Industrial Development Subsidiary Agreement

A Study Of Helicopter-Related Potential In Overhaul, Servicing And Manufacturing In B. C.

Research Report

Province of British Columbia
Ministry of Industry and Small Business Development

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A Study Of Helicopter-Related Potential In Overhaul, Servicing And Manufacturing In B. C.

Prepared for:
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Industrial Development Subsidiary Agreement
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The responsibility for the content of this report is the consultant's alone, and the conclusions reached herein do not necessarily reflect the opinions of those who assisted during the course of this investigation or the Federal and Provincial governments which funded the study.

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1.0 INTRODUCTION

The Industrial Development Committee, which is responsible for administering the Industrial Development Subsidiary Agreement (IDSA), a joint provincial-federal initiative to encourage industrial development, has provided funding to study helicopter-related activities in the overhaul, servicing and parts manufacturing areas to see if they offer a potential industrial opportunity in British Columbia.

In April 1981, the Federal Department of Industry, Trade and Commerce issued a study paper entitled A Study of Helicopter Manufacturing in Canada. This study noted that Canada is the second largest market for helicopter sales and represents a potential market for new equipment and parts of more than $2 billion over the next decade. While Canada is currently not manufacturing any helicopters, Bell Helicopter Textron of Fort Worth, Texas has an agreement of understanding with the Federal Government and the Province of Quebec to manufacture the Bell 400 Series of light twin engine helicopters in Canada. Fleet Industries Ltd., Fort Erie, Ontario and Messerschmitt-Boelkow-Blohm (MBB), the German helicopter manufacturer, have recently entered into a joint venture to produce MBB BO 105s in Canada. There is also some manufacturing of helicopter components in Canada undertaken as sub contracts from United States helicopter manufacturers. British Columbia has a limited aerospace manufacturing industry but substantial repair and overhaul facilities. There may be some potential for British Columbia firms to participate in helicopter-related purchases forecast by the federal government study, particularly in regard to the projected $738 million worth of spare parts which will be needed to support helicopter purchases over the next decade.

In the repair and overhaul servicing of helicopters, most of the larger commercial helicopter operators have the capability of conducting the majority of their own maintenance, overhaul and some repair work. Other helicopter operators rely on contracting their maintenance and repair requirements to specialized helicopter maintenance firms in Canada and the United States. In Canada, some of the larger commercial helicopter companies and over half of the helicopters are based in Western Canada. About one-third of registered helicopters in Canada are owned by British Columbia operators. Similarly in the United States, a third of the total U.S. helicopter fleet is in the west.

Since British Columbia itself constitutes one of the most active helicopter operation areas in Canada and is strategically located close to other active helicopter centres in the Western United States, increased opportunities for British Columbia companies may also exist in servicing, overhaul and repair.

Columbia Pacific Resources Group Ltd., a management consulting firm with expertise in aerospace marketing, was selected to undertake a preliminary research study which would examine the market potential for industrial development related to helicopter activities and suggest how British Columbia firms can exploit these possible opportunities.

The Study Terms of Reference state that the market areas to be addressed, in order of priority, are:

A. **Repair, Overhaul and Servicing:**
An assessment of present and projected demand over the next ten years for specific repair, overhaul and servicing work within that market area serviceable from British Columbia.

B. **Spare Parts:**
Quantify the spare part consumption and, if possible, identify parts that could be produced in British Columbia.

C. **Original Equipment Parts or Components**
Ascertain if there is a need for or interest by prime helicopter manufacturers to have parts or structures produced on a sub-contractor basis and identify opportunities that would be compatible with existing British Columbia capability.

2.0 STUDY APPROACH AND SCOPE

The study approach and scope was developed within the parameters of a constrained study budget. This necessitated limited field investigations and direct contacts with the industry, and heavy reliance on published material and correspondence to obtain the required information. The limited field work program, however, did provide the necessary insight needed to provide a reasonably accurate evaluation of helicopter-related potential in overhaul, servicing and parts manufacturing.

2.1 APPROACH

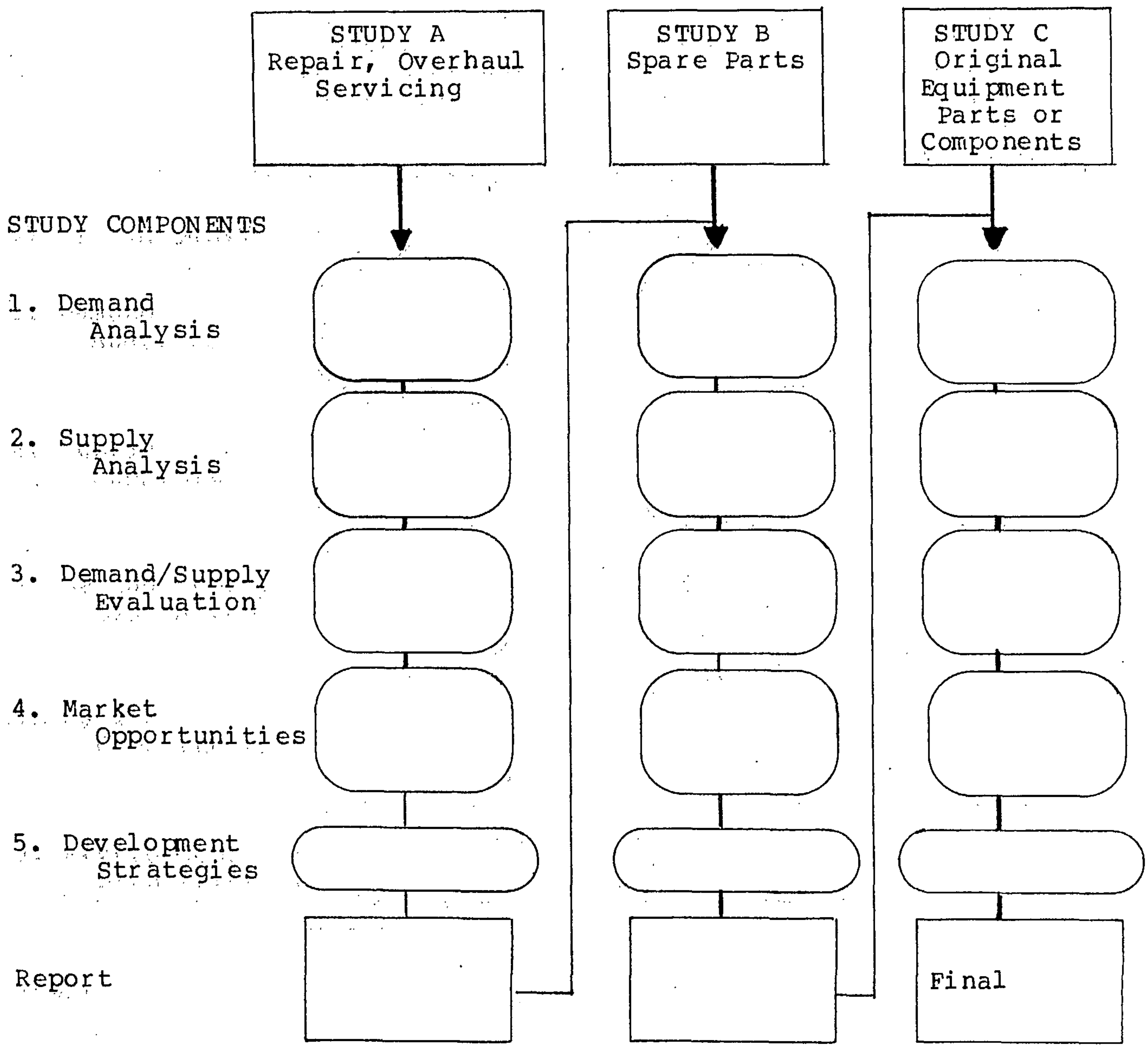
The basic study approach was to study the three market areas in the order of priority suggested in the Study Terms of Reference. Each study area was examined sequentially (to the extent possible) and, in fact, represented separate sub-studies of the overall helicopter market potential study. The results of each sub-study provided initial input to the subsequent sub-study. Within each sub-study, the approach followed was essentially the same. The format for each is as follows.

- Demand
- Supply
- Evaluation
- Market Opportunities
- Development Strategies

Figure 2.1 shows a flow diagram of the relationship between the three market areas and the various study components within each of the sub-studies.

HELICOPTER STUDY

OVERALL STUDY APPROACH



2.2 SCOPE

Given the budget limitations, the research effort was allocated as follows:

A. **Repair, Overhaul and Servicing:**
About 60 percent of the research effort was allocated to this market area due to the potential size of the market in British Columbia. The data and information collected and analyzed in this market area formed much of the document base needed in the subsequent market areas.

B. **Spare Parts:**
This market area was allocated about 15 percent of the total research effort.

C. **Original Equipment Parts and Components:**
The scope of this market area was greatly influenced by the findings of the two other market areas. These market areas also assisted in the short-listing of the number of viable original equipment parts and components which could be considered for possible sub-component manufacture in British Columbia.

2.3 GEOGRAPHIC SCOPE

The geographic region to be addressed as a reasonable market area in which British Columbia helicopter-related firms could effectively compete is difficult to determine. Routine helicopter maintenance, such as time-related maintenance inspections, generally have a market area which is in relatively close proximity to the maintenance facility due to limited maintenance skills and equipment needed. On the other hand, major overhauls and repairs may have a market area of Western Canada and the U.S. Pacific Northwest. Indeed, for some types of helicopters the market may be North America or overseas (eg. Turbomeca turbine engine overhauls[1] are done in France and Hughes 500 main rotor hubs are done in California). For the purpose of this study two market regions were identified. These two regions, a Primary Market Area and a Secondary Market Area, are as follows:

Primary Market Area	Secondary Market Area
British Columbia	Saskatchewan
Alberta	Manitoba
Yukon Territories	Northwest Territories
Washington	Wyoming
Oregon	Nevada
Idaho	Colorado
Alaska	New Mexico
	Arizona
	Montana
	California

In the Primary Market Area, British Columbia and Alberta are the focal areas of identification and are addressed in some detail in the study. In the case of the Secondary Market Area, helicopter activity is generally lower except for the State of California. This one state offers a significant market in terms of the number of helicopters but it is also a state where a

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1/ Turbomeca has some engine component capability adjacent to the Aerospatiale service centre in Grande Prairie, Texas.

considerable amount of the total United States aerospace industry is located and therefore represents one of the most competitive market situations.

2.4 REPORT OUTLINE

The report incorporates the research activities undertaken and the major findings of the study. The research activities reflect the study objectives. The following chapter outline presents a synopsis of the report:

Chapter 3 World Helicopter Market - This chapter provides an overview of the world-wide market for helicopters in order that the potential market for British Columbia helicopter-related companies can be assessed in terms of the total market. It looks at both civilian and military rotorcraft for the period 1970-1983 and provides a forecast to 1990.

Chapter 4 Regional Market Demand - The market area in which British Columbia based firms can reasonably expect to provide helicopter-related services is provided in this chapter. The regional market is divided into two market areas: Primary Market Area and a Secondary Market Area. The chapter presents details on the location of helicopters by type for the years 1982 and 1990.

Chapter 5 Helicopter Maintenance Documentation - Helicopters have to be certified as being airworthy by government authorities. This chapter briefly examines government regulations pertaining to the repair, overhaul and maintenance of helicopters. It examines the documentation needed by government authorities, documentation kept by the operator regarding maintenance records and the manufacturers' manuals and other technical information. Since the helicopter market is both in Canada and the United States, the Canada-U.S. airworthiness agreement is discussed.

