.

The principal desirable characteristics of future training-recreation aircraft, can be derived from the experience of the Western flying schools with the workhorse trainers, Cessna 150, 152 and 172 which is now also becoming popular with Czech aeroclubs. These characteristics emerge as follows:

1. Relatively low operating cost.

For the Cessna typical direct operating cost, defined as maintenance, insurance, landing fee, hangage, fuel and oil are £70 per hour when flying the aircraft approximately 500 hours per annum.

2. Reliability.

The Cessna 150/152/172 type has been flying without major design changes for almost 40 years. Any new aircraft in this category may take some time to gain acceptance from flying schools world wide. The engine must also be reliable between mandatory inspections.

3. Safety.

This is reflected mainly in the handling characteristics and the power/weight ratio of the aircraft. The Cessna type of aircraft has proved itself a particularly safe aircraft over the years and it will clearly take time for any new trainer aircraft on the market to establish such a reputation.

4. Cockpit size, arrangement, visibility and environment appeal.

Comfort is essential in training. A problem area of this research concerned the relative merits of side-by-side and tandem seating for ab-initio flying training. Many current western flying instructors have only taught in side-by-side aircraft since the last tandem seat ab-initio trainer, the very successful Chipmunk, ceased production over thirty years ago. At the same time in the Czech Republic the Zlin Trener tandem trainer was widely and successfully used. As a result most flying schools are biased to side-by-side trainers although the Chipmunk and Zlin-Trener are still in limited use as basic training aircraft and a great many instructors were brought up on these and other tandem seaters. Sailplane pilot instruction has successfully changed from side-by-side to tandem seating. Both seat arrangements are effective and both have their advantages and disadvantages.

Visibility is extremely important and any new modern trainer should clearly be superior to Cessna in this respect.

Noise level and pollution should be minimised to facilitate new environmental requirements.

5. Robust construction.

Robust construction is particularly important in order to withstand severe handling by most operators. Again the all metal Cessna 150/152/172 has proved itself here. The use of modern composite materials is also to be recommended since GRP technology is becoming more and more popular among users of sport/utility aircraft.

6. Other important characteristics.

The research revealed that the future trainers must have aesthetic qualities and must "look right" in order to stimulate pilots' confidence. The aircraft must also have reasonable endurance. Four hours is regarded by most flying schools as a minimum.

### 4.2.3 Surveillance/Aerial Mission Flights Overview

This sector includes aircraft suitable for carrying out special mission flight such as:

Pipeline and overhead cable inspection.

Photography and mapping.

Crime prevention and pursuit.

Traffic control.

Fire control.

Press coverage.

Customs and excise.

Environment control.

The general attributes that aircraft need to perform well in these roles are:

- Ability to fly slowly with high manoeuvrability.
- Good all round visibility from the cockpit.
- Ability to transit quickly to/from operation zone.
- Low vibration.
- Passenger comfort.
- Ability to carry at least basic surveillance equipment.
- Low noise signature and potential endurance.

The College of Aeronautics at Cranfield estimates that 2% of the Western world's aircraft fleet of single engine aircraft were used specifically for aerial photography, survey and specialised observation work. In 1990 this would represent between seven and eight thousand aircraft.

The potential market is, however, likely to be larger than this for at least three main reasons:

1. Aircraft are usually acquired for a range of purposes, i.e. multi-role, although the primary purpose may be for observation use. These aircraft are not counted in the statistics.

2. Strong interest has been shown, particularly by developing countries in the use of ultralight aircraft for observation, surveillance and other commercial duties. The relatively low price of such aircraft is likely to expand the market for observation and surveillance aircraft.

3. Slow flying, fixed wing aircraft, are likely to replace helicopters in certain roles because of the fixed wing aircraft's lower operational

cost. To some extent this advantage may be offset by the development of a range of cheaper lighter helicopters.

For the purposes of analysis, the market area has been divided into two distinct sections - aerial inspection and aerial observation, surveillance and photography. While there is a degree of overlap in the functional requuirements of each, it emerged that aerial inspection operation often required VTOL and hover capabilities and is, therefore, more suited to helicopters.

There is likely to be little potential in the Czech Republic for new two seater aircraft in an aerial inspection role. The picture is probably similar, if indeed, not even more restricted, in the UK and US, where helicopter use is extensive. There may possibly be a wider market in developing countries, where the cost of helicopter operation forces operators to compromise on versatility.

In general it was found that aerial survey and photography operations in the Czech Republic tend to favour cheap ultralight aircraft like Kitfox or if necessary larger aircraft like the Brigadyr to carry heavier equipment, or more support crew.

There are few aircraft designed specifically to meet these market requirements. There are indications that the market is growing, particularly for low cost aircraft with safe slow flying characteristics. The greatest potential for a new aircraft appears to arise from law enforcement agencies and other organisations carrying out observation, surveillance and light photography work.

### 4.2.4 Agriculture Spraying Overview

At present it is estimated that there are around 40000 aircraft in the world used for aerial spraying. This includes insect, weed and plant disease control, the application of fertilisers, defoliation, seeding and fighting forest fires.

In the US there are approximately 9000 crop sprayers, while in the UK there are only between 70 and 80 craft used in this role. The Eastern block countries have the biggest concentration of agricultural aircraft in the world, but generally, the market for agricultural aircraft is stagnant and likely to decline in the future. Tighter restrictions on aerial spraying are expected which are likely to make ground spraying methods more attractive.

The main area of growth is in the developing world, particularly Africa, where aid programs encourage the use of aerial spraying. The International Centre for the Application of Pesticides (ICAP) estimates that Africa will require between 200 and 300 agricultural aircraft in the next few years. In the developing countries as a whole more than 1000 aircraft may be required. Clearly the satisfaction of this need will depend largely on the developing world's resources and trends in international aid.

One area of this market which is poorly covered at present is provision for the training of agricultural pilots. This highlights the need for dual control agricultural aircraft, particulary since international aid packages tend to include training for local pilots.

Agricultural aircraft specially designed for the purpose tend to be relatively highly priced and the market for these aircraft is relatively less sensitive to price than other aviation sectors. In the developing countries politics is a much more important factor than price.

There are certain key characteristics of aerial spraying aircraft which make them particularly suited to this role. These are:

1. Demonstrable Safety.

The aircraft should provide demonstrable safety for the pilot and ground crew. Its design should provide above average protection for the pilot. The aircraft should handle well, particularly during a stall, and it should have a minimum safe flying speed of 80 km/h.

2. Performance.

The aircraft should have a cruising speed of at least 160 km/h, a low stall speed, and a high rate of turn at low speeds. Ideally it should have a low STOL performance. From the pilot's comfort point of view, the forces on the controls should be light.

3. Generally.

The aircraft should have good visibility particularly vertical and rearward; a robust construction; be corrosion resistant and have sufficient capacity to carry a spray or dust load according to customer requirements.

Normal spraying procedures require that an aircraft must be able to carry at least 35 to 40% of its gross weight in chemical spray or dust. There are new methods, however, where by spraying more concentrated chemicals in finer droplets reduce the required capacity. This "Ultra Low Volume" (ULV) spraying has meant smaller aircraft can be used, or larger areas treated. ICAP has tested microlights in this role and they have proved to be generally satisfactory, although ICAP has reservations about their robustness and performance.

The research revealed that only the ULV market can be suitable for a new two-seater aircraft built in the Czech Republic. This assumes that ULV spraying is going to become increasingly popular.

Currently Moravan-Zlin is manufacturing the Z37T turboprop aircraft which is designed for aerial work in agriculture and forestry. The aircraft can be employed advantageously in spreading fertilisers, distributing pesticides and insecticides for the control of vermin and plant diseases as well as for sewing corn and industrial crop seeds. A two-seater side by side model for pilot training is being developed. More than fifty units have been manufactured, although unfortunately the aircraft is relatively expensive to operate.

#### 4.2.5 Military Market Overview

To conduct an in-depth review of the market for military light aircraft proved to be a difficult task. It is an extremely difficult market to analyse because of difficulty of gaining access to information. The examination has been limited to a review of the authoritative aviation journals and interviews with former airforce personnel.

From the broad trends occurring within the world's military aviation procurement three key points suggest themselves:

- The Czech military market is unlikely to offer substantial opportunities for a new two or four seater aircraft. The airforce operates Zlin Z-142 in small numbers. After reconstruction of the whole army and its possible entry to NATO new market opportunities may arise.

- Third world markets are likely to prioritise low price and robust design and so these considerations in addition to ease of construction will be important factors in securing those potential markets.

- The military markets are extremely difficult and costly to penetrate. Military requirements are usually exacting and hence normally very expensive to fulfil and in certain cases political factors may be as influential as economic considerations in securing a contract.

Nevertheless, the potential rewards for successfully penetrating markets are high and should not be dismissed in the longer term.

## 4.3 Statistical Analysis Of The German Market

The German market for 2/4 seater aircraft was overviewed and analysed. Germany is one of the most technologically developed countries in the world, with a long aviation history and is one of the most influential countries for the future development of engineering in general in the Czech Republic. Fig 1.1 shows that Germany represents approximately 30% of the total export of the country in 1994 and is still increasing.

Table 4.2 shows the percentage responses of the questionnaire for customer requirements.

From the data obtaind from Ref. (10) and, analysis of the questionnaire, it was possible to create a preliminary technical specification for a new type of aircraft.

In general the factors affecting the light aircraft market in Germany and in almost every economically developed country are the following:

- Economic strength and its development.
- Standard of living.
- Environment restrictions.
- Politics.

| | | | |
|---|---|---|---|
| How many seats for a new aircraft would you prefer? | 2 seats (56%), 3 seats (7%) 4 seats (37%) | | |
| Do you want to pay for aerobatic capability of the aircraft? | No (81%) | | |
| Which kind of fuel would you prefer? | car petrol (46%), diesel (27%) aviation gas (27%) | | |
| What engine power would you recommend? | 80HP (4%), 100HP (15%) 120-130HP (32%), 150HP (20%) 180HP (13%), 200HP (8%) 250HP (8%) | | |
| What type of undercarriage would you prefer? | fixed (83%), retractable (17%) | | |
| What type of propeller would you prefer | fixed (53%), variable pitch (42%) either (5%) | | |
| What type of cockpit cover would you prefer? | clear (33%), non-transparent (52%) either (15%) | | |
| What type of construction material would you prefer? | composite (34%), metal (40%) either (26%) | | |
| Low or high wing? | high (34%), low (44%), either (22%) | | |
| Instrumentation: IFR or VFR? | IFR (20%), VFR (80%) | | |
| What performances would you expect? | | | |
| Take-off and landing field length | 250-300m (62%), 400-500m (31%) 600m (8%) | | |
| Range | 400km (11%), 500km (23%) 600km (7%), 700km (11%) 800km (37%), 1200km (7%) 1500km (4%) | | |
| | kts | km/h | % |
| Cruise speed | 90<br>100<br>120<br>130<br>150 | 167<br>185<br>212<br>241<br>278 | 3<br>37<br>37<br>20<br>3 |
| | ft/min | m/s | % |
| Rate of climb | 500<br>600<br>800<br>1000<br>1500 | 2.54<br>3.05<br>4.06<br>5.08<br>7.62 | 19<br>13<br>31<br>34<br>3 |
| | ft | m | % |
| Service ceiling | 10000<br>11000<br>12000<br>15000<br>20000 | 3048<br>3353<br>3658<br>4572<br>6096 | 29<br>8<br>17<br>42<br>4 |

**Table4.2:** The Questionnaire.

Economic strength and its development.

Since the Second World War Germany's story has been largely one of economic success. The reputation of German work is high. Germany's development in the future will, however, be affected by the continuing reunification program and the world recession which is already affecting the usually strong German car industry. DASA (Daimler-Benz Aerospace) consortium of aerospace companies is undergoing a painful restructuring program to cut accumulated losses. The ongoing process of the European Union for political and economical unification and for the common currency is another influencial factor. This could bring new cuts in social welfare. It is possible that the German economy will stagnate in the near future. This will, of course, affect the demand for, among other products, the new 2/4 seater aircraft.

Standard of living.

Thanks to the stability of the German economy, a large wealthy social group has developed. This middle class group has been economically strong enough to sustain an expensive life style which also includes business and recreational flying. According to Ref. [10], the biggest sale of new two seater aircraft in Germany was recorded between 1965 and 1980, see Fig. 4.1, when over 800 new aircraft were registered, at an average of around 50 per year. Since 1980 there has been a rapid decline in the sale of new two seater aircraft. The market is slow, and it may be assumed that the average sale of new two- seater aircraft will remain at ten per year until the aircraft life time of approximately 30 years expires. It means in the second half of the nineties the market could accelerate simply because the life time of aircraft bought in the late sixties will be near an end.

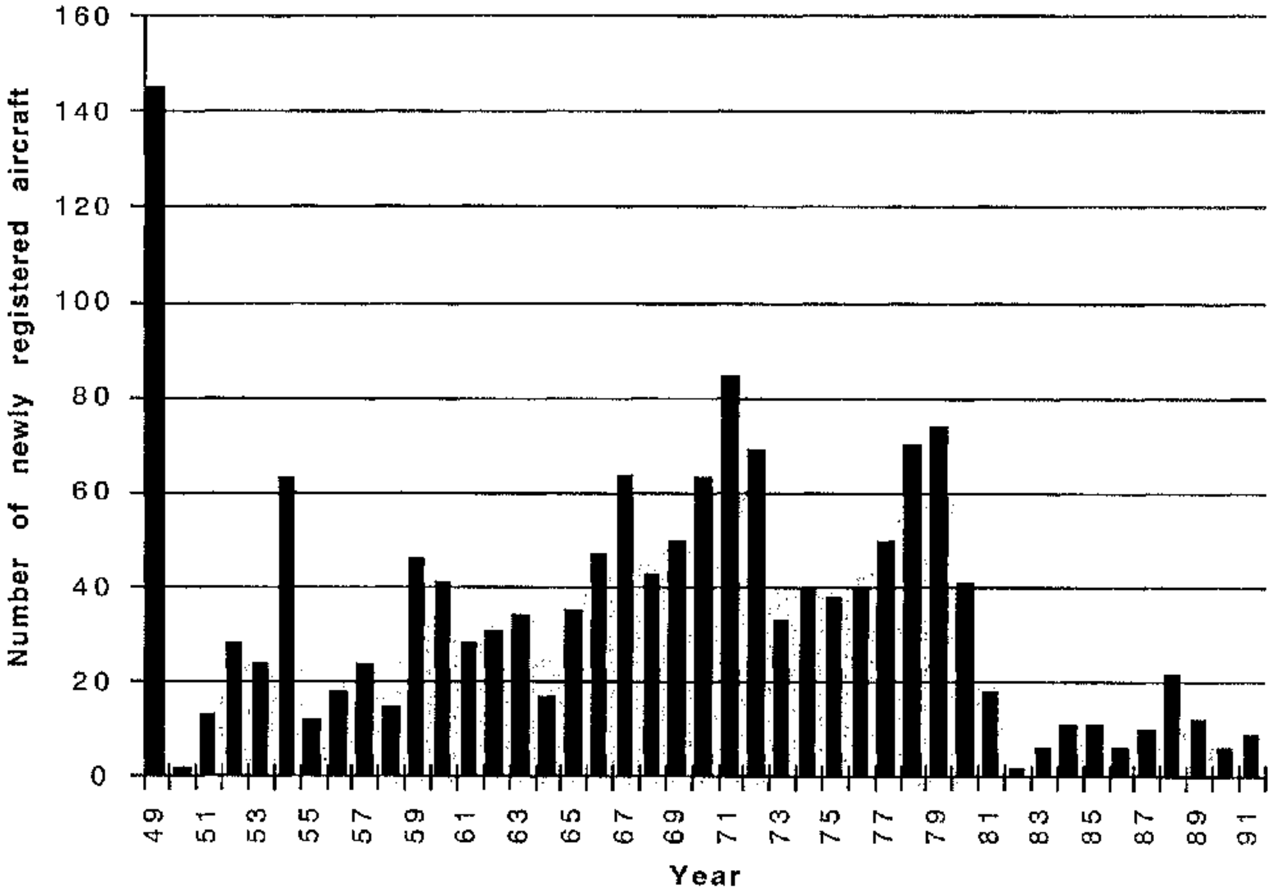



**Fig. 4.1:** Two Seater Aircraft Market in Germany.

An indication is that two seater aircraft pilots are now mostly flying ultra light aircraft, rather than FAR 23 certified aircraft in order to keep operational costs as low as possible.

Fig. 4.2 shows similar statistics for newly registered aircraft in the four seat category. In Germany, a rapid increase in sales can be seen again between 1968-82, when when the graph registers an approximate annual increase of fifty aircraft. In the second half of the nineties, there may be a high demand for aircraft to replace those bought in the late sixties.

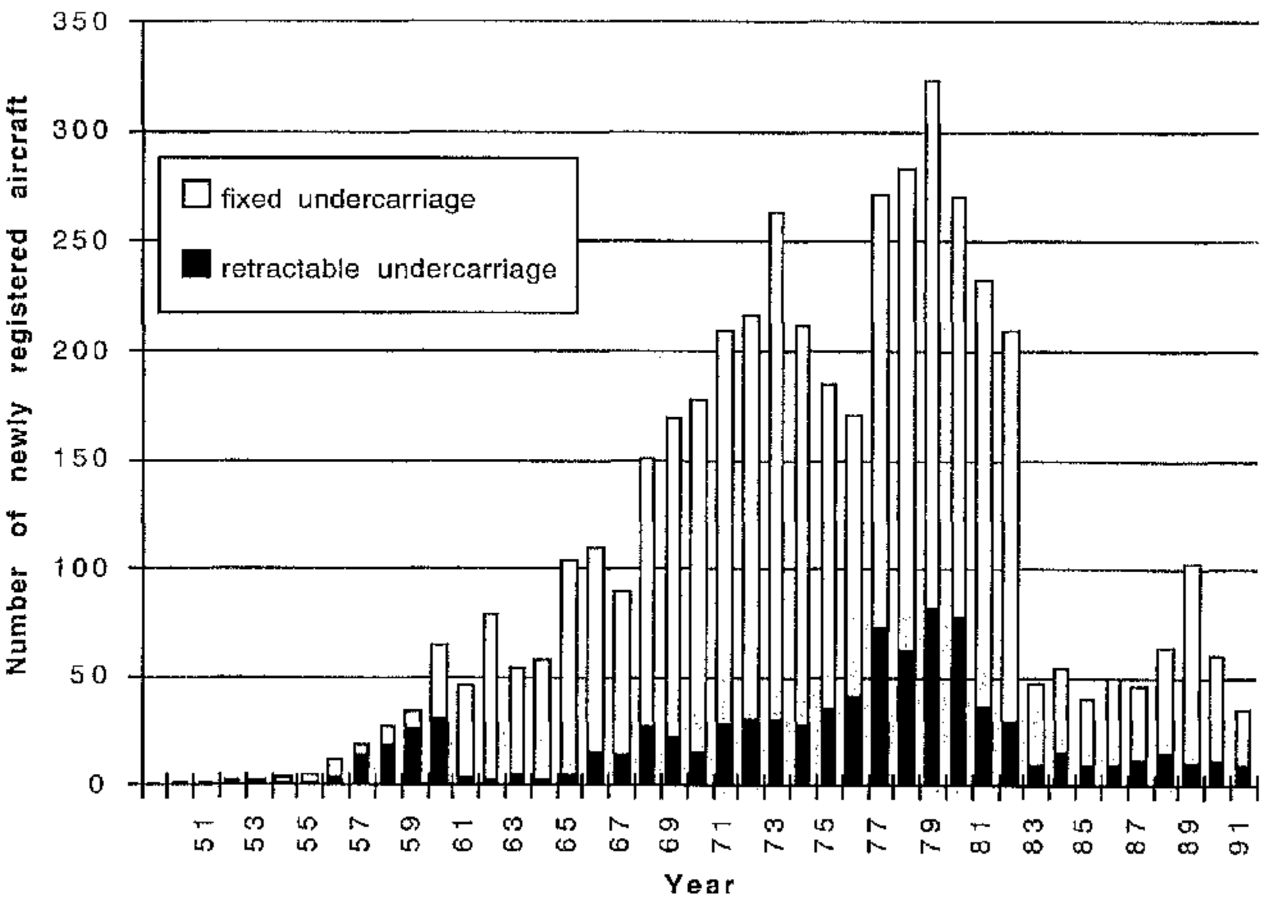



**Fig 4.2:** Four Seater Aircraft Market in Germany.

The combined Fig. 4.3 shows that, two seater aircraft currently represents approximately 30% of the general overall aviation aircraft market.