Chapter 6 Helicopter Maintenance - This chapter introduces the subject of basic helicopter maintenance in order to provide an understanding of the maintenance requirements of helicopters and some familiarity with the relationship of helicopter components and parts to non-technical readers.

Chapter 7 Future Helicopter Technology - New technology, in terms of new designs, materials, power plants, flight controls, navigation equipment and so forth, is changing the helicopter industry rapidly. This chapter presents an overview of technology which is now available or will be within a decade. The impact of new technology on maintenance requirements is also discussed.

Chapter 8 Helicopter Maintenance Reliability - In order to determine the magnitude of the repair, overhaul and servicing of helicopters, it is important to examine maintenance reliability. This chapter looks at some of the research being undertaken to determine the maintenance reliability of helicopters and where the maintenance problems are occurring.

Chapter 9 Helicopter Maintenance Facilities - This chapter discusses the helicopter-related facilities and services in British Columbia as to their skills and helicopter-related capabilities. It also examines those competing companies within the Primary and Secondary Market Areas.

Chapter 10 Helicopter Maintenance Requirements - This chapter examines the specific maintenance requirements of the major helicopter models which are in the study market areas, and estimates the total revenue which could be generated from providing helicopter-related repair, overhaul and maintenance to these helicopters.

Chapter 11 Helicopter-Related Facilities and Service Market Opportunities - Based on the maintenance requirements and revenue calculated in Chapter 10, and the helicopter-related capabilities of British Columbia companies developed in Chapter 9; this chapter provides an overall assessment of the possible market opportunities for British Columbia based companies to strengthen existing services or to provide new services to the helicopter industry.

Chapter 12 Conclusions - This final chapter summarizes the study and highlights the major market opportunities which may be available to existing and/or new British Columbia helicopter-related firms.

3.0 WORLD HELICOPTER MARKET

The purpose of this chapter is to examine the world-wide market for helicopters in order that the prospects for helicopter-related overhaul, servicing and parts manufacturing can be assessed in terms of the total market. The market examination looks at both the civilian and military rotorcraft market for the recent historical period and provides a forecast into the future. The market includes some 75 countries which are termed the "free world" by the helicopter manufacturers. A substantial amount of the historical inventory and future projections are based on a Bell Helicopter Textron study conducted on behalf of the National Aeronautics and Space Administration (NASA) in 1981. There are other sources of helicopter information and market forecasts which could have been used, but the Bell Helicopter Textron study is perhaps the most comprehensive and accurate data base.

There are a number of agencies which have information on helicopter inventory and forecasts, such as the Aerospace Industries Association of America Inc. (AIA), Federal Aviation Administration (FAA), Sikorsky Helicopters Ltd., Detroit Diesel Allison, Helicopter Association International (HAI) and so forth. It should be noted there are wide differences in the inventory and forecasts prepared by these agencies. The differences are largely due to differences in definitions used in their development of a data base. Some include all registered helicopters, while other only include "active" (valid certificate of airworthiness). The definition of civil, commercial and military may differ (e.g., whether the Coast Guard is a military or a civil organization). For the purpose of this study we have accepted the Bell Helicopter Textron inventory and forecasts.[1] There may be some criticism that the Bell Helicopter Textron forecasts prepared in 1981 are too optimistic in light of the economic recession which occurred in 1982 and 1983. It is recognized there is still a world-wide surplus of civil helicopters but it is expected that, by mid-1984 demand will require increased helicopter production. It should also be noted that while civilian helicopter demand is reduced, military helicopter production has increased. The higher value of military helicopters resulted in total production values being close to those forecast by Bell Helicopter Textron for 1982 and 1983. Civil helicopter unit production is down in 1983 by some 30 percent, which indicates that civil forecasts prepared by Bell Helicopter Textron could lag by two years (e.g., forecast 1983 helicopter units may not be achieved until 1985).

3.1 ACTIVE HELICOPTER FLEET

In 1980, there were some 35,856 active helicopter units in the world. The number of civil helicopters total 15,344 units (43 percent) and military units total the remaining 20,512 units. The United States has the world's largest helicopter fleet with half the world inventory. Out of the 18,008 total helicopters in the United States, there are some 8,476 civil helicopters and 9,532 military helicopters.

1/For further information on helicopter data base and forecast differences see Rotor Wing International May, 1983.

Table 3.1 on the following page shows the historical growth in the active helicopter fleet and a forecast of the number of helicopters expected to be in service to 1990. The United States figures are shown in the same table to illustrate the magnitude of the United States fleet in comparison to the rest of the world. The table indicates that during the 1970's the active helicopter fleet has grown by about 3.6 percent per annum and is projected to grow at 4.8 percent per year during the 1980's. It can be seen that the United States military requirements have affected the historical inventory. Military units peaked in 1970 at 12,969 units at the height of the Vietnam war and have steadily decreased due to attrition in the seventies. In the eighties, military units will be added to the fleet as Sikorsky SH60 Black Hawk series, Hughes AH-64A Apaches and other ordered helicopters are delivered to the United States Armed Forces.

The geographical markets for civil helicopters have not accurately been determined but, based on the 1980 total of 15,344, the following approximate distribution is provided.

CIVIL HELICOPTER FLEET

Geographic Region	No. of Units	Percentage
Mid East/Africa	500	3.3
Latin America	1,100	7.2
Asia/Pacific	1,700	11.1
Europe	2,000	13.0
North America	9,500	62.1
Unknown	500	3.3
	15,300	100.0

Table 3.1

WORLD ACTIVE HELICOPTER FLEET

	TOTAL FREE WORLD (Includes United States)			UNITED STATES		
	CIVIL	MILITARY	TOTAL	CIVIL	MILITARY	TOTAL
1970	5,993	19,116	25,109	2,790	12,969	15,759
1971	6,612	19,426	26,038	3,062	12,410	15,472
1972	7,329	19,669	26,998	3,479	12,632	16,111
1973	8,567	19,847	28,414	4,383	11,612	15,995
1974	9,613	19,760	29,373	5,132	11,297	16,429
1975	10,512	19,721	30,233	5,823	10,760	16,583
1976	11,239	19,729	30,968	6,251	10,238	16,489
1977	11,917	19,610	31,527	6,556	9,680	16,236
1978	12,701	19,892	32,593	6,883	9,632	16,515
1979	14,120	20,153	34,273	7,851	9,499	17,350
1980	15,344	20,512	35,856	8,476	9,532	18,008
1981	16,679	20,844	37,523	9,104	9,494	18,598
1982	18,672	21,200	39,872	9,792	9,462	19,254
1983	19,561	21,530	41,091	10,515	9,445	19,960
1984	21,129	21,914	43,043	11,285	9,469	20,754
1985	22,793	22,492	45,285	12,120	9,560	21,680
1986	24,570	23,059	47,579	12,995	9,677	22,672
1987	26,336	23,592	49,928	13,417	9,781	23,198
1988	28,189	24,165	52,354	14,869	9,869	24,738
1989	30,121	24,757	54,286	15,566	9,999	25,565
1990	32,122	25,230	57,352	16,892	10,017	26,909

Source: Based on Bell Helicopter Textron Study.

The regional distribution for the military helicopter fleet has been also developed for 1980, using the same geographic classification as the civil helicopter fleet. The military fleet of 20,512 units are distributed as follows:

MILITARY HELICOPTER FLEET

Geographic Region	No. of Units	Percentage
Mid East/Africa	2,740	13.3
Latin America	745	3.6
Asia/Pacific	2,260	11.0
Europe	5,025	24.5
North America	9,730	47.6
	20,500	100.0

When the civil and military markets are compared, it can be noted that military units form a high proportion of the total fleet in Mid East/Africa and Europe due to the military buildup in Middle Eastern countries and NATO requirements in Europe. Asia/Pacific also has a relatively high proportion of military helicopters in the fleet.

3.2 HELICOPTER PRODUCTION

Helicopter production to meet market demand is composed of two elements, new growth and replacement growth. Replacement growth stems from attrition of helicopters in the active fleet due to accidents and damage which render helicopters not repairable. There are also some helicopters retired from the active fleet due to changes in technology and operating costs. Table 3.2 examines new growth and replacement growth for helicopters which results in changes in market demand. This market demand then forms the basis for helicopter production manufacturing. The table has been developed for both civil and military fleets.

In the seventies, the world's helicopter manufacturers produced some 23,173 units which had a current market value of production of over $15 billion. The civil portion of the total manufacturing of helicopters was nearly 10,000 units valued at $3.2 billion, while the military portion was 13,175 units valued at $11.8 billion.

During the eighties, it is forecast that some 32,428 units will be produced over the ten year period. The estimated value in current dollars (assumes 8 percent inflation) is some $64.1 billion. Civil helicopter production is forecast to be 24,186 units valued in current dollars at $23.8 billion while military production is 8,236 units valued at $40.3 billion. This indicates that civil helicopter production is expected to increase its market share in terms of the number of units and value relative to the military market over the next decade. The value of the military units, however, is expected to increase due to the higher unit cost of military helicopters in the future.

Table 3.3 shows the regional civil markets for helicopter units and their current dollar value for the 1970's and a projection for the period 1981-1990. It can be seen that the

Table 3.2

HELICOPTER NEW GROWTH AND REPLACEMENT GROWTH

	START OF YEAR INVENTORY		ATTRITION REPLACEMENT		NEW GROWTH		END OF YEAR INVENTORY	
	CIVIL	MILITARY	CIVIL	MILITARY	CIVIL	MILITARY	CIVIL	MILITARY
1970	5,508	18,155	-63	1,649	485	963	5,993	19,118
1971	5,993	19,118	-61	1,501	558	308	6,612	19,426
1972	6,612	19,426	-92	1,339	625	243	7,329	19,669
1973	7,329	19,669	-198	1,185	1,040	178	8,567	19,847
1974	8,567	19,847	-133	1,013	913	-87	9,613	19,760
1975	9,613	19,760	-38	1,102	861	-39	10,512	19,721
1976	10,512	19,721	75	892	727	8	11,239	19,729
1977	11,239	19,729	81	733	678	89	11,917	19,818
1978	11,917	19,818	53	706	784	74	12,701	19,892
1979	12,701	19,892	-73	389	1,346	261	14,120	20,153
1980	14,120	20,153	475	312	1,224	359	15,344	20,512
1981	15,344	20,512	515	318	1,335	332	16,679	20,844
1982	16,679	20,844	559	237	1,393	442	18,072	21,286
1983	18,072	21,286	605	405	1,489	252	19,561	21,538
1984	19,561	21,538	653	342	1,568	376	21,129	21,914
1985	21,129	21,914	705	343	1,664	578	22,793	22,492
1986	22,793	22,492	759	351	1,727	567	24,520	23,059
1987	24,520	23,059	814	359	1,815	533	26,336	23,592
1988	26,336	23,592	872	368	1,853	573	28,189	24,165
1989	28,189	24,165	931	377	1,932	592	30,121	24,757
1990	30,121	24,757	994	384	2,001	473	32,122	25,230

Source: Based on Bell Helicopter Textron Study.

Table 3.3

REGIONAL CIVIL MARKETS

	MID EAST/ AFRICA		LATIN AMERICA		ASIA/ PACIFIC		EUROPE		NORTH AMERICA		TOTAL 1/	
	Units	$ (M)	Units	$ (M)	Units	$ (M)	Units	$ (M)	Units	$ (M)	Units	$ (M)
1970	30	4	63	7	98	12	84	12	267	32	548	67
1971	50	14	45	6	66	10	92	18	297	38	558	88
1972	23	5	50	8	69	17	127	28	351	53	625	111
1973	34	9	56	15	104	23	170	43	660	109	1040	200
1974	32	7	52	16	101	30	145	64	559	109	913	233
1975	37	13	63	26	101	28	141	66	503	124	861	260
1976	47	23	80	21	105	32	99	45	464	117	802	239
1977	36	27	101	36	94	30	107	66	415	126	759	288
1978	48	35	66	25	127	53	145	112	446	139	837	365
1979	27	23	89	46	144	65	143	102	933	306	1346	546
1980	89	55	149	86	182	77	228	125	1051	465	1699	808
1981	107	65	152	78	210	108	236	145	1146	674	1851	1070
1982	105	61	162	97	181	105	256	210	1248	847	1952	1320
1983	117	88	170	116	222	149	271	230	1314	977	2094	1560
1984	116	93	175	130	239	184	290	319	1401	1067	2221	1793
1985	118	113	187	154	258	222	301	354	1505	1228	2369	2071
1986	123	126	195	185	273	252	311	397	1584	1375	2486	2337
1987	129	140	207	225	289	292	328	455	1677	1628	2670	2740
1988	132	175	217	382	81	317	344	576	1751	1665	2725	3015
1989	138	205	231	335	301	377	358	677	1835	2021	2863	3615
1990	146	242	243	383	313	435	370	760	1719	2324	2995	4144

1/ Total includes unknown.

Source: Based on Bell Helicopter Textron Study.

North American market is where most of the helicopter production is delivered. Some 60 percent (5,946) of all helicopters manufactured between 1970 and 1980 were for the North American market. The European market sales for the same period were 1,481 units (14.8%), while Asia/Pacific sales were 1,191 (11.9%), Latin America 814 units (8.1%) and Mid East/Africa 453 (4.5%). Unknown market sales of 103 units account for the remaining 1.2%.

Table 3.4 presents the regional military markets for the 1970's and a forecast for the 1981-1990 period. The table shows both the number of helicopter units and the current value. The table shows that during the 1970's some 6,070 helicopters were sold in North America, most in the early 1970's. Europe ranked second with sales of 2,686 units. The Middle East/Africa region ranked a close third with some 2,325 military units. During the 1980's, it is forecast that Europe will be the most important geographic region for military helicopter sales, with an expected 3,134 units sold over the ten year period. North America, with 2,070 units expected to be sold, ranks second. Asia/Pacific, with 1,169 units expected to be sold, and Mid East/Africa, with 1,116 units expected to be sold, are ranked third and fourth in the number of units over the ten year period. In terms of current dollar value, sales to North America are expected to be the highest, followed by Europe. The North American higher value in comparison to Europe reflects the higher unit costs of future U.S. military helicopters.

Table 3.4

REGIONAL MILITARY HELICOPTER MARKET

	MID EAST/ AFRICA		LATIN AMERICA		ASIA/ PACIFIC		EUROPE		NORTH AMERICA	
	Units	$ (M)	Units	$ (M)	Units	$ (M)	Units	$ (M)	Units	$ (M)
1970	162	165	34	13	150	82	386	184	1880	1140
1971	98	75	10	7	103	61	304	193	1294	673
1972	82	67	41	16	142	93	201	163	1116	440
1973	233	263	73	47	141	83	230	221	686	231
1974	207	179	87	36	163	191	259	219	210	203
1975	424	503	25	20	134	118	250	218	230	219
1976	373	432	65	78	108	101	219	180	135	167
1977	346	406	40	91	150	155	198	168	88	117
1978	188	224	71	89	220	173	174	413	127	169
1979	119	472	31	41	157	227	217	517	126	202
1980	93	131	54	49	98	86	248	594	178	391
1981	85	191	47	52	87	238	310	747	121	308
1982	108	276	57	103	118	179	284	665	112	340
1983	93	302	75	137	92	193	265	605	132	710
1984	107	370	76	151	98	312	259	662	178	1481
1985	110	421	64	156	134	376	353	1132	260	2028
1986	114	418	69	193	122	394	348	1342	265	2236
1987	97	465	77	231	128	492	337	1577	253	2398
1988	119	605	95	289	140	548	334	1706	253	2613
1989	136	703	83	305	118	522	330	1551	302	3104
1990	147	900	83	342	132	651	314	1975	181	2221

Source: Based on Bell Helicopter Textron Study.

Table 3.5 summarizes the historical and forecasted helicopter production for both civil and military helicopters. The table shows the number of units sold and the current dollar value of these sales.

3.3 HELICOPTER MARKET CLASSIFICATION

Helicopters are manufactured to meet varying market purposes which is represented by various helicopter classifications. The classification used in this analysis is the following:

CLASSIFICATION TYPE	WEIGHT CLASSIFICATION
Piston	All Weights
Light Single Engine Turbine	0 - 10,000 lbs
Light Twin Engine Turbine	5,000 - 10,000 lbs
Medium Single Engine Turbine	8,000 - 15,000 lbs
Medium Twin Engine Turbine	10,000 - 25,000 lbs
Heavy Multi Engine Turbine	3,000 - 20,000 lbs
Armed	All-Weights

The civil helicopter market is dominated by the light single engine class. In the 1970's, some 5,790 of this class have been manufactured. Examples of this helicopter class are the Bell 206B, Aerospatiale 350, and Hughes 500. It is expected that the class of helicopter will remain the dominant helicopter classification in the eighties, with some 14,311 expected to be manufactured.

Table 3.5

HELICOPTER PRODUCTION SUMMARY

	MILITARY		CIVIL		TOTAL	
	Units	$ Million	Units	$ Million	Units	$ Million
1970	2612	1583	547	67	3159	1650
1971	1808	1009	558	88	2366	1097
1972	1584	761	625	111	2209	872
1973	1363	844	1040	200	2403	1044
1974	926	827	914	233	1840	1060
1975	1063	1076	862	260	1925	1336
1976	901	1010	803	239	1704	1249
1977	822	937	757	288	1579	1225
1978	780	1068	838	365	1618	1433
1979	650	1458	1350	550	2000	2008
1980	671	1251	1699	807	2370	2058
1981	650	1535	1851	1078	2501	2613
1982	679	1569	1952	1320	2631	2889
1983	657	1947	2094	1558	2751	3505
1984	718	2977	2221	1793	2979	4770
1985	921	4116	2369	2071	3290	6187
1986	918	4583	2486	2337	3404	6910
1987	892	5162	2630	2741	3522	7903
1988	941	5766	2725	3104	3666	8870
1989	969	6587	2863	3615	3832	10,202
1990	857	6088	2995	4144	3852	10,232

Source: Based on Bell Helicopter Textron Study.

The piston class of helicopters was at one time the most numerous until the turbine engine, with its improved reliability, evolved in the late sixties. In the seventies some 2,403 piston units were manufactured. In the 1980's, 3,773 are forecast to be produced, most of which will be light, training aircraft such as the Hughes 300 and Robinson R22.

The light twin helicopter class was introduced to the market in 1971 and slowly expanded as as helicopter classification. In the seventies some 482 units were produced. The Aerospatiale Twin Star (AS 355) is a popular example of the class. In the eighties, this classification is expected to show vigorous growth, particularly with the introduction of the Bell 400 series in the mid 1980's. Total units in the ten year period are forecast to be 3,735.

Medium twin engine helicopters also grew in the seventies, particularly for their use in off-shore petroleum exploration. In the seventies some 814 units were produced. The Bell 214ST and the Sikorsky S76 are two examples of the classification. In the eighties, this class of helicopter is also expected to experience vigorous growth and it is forecast that some 2,386 units will be produced in the ten year period.

Medium single engine helicopters were the main heavy-lift helicopter in the seventies but have largely been replaced with medium twin-engine vehicles with their twin engine reliability advantage. The Bell 204 and Bell 205 are examples of the class. There are no civil medium single engine helicopters on the market as of 1982.

Heavy multi-engine helicopters, due to their specialized role and high cost, have been a low production class of helicopter. The Sikorsky S-61 and the Boeing Vertol 107 and 234 "Chinook" are examples of this helicopter class. In the eighties, about 35 of this class will likely be manufactured.

Table 3.6 shows the inventory and forecast of civil helicopters by classification.

The military helicopter market has also been analyzed as to helicopter classification.

The single light helicopter classification is the most numerous military helicopter produced in the seventies. Some 4,986 units were produced between 1970 and 1980. It is expected that in the eighties this classification will be replaced by medium twin engine helicopters as the most dominant classification. In the eighties, it is expected that some 1,361 light single engine units will be produced. The Bell OH-58 and Hughes OH-6 are examples of the classification.

In the seventies, there were some 3,810 units of medium single engine helicopters produced for the military. The Bell OH-1 is an example of this helicopter classification. In the eighties, twin turbine equipment will take over from single tur-

Table 3.6

CIVIL HELICOPTER MARKET BY CLASSIFICATION

	HEAVY MULTI		LIGHT SINGLE		LT/MEDIUM TWIN		MEDIUM MULTI		MEDIUM SINGLE		PISTON	
	No. Units	$ (M)	No. Units	$ (M)	No. Units	$ (M)	No. Units	$ (M)	No. Units	$ (M)	No. Units	$ (M)
1970	0	0	301	41	0	0	7	6	25	10	214	10
1971	0	0	317	47	10	0	24	21	24	10	183	9
1972	1	0	382	61	22	0	41	34	19	9	160	7
1973	5	17	613	98	24	8	68	55	22	11	308	12
1974	2	8	541	94	43	15	83	90	30	15	213	10
1975	2	9	513	101	32	13	102	109	32	18	181	10
1976	0	0	451	98	24	10	59	82	43	34	226	15
1977	0	0	475	118	26	17	74	126	13	14	169	13
1978	2	5	539	129	61	66	71	129	22	25	143	12
1979	0	0	841	242	59	62	113	184	20	23	266	25
1980	0	0	997	313	181	191	169	254	12	16	340	35
1981	1	10	1055	356	223	261	201	361	12	21	355	39
1982	3	32	1101	401	273	344	216	501	16	0	359	43
1983	3	43	1195	469	318	432	214	568	0	0	364	47
1984	4	84	1294	549	349	515	204	595	0	0	370	52
1985	4	91	1394	639	383	606	213	678	0	0	375	57
1986	4	98	1492	741	390	662	220	774	0	0	380	62
1987	4	106	1585	849	416	763	240	954	0	0	385	68
1988	4	114	1645	946	437	866	249	1102	0	0	390	75
1989	4	123	1733	1076	460	986	271	1348	0	0	395	82
1990	4	133	1817	1216	486	1126	288	1576	0	0	400	90

Source: Based on Bell Helicopter Textron Study.

bines as armed forces modernize their fleets for increased operations at night and in inclement weather conditions. The forecast for medium single helicopters is only 106 units over the ten year period.

Medium twin turbine helicopters significantly increased their share of the market during the seventies and some 1,744 were employed by the military. It is expected that in the eighties this classification will demonstrate vigorous growth and become the dominant military helicopter class with some 4,052 units expected to be produced. The Sikorsky OH-60 is an example of a military helicopter in this classification.

Armed helicopters produced in the seventies accounted for 939 units. The number in the eighties is expected to increase slightly to 1,258 units. The Hughes AH-64A is an example of a military helicopter in this classification.

The heavy multi engine helicopter class has been decreasing in numbers since the Vietnam war. The high cost of producing this class of helicopter will keep their quantities low over the forecast period. The Boeing Vertol CH-47 is an example of a helicopter in this classification. In the eighties some 144 are expected to be produced.