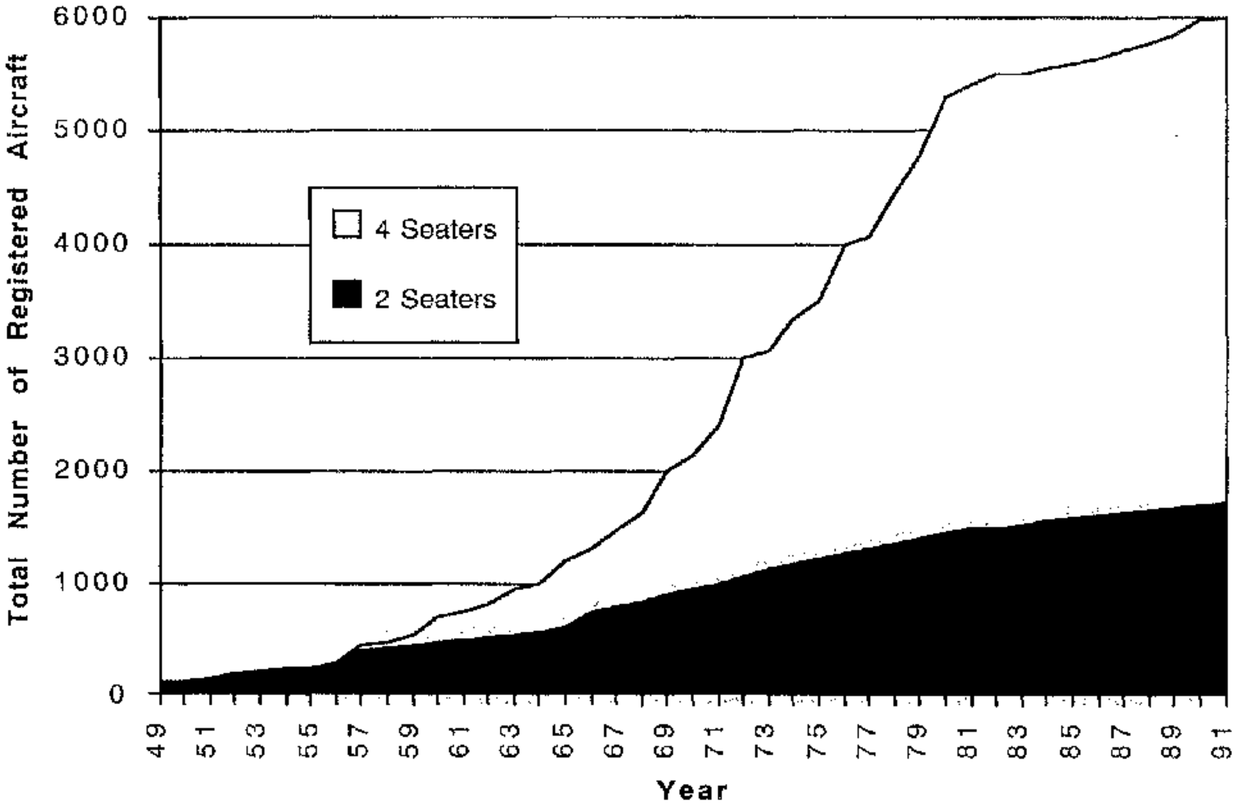



Fig 4.3: Combined Diagram of 2/4 Seater Market in Germany.

Environment Restrictions.

New noise regulations in Germany led to the introduction of a drastic restriction on light aircraft operations from small airports, particularly close to urban areas. Landing fees are differentiated according to the level of external noise the aircraft creates. This could contribute to an increase of aircraft sales when old aircraft have to be replaced to comply with new environmental airworthiness rules. On the other hand, for example, pilot training, because of the strict environment rules could be transferred to the countries with no environment restrictions for light aircraft operation. This could have an adverse affect on the light aircraft market.

Politics.

Germany is a leading member of the European Community. Future European political and economic unification may, on one hand, open up the light aircraft market, but, on the other hand. it may impose restrictions from non European Community countries in order to protect EU products.

A general observation of the German market suggests that there will not be a rapid increase in the demand of sport/utility aircraft in Germany over the next 5 years. The expected sale of two seater aircraft is 20-30 units a year and between 50-100 units of four seater aircraft a year.

Any new light aircraft must be designed to be economic at low levels of purchasing, and direct operating cost with reduced environmental contamination, (noise level and exhaust pollutants).

## 4.4 The World of General Aviation Aircraft

The general aviation industry is slowly emerging from the ravages of a prolonged structural recession. Long term survival in an industry which has traditionally traded in one of the world's most aggressive market places, will impose enormous demands upon everyone involved. Those general aviation manufacturers and operators who are clever enough to take advantage of emerging technologies, operational environment and develop highly skilled and motivated people will be best equipped to meet the global demand of the marketplace.

Today the general aviation industry is faced with many challenges: economic, political, technological and market requirements. Representing a significant and demanding sector of the global aerospace industry, the general aviation business has to recognise the need for radical and fundamental structural change if it is to capitalise on the new market opportunities. Such changes have to include reduction in excess manufacturing capacity through strategic alliance or joint venture and the adoption of loss reduction policies of the kind so successfully applied by the motor vehicle companies. The effects of the recession on the commercial aerospace industry has been devastating for aviation in general. Some companies have fared much worse than others. Some companies have ceased operation, while others have sheltered under the USA's Chapter 11 bankruptcy protection law. For example, Piper and Cessna aircraft only recently emerged from Chapter 11 coinciding with a renaissance of the US General-Aviation Business brought about largely by a watering down of product-liability legislation. Piper, one of the most famous names in aviation, is preparing to launch a derivative aircraft, upgrading certain models, and re-introducing others as part of an ambitious ten-year plan to build production up to 800 aircraft annually. These will include a four-seat primary trainer, four seat retractable gear aircraft, six seat pressurised single engine type and a six or eight seat twin-engine aircraft. Piper Aircraft will also begin development of a quiet, composite general aviation aircraft of the 21st century that will include cutting-edge technologies such as lightweight, compact and more powerful engines, flat panel displays and fly-by-wire or electronic controls.

Cessna Aircraft prediction for the year 1998 is to manufacture 2000 units annually of their models 172/185 and 206. The first Cessna 172 manufactured in ten years, flew in April 1996. The new pilot manufacturing programme is being used to streamline assembly techniques, train workers and rectify the type. Improvements in the new 172 include a fuel-injected 160HP lycoming 10-360 piston engine, new avionics and centre annunciator panel. It also is equipped with a dual vacuum system and improved seats with standard shoulder belt restraints. The aircraft's larger displacement 10-360 engine will operate at lower RPM than the conventionally aspired 160 HP lycoming 0-320 it replaces. This will increase reliability while reducing noise. In the UK general aviation is growing but many problems have arisen because aircraft movements have outstripped the capacity of aerodromes to accommodate them. According to Ref. [19] figures published by the CAA say that in 1979-80 UK registered light aircraft below 5700kg flew 655,000 hrs and in 1989-90 the figure was 1,223,000 which represents an increase of 87% in ten years. Almost 7,000 conventional general aviation aircraft are on the UK registrar. Looking to the manufacturing facts there are only two major general aviation aircraft manufacturers based in the UK, they are Slingsby, whose T67 Firefly was selected as the US Air Force's flight screener and Europa Aviation Ltd. Opportunity of using the T67 aircraft for civil purposes are slim because it is fully aerobatic and expensive unless there is a requirement for civil pilot students and commercial pilots being skilled in three-dimensional flying. For example, some airline companies want highly trained pilots because aircraft technology is getting more and more complex and they want to weed out, in the early stages of training, the candidates who are not going to make it.

Europa Aviation Ltd. has been successfully producing fibreglass made kit for home built light aircraft.

Production of the UK designed ARV Super 2 all aluminium two-seater was shifted to Sweden when it's manufacturer, Scottish Aviation Ltd. was made bankrupt.

Technical data of most existing two seater aircraft, still in operation world wide in 1995 [Ref. 21], can be found in Table 4.3. The representative of the four-seater general aviation aircraft in this dissertation is Cessna C172 which has sold nearly 40,000 copies world-wide. Technical data of the aircraft can be found in Table 4.4.

Set of Figures 4.5 - 4.10 shows the relationship of aircraft major parameters presented in Table 4.3.

Note that in the Figures the numbered points come from Table 4.3 and the asterisk represents the Cessna 172, the most used four seater aircraft for comparison and statistical analysis.

| No. | Aircraft | First Flight | Country | Structure | Span | Length |
|---|---|---|---|---|---|---|
| | | year | | | [m] | [m] |
| 1 | Robin ATL | 1983 | Fra | Wood/Comp | 10.25 | 6.72 |
| 2 | Lancair 320 | 1984 | USA | Comp | 7.16 | 6.4 |
| 3 | Gen. Avia F22 | 1989 | Italy | Alu | 8.5 | 7.3 |
| 4 | H-40 | 1988 | Ger | Comp | 10.84 | 6.99 |
| 5 | Grob G115A | 1985 | Ger | Comp | 10 | 7.36 |
| 6 | Gen. Avia F22/R | 1990 | Italy | Alu | 8.5 | 7.3 |
| 7 | Gen. Avia F220 | 1990 | Italy | Alu | 8.5 | 7.3 |
| 8 | Grob G115B | 1985 | Ger | Comp | 10 | 7.36 |
| 9 | D. Twyler SWISSTR | 1983 | Swiss | Alu | 10 | 7.1 |
| 10 | De Vore 100 Sunbird | 1986 | USA | Alu/Fibre | 9.75 | 7.11 |
| 11 | Champion 7ACA Champ | 1972 | USA | Steel/Fab | 10.71 | 6.64 |
| 12 | Partenavia P-86 Mosquito | 1985 | Italy | Alu Alloy | 10 | 6.77 |
| 13 | ARV Super 2 | 1985 | UK | Alu/Alloy | 8.69 | 5.49 |
| 14 | Nyge VLA-1 Sparrow | 1985 | Swe | Metal | 10.44 | 7.32 |
| 15 | MFI-14B | 1988 | Swe | Comp | 9 | 7.2 |
| 16 | Bolkow 208C Junior | 1962 | Ger | Metal | 8.02 | 5.79 |
| 17 | Partenavia P-59 Jolly | 1960 | Italy | Metal/Fab | 10.21 | 6.56 |
| 18 | Andreasson MFI-9 | 1961 | Swe | Metal | 7.43 | 5.85 |
| 19 | Pottier P 100TS | 1980 | Fra | Metal | 6.85 | 6.5 |
| 20 | Bede BD-4 | 1968 | USA | Metal | 7.77 | 6.67 |
| 21 | Cessna 152 | 1977 | USA | Alloy | 9.97 | 7.34 |
| 22 | Champion 7ECA Citabaria STD | 1964 | USA | Steel | 10.19 | 6.92 |
| 23 | Sao Carlos IPA1-26 Tuca | 1979 | Arg | Metal/G.fibre | 11 | 6.82 |
| 24 | Taylorcraft F-21 | 1980 | USA | Steel/Dacron | 10.97 | 6.78 |
| 25 | Bede BD-4 | 1968 | USA | Metal | 7.77 | 6.67 |
| 26 | Richard 150 Commuter | 1971 | USA | Metal | 9.14 | 6.02 |
| 27 | Partenavia P-66B Oscar 100 | 1975 | Italy | Steel/Alloy | 9.99 | 7.09 |
| 28 | Champion 7GCAA Citabaria | 1965 | USA | Steel | 10.19 | 6.91 |

**Table 4.3:** World wide two seater aircraft data.

| Aircraft | Wing Area | Height | Aspect Ratio | Wing Section |
|---|---|---|---|---|
| | [m2] | [m] | | |
| Robin ATL | 12.15 | 2 | 8.65 | NACA 43015 |
| Lancair 320 | 7.06 | 2.13 | 7.26 | NLF 0215F |
| Gen. Avia F22 | 10.82 | 2.84 | 6.7 | - |
| H-40 | 13.62 | 2.39 | 8.6 | FX 63-137 |
| Grob G115A | 12.21 | 2.75 | 8.19 | E 789 |
| Gen. Avia F22/R | 10.82 | 2.84 | 6.7 | - |
| Gen. Avia F220 | 10.82 | 2.84 | 6.7 | - |
| Grob G115B | 12.21 | 2.75 | 8.19 | E 789 |
| D. Twyler SWISSTR | 15 | 2.92 | 6.67 | NACA 64-15414 |
| De Vore 100 Sunbird | 12.29 | 2.49 | 7.74 | NACA 64-212 |
| Champion 7ACA Champ | 15.79 | 2.13 | - | NACA 4412 |
| Partenavia P-86 Mosquito | 12.5 | 1.93 | - | NACA 63A-416 |
| ARV Super 2 | 8.59 | 2.34 | - | NACA 2415 |
| Nyge VLA-1 Sparrow | - | 2.54 | - | - |
| MFI-14B | 10.5 | - | 7.71 | - |
| Bolkow 208C Junior | 9.38 | 1.98 | 6.9 | NACA 23009 |
| Partenavia P-59 Jolly | 15.17 | 2.13 | 6.9 | NACA 4412 |
| Andreasson MFI-9 | 8.7 | 2 | 6.09 | NACA 23009 |
| Pottier P 100TS | 9.25 | 2.2 | 5.2 | NACA 4415 |
| Bede BD-4 | 9.48 | 1.89 | 6.1 | NACA 64-415 |
| Cessna 152 | 14.59 | 2.59 | 6.7 | NACA 2412 |
| Champion 7ECA Citabaria STD | 15.33 | 2.35 | 6.72 | NACA 4412 |
| Sao Carlos IPA1-26 Tuca | 16.99 | - | 7.12 | NACA 23012 |
| Taylorcraft F-21 | 17.07 | 1.98 | 6.86 | NACA 23012 |
| Bede BD-4 | 9.48 | 1.89 | 6.1 | NACA 64-415 |
| Richard 150 Commuter | 11.1 | 1.69 | 7.5 | - |
| Partenavia P-66B Oscar 100 | 13.4 | 2.77 | 7.45 | NACA 63 SERIES |
| Champion 7GCAA Citabaria | 15.33 | 2.36 | 6.72 | NACA 4412 |

**Table 4.3 (cont).**

| Aircraft | Seats/ Cabin Width | OEW | MTOW | Useful Load |
|---|---|---|---|---|
| | [No.(cm)] | [kg] | [kg] | [kg] |
| Robin ATL | 2 | 360 | 580 | 220 |
| Lancair 320 | 2(108) | 465 | 763 | 298 |
| Gen. Avia F22 | 2 | 520 | 800 | 280 |
| H-40 | 2 | 570 | 850 | 280 |
| Grob G115A | 2 | 550 | 850 | 300 |
| Gen. Avia F22/R | 2 | 560 | 900 | 340 |
| Gen. Avia F220 | 2 | 620 | 900 | 280 |
| Grob G115B | 2 | 580 | 900 | 320 |
| D. Twyler SWISSTR | 2(112) | 633 | 920 | 287 |
| De Vore 100 Sunbird | 2(101) | 256 | 476 | 220 |
| Champion 7ACA Champ | 2 TAND | 340 | 553 | 213 |
| Partenavia P-86 Mosquito | 2(100) | 320 | 520 | 200 |
| ARV Super 2 | 2(99) | 280 | 499 | 219 |
| Nyge VLA-1 Sparrow | 2 TAND | 385 | 590 | 205 |
| MFI-14B | 2 | 615 | 900 | 285 |
| Bolkow 208C Junior | 2 | 380 | 630 | 250 |
| Partenavia P-59 Jolly | 2 | 520 | 750 | 230 |
| Andreasson MFI-9 | 2 | 340 | 575 | 235 |
| Pottier P 100TS | 2 | 435 | 680 | 245 |
| Bede BD-4 | 2(107) | 435 | 703 | 268 |
| Cessna 152 | 2 | 503 | 757 | 254 |
| Champion 7ECA Citabaria STD | 2 TAND | 484 | 748 | 264 |
| Sao Carlos IPA1-26 Tuca | 2 | - | 700 | - |
| Taylorcraft F-21 | 2 | 435 | 680 | 245 |
| Bede BD-4 | 2(107) | 458 | 816 | 358 |
| Richard 150 Commuter | 2 | 458 | 680 | 222 |
| Partenavia P-66B Oscar 100 | 2(106) | 560 | 820 | 260 |
| Champion 7GCAA Citabaria | 2 TAND | 508 | 748 | 240 |