Table 3.7, overleaf, provides details of the inventory and forecast of military helicopters by classification. Both the number of helicopter units and their current dollar value are shown in the table.

Table 3.7

MILITARY HELICOPTER MARKET BY CLASSIFICATION

	ARMED		HEAVY MULTI		SINGLE LIGHT		LT/MED TWIN		MEDIUM MULTI		MEDIUM SINGLE		PISTON	
	No. Units	$ (M)	No. Units	$ (M)	No. Units	$ (M)	No. Units	$ (M)	No. Units	$ (M)	No. Units	$ (M)	No. Units	$ (M)
1970	93	59	307	601	989	176	0	0	125	123	1019	617	79	7
1971	39	22	122	254	778	126	4	0	271	241	576	365	18	1
1972	170	94	40	118	752	121	0	0	139	151	459	296	24	1
1973	44	26	110	327	702	125	19	5	116	136	316	212	56	13
1974	32	32	140	356	342	73	7	7	114	154	277	204	14	1
1975	96	106	90	307	285	73	29	11	186	261	374	318	3	0
1976	68	79	95	292	269	81	25	16	166	273	278	269	0	0
1977	77	87	81	248	274	80	22	39	118	212	259	271	11	0
1978	114	145	34	122	244	71	93	336	150	286	100	106	45	3
1979	127	398	54	193	187	56	96	407	130	317	76	87	0	0
1980	79	100	32	190	144	46	111	279	229	550	76	83	0	0
1981	21	29	37	230	145	52	185	397	246	810	16	18	0	0
1982	41	67	14	118	164	66	185	426	265	880	10	11	0	0
1983	38	76	14	128	138	63	163	352	294	1317	10	12	0	0
1984	74	305	14	138	127	59	156	353	337	2108	10	13	0	0
1985	212	948	14	149	176	94	102	251	405	2660	10	14	0	0
1986	214	1058	11	170	169	91	87	225	427	3204	10	15	0	0
1987	212	1162	11	183	111	61	91	252	457	3488	10	16	0	0
1988	214	1221	11	198	112	66	90	191	504	4072	10	17	0	0
1989	136	1118	10	191	109	70	97	222	577	4966	10	19	0	0
1990	88	451	8	156	110	76	101	251	540	5132	10	20	0	0

Source: Based on Bell Helicopter Textron Study.

3.4 HELICOPTER PURPOSE

Civil helicopter markets are dependent on the industrial sectors which use helicopters to assist in carrying out their business activities. Industrial concerns which now use helicopters extensively, and which are part of industrial sectors of the economy which are growing and which are expected to continue to grow, will tend to employ more helicopters in the future. This section examines the major user groups of helicopters. An inventory of uses in the 1970-1980 period is examined and a forecast of expected helicopter requirements is developed for the next decade.

- **Agriculture.** In the agricultural industry helicopters are used mainly for spraying crops, livestock inventory and crop surveying. Procurement of new helicopters in the seventies was low since most helicopter operators employ used, light piston engine helicopters for agricultural tasks. Some 470 units in the 1970-1980 period were allocated to the agricultural industry. In the eighties, this number is expected to double to 940 units. This increase is related to the requirement for increased food production and attrition of many of the existing agricultural helicopters. (eg. Recent Hughes 300 sales to Egypt are for agricultural purposes)

- **Air Transport.** This use category is composed of private, corporate and commercial air taxi operators which use helicopters for air transporting of personnel and goods. This category in the seventies expanded considerably and some 2,394 units were allocated to this category. The main growth came from corporate operators and there are now 1,000 companies which operate over 2,000 corporate helicopters. In the eighties, this use category is expected to show a high growth rate and some 6,790 units are forecast to be allocated to the air transportation sector. Corporate operators are expected to be the dominant users, but scheduled commercial helicopters are expected to become a larger part of this category in the future.

- **Cargo Distribution.** This use is characterized by ship-to-shore cargo unloading which has been used to overcome harbour congestion in such ports as Lagos, Nigeria and Jedda, Saudia Arabia. The use is very small and sporadic. Only about 21 units were employed in this use category in the seventies. No units are forecast in the eighties.

- **Construction.** The construction industry uses helicopters to lift transmission towers, module structures, building equipment units, ski lift towers, and to do other specialized construction work. In the seventies, 402 helicopters were allocated to this use category. It is expected in the eighties that the use of helicopters in construction will nearly double with some 758 units produced. Minimization of environmental impact is one of the reasons helicopters will be used more in construction.

- **Forestry.** The forest industry uses helicopters for timber cruising, tree spraying and helicopter logging. Historically the use of helicopters has fluctuated and used helicopters have dominated the industry. In the seventies, 212 units were used by the forestry industry. In the eighties, there is expected to be strong growth. The higher cost of forest products will increase the use of helicopters as the productivity contribution of helicopters becomes better known by the forest industry. Minimization of environmental impact and access to remote areas are other reasons. The forecast for the ten year period is 926 units.

- **Specialty.** This use category incorporates such diverse uses such as powerline and pipeline patrol, training flights, surveying and mapping, and media use by television and press. This use category is the largest of all the use categories with some 3,637 units allocated to this category in the seventies. It is forecast that this use category will remain dominant and the number of units will double to 7,850 for the next ten years. Media use will in particular contribute to the growth of this category.

- **Public Service.** Helicopters are used by public service agencies for emergency medical services, police and fire protection, and government businesses such as fish and wildlife surveys. In the seventies, some 1,179 units were allocated to public service use. The number of units is expected to double to 2,227 units in the next ten years. A large portion of the growth will be attributable to aerial ambulance use which has been extensively developed in the United States.

- **Resource Exploration and Development.** The resource industry uses helicopters extensively for off-shore petroleum exploration and development as well as for on-shore mineral exploration and development. The following paragraphs present additional details on this industrial use category.

Use of helicopters in off-shore exploration began in the Gulf of Mexico in 1948 and helicopters have been an integral part of the industry's support program since that time. Increased requirements by the petroleum industry have been one of the strong stimulators for technology improvements in helicopters, particularly twin-engine vehicles. The following illustrates the current and expected use of helicopters for off-shore exploration by geographic region.

	1980	1983	1988
Gulf of Mexico	600	1007	1405
Canada/Alaska/Rest of U.S.	50	82	110
Caribbean/Mexico	62	115	165
South America	77	96	111
North Sea	204	252	280
Middle East	56	70	75
Southeast Asia	136	160	190
Rest of World	183	204	254
TOTAL	1367	1986	2590

Source: Ocean Industry, October 1981.

In a recent survey of commercial and petroleum companies which operate off-shore helicopters, the following figures are provided.

Geographic Region	Operating 1983	Planned or on Order
Canada	30	6
U.S.		
East Coast	3	N/A
Gulf of Mexico	659	55
West Coast	58	13 (EST)
Arctic/Alaska	68	6
S.Central America	268	10 (EST)
North Sea	186	58 (EST)
Mediterranean	12	N/A
West Africa	60	2
Middle East	108	N/A
India	25	20
S.E. Asia	200	16 (EST)
Far East	54	2
Australia/N.Z.	56	N/A
	1787	188

Source: Ocean Industry, October, 1983

This recent survey indicates that the number of helicopters in 1983 is 11 percent less than predicted in 1981. Yet, it still represents a growth of over 30 percent in the two years. The Gulf of Mexico and North Sea are lower than predicted but higher growth was experienced in the Middle East and Southeast Asia. The planned or on order figures will add another 188 helicopters to the off-shore helicopter fleet.

On-shore exploration uses helicopters to service oil and gas drill rigs. Helicopter are used extensively in North and South America and Southeast Asia for exploration and development.

The mining industry uses helicopters for surveys, exploration and moving critical personnel and equipment. Most of the mining use is in North America, with particular emphasis on coal mining explorations.

In the seventies, some 1,678 units were allocated to resource exploration duties. The next decade is forecast to nearly triple, to some 4,676 units, the number of helicopter units used by the resource industry.

Tables 3.8 and 3.9 provide a summary of the number of helicopter units and the current dollar value of the helicopters classified by industrial use category.

3.5 DIRECT EMPLOYMENT

Helicopter manufacturing and spare parts support production in the Western World directly employs about 24,000, of which 60 percent are employed by United States manufacturers. Total direct and indirect employment is estimated to be 51,000, of which 28,000 are associated with the United States helicopter manufacturing industry. Helicopter manufacturing labour employment peaked in the late sixties with over 30,000 direct employees to meet the military helicopter needs of the Vietnam war. Immediately after the war, employment dropped and by 1972 was down to 19,000. In the late seventies, the growth pattern in direct employment resumed as the demand for helicopters resulted in increased unit production and therefore more employees.

Table 3.8
CIVIL HELICOPTER MARKET BY USE
(Helicopter Units)

	AGRI	AIR TRAN	CARGO DIST.	CONST	FOR-ESTRY	OTHER	PUBLIC SERV.	RE-SOURCE	TOTAL
1970	41	84	2	26	6	248	72	68	547
1971	23	93	3	22	14	229	112	62	558
1972	25	108	1	35	12	233	102	109	625
1973	51	261	6	52	20	439	101	110	1040
1974	32	204	2	48	22	329	121	156	914
1975	40	155	1	31	16	318	119	182	862
1976	55	228	3	30	18	249	91	129	803
1977	42	206	1	23	17	250	71	147	757
1978	46	189	1	35	11	303	91	162	838
1979	51	390	1	45	33	467	132	231	1350
1980	64	476	0	55	43	572	167	322	1699
1981	70	520	0	59	52	618	179	353	1854
1982	75	548	0	62	60	647	187	373	1952
1983	81	588	0	66	69	690	198	402	2094
1984	86	623	0	70	78	727	208	429	2221
1985	92	665	0	74	88	772	219	459	2369
1986	97	698	0	78	97	805	229	463	2486
1987	103	738	0	82	107	848	239	513	2630
1988	106	765	0	85	115	875	246	533	2723
1989	112	804	0	89	125	915	256	562	2863
1990	118	841	0	93	135	953	266	589	2995

Source: Bell Helicopter Textron Study.

Table 3.9

CIVIL HELICOPTER MARKET BY USE

($ Millions)

	AGRI	AIR TRAN	CARGO DIST.	CONST	FOR- ESTRY	OTHER	PUBLIC SERV.	RE- SOURCE	TOTAL
1970	3	9	0	3	1	29	8	14	67
1971	3	15	0	3	1	31	17	18	88
1972	2	21	0	6	1	35	13	33	111
1973	5	31	15	9	3	63	30	43	200
1974	4	35	1	14	4	58	32	84	233
1975	7	33	0	7	12	69	35	97	260
1976	6	64	2	8	7	53	36	64	239
1977	6	56	0	11	9	54	38	115	288
1978	7	66	0	16	3	98	51	123	365
1979	12	125	0	16	13	145	69	167	546
1980	32	239	0	28	22	243	84	161	809
1981	42	313	0	35	31	337	108	212	1078
1982	52	381	0	43	42	412	130	259	1319
1983	62	450	0	50	53	487	151	307	1560
1984	71	515	0	58	65	557	172	355	1793
1985	83	599	0	67	79	632	197	414	2071
1986	94	676	0	75	94	711	221	467	2338
1987	110	790	0	88	114	833	256	549	2740
1988	124	894	0	99	134	9742	287	623	3103
1989	145	1039	0	115	162	1097	331	727	3616
1990	167	1190	0	132	191	1255	376	833	4144

Source: Based on Bell Helicopter Textron Study.

In the eighties, employment is expected to grow, even taking into account improved manufacturing technologies and increased employee productivity. Despite the recent economic recession, the larger manufacturers have not reported significant reductions in personnel; in fact, Sikorsky has added to its employment due to its military orders.