**Table 4.3 (cont).**

| Aircraft | Wing Loading | Power Loading | Fuel | Fuel Location | Oil |
|---|---|---|---|---|---|
| | [kg/m2] | [kg/kW] | [ltr] | | [ltr] |
| Robin ATL | 47.7 | 12.1 | 42 | WING | - |
| Lancair 320 | 106 | 6.42 | 200 | WING | - |
| Gen. Avia F22 | 73.9 | 9 | 105 | - | - |
| H-40 | 62.4 | 7.3 | 100 | WING | - |
| Grob G115A | 69.6 | 8.83 | 100 | FUSE | - |
| Gen. Avia F22/R | 78.56 | 7.13 | 135 | - | - |
| Gen. Avia F220 | 97.2 | 7.72 | 245 | - | - |
| Grob G115B | 75.3 | 7.55 | 120 | WING | - |
| D. Twyler SWISSTR | 61 | - | 148 | WING | 7.6 |
| De Vore 100 Sunbird | 38.7 | 11.61 | 49 | FUSE | - |
| Champion 7ACA Champ | 35.1 | 12.54 | 50 | - | - |
| Partenavia P-86 Mosquito | 43.2 | 9.15 | 70 | WING | 2.5 |
| ARV Super 2 | 58.1 | 8.69 | 55 | FUSE | - |
| Nyge VLA-1 Sparrow | - | 9.9 | 49 | - | - |
| MFI-14B | 85.71 | 7.55 | 80 | - | - |
| Bolkow 208C Junior | 67.2 | - | 100 | FUSE | 4.7 |
| Partenavia P-59 Jolly | 49.5 | 10.22 | 100 | WING | 5 |
| Andreasson MFI-9 | 66.1 | 7.82 | 80 | FUSE | 4.5 |
| Pottier P 100TS | 73.5 | 9.13 | 90 | - | - |
| Bede BD-4 | 74.2 | 8.87 | 194 | WING | - |
| Cessna 152 | 51.9 | 9.23 | 98 | WING | 6.6 |
| Champion 7ECA Citabaria STD | 48.8 | 8.75 | 136 | WING | 5.8 |
| Sao Carlos IPA1-26 Tuca | 41.2 | 8.14 | - | - | - |
| Taylorcraft F-21 | 39.9 | 7.73 | 91 | FUSE/WING | 5.7 |
| Bede BD-4 | 86.1 | 7.25 | 194 | WING | - |
| Richard 150 Commuter | 61.3 | 6.18 | 189 | WING | - |
| Partenavia P-66B Oscar 100 | 61.2 | 9.7 | 108 | WING | - |
| Champion 7GCAA Citabaria | 48.8 | 6.68 | 136 | WING | 5.75 |

**Table 4.3 (cont).**

| Aircraft | Landing Gear | Power | | Engine |
|---|---|---|---|---|
| | [Type] | [HP] | [kW] | [Type] |
| Robin ATL | TRI | 65 | 48 | JPX 4760A |
| Lancair 320 | RETRACT | 160 | 119 | Lycoming I0-320 |
| Gen. Avia F22 | TRI | 116 | 87 | Lycoming 0-235 |
| H-40 | TRI | 116 | 87 | Lycoming 0-235 |
| Grob G115A | TRI | 100 | 87 | Lycoming 0-235 |
| Gen. Avia F22/R | RETRACT | 160 | 119 | Lycoming 0-320 |
| Gen. Avia F220 | RETRACT | 200 | 149 | Lycoming 0-360 |
| Grob G115B | TRI | 150 | 119 | Lycoming 0-320 |
| D. Twyler SWISSTR | TRI | 160 | 119 | Lycoming 0-320 |
| De Vore 100 Sunbird | TRI | 62 | 41 | Emdair CF-077A |
| Champion 7ACA Champ | TAIL | 60 | 44 | Franklin 2A-120-B |
| Partenavia P-86 Mosquito | TRI | 80 | 59 | KFM-112M |
| ARV Super 2 | TRI | 77 | 57 | Hewland AE 75 |
| Nyge VLA-1 Sparrow | TRI+TAILSKID | 80 | 60 | Duncan-Wankel SR-120R |
| MFI-14B | TRI | 160 | 119 | Lycoming O-235 |
| Bolkow 208C Junior | TRI | 100 | 74 | Rolls-Royce-Cont O-200 |
| Partenavia P-59 Jolly | TAIL | 100 | 74 | Continental O-200 |
| Andreasson MFI-9 | TRI | 100 | 74 | Continental O-200 |
| Pottier P 100TS | TRI | 100 | 75 | Continental |
| Bede BD-4 | TRI | 108 | 79 | Lycoming O-235-CI |
| Cessna 152 | TRI | 110 | 81 | Lycoming O-235-N2C |
| Champion 7ECA Citabaria STD | TAIL | 115 | 86 | Lycoming O-235-K2 |
| Sao Carlos IPA1-26 Tuca | TRI | 115 | 86 | Lycoming O-235-CI |
| Taylorcraft F-21 | TAIL | 118 | 88 | Lycoming O-235-L2C |
| Bede BD-4 | TRI | 150 | 110 | Lycoming O-320 |
| Richard 150 Commuter | TAIL | 150 | 110 | Lycoming O-320-A2A |
| Partenavia P-66B Oscar 100 | TRI | 115 | 110 | Lycoming O-235-CIB |
| Champion 7GCAA Citabaria | TAIL | 180 | 134 | Lycoming O-320-A2D |

**Table 4.3 (cont).**

| Aircraft | Prop | Rate of Climb | | Cruise | | Vmax | |
|---|---|---|---|---|---|---|---|
| | [Type] | [ft/min] | [m/s] | [kts] | [km/h] | [kts] | [km/h] |
| Robin ATL | Fixed Wood | 550 | 2.8 | 94 | 174 | 100 | 185 |
| Lancair 320 | Variable | 1650 | 8.4 | 200 | 370 | 226 | 418 |
| Gen. Avia F22 | Fixed Wood | 700 | 3.6 | 119 | 220 | 128 | 237 |
| H-40 | Var 3-bl | 700 | 3.6 | 113 | 209 | 150 | 278 |
| Grob G115A | Fixed | 690 | 3.5 | 111 | 206 | 129 | 238 |
| Gen. Avia F22/R | Const Speed | 1378 | 7 | 146 | 270 | 164 | 305 |
| Gen. Avia F220 | Const Speed | 1400 | 7.1 | 175 | 324 | 185 | 343 |
| Grob G115B | Variable | 1165 | 5.9 | 119 | 220 | 167 | 309 |
| D. Twyler SWISSTR | Fixed Wood | 1378 | 7 | 130 | 241 | 161 | 298 |
| De Vore 100 Sunbird | Fixed Push | 755 | 3.8 | 100 | 185 | 111 | 206 |
| Champion 7ACA Champ | Fixed | 460 | 2.3 | 75 | 139 | 79 | 146 |
| Partenavia P-86 Mosquito | Fixed | 770 | 3.9 | 86 | 159 | 97 | 180 |
| ARV Super 2 | Fixed | 800 | 4.1 | 96 | 178 | 109 | 202 |
| Nyge VLA-1 Sparrow | Pusher | 600 | 3 | 70 | 130 | - | - |
| MFI-14B | Var w/gfrp | 1100 | 5.6 | 113 | 209 | 124 | 230 |
| Bolkow 208C Junior | fixed | 785 | 4 | 111 | 206 | 124 | 230 |
| Partenavia P-59 Jolly | fixed | 655 | 3.3 | 97 | 180 | 106 | 196 |
| Andreasson MFI-9 | fixed | 885 | 4.5 | 127 | 235 | 130 | 240 |
| Pottier P 100TS | - | 1220 | 6.2 | 127 | 235 | 135 | 250 |
| Bede BD-4 | fixed | 900 | 4.6 | 126 | 233 | 135 | 250 |
| Cessna 152 | fixed | 715 | 3.6 | 107 | 198 | 110 | 202 |
| Champion 7ECA Citabaria STD | fixed | 725 | 3.7 | 107 | 198 | 140 | 259 |
| Sao Carlos IPA1-26 Tuca | - | - | - | 100 | 185 | 102 | 190 |
| Taylorcraft F-21 | fixed | 875 | 4.4 | 106 | 196 | 108 | 201 |
| Bede BD-4 | fixed | 1250 | 6.4 | 143 | 265 | 149 | 277 |
| Richard 150 Commuter | fixed | 1100 | 5.6 | 95.5 | 177 | 104 | 193 |
| Partenavia P-66B Oscar 100 | fixed | 728 | 3.7 | 102 | 189 | 166.5 | 308 |
| Champion 7GCAA Citabaria | fixed | 1120 | 5.7 | 112 | 207 | 140 | 259 |

**Table 4.3 (cont).**

| Aircraft | Range | Ceiling | Ground Run | T/off H=15m |
|---|---|---|---|---|
| | [km] | [m] | [m] | [m] |
| Robin ATL | 790 | 3960 | - | 420 |
| Lancair 320 | 2333 | 5485 | 214 | - |
| Gen. Avia F22 | 1102 | 4100 | 295 | - |
| H-40 | 680 | 4500 | - | 350 |
| Grob G115A | 540 | - | 210 | 410 |
| Gen. Avia F22/R | 1300 | 5650 | 200 | - |
| Gen. Avia F220 | 1853 | 5945 | 259 | - |
| Grob G115B | 755 | - | 200 | 390 |
| D. Twyler SWISSTR | 1090 | - | 108 | - |
| De Vore 100 Sunbird | 712 | - | 229 | 305 |
| Champion 7ACA Champ | 483 | - | 160 | 274 |
| Partenavia P-86 Mosquito | 630 | 3995 | 149 | 311 |
| ARV Super 2 | 685 | - | 143 | - |
| Nyge VLA-1 Sparrow | - | - | 152 | 305 |
| MFI-14B | - | - | 250 | - |
| Bolkow 208C Junior | 1000 | 4500 | 200 | 450 |
| Partenavia P-59 Jolly | 810 | 5000 | 210 | - |
| Andreasson MFI-9 | 800 | 4500 | 150 | - |
| Pottier P 100TS | 650 | - | 230 | - |
| Bede BD-4 | 1448 | - | 198 | 366 |
| Cessna 152 | 1158 | 4480 | 221 | 408 |
| Champion 7ECA Citabaria STD | 1154 | 3660 | 139 | 273 |
| Sao Carlos IPA1-26 Tuca | - | 3600 | 250 | - |
| Taylorcraft F-21 | 644 | 5485 | 84 | 107 |
| Bede BD-4 | 1448 | - | 198 | 366 |
| Richard 150 Commuter | - | - | - | - |
| Partenavia P-66B Oscar 100 | - | 4000 | 250 | - |
| Champion 7GCAA Citabaria | 810 | 5180 | 116 | 202 |

**Table 4.3 (cont).**

| Aircraft | Landing H=15m | Decel Stop | Vs (land) | Vs (cruise) |
|---|---|---|---|---|
| | [m] | [m] | [km/h] | [km/h] |
| Robin ATL | 380 | - | 75 | - |
| Lancair 320 | - | - | 102 | - |
| Gen. Avia F22 | 160 | - | 89 | - |
| H-40 | 250 | - | - | 85 |
| Grob G115A | - | - | 85 | - |
| Gen. Avia F22/R | - | 230 | 98 | - |
| Gen. Avia F220 | - | 244 | 106 | - |
| Grob G115B | - | - | 88 | - |
| D. Twyler SWISSTR | - | 130 | 85 | 104 |
| De Vore 100 Sunbird | 283 | - | 70 | 80 |
| Champion 7ACA Champ | - | - | 45 | - |
| Partenavia P-86 Mosquito | 120 | 120 | 67 | 76 |
| ARV Super 2 | - | - | 89 | 98 |
| Nyge VLA-1 Sparrow | 244 | 122 | 74 | - |
| MFI-14B | - | 250 | 84 | - |
| Bolkow 208C Junior | - | 240 | 90 | - |
| Partenavia P-59 Jolly | - | 110 | 65 | - |
| Andreasson MFI-9 | - | 130 | 80 | - |
| Pottier P 100TS | - | - | 80 | - |
| Bede BD-4 | - | 152 | 87 | 93.5 |
| Cessna 152 | 366 | 145 | 80 | 89 |
| Champion 7ECA Citabaria STD | 236 | 121 | 82 | - |
| Sao Carlos IPA1-26 Tuca | - | 250 | 76 | - |
| Taylorcraft F-21 | 107 | - | 70 | - |
| Bede BD-4 | - | 152 | 93.5 | 101.5 |
| Richard 150 Commuter | - | - | 87 | - |
| Partenavia P-66B Oscar 100 | - | 120 | 66 | 83 |
| Champion 7GCAA Citabaria | 230 | 121 | 82 | - |

**Table 4.3 (cont).**

| CESSNA C172 | | | |
|---|---|---|---|
| First Flight | | 1966 | |
| Country | | USA | |
| Structure | | Alu | |
| Span | m | 10.92 | |
| Length | m | 8.20 | |
| Wing area | $m^2$ | 16.3 | |
| Height | m | 2.68 | |
| Aspect Ratio | | 7.52 | |
| Wing Section | | NACA 2412 | |
| Seats | | 4 | |
| OEW | kg | 592 | |
| MTOW | kg | 1043 | |
| Useful Load | kg | 451 | |
| Wing Loading | $kg/m^2$ | 64.45 | |
| Power Loading | kg/hp kg/kW | 6.95 | 9.23 |
| Fuel | ltr | 159 | |
| Fuel Location | | Wing | |
| Oil | ltr | 7.5 | |
| Landing Gear | | Tri | |
| Power | hp/kW | 150/113 | |
| Engine | | Lyc. 0320-E2D | |
| Prop | | Fixed Met | |
| Rate of Climb | ft/min m/s | 645 | 3.3 |
| Cruise (max. H=2440m) | kts km/h | 117 | 217 |
| $V_{max}$ (NE) | kts km/h | 151 | 280 |
| Max. Range | m | 3050 | |
| Ceiling | m | 3995 | |
| T/O Ground Run | m | 264 | |
| T/O H = 15m | m | 465 | |
| Landing H = 15m | m | 381 | |
| Landing Ground Run | m | 158 | |
| $V_s$ (Flaps down) | km/h | 79 | |
| $V_s$ (Flaps up) | km/h | 92 | |