The direct world labour figures are shown in Table 3.10. The table includes both civil and military production. The table also shows the United States employment in relation to the rest of the world. It should be noted that direct employment includes the manufacture of spare parts by the major helicopter manufacturers. As inventories grow, and helicopter complexity increases, spare parts requirements become increasingly significant as part of the helicopter manufacturer's direct labour.

3.6 HELICOPTER MANUFACTURERS

There are number of companies which manufacture helicopters of their own design and/or manufacture units under license. This section addresses these manufacturers and discusses the helicopter models which are produced. It should be noted that the industry is dynamic and helicopter models and their variants are being introduced or retired from the market continually. It is also difficult to obtain production figures due to joint military production by some manufacturers and also those which have licensing agreements.

Table 3.10

DIRECT EMPLOYMENT
CIVIL AND MILITARY HELICOPTER PRODUCTION

	FOREIGN	UNITED STATES	TOTAL
1970	9,800	14,408	24,208
1971	10,355	10,607	20,962
1972	10,315	8,878	19,193
1983	11,351	9,269	20,620
1974	10,385	10,714	21,099
1975	10,691	12,091	22,782
1976	10,903	11,642	22,545
1977	9,740	10,317	20,057
1978	11,217	11,075	22,292
1979	9,736	13,175	22,911
1980	9,222	14,675	23,897
1981	12,115	15,360	27,475
1982	12,483	15,247	27,730
1983	12,569	16,993	29,562
1984	13,085	19,238	32,320
1985	14,768	21,762	36,530
1986	15,072	22,166	37,238
1987	16,051	22,918	38,969
1988	16,795	23,842	40,637
1989	16,420	28,150	44,570
1990	16,009	25,475	41,484

Source: Based on Bell Helicopter Textron Study.

3.6.1 Aerospatiale Helicopter Corporation. La Courneuve (Marigname), France

This large aerospace corporation is owned by the French Government and manufacturers the A300/A310, Transall and Epsilon aircraft, as well as missiles, and space and ballistic systems. It operates a separate helicopter division which employs about 8,000.

The following helicopters are in production:

- AS 350 ECUREUIL/ASTAR - First flight June, 1977. There were 1,000 delivered in 31 countries as of November 1983 and further 500 on order of this popular single engine helicopter. Helibras Brazil has a licensing agreement to manufacture 400 "Esquilos" for the South American market, of which 32 had been delivered in the first quarter of 1982. There are 228 AStars in the United States and 85 in Canada.

- AS 355 ECUREUIL 2/TWIN STAR - First flight September, 1979. The Ecureuil is powered by two Turbomeca Arriel engines while the Twin Star has two Avco Lycoming LTS 101 engines. There were 461 sold to operators in 21 countries as of May 1982. There are 122 Twin Stars in the United States and eight in Canada.

- SA 365 N DAUPHIN - First flight March, 1979. The 365 N is a 10-14 seat helicopter powered by two Turbomeca Arriel engines. Its design uses composite materials and has a retractable undercarriage. There have been 320 sold including 50 to China as of May, 1982. Only 5 are in the United States.

- SA 366 G DAUPHIN 2 (HH 65 A DOLPHIN) - First flight July, 1980. This helicopter is similar to the SA 365 N, but is powered by two Avco Lycoming turbo shaft engines. U.S. Coast Guard have a requirement for 90. As of May, 1982, 23 had been sold and delivered.

- SA 332 SUPER PUMA - First flight September, 1977. A modified version of the Puma with higher powered Turbomeca Makila engines and a larger fuselage. More than 100 Super Pumas have been ordered, including 55 Super Tigers for Bristow Helicopters. As of May, 1982 some 114 units sold to 14 countries. The U.S. register shows only two Super Pumas and there are seven Pumas and Super Pumas in Canada.

In addition to the current production models, Aerospatiale has a number of helicopter models which are still in service in fleets around the world. These include:

- SA 313-SA 318 ALOUETTE 11- All the helicopters in this family are basically similar and differ principally in their power plants. The first production model was the SA 313 B powered by a Salmson 9 engine. The Astazou turbine powered SA 318 C first flew in 1961. When production ended in 1975, some 900 piston engine versions and 350 turbine versions had been manufactured. The SA 315 B Lama was also developed from the Alouette 11 family.

- SA 315 B LAMA- First flight September, 1970. As of May, 1982 some 369 units sold to 29 countries. It is a popular helicopter for operations in high altitude regions. It may be re-introduced with an AS 350 airframe and 850 hp Turbomeca engine in 1984-85. The SA 315 is also manufactured by Hindustan Aeronautics Ltd. under license as the "Chetak" for the Indian Army. Some 140 units have been manufactured in India. Helibras Brazil also manufacturers the SA 315 under the name "Gavio" and some 30 units had been made by the first quarter of 1982. There are 80 Lamas in the United States.

- SA 316-SA 319 ALOUETTE III - The first flight of a SA 316 B was February, 1959. The Alouette III series was derived from the Alouette II, offering a larger cabin, more powerful engine and improved performance. When production ended in May, 1982 some 1,439 units had been built for delivery in 74 countries. Hindustan Aeronautics Ltd. continue to build the SA 316 B under the name "Chetak" and some 253 had been made as of May, 1982. There are about 100 Alouette III's in the United States.

- SA 321 SUPER FRELON - First flight December, 1962. This large three engine helicopter, which can carry up to 37 passegers, has been sold in 8 countries and some 99 units manufactured before production was stopped. Most of which were ordered by the French Airforce and Navy. None are in North America.

- SA 330 PUMA - First flight April, 1965. This twin-engine, 20 passenger helicopter is the forerunner to the Super Puma. Some 681 units were produced by Aerospatiale. Nurtanio of Indonesia is licensed to build the Puma (and Super Puma) and as of May, 1982, 11 Pumas had been built by Nurtanio. There are 15 Pumas in the United States.

- SA 341/342 GAZELLE - First flight April, 1967. This helicopter is an advanced version of the Alouette III helicopter with an uprated Astazou turboshaft engine. Some 1,060 units of this helicopter were sold to 36 countries before Aerospatiale stopped production in 1982.

Westland Helicopters of England has a joint-venture agreement to manufacture the helicopter and Soko of Yugoslavia has a license agreement. There are 63 Gazelles in the United States.

- SA 360 - SA 361 H DAUPHIN - First flight May, 1973. This is a single engine version of the Dauphin 2. No production figures are available. Some 15 single engine Dauphins are in the United States.

- SA 365 C - The SA 365 C Dauphin 2 is marginally larger than the standard Dauphin and differs principally in having two 650 shp Turbomeca Arriel engines and accommodation for up to 13 persons. The current production SA 365N and SA 366G are based on the SA 365C design.

Aerospatiale has a Grande Prairie, Texas completion centre for final assembly of Aerospatiale helicopter products for the North American market. It is also the North American spare parts depot.

3.6.2 Agusta SpA - Costruzioni Aeronautiche Giovanni Agusta. Milan, Italy

This Italian manufacturer and its subsidiary Elicotteri Meridionali SpA (Frosinone, Italy) manufactures a variety of helicopters. One helicopter, the Agusta 109A, is their own design while the others are built under licensing agreements with Bell Helicopter and Boeing Vertol. Agusta built its first helicopter a Bell 47G in 1952 under license from Bell Helicopter. Agusta employs about 6,000.

- AGUSTA 109A MK II - First flight August, 1971. Some 250 ordered and 170 delivered as of January 1982. Deliveries in North America were 30 and a total of 50 expected by the end of 1983.

- AB 204 - The Agusta - Bell 204 B, was in production between 1961 and 1974 and was powered by a Rolls-Royce Gnome turbo shaft engine.

- AB 205 - First production in 1965, no production figures available. Licensing agreement with Bell.

- AB 206B - First production in 1966 and some 1,000 built under license by Bell Helicopter at the end of 1981.

- AB 212 - First production in 1970 and some 49 sold by the end of 1981. The Italian Navy, Turkey, Iran, Peru and Venezuela have purchased the AB 212. Licensed by Bell Helicoper.

- AS SH 3 D/H - First production in 1965. Manufactured under license by Sikorsky.

- AS 61N SILVER - First production in 1980. Some 20 have been built under license from Sikorsky. Agusta has world-wide rights to the S-61N design.

- EM CH47C - First production 1970. This tandem helicopter is built by Elicotteri Meridionali under a license agreement with Boeing Vertol. Some 151 had been built by the first quarter of 1982.

- EM 234 - Elicotteri Meridionali has a license agreement with Boeing Vertol for the "Chinook" but to date none have been built in Italy.

3.6.3 Bell Helicopter Textron. Fort Worth, Texas (Amarillo)

This is the largest helicopter manufacturer in the world and is operated as a division of Textron Industries Inc. The parent company is headquartered in Providence, Rhode Island and is a $3 billion corporate conglomerate. Bell Helicopter employs over 9,000 to manufacture civil and military helicopters. It has been producing helicopters since 1946 when Larry Bell, the founder, introduced the Bell 47, the first commercially licensed helicopter The following models are in production.

- BELL 206B III JET RANGER - First flight of the Bell 206A was in 1963 and the Bell 206B in 1970. This is by far the largest production helicopter in terms of the number of units built. As of

January, 1982 over 7,000 had been built by Bell and its authorized licensees. Out of this total, some 4,500 are operated by commercial customers. There are 1,827 units registered in the United States and some 423 in Canada.

- BELL KIOWA (Military OH-58, TH-57A SEA RANGER CH 136 Canadian Armed Forces). This is the military version of the Bell 206. Some 2,446 have been built including 86 sold to the Canadian Armed Forces. The U.S. Navy recently took delivery of an additional 85 TH-57 Sea Ranger versions.

- BELL 406. This is a current modification program to up-date engines, electronics, etc., on 578 existing OH-58A's.

- BELL 206L-1. First flight in May, 1978. This is a larger civil version of the Bell 206B. In the second quarter of 1983, a total of 780 units had been sold. Bell reported it had sold out of entire 1983 production quota by October 1983. The United States has 436 Long Rangers on the civil register and there are 186 in Canada.

- BELL 209 HUEY COBRA (Military AH-1G, AH-1Q, AH-1R, AH-1J AH-1T, AH-1S). First flight 1965. Extensively used in Vietnam war and some 2,800 have been manufactured. Currently 249 are being modernized for the U.S. Army by Bell Helicopter.

- BELL 212 [Military UH-1N, CH-135 (Canadian)]. First flight in October, 1970. This is a twin engine helicopter used by both civil and military, using the Pratt & Whitney of Canada Ltd. PT 6T-3 engine. It can accommodate up to 15 passengers. The U.S. Army has 300, and the Canadian Armed Forces have 50 Bell 212s in operation. In total, more than 1,200 had been produced to the end of 1983. The U.S. civil register shows 169 Bell 212s. There are about 37 civil Bell 212s in Canada.

- BELL 214 [BIG LIFTER]. First flight in 1974. This helicopter was developed from the Bell 205 specifically for the military in Iran. It can carry 14 passengers or can be used for crop spraying or firefighting. It is powered by a single General Electric T55 engine. The Bell 214 ST is the latest version and is powered by two GE CT7 engines. There are 8 Bell 214s in Canada including the ST version.

- BELL 412. First flight August, 1979. As of June 1982, 74 units of this four-bladed rotor-helicopter had been delivered to operators in 15 countries and another 90 were on order. There are 47 Bell 412s in the United States and 4 in Canada.