**Table 4.4:** CESSNA C172 four-seater aircraft data

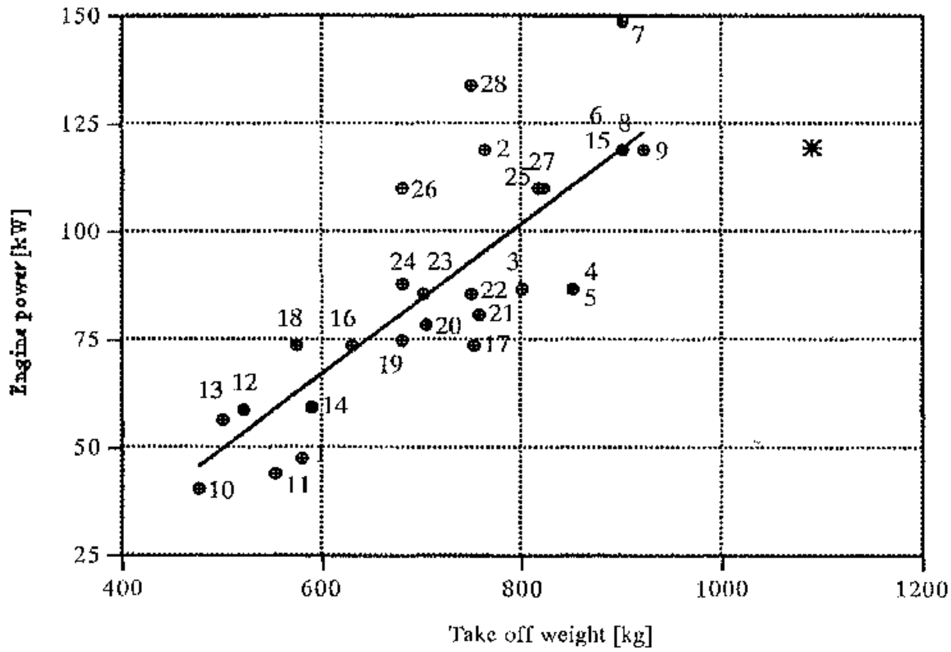



**Fig 4.4:** Engine Power and Take-Off Weight Relationship

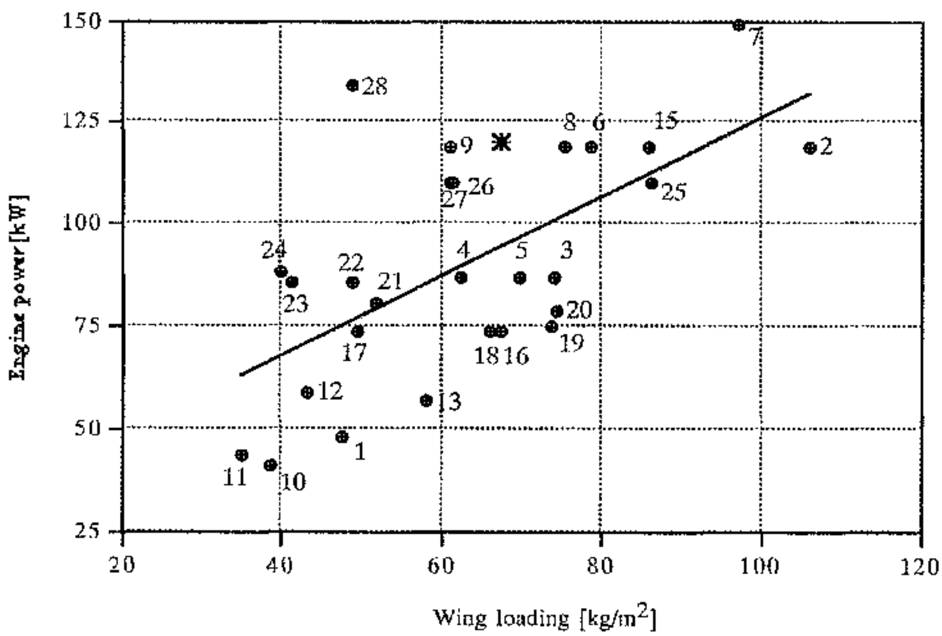



**Fig 4.5:** Engine Power and Wing Loading Relationship

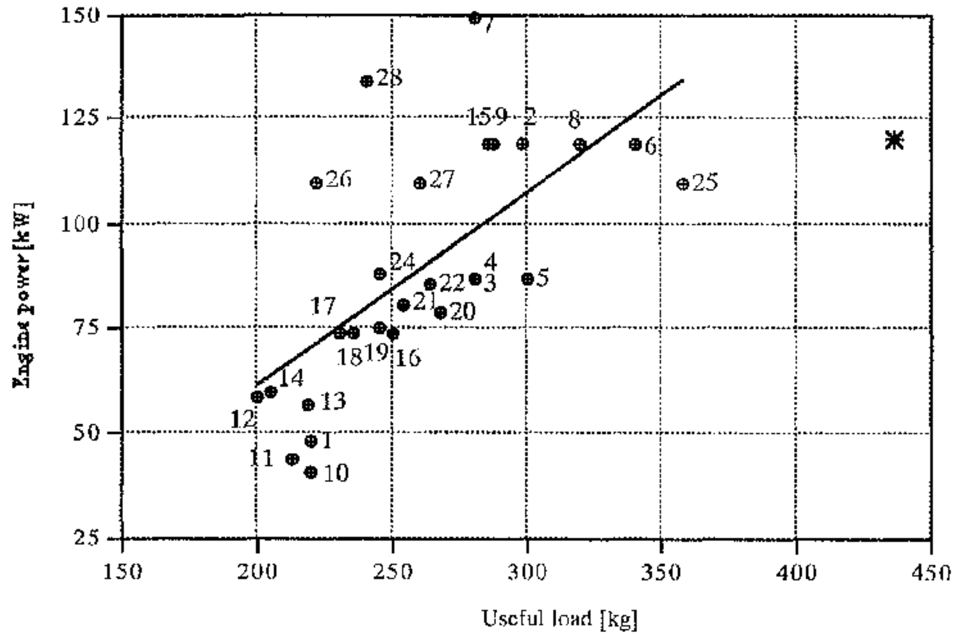



**Fig 4.6:** Engine Power and Useful Load Relationship

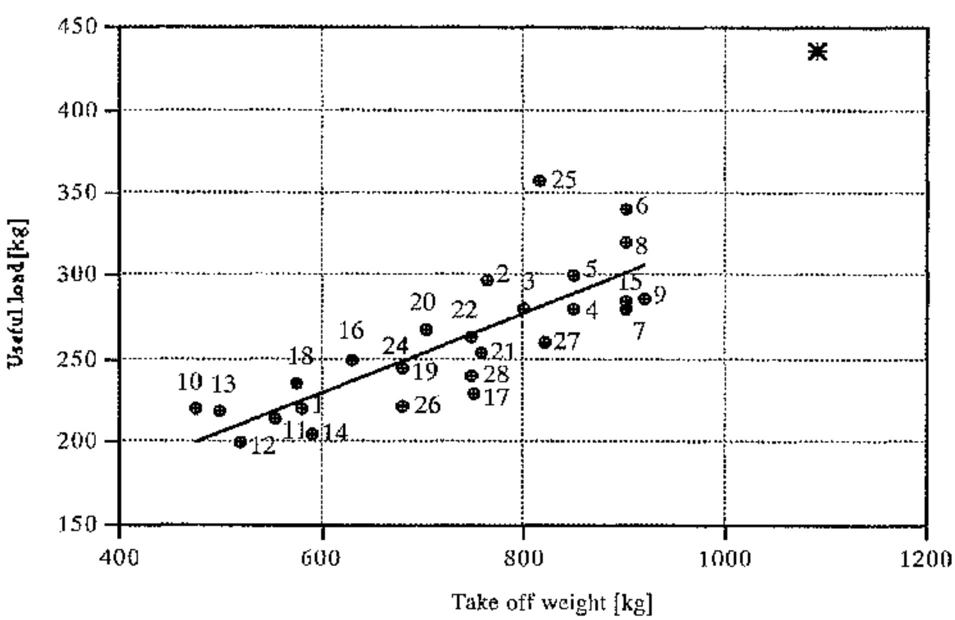



**Fig 4.7:** Useful Load and Take-Off Weight Relationship

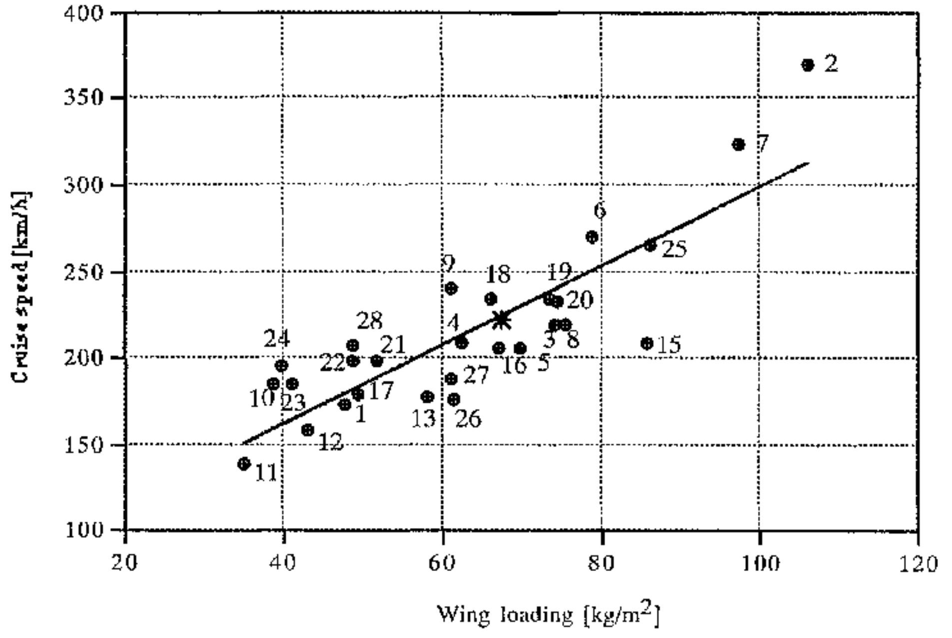



**Fig 4.8:** Cruising Speed and Wing Loading Relationship

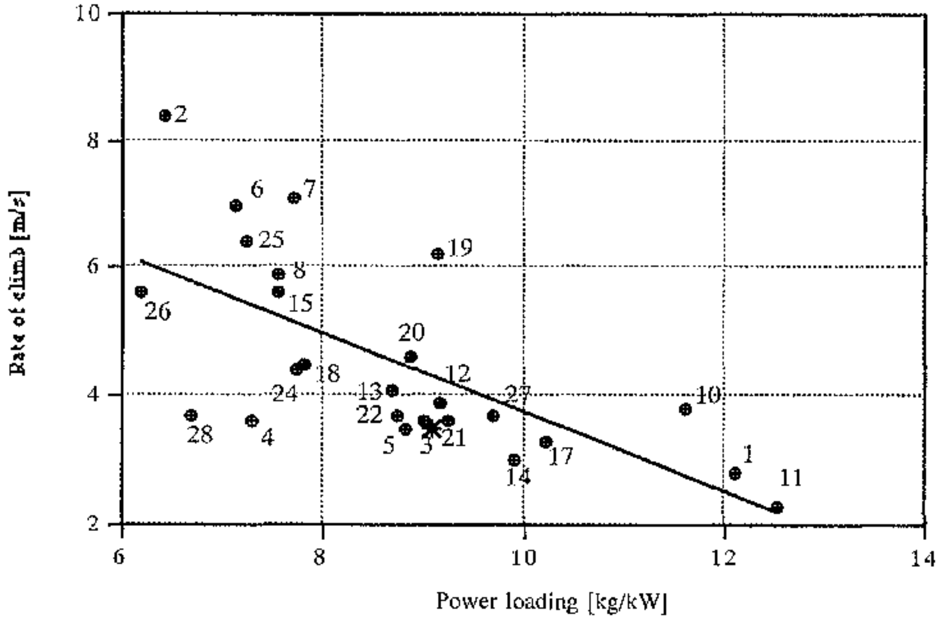



**Fig 4.9:** Rate of Climb and Power Loading Relationship

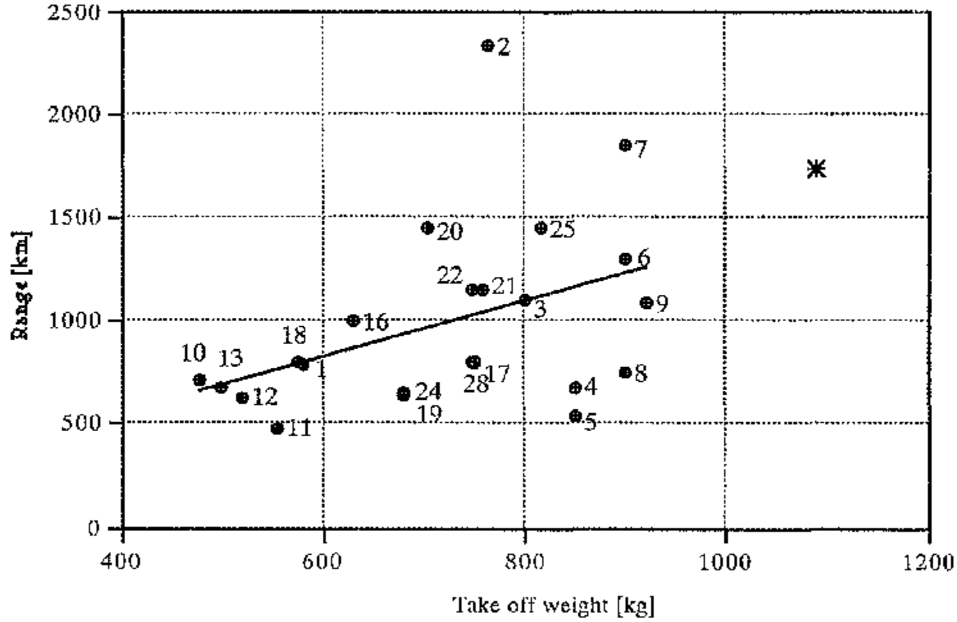



**Fig 4.10:** Range and Take-Off Weight Relationship

# CHAPTER 5

# DEVELOPMENT AND PRODUCTION COST

## 5.1 Introduction

The fundamental objective of all commercial enterprises is initial survival and subsequent financial equilibrium. These fundamental objectives require that after a certain period the enterprise should trade at a profit. The profit must be high enough to fund necessary expenditure which includes profit development, capital investment and payments of dividends. Enterprises involved in designing and manufacturing small aircraft need to work to such a small profit margin that they must ensure that every project will be commercially successful. The following chapter presents calculations by using generalised equations, Ref. [11], for estimating aircraft development and production costs.

The designer of aircraft must be aware of the extent of his/her influence over the cost of the aircraft, must assess the amount of energy it will use and must consider its likely pollution characteristics. The designer must recognise their obligation to design for: reduced life cycle cost, reduced energy consumption and reduced environmental contamination. Design consideration for reduced life cycle cost, (LCC), will be discussed in the following sections.

## 5.2 Features Of A Commercially Successful Project

A commercially successful project must meet four fundamental requirements. It must satisfy the requirements of the market; it must be available for the customer at right time and right price; it must have reliable product support. Sometimes, the right time, can also include exact delivery, which for example, could be that the product is to be delivered to the customer in May 2002.

Generally in the light aircraft market there are comparable products competing at the same time. This means that the customers have a choice and if their requirements can be met at the right time by more than one manufacturer, then price, available servicing and product support are critical. The price is what the customer pays for the aircraft, it is made up by the initial cost and the cost of ownership. These two aspects together make up the life cycle cost. An analysis of life cycle cost is shown in the following sections.

### First or Initial Cost and Cost of Ownership

First cost is the lump sum that the customer has to find to acquire the aircraft. In practice, the customer normally requires a financial package which allows a form of easy payments to cover the initial cost.

The first cost essentially depends on the specification of the aircraft and manufacturing costs. Neither of these are under the direct control of the customer, although they effectively influence the specifications by their choice of competing aircraft in the market place. The customer does influence the cost of manufacture by simply refusing to buy an aircraft if its manufacturing costs are higher than those of competing aircraft of similar specification. And so designers have to judge the specifications correctly to suit market demands and companies then have to produce the aircraft at a competitive cost.

The production costs of civil light aircraft can be grouped into three main categories, airframe, engine, systems and avionics. For example, in the case of the Zlin 143L aircraft, the airframe represents approximately 40% of the cost, engine 50%, and systems and avionics 10% of manufacturing costs.

In the Czech Republic the airframe is now becoming a large source of the production cost. Mainly due to increased labour cost, this element has steadily increased (in percentage terms) over the years. However, the airframe cost remains entirely within the control of the manufacturer.

As the cost of systems, and especially avionics is steadily growing, it follows that these costs will be subject to greater control in the future.

The propulsion unit represents a significant part of the aircraft's cost. Higher thrust or power levels cost more to buy and operate. Lower thrust and power gives poorer field and flight performance.

The cost of ownership (in some respects) depends on the aircraft specification and, probably to a large extent, on the way in which the aircraft is used. The factors affecting cost of ownership are numerous, and include the following:

- Flying rate and aircraft life
- Fuel and crew requirements and costs
- Aircraft and engine maintenance requirements and costs
- Cost of spares and spares provisioning policy
- Miscellaneous charges
- Others

The factors in this list which are within the control of the aircraft manufactuer are among the more critical features to be considered in the development of light aircraft. They are critical because they directly affect the cost of ownership which can typically be several times higher than the initial cost. And so the customer may be more concerned about the cost of ownership than about the initial cost.

The cost of ownership, then is becoming the most significant factor considered by the customer buying an aircraft.

Investment Recovery

The critical commercial feature of a project is the recovery of the launching investment. If this is not achieved, the project is a commercial failure, no matter what technical success levels it may have reached. Real profits are not achieved until the launch investment has been recovered. "Break even" is accomplished when investment recovery is complete.

Normally a selling price is established which will recover the investment at a break even point which is believed to be achievable. The fundamental profitability of the project depends then on the length of the production run beyond the break even point. The length of the production run is, therefore, the second critical factor.

The production run is affected by the following issues and situations:

a) Collaboration by manufacturers can bring the benefit of increasing the market opportunities as each partner will bring with it it's own market as well as it's own traditional export market. No project can make any significant progress until long-term financing has been arranged, and this process is usually considerably eased if the investment can be shared between two or more partners. The politics of establishing collaborative partnerships can be complicated, but once established, such partnerships usually provide greater political stability than single company/country projects. This better political stability can be an important help in arranging finance.

b) Exports are obviously important for the health of a project, but international prices are usually very competitive.

c) Costs may be reduced by what has been learned in the later part of the production run. This learning process may allow very competitive prices ultimately to be offered. This continued learning process is represented by the learning curve described in the following section.

The notion of a continued/continuing learning process depends, of course, on the level of awareness of design and production engineers. They must be aware in the first place of the priority to reduce production costs and as a result of this awareness be prepared to learn in the course of the production run.

## 5.3 The Life Cycle Cost Calculation Methodology

The life cycle cost of a project is made up of the "non-recurring" and "recurring" costs.

The non-recurring project investment costs include:

The cost of initial research.
The cost of design and development.
The cost of production investment.
The cost of production start-up.

These costs can be recovered by charging a levy on each aircraft sold, or by the customer paying directly, as in the case of MOD contracts, when the recurring cost is usually referred to as unit production cost.

The only way of recovering production costs directly is in the selling price. But in the Czech Republic the actual production costs have never been carefully monitored. Consequently, although the auhorities are concerned to establish prices that ensure profits, they do this on inadequate information. Significant improvement, in recent years, in observing production cost has been achieved.

When considering the cost of production, particular attention must be paid to the learning curve, typical examples of which are shown in Fig. 5.1. Aircraft cost is expressed in terms of production direct man hours and plotted on a log scale. The number of aircraft built is also plotted on a log scale. Direct man hours are initially high, but fall rapidly during the building of the early aircraft. As production progresses, the rate of learning declines and the slope of the curve reduces. It may become flat, i.e. learning ceases, at about 300 or 400 aircraft, if positive action is not taken to ensure that learning continues.

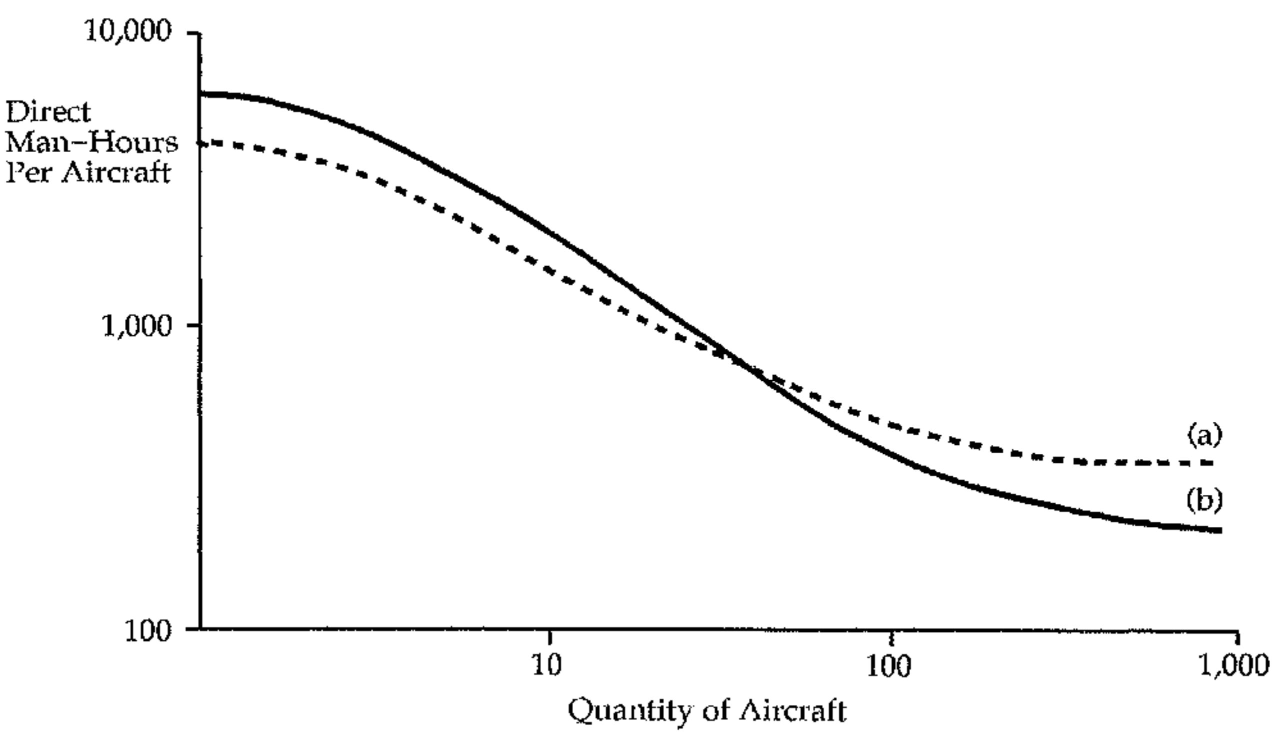



**Fig. 5.1:** Typical learning curves.

Factors which contribute to learning care as follows:

Project management.

Design changes.

Operator learning.

Tooling changes.

Manufacturing quality and control.

Manufacturing methods.

According to Ref. [12], there are two types of project management. The first type of project management is extensive-quantitative and the second is intensive-qualitative. The first was the type commonly adopted in former Eastern European countries. What it means is that the project starts almost immediately after the management approval. Investment needs and market research are worked out during the project. This normally brings a large number of unpredicted obstacles into the project, even if the aircraft prototype is manufactured relatively quickly. The typical learning curve is modified, and can be seen in Fig. 5.1(a).

Intensive-qualitative project management is different in the sense that the project begins with a long period of analysis and calculation, technical and economical, which is followed by immediate project realisation. This organisation usually delivers a high quality and reliable product which complies with airworthiness requirements and market needs. The learning curve, Fig. 5.1(b), is characterised by the relatively high man hours needed at the beginning of the project followed by a rapid reduction in man hours as the project progresses.

One of the designer's roles at the conceptual and early preliminary aircraft design stage is to minimise the aircraft life cycle cost, Fig. 5.2. Design consideration for reduced life cycle cost, for a new two seater aircraft, will be discussed in the following sections of this chapter. The method used for the life cycle cost analysis has been taken from Ref. [11], which was originally developed for use in the US, but proved to be accurate enough for cost predictions at the conceptual design stage of an aircraft, in the Czech Republic, Ref. [15].

The life cycle cost, Fig. 5.2, of an aircraft includes the following phases:

- Fundamental Research
- Development, Test, and Evaluation
- Acquisition (production, ground equipment, initial spare parts, training equipment, etc.)
- Aircraft operation and maintenance

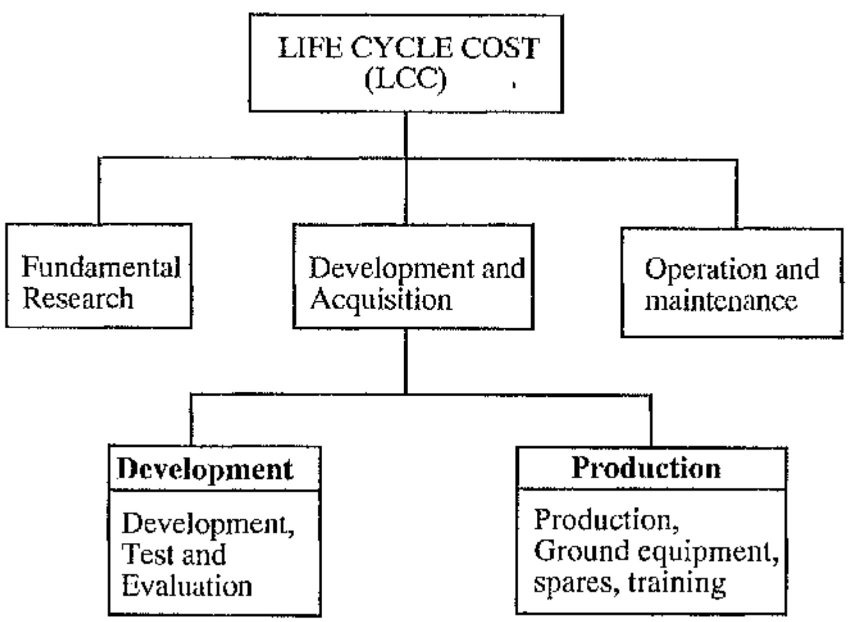



**Fig 5.2:** Life Cycle Cost Diagram

When an aircraft is at its preliminary design stage, the characteristics that affect estimates of the cost development and production, according to Ref. [11], are aircraft empty weight - (AMPR weight), maximum speed, the number of aircraft produced during its development and production stages and the monthly production rate. All other aircraft characteristics appear to be second order.

Direct labour hours to produce an item, such as engineering, assembly or tooling, will decrease as the cumulative number of aircraft produced (Q) increases, according to the learning curve. The basis for this is that the personnel involved in producing the item become skilled as they produce more and more aircraft. Previous Czech cost estimating relationship methodologies were based upon an 80% learning curve where the labour hours reduced by 20% every time the quantity produced, doubled. Thus, the second unit labour cost was 80% of that for the first unit, the fourth was 80% of the second, the eighth was 80% of the fourth and so on. When large quantities of the same item are produced, the rate of improvement with respect to time may be so small that it goes unnoticed. Positive actions have to be taken by company management to ensure learning still continues in the later parts of the production run.

Reference [11] examined the cost-quantity relationship and found it to vary for the different cost elements representing aircraft development and production. Thus, the cost estimating relationships presented in this dissertation will have different single values of the cost-quantity curve slope for each cost element. The learning curve is close to 80% in only a few of the cost elements.

In the following sections, life cycle cost, as described in Fig. 5.2, methodology for fundamental research, development, production, aircraft operation and maintenance will be discussed.

### 5.3.1 Fundamental Research Cost

The research phase involves fundamental research and advanced development research. This phase can include advanced material testing, computer modelling and also in some cases, technology demonstration aircraft as a test bed. The research phase can be expensive and it is also difficult to estimate its cost exactly, because of the inherent uncertainty in a research and development program.

The methodology for estimating the cost of the research phase depends largely upon the individual aircraft program. In the Czech Republic until recently fundamental research on light aircraft has only been practised in the Institute of Aerospace Engineering, (IAE), VUT Brno.

### 5.3.2 Development and Production Cost

a) Development

The development, test and evaluation cost means the engineering cost to develop, manufacture and flight test a number of prototype aircraft ($Q_D$), prior to full serial production. The usual number of flying prototype aircraft in the case of development of light aircraft is between one and four.

The cost elements representing aircraft development consists of:

- Airframe engineering.
- Support for development.
- Flight test operations.
- Flight test aircraft.

  a) Manufacturing labour
  b) Manufacturing materials and equipment
  c) Tooling
  d) Quality control
  c) Engines and avionics

- Testing facilities.
- Contracted work
- Profit.

b) Production

The production cost includes the cumulative cost of the number of production aircraft (QP), and associated ground equipment, such as starting devices and special equipment for maintenance and operation, initial spare parts and training aids such as simulators, manuals, etc.

The cost elements representing production are:

- Airframe engineering (sustaining).
- Manufacturing labour.
- Manufacturing material and equipment.
- Tooling.
- Quality control.
- Engines and avionics.

- Manufacturing facilities.
- Profit.

In the following paragraphs, individual cost elements representing aircraft development and production will be analysed.

<u>Airframe Engineering-Cost Methodology (Development and Production)</u>

Engineering hours not directly related to airframe design and development, such as flight test engineering, ground handling equipment design and development are not included in airframe engineering cost calculations. The engineering activities involved in development and production are assumed to be as follows, Ref. [11]:

- Design studies and integration.
- Engineering for wind tunnel models, mock-ups and engine tests.
- Test engineering, laboratory work on subsystems and static test items and development testing.
- Release and maintenance of drawings and specifications.
- Shop floor liaison.
- Analysis and incorporation of changes.
- Materials and technology specification.
- Reliability.

Cumulative total airframe engineering hours, (E), can be estimated by means of the following expression, according to Ref. [11]:

$$E = 0.396 . A^{0.791} . S^{1.526} . Q^{0.183} \tag{5.1}$$

Equation (5.1) gives the total engineering hours for either the development or the production phases. For development, the quantity (Q), is equal to the number of flight test aircraft ($Q_D$), and calculated engineering hours are just for the development phase. For the production phase, the quantity (Q) is equal to the total number of produced units ($Q_D + Q_P$). The production phase engineering (sustaining) hours are the hours calculated by using equation (5.1), minus development engineering hours. The resultant hours are multiplied by an appropriate engineering man hour rate. This rate should include engineering direct labour, overheads, general and administrative expenses as well as miscellaneous direct charges.

Support for Development-Cost Methodology (Development)

Support for development is conventionally defined as the non-recurring manufacturing activities undertaken in support of engineering during the development phase of an aircraft program. The cost of development support is the cost of manufacturing labour and material required to produce mock-ups, test parts, static test items, as well as other items of hardware that are needed for airframe design and development work. The level of this effort is largely dependent upon the extent of new technologies that are adopted into the aircraft program. For example, if the aircraft design involves new and untried concepts, then the support for development cost can be high.

According to Ref. [11], the support for development can be calculated using:

$$D = 0.008325 . A^{0.873} . S^{1.89} . Q_D^{0.346} \qquad (5.2)$$

Calculated support for development cost is in 1970 US$ and has to be multiplied by the corresponding economic inflation factor. The inflation factor curve, taken from Ref. [11], uses 1970 as a base and is shown in Fig. (5.3).

Flight Test Operation-Cost Methodology (Development)

Flight test operation cost, an element of total development cost, includes all costs incurred by the aircraft manufacturer in carrying out flight tests, except the cost of the flight test aircraft. It includes flight test engineering, planing and data reduction, manufacturing support, instrumentation, spares, fuel and oil, pilot's salary, rental of facilities and insurance. The flight test establishes the operating envelopes of the aircraft, its flying and handling qualities, general airworthiness, initial maintainability features, and compatibility with ground support equipment. Most importantly it establishes the aircraft's compliance with the civil aviation authority's requirements for airworthiness certification.

According to Ref. [11], the cost for flight test operations can be calculated using:

$$F = 0.001244 . A^{1.16} . S^{1.371} . Q_D^{1.281} \qquad (5.3)$$

Calculated flight test operation cost is in 1970 US$ and must be multiplied by the corresponding economic inflation factor, taken from Fig. (5.3).

Manufacturing Labour-Cost Methodology(Development and Production)

Manufacturing labour hours include those hours necessary to machine, process, fabricate and assemble the major aircraft AMPR weight structure, of an aircraft and to install purchased parts and sub-contract component assemblies and parts. Manufacturing labour hours also include labour hours on those parts which, because of their configuration or weight characteristics, are design-controlled for the basic aircraft. These normally represent a significant proportion of the airframe weight and manufacturing effort, and are included regardless of their method of acquisition. According to Ref. [11], such parts include actuating hydraulic cylinders, radomes, canopies, ducts, passenger and crew seats and fixed external fuel tanks.

The manufacturing labour hours can be estimated using the expression from Ref. [11]:

$$L = 28.984 . A^{0.74} . S^{0.543} . Q^{0.524} \qquad (5.4)$$

The manufacturing labour hours for development are determined separately from production manufacturing labour, using equation (5.4), as discussed previously. The manufacturing cost for development and production is obtained by multiplying the manufacturing labour hours by a representative hour rate.

Manufacturing Material and Equipment - Cost Methodology (Development and Production)

For development, as well as for production, material and equipment includes the raw materials, hardware, and purchased parts required for the fabrication and assembly of the airframe. All airframe equipment, except engines and avionics are included in this cost item. According to Ref. [11], special items in the material and equipment cost item are as follows:

- Raw materials in sheets, plates, bars, rods, etc.
- Raw castings and forgings.
- Wires, cables, fabrics, tubing's, windshield glass and canopies, etc.
- Fasteners, clamps, bushings, etc.
- Hydraulic and plumbing fittings, valves and fixtures.
- Standard electrical products such as motors, transformers, inverters, alternators, voltage regulators, switches, controls, generators, and APU's.
- Pumps - fuel, hydraulic, water, etc.
- Environmental systems, air conditioning and oxygen equipment.
- Crew furnishings, seats, interior materials, etc.

The manufacturing material and equipment cost can be estimated according to Ref. [11] from the expression :

$$M = 25.672 . A^{0.689} . S^{0.624} . Q^{0.792} \tag{5.5}$$

The calculated cost using the equation (5.5) is in 1970 US$ and must be multiplied by the corresponding economic inflation factor taken from Fig. [5.3] The cost for development and production is determined separately, as indicated in previous sections.

Tooling-Cost Methodology (Development and Production)

Tools are the jigs, fixtures, and special equipment used in the fabrication of an aircraft during development and production. Tooling hours are defined as the hours charged for tool design, tool planning, tool fabrication, production of test equipment, checkout of tools, maintenance of tooling, normal changes and production planning. Tooling hours are dependent upon production rate per month of aircraft. Tools designed for low production rates do not have to be as well designed and manufactured as tools for high production rates. Some tools may be destroyed during aircraft production and, therefore, have to be re-built specially for each aircraft. Tooling can be simple and cheap or extremely complicated and expensive.

According to Ref. [11], tooling hours can be calculated from:

$$T = 4.0127 . A^{0.764} . S^{0.899} . Q^{0.178} . R^{0.066} \qquad (5.6)$$

Equation (5.6) gives the total tooling hours for either development or production. For development tooling hours, the number of aircraft, Q, is $Q_D$. For the production phase, the number of aircraft, Q, is equal to the number of produced aircraft ($Q_D + Q_P$). Then tooling hours are the hours calculated by using equation (5.4), minus development tooling hours.

The total tooling cost is the tooling hours multiplied by an appropriate representative tooling hourly rate. This rate should include tooling direct labour, overheads, general and administrative expenses as well as miscellaneous direct charges.

Quality Control-Cost Methodology (Development and Production)

Quality control is the task of inspecting fabricated and purchased parts, sub-assemblies and assembled items against material and process standards, drawings and specifications. Quality control is an extremely important activity in the manufacture of an aircraft because of it's complexity.

Government specifications and standards require close inspection of all aspects of manufacture. Quality control is closely related to direct manufacturing labour and at the present time averages about 13% of the total manufacturing labour hours. The quality control hours can be estimated according to Ref. [11], as:

$$\textbf{Quality Control Man Hours} = \mathbf{0.13L} \qquad (5.7)$$

The cost for quality control is obtained by multiplying the man hours from equation (5.7), by the representative manufacturing hourly rate. This rate should include manufacturing direct labour, overheads, general and administrative expenses as well as miscellaneous direct charges.

The cost for development quality control is determined separately from that of production quality control cost, as explained in previous sections.

Engine and Avionics Cost (Development and Production)

It is assumed that costing for engine and avionics will be based on the selling price of their manufacturers.

Manufacturing Facilities Cost (Development and Production)

Under this section, the cost of all new facilities built for the purpose of manufacturing a new aircraft will be accounted for.

Profit (Development and Production)

Under this section company profit is accounted for.

### 5.3.3 Operation and Maintenance Cost

The operation and maintenance costs comprise fuel and oil costs including storage and delivery, salaries of operating and support personnel, day-to-day maintenance, overhaul, spares, depreciation of equipment and indirect costs.

Operations and maintenance cost calculation is based on a specific period of aircraft operation. Fleet size and the number of flying hours per year must be estimated. When aircraft operating characteristics are known, the average fuel flow per hour can be determined. The designer should obtain a representative fuel price and determine the operating fuel cost. The oil and lubricant costs are very small compared to the operating fuel cost and can be neglected in the operation cost calculation, in the preliminary stage of the aircraft design.

The direct maintenance personnel costs are best determined using the ratio of maintenance man hours to flying hours. This ratio varies with the type of aircraft, the utilisation rate (flying hours per period of time), and the years-in-service of the aircraft.
Increased utilisation rate usually reduces maintenance man hours per flying hour because, aircraft systems used daily, normally receive better upkeep, and experience less failures per flight hour. Also, aircraft that fly frequently are on the ground for smaller periods of time, and hence require maintenance to be carried out in a shorter period of time. Because of this pressure, maintenance is accomplished more efficiently and frequently by highly skilled personnel. Maintenance personnel are able to retain knowledge of failure and maintenance accomplished only the day before, thus there is helpful continuity between maintenance tasks.

The maintenance man hours per flying hour for a new aircraft are usually increased because maintenance personnel must learn about the characteristics of the new aircraft. It can take several years before maintenance technicians settle into an efficient routine. In the preliminary design stage of an aircraft, the operation and maintenance are estimated using the data from operational statistical analysis of similar aircraft.

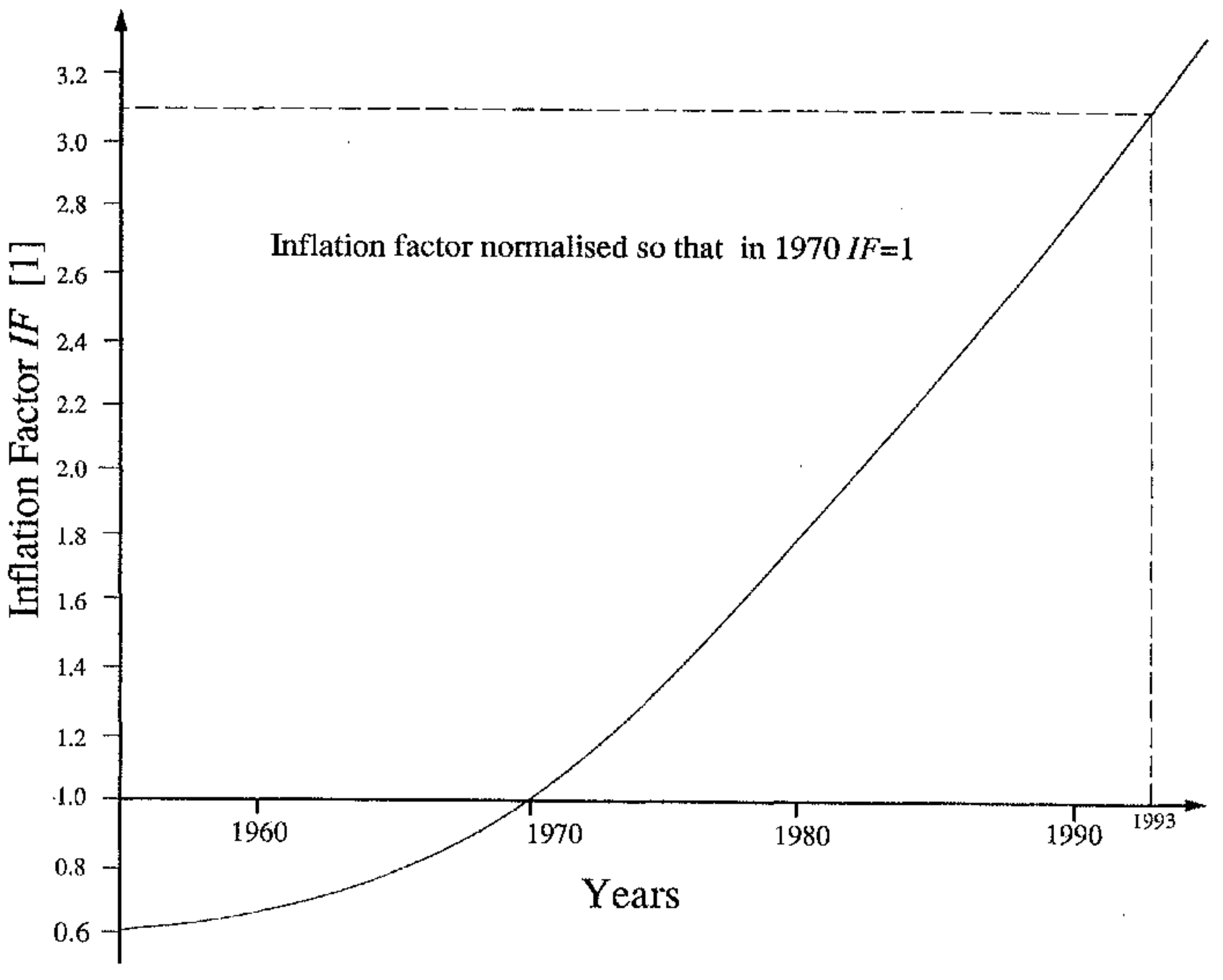



**Fig. 5.3:** US$ inflation curve.

## 5.4 Development And Production Cost Analysis

A project cost analysis of a new aircraft can be done either by calculation based on the company's own experience, or by a suitable theoretical method.