- BELL 214 ST.(Super Transport) First flight February, 1979. Bell plans a production of 100 units. As of September, 1983, 14 were in service and 6 were on order primarily from off-shore petroleum helicopter operators. There are 10 on the U.S. register. Okanagan Helicopters has two Bell 214 STs.

- BELL 222. First flight August, 1976. The helicopter is powered by two Avco Lycoming LTS 101 engines. Some 71 have been delivered by the fourth quarter of 1983 out of a total of 80 ordered including one to the Alberta Government. This helicopter model has been purchased primarily by corporate operators. There are 53 registered in the United States.

In addition to the above production models, the following models are noted:

- BELL 47 (Military OH 13 TH 13 AH 1 SIOUX) Introduced in 1946 and more than 2,500 produced before production stopped in 1974. The original engine was a Franklin GV 4 which was replaced in 1956 by a Lycoming TVO engine. There are still 1,519 Bell 47s registered in the U.S. and about 93 in Canada.

- BELL 204/205 (Military UH 1D/H, EH-1H, HH-1H IROQUOIS). Bell 204 certified in 1963 and Bell 205 in 1968. The Bell 205 is basically similar to the Bell 204 but has a longer fuselage which accommodates up to 15 passengers. The United States military still operates close to 4,000 of the medium single engine helicopters. There are a number of civil versions still operating, particularly in Western Canada. There are some 288 civil Bell 204/205 in the United States and 59 in in Canada.

- BELL D 292 (ACAP) Army Advanced Composite Airframe Program. This is a joint research program for development of a design using composite material construction by Bell and Grumman Aerospace Corporation. The Bell 222 design dynamics are used. The helicopter will be tested by the U.S. Army in 1984.

- BELL 406 SCOUT (AHIP) Army Helicopter Improvement Program. This research military model is an up-dated version of the existing OH-58A model developed for a potential military contract for production. McDonnell Douglas Astronautics and

Northrop Corporation are also co-developers of the Bell 406. Some 578 units will be produced at a cost of $2.5 billion if Bell is selected by the U.S. military.

- BELL MODEL 301 (Military XV-15) Bell and Boeing Vertol are co-developers of the JVX (Joint Services Advanced Vertical Lift) tilt-rotor model jointly funded by NASA, the U.S. Army and the U.S. Navy. The Army funding was recently curtailed but the Navy has agreed to continue sponsorship. The U.S. Marines have also indicated a requirement for 552 units of a JVX type helicopter.

- BELL MODEL 249 (AH-1S) (COBRA) The U.S. Army has ordered 988 Cobras for delivery in the late eighties. This is an armed attack helicopter using composite rotor blades and other advanced materials. These improvements are based on particpation in the Army's Advanced Rotorcraft Technology Integration (ARTI) program, and a research contract with Sperry, Honeywell and Texas Instruments to develop a technology base for electronic (digital fly-by-light control) systems, and a pre-production prototype is at Bell Helicopters, Arlington, Texas test centre.

- BELL MODEL 400 Series This is a new light twin helicopter series for the civilian market announced in February 1983. The helicopter is planned to be manufactured in Canada. Bell expect to sell 5,000 units between 1985 and 2000. The Bell 400 will be powered by twin Allison 250-C20 P engines and use conventional production materials. The Bell 440 is to be flown in 1989 with the use of Pratt & Whitney Canada Ltd. STEP engines (PW 209 T) and extensive composite materials in the airframe and rotating components. A 400A to be flown in 1988 will also have PW 209 T engines.

- BELL LHX (Light Helicopter Experimental). Three research models are being developed by Bell Helicopter for a U.S. Army competition, one of which is the Bell Advanced Tilt Rotor (BAT). The three models differ in their speed and range. They incorporate the 680 all-composite bearing-less rotor system developed by Bell Helicopter.

3.4.4 Boeing Vertol. Philadelphia, Pennsylvania

The company is a subsidiary of the Boeing Airplane Company of Seattle, Washington, the world's largest aerospace firm. The helicopter subsidiary employs about 5,000. Boeing Vertol manufacture heavy tandem rotor helicopters, most of which are used by the military.

- BV 234 CHINOOK - First flight August, 1980. This 44 seat helicopter has been ordered for off-shore petroleum exploration to shuttle drilling crews over long distances. There are 12 BV 234s which have been manufactured.

- BV 114-414 SERIES [Military CH-47 SERIES, CH 147 (Canada)]. All the units produced in the series have been military versions. The BV 414 is in production and the Spanish Army has acquired this version. As of February, 1982, some 959 of the series had been manufactured including 151 by Elicotteri Meridionali SpA under license to Boeing Vertol. The Canadian Armed Forces acquired 8 BV 173 (CH-147) in 1974 and 4 are stationed with the 447 Squadron in Edmonton and the other 4 with the 450 Squadron in Ottawa. Boeing Vertol is now modernizing 436 of the U.S. Army's CH-47D with fibreglass rotor blades, new avionics, advanced flight control system, new electrical systems, up-dated airframe and Lycoming T55-L-712 engines.

- BV 107-11 (Military CH-46 UH-46 SEA KNIGHT CH-113 CANADA). First certified in 1962. This is a smaller version of the BV 114-414 series with 28 seats and General Electric CT-58 engines. There were 624 units manufactured for the U.S. military as well as 6 CH 113 Labradors and 8 CH 113A Voyagors for the Canadian military. The Royal Swedish Air Force also ordered the HKP-4 version with Roll Royce Gnome 1200 engines. Boeing Vertol no longer manufacture the BV 107-11 but transferred the rights to Kawasaki in Japan in 1965. Since 1965, Kawasaki has manufactured another 131 units most for the military but some are now used by civilian operators. Boeing Vertol is also modernizing 273 CH-46E Sea Knights by installing fibreglass rotor blades, up-dated airframe, electrical system, drive system and hydraulics. Columbia Helicopters, Aurora, Oregon, is the largest private operator with 12 BV 107-11s used mainly in helicopter logging. Columbia Helicopters lease a BV 107 to Whonnock Industries for helicopter logging in British Columbia.

- BV 360. This is a research and development model being developed by Boeing Vertol to test the application of composite materials in the manufacture of heavy tandem rotor helicopters. It is a smaller version of the Model BV 234 and is expected to carry 25-35 passengers. It should be flying by mid-1985.

Boeing Vertol Canada Ltd. is a subsidiary of Boeing Vertol located in Arnprior, Ontario. It employs some 230 people in its 100,000 sq. ft. facility. The company does not manufacture but was established to repair Boeing Vertol helicopters in the Canadian Armed Forces. Presently the CH 113 and CH 113A are undergoing a modification program similar to the U.S. military program for the CH 46. Boeing of Canada Ltd. is a Boeing Aircraft Company subsidiary located in Winnipeg, Manitoba which provides composite helicopter and fixed-wing components principally to Boeing Vertol helicopters and the Boeing Airplane Company.

3.6.5 Brantly-Hynes Helicopter Inc. Frederick, Okalahoma

This is a small firm which manufactures two small types of piston engine helicopters. The firm has been in existence for several years but has not produced many helicopters. It was reorganized in 1982, with the introduction of Mr. Hynes to the firm, and apparently a more aggressive marketing program has been now initiated. It is now called Hynes Helicopter Divison of Hynes Aviation Industries.

- (H-2) B-2B. Certified first in 1959, this is a small, two seat helicopter powered by a Lycoming TVO-136 engine. In 1982, only 6 units were produced. No sales are reported for 1983. Since being introduced in 1959, only 150 units are in service.

- B 305. Certified in 1965, this is a five seat helicopter powered with a Lycoming TVO-540 piston engine. There were no production units made in 1982 but the company planned to market this version in 1983. Only 15 are currently in service.

3.6.6 Bredanardi Costruzioni Aeronautiche SpA. Ascoli Piceno, Italy

Bredanardi Costruzioni Aeronautiche have a license to manufacture the Hughes 300C and 500D for European, African and Middle East markets. Production figures are not available.

3.6.7 Construcciones Aeronauticas, SA (CASA). Madrid, Spain

This is the government-owned aerospace company which manufactures the CASA C 212 aircraft and components for the French aerospace market. It also repairs Bell helicopter models and will manufacture under licence the MBB BO 105.

- MBB BO 105 C. CASA has an agreement with the German MBB company to assemble 70 BO 105 Cs for the Spanish Army.

3.6.8 Enstrom Helicopter Corp. Menominee, Michigan

A manufacturer of a series of three seat piston engine helicopters designed by Rudy Enstrom. Some 800 helicopters have been produced by this manufacturer. In 1981, 47 units were produced and in 1982 some 22 units and reportedly only 6 units in 1983. The models in production are the following:

E 280C and 280F (First certified in 1974). There 150 in the United States. A 280 FX version has been introduced with improved aerodynamics and a turbo charged Lycoming H10-360 engine.

F 28C and F28F (First certified in 1965). There are some 350 in the United States.

Enstrom also makes auxiliary fuel tanks for Boeing 727 modifications. The company is reportedly up for sale.

3.6.9 Fuji Heavy Industries Ltd. Utsunomiya, Japan

Manufacturers under license from Bell Helicopter Textron the Bell 204B and Bell UH1H for the Japanese market. No figures are available on production numbers.

3.6.10 Fleet Aerospace Corp. Fort Erie, Ontario

This is an aerospace component manufacturer controlled by the Ronyx Corporation Ltd. of Toronto, Ontario. Fleet, in 1983, had sales of $35.2 million from manufacturing aerospace components for the F-18 fighter, Lockheed P3C, Bowing Awac and McDonnell Douglas MD80 passenger aircraft. It is actively manufacturing sub-components for the Sikorsky S 60 Black Hawk including Medivac medical evacuation kits, composite BIM blankets and assembly and bonding of composite blade components. It also makes composite fairings for the Sikorsky CH-53 E Stallion. In 1950, Fleet developed a complete helicopter - the

DOMAN-FLEET LZ 5, but no sales resulted and production was not started. MBB of Germany announced December 13, 1983 that Fleet will assemble BO 105 helicopters at a new $80 million plant to employ 760 after the helicopter is certified in 1984 by the FAA. The Federal and Ontario governments will assist with $34.9 million of the $69.3 million needed for the new facilities. No details are available as to the number of units to be produced. The BO 105LS model will be manufactured with the high performance Allison 250 C-28 engines. It is planned that the Pratt & Whitney STEP engine will eventually replace the Allison engine.

3.6.11 Helibras. San Jose dos Campos, SpA Brazil

Helibras is a division of Avibras Industria Aeroespacial SA, a manufacturer of missile and other aerospace equipment. Helibras has a license to manufacture the Aerospatiale 315B Lama under the name "Gaviao" and some 30 units have been manufactured. It is also licensed to manufacture up to 400 Aerospatiale AS 350s under the name "Esquilo". As of the first quarter of 1982, 32 Esquilos had been delivered.

3.6.12 Hiller Aviation. Porterville, California

This company was started in the late 1940's by Stanley Hiller and has produced hundreds of small helicopters. Mr. Hiller sold his interests in the 1970's. The company has been looking for new equity capital or opportunities to sell the company. In July 1983, an agreement to sell 70% of the shares to the Cezar-Cook Group of Toronto, Ontario was announced. The Canadian group's financing was contingent on support of the

Federal Government for $3 million. Hiller Aviation has now cancelled the agreement and was looking at other offers. It is now reported that the company is in financial difficulty and Rogerson Aircraft of Irvine, California has purchased the company assets as the result of a court order. It is expected that production of the UH-12 E and FH-1100 will resume under the new owners. There are 85 people employed in the company. The company produces two basic designs.