Aircraft development and production cost analysis presented in this section is based upon the methodology discussed in Chapter 3. In some cases the methodology has been modified to suit the Czech environment. The presented results must be considerd carefully, because economic and industrial relationships within the country change each year, together with cost of labour, material, equipment, level of inflation, exchange rate, etc. A peak in inflation and change in hourly labour rates in the Czech Republic was recorded in 1993, Ref. [16], since then prices have increased, at a steady but moderate rate. For this reason, the following development and production cost analysis of light two seater aircraft corresponds to 1993.

The results of the calculated costs have been rounded and are presented in two parts. The first part is the development cost and the second part is the production cost analysis. The results are shown in table and graph formats. For comparison purposes, the aircraft development cost calculation was done for the 1993 Czech and US economic environments.

Aircraft input data, Table 5.1, needed for cost analysis method, in imperial units, is derived through the conceptual design study in Chapter 6. 1993 Czech man hour rates were taken from Ref. [17], and typical US man hour rates, for the same year, were derived using Refs. [11, 14, 18].

| Parameter | Value | Unit |
|---|---|---|
| [A] AMPR weight (58% of empty weight) | 320 / 705 | kg / lb |
| [S] Maximum level speed at optimum altitude | 241 / 130 | km/h / knots |
| [Q] Cumulative quantity of aircraft produced | 500 Aircraft | |
| [$Q_D$] Number of prototype aircraft produced | 4<br>2 flying prototypes<br>2 for static/dynamic testing | |
| | | |
| 1993 Czech Man Hour Rates | | |
| [$E_h$] Engineering | CK 250/h | |
| [$T_h$] Tooling | CK 188/h | |
| [$M_h$] Manufacturing | CK 145/h | |
| | | |
| 1993 US Man Hour Rates | | |
| [$E_h$] Engineering | US$ 60/h | |
| [$T_h$] Tooling | US$ 45/h | |
| [$M_h$] Manufacturing | US$ 35/h | |
| In 1993, US$1 = 30 CK | | |

**Table 5.1:** Cost Analysis Input Data

### 5.4.1 Development Cost Analysis

1) Airframe Engineering (EH)

Number of Prototype Aircraft $Q_D = 4$

Number of Airframe Engineering hours was calculated using (Eq. 5.1)

$$E_D = 0.396 . A^{0.791} . S^{1.526} . Q_D^{0.183} \quad (5.8)$$

then,

$$E_D = EH = 15\,400 \text{ hrs}$$

According to Ref. [17], it would be advisable to increase airframe engineering hours in the Czech Republic by 5000 man hours for special engineering tasks related to aircraft future development.

Cost:

$E_D(CZ) = EH \, . \, E_h = (15400 + 5000) \, . \, 250 =$ CK 5 100 000

$E_D(US) = EH \, . \, E_h = 15400 \, . \, 60 =$ US$ 924 000

2) Support For Development (D)

Number of Flying Prototype Aircraft $Q_D = 2$

Cost of Support for Development in 1970 US$ was calculated using (Eq. 5.2)

$$D = 0.008325 . A^{0.873} . S^{1.89} . Q_D^{0.346} \quad (5.9)$$

then,

D = US$ 32 100

Taking inflation factor IF = 3.1 for the year 1993, (Fig. 5.3), then:

D(US) = US$ 99 500

According to Ref. [17], the number of hours needed for Development Support can be calculated on the assumption that 20% its of cost is represented by material, 40% of its cost is represented by engineering hours, and 40% of the cost goes into manufacturing hours. This assumption allows the theoretical cost, D = US$ 99 500 to be split into the following:

Material = US$ 19 900 (CK 597 000)
Engineering Hours (EH) = 660 hrs
Manufacturing Hours (MH) = 1140 hours

Cost:

$D(CZ) = EH \,.\, E_h + MH \,.\, M_h$ + cost of material
D(CZ) = 660 . 250 + 1140 . 145 + 19 900 . 30 = CK 927 300
D(US) = US$ 99 500

3) Flight Test Operation (F)

Number of Prototype Aircraft $Q_D = 2$

Cost of Flight Test in 1970 US$ was calculated using (Eq. 5.3)

$$F = 0.001244 \,.\, A^{1.16} \,.\, S^{1.371} \,.\, Q_D^{\;1.281} \qquad (5.10)$$

then,

F = US$ 4 800

Taking the inflation factor IF = 3.1 for the year 1993, (Fig. 5.3), then:

F(US) = US$ 14 900

According to Ref. [17] it could be assumed that 400 flying hours will be needed to complete the flight test program. In the Czech Republic, each flying hour then requires 20 engineering hours (EH), and 40 manufacturing hours (MH). Czech fuel price in 1993 was 10 CK/ltr and aircraft fuel consumption can be assumed to be 60 ltr/h.

Hence flight test operation in the Czech Republic will require:
Engineering hours (EH) = 400 . 20 = 8 000 hrs
Manufacturing hours (MH) = 400 . 40 = 16 000 hrs

Cost:

$D(CZ) = EH \cdot E_h + MH \cdot M_h$ + cost of fuel
D(CZ) = 8 000 . 250 + 16 000 . 145 + 400 . 60 . 10 = CK 4 560 000
D(US) = US$ 14 900

4) Manufacturing Labour (L)

Number of Prototype Aircraft $Q_D$ = 4

Number of Manufacturing Labour hours are calculated using (Eq. 5.4)

$$L_D = 28.984 \cdot A^{0.74} \cdot S^{0.543} \cdot Q_D^{0.524} \qquad (5.11)$$

then,

$L_D$ = MH = 108 000 hrs

Cost:

$L_D(CZ) = MH \cdot M_h = 108\ 000 \cdot 145 =$ CK 15 660 000

$L_D(US) = MH \cdot M_h = 108\ 000 \cdot 35 =$ US$ 3 780 000

5) Manufacturing Material and Equipment (M)

Number of Prototype Aircraft $Q_D = 4$

The Manufacturing and Equipment cost for 1970 is calculated using (Eq. 5.5)

$$M_D = 25.672 . A^{0.689} . S^{0.624} . Q_D^{0.792} \qquad (5.12)$$

then,

$M_D =$ US$ 147 193

Taking into account the inflation factor IF = 3.1 for 1993 (Fig. 5.3), then:

$M_D =$ US$ 456 300

The cost of material and equipment in the Czech Republic will be similar to the US cost in 1993.

Cost:

$M_D(CZ) = M_D.30 = 456\ 300 \cdot 30 =$ CK 13 689 000

$M_D(US) =$ US$ 456 300

6) Tooling (T)

Number of Prototype Aircraft $Q_D$ = 4 with production rate $R_D$ = 0.2 (according to Ref. [17], it can be assumed that prototype airframe production will take 5 months)

Number of Tooling hours is calculated using (Eq. 5.6)

$$T_D = 4.0127 . A^{0.764} . S^{0.899} . Q_D^{0.178} . R_D^{0.066} \qquad (5.13)$$

then,

$T_D$ = TH = 55 000 hrs

According to Ref. [17], from the total number of tooling hours, $T_D$, in aircraft development phase, in the Czech Republic 20% is represented by engineering hours (EH), and 80% by tooling hours (TH)

then,

EH = 11 000 hrs

TH = 44 000 hrs

Cost:

T(CZ) = EH . $E_h$ + TH . $T_h$ = 11 000.250 + 44 000.188 = CK 110 022 000

T(US) = TH . $T_h$ = 55 000 . 45 = US$ 2 475 000

7) Quality Control (QC)

Number of Quality Control hours are calculated using (Eq. 5.7)

$QC_D = 0.13 . L_D$

$QC_D$ = 0.13 . 108 000 = 14 000 hrs

According to Ref. [17], the total quality control hours, $QC_D$, in the Czech Republic are represented by, 20% engineering hours (EH), and 80% manufacturing hours (MH)

then,

EH = 2 800 hrs

MH = 11 200 hrs

Cost:

$QC(CZ) = EH \,.\, E_h + MH \,.\, M_h$ = 2 800. 250 + 11 200. 145 = CK 2 324 000

$QC(US) = QC_D \,.\, M_h$ = 14 000 . 35 = US$ 490 000

8) Engines and Avionics (MA)

For two flying prototypes, engine, propeller and avionics will be supplied by their US manufacturers at the usual selling price (MA).

1993 Estimated Prices:

| | | |
|---|---|---|
| Engine | 2 x US$ 25 500 = | US$ 51 000 |
| Propeller | 2 x US$ 3 000 = | US$ 6 000 |
| Avionics | 2 x US$ 16 500 = | US$ 33 000 |
| | MA = | US$ 90 000 |

Cost:

MA(CZ) = MA. 30 = CK 2 700 000

MA(US) = US$ 90 000

9) Manufacturing Facilities

It is assumed that there is no cost for new manufacturing facilities needed for aircraft development testing and evaluation activities.

10) Contracted Work

Except for the calculated development cost above, it will be necessary in the Czech Republic, to account for special contract work costs, which could, for example, include special dynamic tests of cabin seats, fatigue tests of primary structures, undercarriage tests, wheel and brake tests, etc. According to Ref. [17], assumed cost for contract work for light aircraft development in the Czech Republic will be 20 million CK. This can be split, so that 20% is reserved for materials and 80% for labour.

11) Profit

No financial profit on aircraft development, testing and evaluation activities.

The results of development cost of light two seater aircraft are summarised in Table 5.2.

| | |
|---|---|
| Aircraft empty weight | 520kg (1146lb) |
| Aircraft AMPR wieght | 320kg (705lb) |
| Typical cruising speed | 241km/h (130kts) |
| Total number of prototypes | 4 |

(two flying prototypes and two for static and dynamic testing)

Prototype airframe production time is five months. Ref. [17].

| Man Hour Rates | CZ | | US |
|---|---|---|---|
| 1993 | CK | US$ | US$ |
| Engineering | 250 | 8.3 | 60 |
| Tooling | 188 | 6.3 | 45 |
| Manufacturing | 145 | 4.8 | 35 |

| AIRCRAFT DEVELOPMENT COST 1993 | Man Hours [1000hrs] | | | Cost [1000's] CK | | | US$ |
|---|---|---|---|---|---|---|---|
| | Design Engineering (CZ) | Tooling (CZ) | Production (CZ) | Labour (CZ) | Material (CZ) | Totals (CZ) | Totals for comparrison (US) |
| E-Airframe Engineering | 20.40 | - | - | 5100.0 | - | 5100.0 | 924.0 |
| D-Support for Development | 0.66 | - | 1.14 | 330.3 | 597.0 | 927.5 | 99.5 |
| F-Flight Test Operations | 8.00 | - | 16.00 | 4320.0 | 240.0 | 4560.0 | 14.9 |
| L-Manufacturing Labour | - | - | 108.00 | 15660.0 | - | 15660.0 | 3780.0 |
| M-Manufacturing Material | - | - | - | - | 13689.0 | 13689.0 | 456.3 |
| T-Tooling | 11.00 | 44.00 | - | 11002.2 | - | 11002.2 | 2475.0 |
| Q/C-Quality Control | 2.80 | - | 11.20 | 2324.0 | - | 2324.0 | 490.0 |
| M/A-Engine and Avionics | - | - | - | - | - | 2700.0 | 90.0 |
| Contract Work | - | - | - | 16000.0 | 4000.0 | 20000.0 | - |
| Manufacturing Facilities | - | - | - | - | - | - | - |
| Profit | - | - | - | - | - | - | - |
| Total: | 42.86 | 44.00 | 136.34 | 54736.5 | 18526.0 | 75962.7 | 8329.7 |

**Table 5.2:** Aircraft Development Cost (1993).

### 5.4.2 Production Cost Analysis

Production cost analysis is based on the assumption that the total cumulative quantity of aircraft produced is five hundred, (Qp = 500).

1) Airframe Engineering (E)

Accumulated airframe engineering hours ($E_P$) were calculated using (Eq. 5.1) minus the development engineering hours, $E_D$.

$$E_P = EH = 0.396 . A^{0.791} . S^{1.526} . Q_P^{0.183} - E_D \tag{5.14}$$

then,

| QP | | 50 | 100 | 200 | 300 | 400 | 500 |
|---|---|---|---|---|---|---|---|
| EP = EH | hrs | 24400 | 27700 | 31500 | 33900 | 35700 | 37200 |
| EP/QP | hrs | 488 | 277 | 158 | 113 | 89 | 74 |
| Cost CK 1000's | | | | | | | |
| EH . Eh | | 6100 | 6925 | 7875 | 8475 | 8925 | 9300 |
| (EH . Eh)/QP | | 122.0 | 69.3 | 39.4 | 28.3 | 22.3 | 18.6 |

2) Manufacturing Labour (L)

Manufacturing labour hours ($L_P$) were calculated using (Eq. 5.4) minus the development manufacturing hours, $L_D$.

$$L_P = MH = 0.008325 . A^{0.873} . S^{1.89} . Q_P^{0.346} - L_D \tag{5.15}$$

then,

| QP | | 50 | 100 | 200 | 300 | 400 | 500 |
|---|---|---|---|---|---|---|---|
| LP = MH | 1000 hrs | 292.8 | 467.4 | 720.0 | 913.7 | 1080.0 | 1227.0 |
| LP/QP | 1000 hrs | 5.9 | 4.7 | 3.6 | 3.0 | 2.7 | 2.5 |
| Cost CK million's | | | | | | | |
| MH . Mh | | 42.46 | 67.77 | 104.4 | 132.49 | 156.6 | 177.92 |
| (MH . Mh)/QP | | 849.1 | 677.7 | 522.0 | 441.6 | 391.5 | 355.8 |

3) Manufacturing Material and Equipment (M)

Accumulated manufacturing material and equipment cost ($M_P$) was calculated using (Eq. 5.5) minus the development material and equipment cost, $M_D$.

$$M_P = 25.672 . A^{0.689} . S^{0.624} . Q_P^{0.792} - M_D \quad (5.16)$$

then,

| $Q_P$ | 50 | 100 | 200 | 300 | 400 | 500 |
|---|---|---|---|---|---|---|
| Cost US$ 1000's | | | | | | |
| $M_P$ | 2900 | 5400 | 9700 | 13500 | 17100 | 20400 |
| Cost CK million's | | | | | | |
| $M_P$ | 87.0 | 162.0 | 291.0 | 405.0 | 513.0 | 612.0 |

In the Czech Republic accumulative manufacturing material and equipment cost of aircraft, will be CK 400 000 per unit, (Ref. [17]). Because this is significantly lower than the cost calculated theoretically, and is in fact most probable, it was decided in this dissertation to use the lower material and equipment cost which corresponds better to the Czech environment.

4) Tooling (T)

Accumulated tooling hours ($T_P$) were calculated using (Eq. 5.6) minus the development tooling hours, $T_D$.

Production Rate, $R_P$, is assumed to be equal to 8 aircraft per month, Ref. [17]

$$T_P = T = 4.0127 \cdot A^{0.764} \cdot S^{0.899} \cdot Q^{0.178} \cdot R_P^{0.066} - T_D \qquad (5.17)$$

If, according to Ref. [17], 20% of the total $T_P$ are engineering hours (EH), and 80% are tooling hours, (TH), then:

| Qp | | 50 | 100 | 200 | 300 | 400 | 500 |
|---|---|---|---|---|---|---|---|
| Tp | hrs | 56600 | 70400 | 86400 | 96800 | 104700 | 111100 |
| EH | hrs | 11320 | 14080 | 17280 | 19360 | 20940 | 22220 |
| TH | hrs | 45280 | 56320 | 69120 | 77440 | 83760 | 88880 |
| Tp/Qp | hrs | 1132 | 704 | 432 | 333 | 262 | 222 |
| Cost CK 1000's | | | | | | | |
| $EH.E_h+TH.T_h$ | | 11343 | 14108 | 17315 | 19399 | 20982 | 22264 |
| $\frac{EH.E_h + TH.T_h}{Q_P}$ | | 226.9 | 141.1 | 86.6 | 64.6 | 52.45 | 44.5 |

5) Quality Control (QC)

Accumulated quality control hours ($QC_P$) were calculated using (Eq. 5.7).

$QC_P = 0.13L_P$

According to Ref. [17], in the Czech Republic, 20% of the total $QC_P$ are engineering hours (EH), and 80% are manufacturing hours (MH), then:

| $Q_P$ | | 50 | 100 | 200 | 300 | 400 | 500 |
|---|---|---|---|---|---|---|---|
| $QC_P$ | hrs | 38700 | 61800 | 94800 | 120800 | 142700 | 162200 |
| EH | hrs | 7740 | 12360 | 18960 | 24160 | 28540 | 32440 |
| MH | hrs | 30960 | 49440 | 76340 | 96640 | 114160 | 129760 |
| $QC_P/Q_P$ | hrs | 774 | 618 | 474 | 403 | 357 | 324 |
| Cost CK 1000's | | | | | | | |
| $EH.E_h+MH.M_h$ | | 6424 | 10259 | 15809 | 20053 | 23688 | 26915 |
| $\frac{EH.E_h+MH.M_h}{Q_P}$ | | 128.5 | 102.6 | 79.0 | 66.9 | 59.22 | 53.8 |

6) Engine and Avionics (M/A)

In the development cost analysis section it was assumed that engine and avionics cost for one aircraft was CK135000. For serial production aircraft the cost of engine and avionics per unit is assumed to be 25% lower.

MA = CK 100 000 per aircraft

then, MA cost for $Q_P$ number of aircraft is:

| $Q_P$ | 50 | 100 | 200 | 300 | 400 | 500 |
|---|---|---|---|---|---|---|
| Cost CK million's | | | | | | |
| MA | 50.0 | 100.0 | 200.0 | 300.0 | 400.0 | 500.0 |

7) Manufacturing Facilities

Figures assume zero cost for the new manufacturing facilities needed for aircraft production.

8) Profit

The calculated production cost of light four seater aircraft as summarised in Table 5.3, are shown at zero profit.

Profit magnitude will depend on aircraft selling price and examples can be seen in Fig. 5.4.

### 5.4.3 Break Even Point

According to Ref. [17], development of light two seater aircraft in the Czech Republic to full certification of airworthiness will take on average 3.5 years. Total aircraft development cost calculated in section 5.4.1, is assumed to be divided linearly over the first 200 aircraft produced. Then this divided development cost is added to the production cost curve, Fig. 5.4 and Fig. 5.5. The break even point depends on the aircraft selling price and the monthly production rate, also shown in Figs. 5.4, 5.5.

| | |
|---|---|
| Aircraft empty weight | 520kg (1146lb) |
| Aircraft AMPR weight | 320kg (705lb) |
| Typical cruising speed | 241km/h (130kts) |
| Total number of Aircraft Produced | $Q_P = 500$ |

| Cost CK million's | | | | | | |
|---|---|---|---|---|---|---|
| Qp | 50 | 100 | 200 | 300 | 400 | 500 |
| E-Airframe Engineering | 6.10 | 6.93 | 7.88 | 8.48 | 8.93 | 9.30 |
| L-Manufacturing Labour | 42.46 | 67.77 | 104.40 | 132.49 | 156.60 | 177.92 |
| M-Manufacturing Material | 20.00 | 40.00 | 80.00 | 120.00 | 160.00 | 200.00 |
| T-Tooling | 11.34 | 14.11 | 17.32 | 19.40 | 20.98 | 22.26 |
| Q/C-Quality Control | 6.42 | 10.26 | 15.81 | 20.05 | 23.69 | 26.92 |
| M/A-Engine and Avionics | 50.00 | 100.00 | 200.00 | 300.00 | 400.00 | 500.00 |
| Manufacturing Facilities | - | - | - | - | - | - |
| Profit | - | - | - | - | - | - |
| Total: | 136.30 | 239.10 | 425.40 | 600.00 | 770.20 | 936.40 |
| Total / Aircraft: | 2.70 | 2.39 | 2.13 | 2.00 | 1.92 | 1.87 |

| TOTAL AIRCRAFT PRODUCTION COST 1993, Qp = 500 | Man Hours [1000hrs] | | | Cost million's CK | | |
|---|---|---|---|---|---|---|
| | Design Engineering (CZ) | Tooling (CZ) | Production (CZ) | Labour (CZ) | Material (CZ) | Totals (CZ) |
| E-Airframe Engineering | 37.20 | - | - | 9.30 | - | 9.30 |
| L-Manufacturing Labour | - | - | 1227.00 | 177.90 | - | 177.90 |
| M-Manufacturing Material | - | - | - | - | 200.00 | 200.00 |
| T-Tooling | 22.20 | 88.90 | - | 22.30 | - | 22.30 |
| Q/C-Quality Control | 32.40 | - | 129.80 | 26.90 | - | 26.90 |
| M/A-Engine and Avionics | - | - | - | - | - | 500.00 |
| Contract Work | - | - | - | - | - | - |
| Manufacturing Facilities | - | - | - | - | - | - |
| Total: | 91.80 | 88.90 | 1356.80 | 436.40 | 200.00 | 936.40 |

**Table 5.3:** Production cost for Qp number of aircraft produced

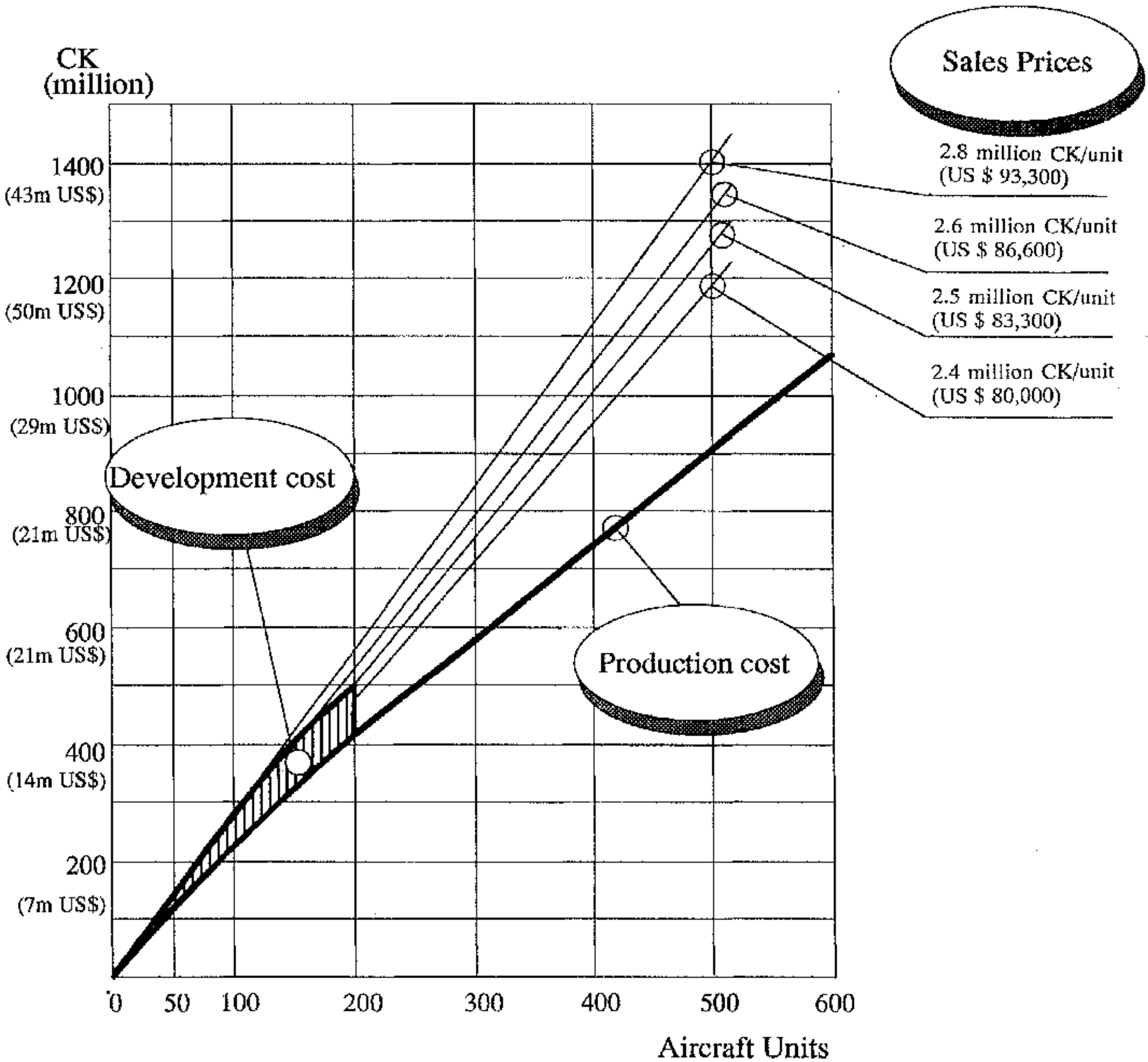



**Fig. 5.4:** Expenses and Profits for different aircraft selling prices.

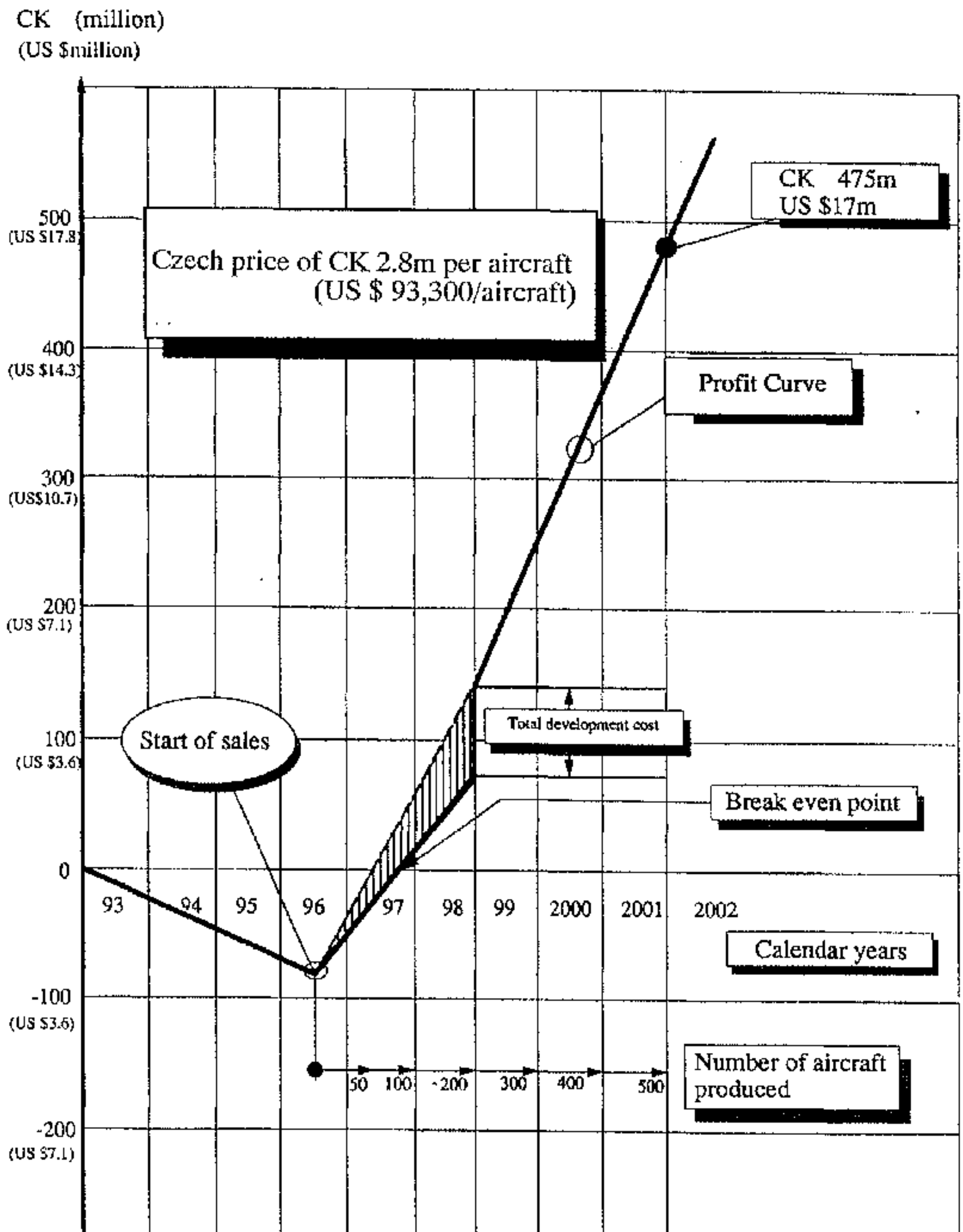



**Fig. 5.5**: Expenses and Profits for typically priced aircraft

### 5.4.4 Design for Product Quality

As was discussed in Chapter 5 the objective of potential manufacturers of light aircraft is to sell a range of equipment at a profit. This profit can only be achieved if the company remain competitive with the ever increasing opposition. For example, small companies like Kappa, Inteco, Evector and many others all of whom were previously involved in other activities, probably most profitable, are now entering the field as competitors. To achieve a prominent position the manufacturer has to offer delivery on time at the right cost and the right quality. Quality is now more important because of increased complexity and the need to reduce costs to remain competitive. In recent years new concepts and disciplines have merged to facilitate the above. These concepts and techniques are collectively identified in most countries as quality control.

Such modern quality control is based on the premise of a few relatively simple concepts. The most essential are:

1. The quality of manufactured products depends upon the manufacturer's control over his design, manufacture and inspection operations. Unless a product is properly designed and manufactured it will not meet the requirements of the buyer. Accordingly, manufacturers must be prepared to institute such control of quality as is necessary to ensure that their products conform to the purchaser's quality requirements.

2. Manufacturers should be prepared, not only to deliver products on schedule at an agreed price but, in addition, to substantiate by

objective evidence, that they have maintained control over the design, development, and manufacturing operations and have performed inspection which demonstrates the acceptability of the product. The design phase is considered to embrace all activities after the statement of the operational requirement through to the point at which the requirement has been satisfied.

**Impact of Project Phase on Design Quality**

In any systematic attempt to improve product design quality, the phase of project engineering is obviously a major factor in establishing what needs to be done and, hence, who should be responsible for doing it.

In our particular field these phases can be sub-divided into the following:-

Phase 1 Preparation of basic aircraft specification.
" 2 Establishment of basic project configuration.
" 3 Preliminary technical definition.
" 4 Detail definition.
" 5 Technical validation.
" 6 Production of design.
" 7 In-service product support.

**Phase 1**

From the above, it will be evident that, on certain projects, the greatest influence on marketability is dictated by the project specification, a fact which will be self-evident to all. It is of little comfort to some manufacturers that the failure of some projects to appeal to the domestic and international market is frequently due to lack of proper public relations.

It is also of interest to note that the impact of the specification is much more critical on military application of aircraft than civil. In the case of GA aircraft, it is often clearer to understand market requirements.

**Phase 2**

It follows from the preceding statement on specifications that the more inadequate or poorly defined the specification, the higher will be the influence of basic project configuration. General performance and costs defined during this phase, together with phase 3, will tend to dominate marketability.

**Phase 3**

This is predominantly the scheming phase for the project during which major decisions are made which can have a major effect on unit costs. Competitive performance and cost target need to be finally agreed during this phase numerous trade studies are performed in an effort to improve on the targets before detailed engineering commences.

It is worth noting in this phase that the preceding activities will invariably be manned and organised by small teams of high quality designers and there will be high visibility by senior technical management. It therefore follows that definition of project performance and cost lies in few hands. These hands must consider both factors as of equal importance if the company is to progress beyond the three initial phases. The real problems of quality arise in phases 4 and up.

**Phase 4**

Although the decisions taken in previous phases will fix the range of probable costs, it is during this activity that the actual project unit cost will be committed. The quality of design and engineering is particularly crucial since massive cost overshoots and performance shortfalls can be incurred with catastrophic consequences on project marketability if poor detailed design and engineering is permitted. Much depends here on the quality of the middle management since during this phase considerable pressures will be applied from other sources. Detail design quality must take at least an equal priority with timescales. Detail design produced "right-first-time" has a considerable knock-on effect in manufacturing times and costs, as well as producing design office savings.

One further essential feature which appears at the detail design phase is procedural control. Mention of this will often cause glazed expressions to appear on the faces of designers but the customer does expect to know what he has bought (or is about to buy). Perhaps it is sufficient at this point to say that clerical staff may maintain records but the responsibility for definition lies firmly with the designer.

**Phase 5**

Failure to identify performance quality shortfalls until too late can have dire consequences on project sales. The timely exposure and resolution of problems is therefore imperative.

**Phase 6**

The principal involvement of design during Phase 5 is to minimise changes, restricting them to those which will favourably influence project marketability and to directly support production in reducing unit cost.

Inevitably, the manufacture of the first article is going to high-light areas where manufacturing and assembly costs are higher than might be expected or where maintenance or reliability requirements may not be achievable.

A properly organised system for the assessment of costs of change against prospective savings will identify those changes which are viable, thereby minimising costs and unnecessary changes whilst improving the quality of the finished product.

**Phase 7**

Cost of ownership and its influence on marketability was referred to earlier (Chapter 4).

There can be of little doubt that, whilst the company customer support may have little direct influence on the marketability of a new product, a poor performance in a past project can become a major barrier for future sales and vice-versa. Product support is thus a major factor albeit an indirect one, in marketability.

To support most of the project phases and improve their impact on design quality, investment in advanced computer aided design engineering and manufacturing integrated system is needed. An example of such a system for a typical aircraft manufacturer can be seen in Figure derived from ref.

**The Means of Improving Design Quality**

The means by which management can influence product design quality are outlined below. They apply equally to all disciplines involved, whether concerned with the drawings, the calculations or the specifications of the equipment and engines. Each management technique can be considered against any one of the quality characteristics as a way of improving it. Included are the following:-

**Manpower**

- motivation
- number of staff
- range of disciplines involved
- attracting the best staff

**Communications**

- group discussions, productivity boards, etc.
- displays, posters

**Training**

- training in basic skills in design and engineering (establish what we need, what we already have and the gap to be filled)
- training in innovative techniques
- engineering skills etc.
- refresher/update training

**Methods and Data**

- codes of design practice, handbooks of technical data, engineering manuals, etc.
- use of specialist departmental knowledge

**Design Procedure**

- use of task definition document, design reviews, auditing, checking procedures etc.

**Organisation of Design Engineering**

- co-located project teams, mix of disciplines within a design team, breakdown of responsibility between group leader and his subordinates etc.

**Interfaces between Departments and Directorates**

- improved definition of requirements by all department and their relative importance
- communication problems between the departments

**Computing and Software**

- interactive graphics, on-line monitoring of defects, computer aids for design selection, information storage and retrieval systems, intelligent knowledge based systems as an aid to design

**Research**

- evaluation of new engineering concepts, materials
- new methods and techniques.

# CHAPTER SIX

## AIRFRAME AND PERFORMANCE DATA PREDICTION

### 6.1 Introduction

The arrangements of nearly all general aviation aircraft, in current world-wide production, are based on the design concepts of the 1960s. Most aircraft of new construction are usually expensive or aircraft of amateur construction without JAR/FAR certification of airworthiness. There are a few exceptions: the Eurotrainer 2000 and the Katana, for example, are general aviation aircraft of modern design and also in serial production.

Information obtained from market research shows that future aircraft designs will have to be aerodynamically more efficient to achieve better performance and lower operating costs. The main structure will have to be light and will have to allow for modifications to cater for the use of a fixed or retractable undercarriage. The landing gear will have to be rugged and suitable for operation from grass or dirt strips. If possible the aircraft should be capable of being easily adaptable for amphibian use.

An important part of the aircraft's design concept will be production simplicity: it should be able to be sub-assembled with the minimum number of components; it should have a low empty weight; and construction should be possible from readily available materials. The aircraft will ideally be able to accommodate different standard production engines according to customer requirements. In order to achieve commercial success it is essential that the aircraft is designed to JAR 23 and that a very high standard of customer support is available.

## 6.2 General Description of the New Aircraft

The TP-41 is an economic multipurpose aircraft which can be configured for either two or four-seat operation. It is aimed at applications such as business, training and recreational flying. The aircraft was developed at the Institute of Aerospace Engineering, VUT Brno, and at present exists as an advanced conceptual design.

In the initial stages of development, a market survey was undertaken to assess the viability of the aircraft. This study drew heavily on research carried out by the Czech aircraft industry and similar studies conducted in Germany, the U.K., Canada and the U.S. By aiming the aircraft at the N (normal) and U (utility) categories of the FAR23 and JAR23 regulations, the potential for around 2100 units per annum, covering applications such as recreation, business, post and cargo, training and surveillance, was identified. Approximately 8% of this requirement is derived from the internal market in the Czech Republic.

### Wing

The N category variant can be characterised as a low-wing, all-metal, four-seat aeroplane for business and tourist applications. The aircraft, which has a maximum take-off weight of around 950kg and a maximum payload of 350kg, is illustrated in Fig. 6.1. Its wing is an all-metal, self-supporting, double-spar (35% and 70% chord), structure which is divided into a trapezoidal outboard and a rectangular inboard section. The wing skin is made from duralamin sheets covered by an aluminium protective layer. The wing design includes integral fuel tanks which are located in the front part of the outer wing sections. A slotted flap, which can be deflected to 20° on take-off and 40° on landing is located on outboard sections of the wing while hinged inner flaps are preferred. These inboard flaps are are only used during landing when they are deflected to 40° with the main flaps.