- UH-12E (Military OH-23 RAVEN). First UH-12 certified in 1948 and was then powered by a Franklin GV 4 engine. This three seat helicopter is now normally powered by a Lycoming 540 piston, but a turbine version with an Allison 250C-20B engine is available (UH-12ET). Figures are not available but likely about 1,000 have been produced, of which 775 are in the United States. There are only 9 in Canada.

- FH1100 PEGASUS (Military OH-5). The helicopter was first certified in 1963 by Fairchild Industries Ltd. which at the time owned Hiller. Fairchild built 246 units of the 5-seat Allison 250 powered vehicle. In 1982, Hiller acquired the rights to the helicopter. Orders in 1983 were 20. There are 86 FH1100s in the United States out of 150 still operating around the world. There are 13 FH1100s in Canada.

3.6.13 Hillman Helicopter Associates. Chandler, Arizona

This is a new manufacturer which has had its 3-place Lycoming piston engine Hillman 360 certified in 1983 and planned to make its first deliveries in 1984. The helicopter is a small training vehicle. The company has a division in Beek in Donk, The Netherlands, for sales to the European market. Unfortunately, the company founder died in an accident and the company is no longer active. Evergreen Helicopters is negotiating with potential new owners to produce the helicopter at its Marana Park, Arizona facilities.

3.6.14 Hindustan Aeronautics Ltd. Bangalore, India

This company manufactures under license the Aerospatiale SA 315B Lama (Cheeta) and Aerospatiale SA 316B Alouette III (Chetak) for the Indian Army. As of May, 1982, it had produced 140 Cheetas and 253 Chetak units. The company is also developing its own twin-engine advanced light helicopter.

3.6.15 Hughes Helicopters Inc. Culver City, California

This company, with some 5,000 employees, was privately controlled by the Summa Corporation which also owns Hughes Aircraft Company, one of the largest aerospace companies in the United States, manufacturing aerospace products, missiles, electronic guidance systems and communications products. Summa Corporation has recently sold Hughes Helicopters and Hughes Aircraft on behalf of the estate of Howard Hughes who was the major shareholder. It is reported that McDonnell Douglas has agreed to buy Hughes Helicopters Inc. for $470 million and will operate it as a separate company. Hughes Helicopters manufactures civil and military helicopters; some 6,000 units have been manufactured for service in some 100 countries. In addition to its own manufacturing, Hughes Helicopters has licensed manufacturing for the Hughes 300 and Hughes 500 series of helicopters to the following:

Representaciones Aero Commerciales Argentina SA
Kawasaki Heavy Industries Ltd.
Korean Air Lines (Jedong Industries Ltd.)
Bredanardi Costruzioni Aeronautiche SpA

Models produced by the firm include:

- HUGHES 300/269 (Military TH-55A OSAGE). This is a three seat piston engine helicopter first flown in December 1959. As of January, 1982, it is reported that some 2,750 units have been manufactured by Hughes and its licensees, including 800 for the U.S. Army. Hughes Helicopters announced in mid-1983 that, due to high production costs, the Hughes 300 production would be transferred to the Schweizer Aircraft Corp. of Elmira, New York. The Hughes name would be retained and Hughes would continue to support the helicopter. Schweizer now employs 200 to make subcontract parts for Boeing, Sikorsky and Bell. The Hughes 300C production will double employment. The first Schweizer produced model will be by May 1984. In 1984, it is planned that 40 units will be built and 125 the year after. There are 900 of the series in the United States civil register. There are 48 Hughes 300 series in Canada.

- HUGHES 500/530/369 (Military OH-6A CAYUSE). This helicopter first flew in November 1968 and is a 5-7 seat turbine powered vehicle. There have been over 3,000 units of the series manufactured. The Hughes 530 is the latest version and is a high performance Hughes 500 with an Allison 250-C30 engine. The helicopter was certified in July, 1983. The Hughes 500D model alone contributed 1,000 units to the total before production stopped in January 1981. The U.S. Army still operates about 550 units (OH-6A) There are nearly 700 civil versions in the United States. There are 91 Hughes 500 series in Canada.

- HUGHES 77 (Military YAH-64 APACHE). This armed attack helicopter was first developed in September 1975 and is only now in production. It is powered by two General Electric T 700 turbo shaft engines. The Apache is highly manoeuverable and equipped with infrared, laser and other high technology systems. The U.S. Army plans to acquire some 446 Apache units at a cost of $4,990 million. Hughes are planning to sell 515 units including the U.S. Army order. The company is currently testing composite tail rotors on the Apache and has flown it with composite main rotor blades.

- NOTAR. This is a research development helicopter based on the Hughes OH-6A model but does not have a traditional tail rotor for directional stability. It produces air flow by a fan located in the tail boom.

3.6.16 Kaman Aerospace Corporation. Bloomfield, Connecticut

This firm designs and produces aerospace and energy systems. It has for a number of years manufactured helicopters but is now principally a successful sub-contractor to major helicopter manufacturers. The firm has manufactured helicopters for the U.S. military. These include the following models:

- K-860 SEASPRITE (Military HH-2D). First flight in 1959. Six seat, twin engine General Electric T58-8B engine - not in production. Originally developed as a single engine helicopter for the U.S. Navy for anti-submarine defence. Now converted to twin-engines and used for coastal survey.

- K-600 HUSKIE (Military HH-43). Twelve seat helicopter powered by a Lycoming T-53-11 engine - not now in production. The Huskie is unusual in having twin rotor masts and intermeshing rotors. The U.S. Navy, USAF, Burma, Columbia, Iran, Moroçço, Pakistan and Thailand all ordered the helicopter. The U.S. Navy still uses it as a drone. There are 15 showing in the U.S. civil register.

- K-888 LAMPS MKl (Military SH-2F). A three seat helicopter with twin engine General Electric T-58-8 engines. This helicopter still is in production and some 103 are in service or soon will be with the U.S. Navy.

3.6.17 Kawasaki Heavy Industries Ltd. Gifu, Japan

This manufacturer has a joint manufacturing agreement with MBB to manufacture the BK 117 helicopter. The twin-turbine aircraft is now being manufactured at Gifu for markets in Southeast Asia. Kawasaki Heavy Industries manufactures the drive shaft and gears for all BK 117 products, while MBB produces the airframe and other components. Lycoming provides the turbine engines. In addition to the manufacture of the BK 117, Kawasaki Heavy Industries manufacture the BV 107-11 for which they acquired the world rights from Boeing Vertol in 1965. Some 131 BV 107-11s have been built by Kawasaki. The firm also has a license to manufacture the Hughes 500D and the military version UH-6D. Kawasaki by mid-1983 had produced 210 Hughes 500 D including 40 UH-6 D's for the Japanese military. Another 14 were to be delivered in 1983.

3.6.18 Messerschmitt-Boelkow-Blohm GmbH (MBB). Donaworth, West Germany

This is a large, government-controlled aerospace company which develops and manufactures military and civilian aircraft, space systems, defense systems and special products. It has a helicopter manufacturing division which employs about 1,500. It currently manufactures the BO 105 twin-turbine multi-purpose helicopter and the BK 117, built in cooperation with Kawasaki. It also provides product support for other helicopters.

- MBB BO 105 - First flight 1975. This six seat helicopter is powered by twin Allison 250-C20B turbine engines. The German government has ordered for both civil and military purposes 490 units. North American sales are reported to be 72 by the first half of 1983. In North America, MBB have a final assembly plant at West Chester, Pennsylvania. In addition, MBB have licensed manufacturing of the BO 105 to the following:

	Units Sold January 1982
Construcciones Aeronauticas SA	70
Nurtanio Aircraft Industry Ltd.	80
Philippine Aerospace Dev. Corp.	44

It is expected that the recent joint announcement between MBB and Fleet Industries will result in MBB BO 105's being manufactured in Fort Erie, Ontario.

MBB BK 117 - First flight December, 1981. Deliveries of this eleven seat, twin Lycoming LTS-101 turbine powered helicopter commenced in 1983. As noted, this helicopter is jointly built with Kawasaki. The orders for the BK 117 stood at 135 in the first quarter of 1982, when production commenced.

3.6.19 Nurtanio Aircraft Industry Ltd. Jakarta Pusat, Indonesia

This aerospace manufacturer is jointly producing the CASA 212 aircraft. It also manufactures under license the following helicopters.

	Units Manufactured
Aerospatiale SA 330 Puma	11
Aerospatiale SA 332 Super Puma	none reported
MBB 105	80(to be built)

3.6.20 Piasecki Aircraft Corporation Sharon Hill, Pennsylvania

This firm today is not an active helicopter manufacturer. It was a developer of early model helicopters. Its design capabilities for twin tandem helicopters were acquired by Boeing Vertol some years ago. There are still 25 HUP-2/3 models on the U.S. civil register. The HUP was also used by the Canadian Armed Forces. The company now has a prototype high speed compound helicopter design "Pathfinder". It also manufactures missile, electronic and aircraft components, including helicomponents for the major manufacturers.

3.6.21 Philippine Aerospace Development Corporation Manila Airport, The Philippines

Manufacture under license the Pilatus BN Trislander and the MBB 105 helicopter. Some 44 BO 105 helicopters sold by the first quarter of 1982 by this licensed manufacturer.

3.6.22 Pratt & Whitney Aircraft Canada Montreal, Quebec

Pratt & Whitney, the manufacturer of the PT 6 turbine engines, acquired the United Aircraft of Canada facility at St. Hubert, P.Q. This facility was established in 1963 to assemble and service in Canada some 36 Sikorsky Sea Kings (CH-124's) for the Canadian military. Pratt & Whitney announced the closure of this facility at the end of 1983. The 200 employes are to be absorbed by Spar Aerospace Ltd. of Toronto and IMP Group Ltd. of Halifax which will take over the maintenance of the remaining 35 Sea Kings.

3.6.23 Representaciones Aero Commerciales Argentina SA Cordoba, Argentina

Licensed by Hughes Helicopters to manufacture Hughes 300 and Hughes 500. No production figures available. Facilities likely contracted from Technologia Aerospacial SA.

3.6.24 Robinson Helicopters Company Inc. Torrance, California

This manufacture produces the R22, a low cost, two seat training helicopter powered by a Lycoming 0-320 piston engine. It first flew in August 1975. As of the end of 1982, some 335 R22s had been sold and delivered. There are 205 R 22s on the U.S. civil register. There are 11 R22s in Canada.

3.6.25 Rotorway Aircraft, Inc. Chandler, Arizona

Reportedly manufacture an executive helicopter but no details are available nor production figures.

3.6.26 Sikorsky Aircraft. Stratford, Connecticut

Sikorsky Aircraft is a division of United Technologies Corporation. This large aerospace company also controls the Pratt & Whitney Group, Pratt & Whitney Canada, Hamilton Standard Division and Norden Systems (electronic control systems) including Mosteck Corporation. Sikorsky Aircraft is a pioneer helicopter manufacturer. Igor Sikorsky, the company founder, flew the first practical helicopter, a VS-300 on September 14,

1939. The first production helicopter was the R-4 in 1942, of which there are still 3 in the U.S. Sikorsky has produced a number of helicopters which are still in the active helicopter fleet. They currently are manufacturing three helicopter models and have two research and development models. Sikorsky employment is now 12,000, about 3,000 more than in 1980.