### Fuselage

The fuselage is of similar construction to the wing and is again all-metal. Figure 6.1 also shows the location of the fuselage support structure and the integrated central wing section. Access to the cockpit is via doors hinged on the central column of the canopy frame. The cockpit itself is designed for good visibility and, in the four seater configuration, has two adjustable front seats and bench type seats in the rear. Luggage can be stored either on the rear shelf or in a compartment located behind the rear seats. This compartment is accessible from within the cabin or via a side door in the fuselage.

### Tail

The vertical fin is a part of the fuselage. Horizontal stabiliser is an all metal passing through construction. The rudder and elevator are all-metal, partially mass and aerodynamically balanced type.

### Controls and Systems

Control systems in the aircraft are of classical design using rigid rod transmission from the stick and pedals in the cockpit. Twin channel aileron, elevator and rudder controls and single channel landing flap, engine, propeller, longitudinal and directional trim controls are provided. The aircraft also incorporates a fixed tricycle nose-wheel type undercarriage which is controlled from the cockpit.

The fuel and oil system are of standard type. The air-conditioning system enables both adjustable ventilation and efficient heating of parts of the passenger compartment and windshield.

The electrical system is plus pole one wire type. The primary electrical power source is the AC generator (28V) and the auxiliary power is a standard battery.

The fire-extinguishing system is supported by a fireproof wall which separates the engine from the cockpit. There is also a quick acting fuel switch and approved fire extinguisher in the cockpit. Each part of the oil and fuel system has a fire-resistant characteristic.

Avionics instrumentation will be arranged according to customer operational requirements.

### Undercarriage

Fixed tricycle nose-wheel type, provided with hydro-pneumatic shock-absorbers both at nose and main undercarriage parts. The main undercarriage is attached at the end of the centre section of the wing. The hydraulic disc-type brakes are installed on both wheels which are individually controlled by levers installed on the directional control pedals.

The nose-wheel is directionally controlled with directional control pedals and furnished with hydraulic anti-shimmy damping.

### Propulsion

The following power plants were considered for the aircraft.

| | | | |
|---|---|---|---|
| LYCOMING | 0-325 | 115 hp | 85.7 kW |
| LYCOMING | 0-320 | 160 hp | 119.2 kW |
| CONTINENTAL | 0-200 | 100 hp | 74.5 kW |
| CONTINENTAL | 0-300 | 145 hp | 108.0 kW |
| WALTER | M 322 | 140 hp | 104.3 kW |

| | | | |
|---|---|---|---|
| JAROS | M 60 | 120 hp | 89.4 kW |
| TATRA | AT 725 R | 150 hp | 111.9 kW |
| TATRA | AT 714 | 130 hp | 96.9 kW |
| ROTAX | 914 | 115 hp | 85.7 kW |

Several powerplants were considered for the aircraft but the prefered option is the four-cylinder, four stroke, air-cooled Textron Lycoming model O-320-E2A which has a maximum sustainable power of 140hp. This unit is combined with a two-bladed constant-speed propeller. Preliminary technical and performance figures for the aircraft are shown in paragraph 6.3.

At present, the TP-41 design study has encompassed a weight analysis, a detailed aerodynamic study, detailed analysis of loading according to JAR/FAR23 regulations, preliminary structural component design and a cost analysis. In the cost analysis, it is assumed that the aircraft will be built in the Czech Republic where labour costs are low. On this basis, the cost of development, including certification, has been estimated at 2.9 million U.S. dollars. This figure, when set against a unit sale price of 100 000 US dollars, leads to a projected breakeven point being reached approximately four years from initiation of product development. This is shown in Fig. 4. where the projected cummulative profit is plotted against calendar year and production units.

## 6.3 Preliminary Technical and Performance Data

### Dimensions (m)

| | |
|---|---|
| Wing span | 10.2 |
| Height | 2.68 |
| Wheel track | 2.4 |
| Wheel base | 1.7 |
| Length | 7.4 |

### Areas ($m^2$)

| | |
|---|---|
| Wing area | 13.18 |
| Aileron | 2 x 0.625 = 1.25 |
| Wing flaps | 2 x 0.94 = 1.88 |
| Horizontal tail | 2.8 |
| Vertical tail | 1.42 |

### Aerodynamic Characteristics

| | |
|---|---|
| Wing aspect ratio | 7.9 |
| Wing taper ratio | 0.5 |

### Airfoils

| | |
|---|---|
| Wing root | NACA $63_2$ - 415 |
| Wing tip | MS (1) 313 |
| Horizontal tail | NACA 009 |
| Vertical tail | NACA 009 |

## Undercarriage

| | |
|---|---|
| Main landing gear | fixed |
| Main wheels tyre size | 350x135-5 Barum Aero |
| Nose landing gear | fixed |
| Nose wheel tyre size | 350x135-5 Barum Aero |
| Tyre pressure | 250 kPa |

## Weights

| | |
|---|---|
| Empty weight | 450 kg |
| MTOW | 850 kg |
| Max. payload | 350 kg |
| Max. fuel capacity | 200 l |

## Power Plant

Given performance data corresponds to:

| | | |
|---|---|---|
| TREXTRON Lycoming engine | | 0 - 320-E2A |
| Maximum continuous power | 140 hp | 2400 rpm |
| Maximum cruise power | 130 hp | 2200 rpm |
| Economy cruise power (75%) | 110 hp | |
| Economy cruise fuel consumption | | 35 l/hod |
| Diameter of propeller | | 1800 mm |
| Number of blades | | 3 |

**Preliminary performance data**

| | |
|---|---|
| Maximum cruising level flight speed (ISA, H=S.L.) | 280 km/hr |
| Cruising speed 75% | 230 km/hr |
| Stalling speed flaps down | 84 km/hr |
| Stalling speed flaps up | 97 km/hr |
| Maximum rate of climb | 4.9 m/s |
| Endurance (+45' reserve) | 5 hr 50 |
| Range | 1100 km |
| Take-off distance to 15 m (ISA, H=S.L.) | 500 m |
| Landing distance from 15 m (ISA, H=S.L.) | 420 m |

Performance data corresponds to aircraft weight of 850 kg.

Payload-range diagram corresponding to economy cruise power can be seen in Figure 6.2.

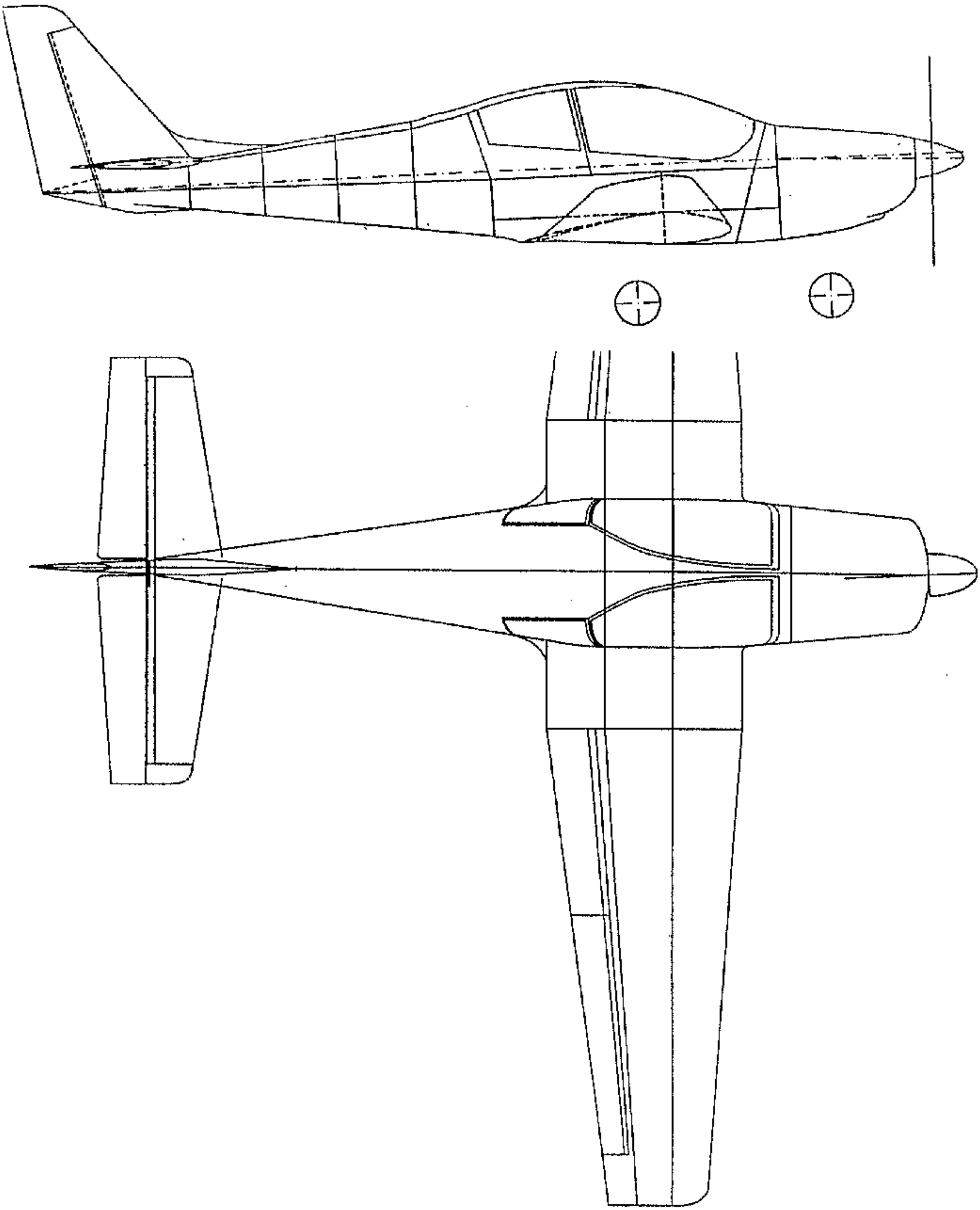
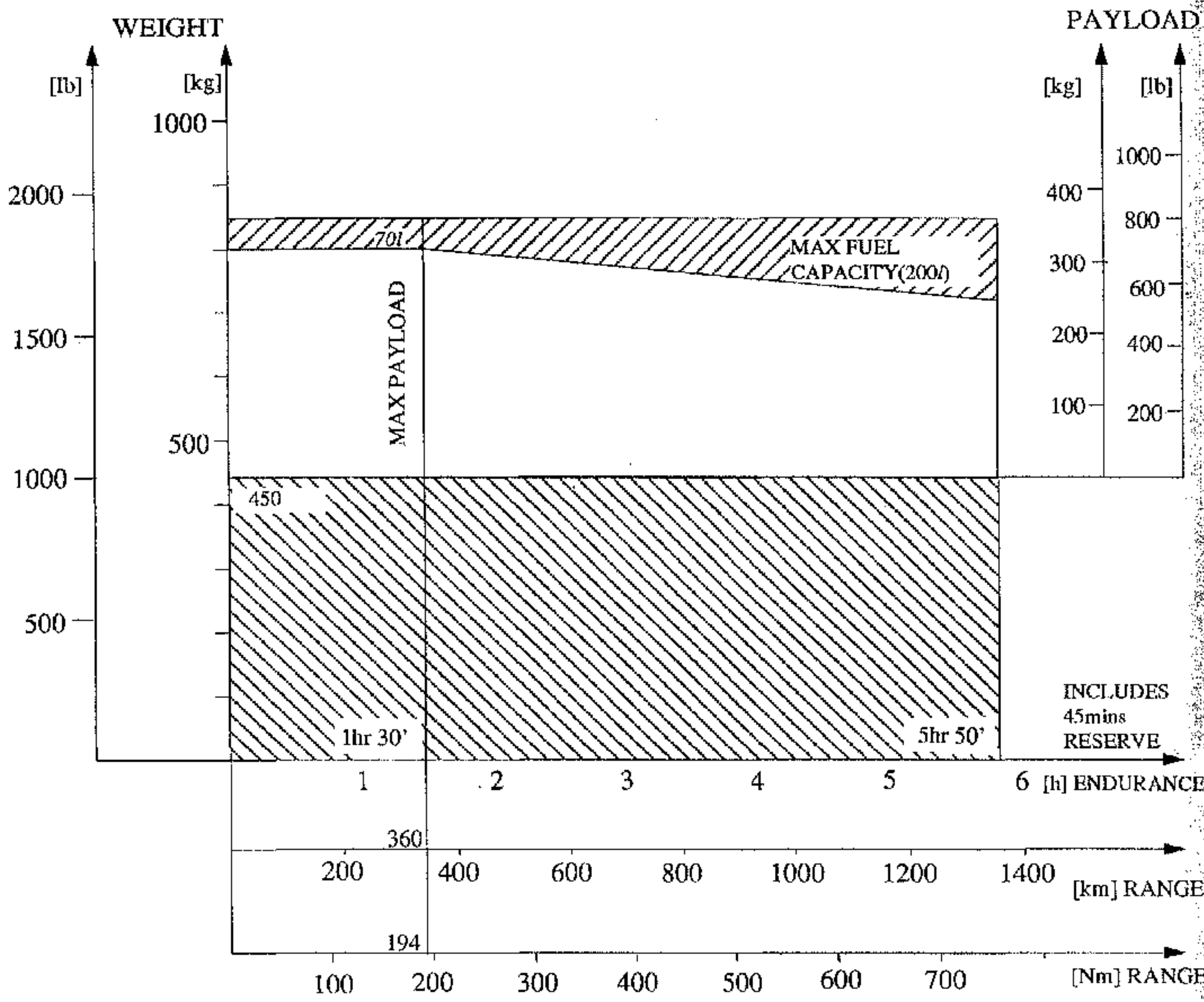


**Fig. 6.1:** TP-41 Basic Layout




| | |
|---|---|
| Economy cruise power (75%) | 82kW (110hp) |
| Economy cruise speed | 230km/h (142 knt) |
| Fuel Consumption | 30l/h (7.9USg/h) |

**Fig. 6.2:** Payload - Range Diagram, TP-41

# CHAPTER SEVEN

## CONCLUSION

### 7.1 Introduction

Assessing the manufacturing, research and development prospects in the field of general aviation aircraft for former Communist countries is a complex task in which many of the orthodoxies turn out to be simplifications. In the Czech Republic, evidence concerning the relationship between a fast-track transition to the open market and economic performance is still mixed, particularly when measured against investment, debts, profit, level of employment and real wages. It is probably the case, however, that all existing strategies will turn out to have similar effects in terms of prosperity. Successes will probably turn out to be short-term and those companies which have preserved employment by borrowing will find that long-term recovery has simply been impeded and bankruptcy may become endemic.

Most of the aircraft companies in the Czech Republic have difficulty in establishing a clear relationship between marketing and commercial success on the one hand, and popular attitudes on the other. In fact, in some companies, the prospect may be that a choice between the two, rather than a balanced relationship, will need to be made very soon.

## 7.2 Conclusions

Moravan Aircraft is still the only manufacturer of sport/touring aircraft in the Czech Republic to comply with FAR/JAR23. Current aircraft types in production have 10-15% lower performance than Western made aircraft. This fact is compensated by aerobatic capabilities and in some cases (the Z-142) good flying characteristics. Major modifications of existing aircraft to increase performance will not be a good option because of cost and certification obstacles. The time required for these modifications would be equivalent to that required for the design of a completed new aircraft. Most of the world light aircraft manufacturers see a steadily ageing trainer/tourer fleet around the world and believe that customers will eventually buy in various market sectors. The characteristics of this situation are similar in the Czech Republic where there are a lot of flying clubs asking for new low cost direct operation aircraft. According to *Flight International* , there is a need for 10000 aircraft in the U.S.A. and a market worldwide for around 2000 aircraft per year. Piper Aircraft emerged from bankruptcy court in 1995 under new management and with a new name, New Piper Aircraft, and continues to build trainers (the Warrior III, the Arrow, Dakota and Seminole) personal aircraft (the Archer III and Saratoga II HP) and business models (the Malibu, Mirage and Seneca IV). According to *Flight International*, New Piper Aircraft, delivered 174 aircraft during 1995 and predicts 207 sales in 1996. In five years, the company expects the production rate to reach 500-600 of its old type aircraft.

The following principal features of the Czech General Aviation industry make the industry viable and well placed for the near future.

- High engineering and production capacity
- Highly skilled and motivated aviation personnel
- Low labour costs

The industry has a steady supply of motivated young people. The technical universities in Brno and Prague are sources of supply, as are small and medium sized newly established private companies who can explore new technology and materials inexpensively and quickly. The close links which existed between the light aircraft industry and sport flying before the Second World War urgently need to be strengthened. Future designers of light aircraft will have to deal with an aircraft as an entity and discover soon that design, construction, maintenance and operating are interrelated and affect aircraft success and safety. Recent expansion in home building of ultra light aircraft in the Czech Republic can provide this experience for future generations of aircraft designers.

The calculation of the development cost of light aircraft presented in Chapter 5 has shown the attractiveness of the industry for collaborative programmes with Western partners. To be even more attractive the industry has to adopt restructuring measures. The Czech Central Bank's priority is to keep inflation down to help its application to join the European Union. This has led it to keep interest rates high, and the currency strong. Without devaluation, the Czech Aircraft companies will have to become more efficient to compete in the export market. Most of the Czech companies have been slow in the last five years to close uneconomical operations and shed surplus staff. This is not sustainable, the goals of internal restructuring of the aircraft industry will, of necessity, be as follows:

- To adopt new administrative structures and new structures of financing with implementation of modern management principles.
- To create new commercial and sales mechanism and to create a new internal mechanism to control the company's economy.
- To adapt their size and structure to the new sales output
- To stop production where there is no market
- To set up partnerships with tried and trusted aircraft companies with good reputations to work on joint programmes under a risk and profit sharing principle.

The saga of the restructuring of the Czech aircraft industry over the past three years is often complex. But it seems clear that the breakdown of a number of serious discussions of joint ventures will create difficulties in the long run.

The question of how joint venture products can be certificated should be of primary concern to most companies involved in any cooperation agreement with western partners. The opening up of new markets and of new joint ventures presents a technical challenges to certification authorities from both East and West. In many cases the certification authority will, for the first time, be dealing with compatibility issues. In many Western countries, imported products are only eligible for type certification and standard certificates of airworthiness if they are designed and manufactured in a country with which they have a bilateral airworthiness agreement. In developing a bilateral agreement the Czech Republic Civil Aviation Authority together with involved companies has to make public its procedures in the general areas of type certification, production certification and continuing airworthiness.

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