The current production models are the following:

- S-65 E (Military CH-53E, MH-53E SUPER STALLION). This is a heavy military helicopter powered by three General Electric T64-turbine engines. It first flew in March 1974. The U.S. Marines in 1983 were operating 128 CH-53s and an additional 12 were to be delivered. The U.S. Navy were operating 23 RH-53Ds and expected 26 CH-53E and 32 MH-53s to be delivered. The U.S. Army operates 8 earlier HH-53 helicopters. The fuel sponsons on the S-65 are the largest composite structure ever produced in composites.

- S-76 MARK II - First flight March, 1977. This is a 14 seat vehicle powered by twin Allison 250-C30 turbine engines which is proving to be a popular machine with off-shore petroleum operators and corporate operators. It is also being developed into a military armed helicopter (H-76) with orders for 13 from the Philippine Army. There have been 374 S-76 ordered by December 1983. Some 214 have been delivered in

25 countries including 106 for off-shore operators, 59 to corporations and 33 by government agencies. Sikorsky plans to produce 1,600 units over the next 15 years. A composite rotor head and blades will be introduced into production in 1984. A S-76 B with Pratt & Whitney PT6B-36 engines will be flown in 1984 and certified by early 1985. There are now 112 S-76's on the U.S. civil register. In Canada there are 15 S-76s.

- S-70 (UH-60 BLACK HAWK, SH-60 SEA HAWK) - First flight October, 1978. This military helicopter is powered by twin General Electric T700 turbine engines. The U.S. Army has ordered 1,107 UH-60 Black Hawks of which 300 have been delivered. An additional 77 EH-60s have also been ordered. The U.S. Navy has ordered 18 SH-60B and indicate there is a further requirement for 204 units of this type of helicopter. The U.S. Air Force plans to purchase 155 HH-60D Night Hawks with deliveries scheduled to begin in 1988.

- S-69 (Military XH-59) A research and development helicopter which has an Advancing Blade Concept (ABC). It has two coaxially-mounted rotors (P&W PT6T-3), as well as two jet engines (P&W J60-P-2) mounted alongside which provides high hover efficiency but lower forward speeds. Sikorsky anticipates the S-69 design may be selected for the U.S. Army's Light Helicopter Program (LHX) to eventually replace OH-58, UH-14, and AH-1 helicopters. A requirement of 3,000 LHX units have been identified by the U.S. Army.

- S-72 (Rotor Systems Research Aircraft -RSRA). This is a research helicopter powered by two General Electric T58 turbine engines and two General Electric TF-34 turbo fan jet engines.

- S-75 (ACAP). This is an advanced composite airframe program (ASCAP) helicopter designed for the U.S. Army which Sikorsky is developing in cooperation with LTV Corp. and Hercules Corp. It is based on the S-76 airframe design. Composite materials will contribute to 48 percent of the total weight of the helicopter.

The following summarizes Sikorsky helicopters which Sikorsky no longer manufactures but which are still in the active fleet. Some are still made under license agreements.

- S-51 (Military H-5H, HO-3S) First certified in 1947. Powered by a P & W. R985 piston engines. Used extensively in 1950's and 1960's. There are still 26 S-51s shown in the U.S. civil register.

- S-55 (Military UH-19 CHICKASAW, CH-19) A 9 seat piston engine (Wright R 1300 or PW R-1340) helicopter which was certified in 1952. It was the first U.S. helicopter certified for commercial operation. There are 135 in the United States. There are 10 S-55s in Canada. More than 1200 were built and are still being extensively used in South America, Greece and Turkey.

- S-58 (Military CH-34 CHOCTAW, UH-34) Sea Horse. A 14-16 seat helicopter powered by a Wright Cyclone R-1820. Subsequent versions after 1972 were turbine powered with P&W PT6T-3/B Twin Pac engines. There were some 1821 built. There are firms such as Orlando Helicopter Airways, Orlando, Florida; Globle Airlines, Mesa, Arizona, and California Helicopter Parts of Sun Valley, California which offer conversion of the early S-55 and S-58 models to turbine power. There are 140 S-58s in the United States, of which 34 are turbine powered S-58Ts. It is estimated there are still 1,000 S-58s in the world, of which 100 are turbine powered. There are 12 S-58s in Canada.

- S-62 (Military HH-52) First flight in 1958. A 14 seat helicopter powered by a General Electric T-58 turbine engine. It was the first amphibious helicopter built by Sikorsky. Most were military, including 99 for the U.S. Coast Guard, but there are 10 on the U.S. civil register. Mitsubishi licence-built the S-62A in Japan.

- S-61 (Military CH/HH 3E PELICAN, SH 3D SEA KING, VH-3, CH-124 Canada) - First flight of the series in March 1959 and it was certified in 1961. Sikorsky produced this heavy multi engine helicopter until 1980 when the rights were transferred to Agusta. Sikorsky built 750 units and licensed manufacturers build an additional 350 including 36 CH-124s for the Canadian military built by Pratt & Whitney Canada Ltd. It can carry up to 30 passengers and is powered by two General Electric CT-58 turbine engines. In addition to its military uses, it is used by civilian operators for off-shore exploration and helicopter logging. It also has been used in scheduled airline service. There are 16 civil units in the United States. In Canada there are 18 S-61s most of which are operated by Okanagan Helicopters.

- S-64 (Military CH-54 SKY CRANE/TARHE). First certified in 1965. This is heavy helicopter powered by two P&W JFTD 12-A engines, and is capable of carrying 25,000 pounds of external cargo. It was a limited production of about 100, of which the U.S. Army still operate 72. There are 7 civilian models, most of which are used in helicopter logging or unique applications where heavy loads must be transported by air. Used occasionally in Canada, particularly by Silver Grizzle Logging in the Prince Rupert, B.C. area.

3.6.27 SOKO Industries. Belgrade, Yugoslavia

This firm has a license agreement with Aerospatiale to manufacture the SA-341 Gazelle. It is believed the Yugoslavian Air Force operate 20 "Partizan" helicopters and has on order an additional 44 units.

3.6.28 Spitfire Helicopter Company Ltd. Media, Pennsylvania

This new small company has three models of helicopters it plans to market.

- SPITFIRE MK1. A three seat helicopter powered by Allison C250-C20B turbine engine.
- SPITFIRE MK11. A five seat helicopter powered by Allison C250-C20B in an Enstrom Shark airframe.
- SPITFIRE MKIV (TAURUS). A ten seat helicopter powered by twin Allison C250B turbine engines. This helicopter is based on the Polish Pezetel Swidnik Kania design.

It is understood that Spitfire now has an agreement with Spanish International Helicopters SA, Malaga, Spain, to manufacture the series in Spain.

3.6.29 Texas Helicopter Corporation. Irving, Texas

Manufacture the Wasp helicopter which is based on the Bell 47 airframe and powered by an Allison C250-C20B turbine engine.

3.6.30 Westland Helicopters Ltd. Yeovil, England

This is the helicopter division of British Aerospace PLC which is the government-controlled aerospace manufacturing complex in Great Britain. Westland, in addition to helicopters, owns Normad, Air-Garrett, British Hovercraft and other subsidiaries. Westland Helicopter at Weston-Super Mare employs 1,600 people to manufacture, in cooperation with Aerospatiale, Puma and Gazelle helicopters and product support components and refurbishment of Wasp helicopters. At Yeovil, they employ 5,600 people to manufacture the Lynx, Sea King, Commando, and the Westland 30. At Milton Keynes, a further 300 people are working on precision assemblies.

- LYNX. First flight in 1971. The Lynx is a 13 seat helicopter powered by two Rolls Royce Gem 41 turbine engines. It is used by a number of Army and Navy military forces in addition to the

British military. The Lynx 3 is the latest variant. As of the first quarter of 1982, some 310 units had been ordered and 235 delivered.

- SEA KING. (Military HAS, HAR) This is the military version of the Sikorsky S-61 which Westland Helicopters has been building for some years. It is powered by Rolls Royce Gnome H1400 turbine engines instead of General Electric engines as in the Sikorsky version. There have been 204 Sea Kings manufactured by Westland, primarily for the British Navy, but it has also been exported to West Germany, Australia, Norway, Egypt, Belgium, India and Pakistan.

- COMMANDO. This is a development from the Sea King design, but it is not amphibious. It can carry 30 troops and powered by two Gnome H-1400 engines. Some 50 Commandos have been ordered by the military.

- WESTLAND 30 - First flight September, 1981. This is a 17 seat civil helicopter powered by two Rolls Royce Gem 60-3 turbine engines. General Electric CT 7 engines will be offered in the Westland 30-200 series, when certified in late 1984. A 30-300 series with CT-7 engines and a 5-blade composite rotor system is anticipated to be certified by the end of 1986.It is planned to market the helicopter to off-shore corporate and air taxi operators. Some 13 helicopters have been ordered including sales to Air Spur in Los Angeles for 4 units. Options are held on another 17 units.

- SCOUT/WASP- This helicopter was derived from the Saunders-Roe P531, which first flew in 1958. The British Army took delivery of 150 Scouts. In 1963, Wasps were delivered to the Royal Navy. The helicopter is also used in Australia, Brazil, the Netherlands, New Zealand and South Africa.

- WHIRLWIND - First flight in 1952. A licence-built version of the Sikorsky S-55 with later versions powered by a Rolls Royce Gnome engine.

- WESSEX - First flight in 1958. A twin engine helicopter used by the Royal Navy and RAF and similar to the Sikorsky S-58 in design.

- EH101. This is a joint development project with Agusta of Italy entered into by the two companies in 1982 to develop a new generation of helicopters for naval, civil and military transport purposes. It is expected to have 50 percent more payload and more than twice the radius of the Sea King. A prototype is now being designed and is scheduled for its first flight in 1986. Production is planned for 1989.

In addition to the manufacturers reviewed there are helicopters manufactured in the USSR, Poland and China. It is likely there are over 5,000 military helicopters and 2,500 civilian helicopters in the Soviet Union and several hundred in Eastern Block countries and China.

3.6.31 Mil Helicopters - U.S.S.R.

Mil is the largest designer and manufacturer of military and civilian helicopters in the Soviet Union and has licensing agreements with Poland and China. A number of Mil helicopters are used in Eastern Europe, Africa, Middle East and China. The following summarizes the known models:

MI-1 HARE - powered by a Ivchencho piston engine. The first U.S.S.R. production helicopter. It was in production from 1948 to 1964 and several thousand produced for civilian and military use. The Soviet Airforce still has 700 and Poland 165.

MI-2 HOPLITE - powered by two Isotov turboshaft engines. This helicopter was in production from 1965 and there were 2,000 produced for the USSR and an additional 1,000 were exported.

MI-4 HOUND - powered by a Shvetsov piston engine. First produced in 1952. The Soviet Airforce still operates 50. Jugoslavia, Middle East and African countries still operate several. It is also produced in China under licence.

MI-6 HOOK - powered by two Soloviev turboshaft engines. Introduced in 1957. It was at the time the world's largest helicopter. About 800 have been manufactured, including 400 for the Soviet Airforce. Aeroflot, Egypt and Bulgaria also have the Mil-6.

MI-8 HIP - powered by two Isotov turboshaft engines. This is a replacement for the M-4 and is one of the most popular Soviet helicopters. There are over 1,500 in the Soviet Airforce. Aeroflot also has several hundred Mil-8s. It is used in Jugoslavia, Syria, Sudan, Somalia, and Eastern block countries.

MI-10 HARKE - powered by two Soloviev turboshaft engines. First introduced in 1960, it is used by the military and Aeroflot. It is similar to the Sikorsky S-64 Crane.

MI-14 HAZE - powered by two Isotov turboshaft engines. Used by the Soviet Navy for antisubmarine detection. Is now in production with 80 delivered and a production rate of two helicopters per month.

MI-24 HIND - powered by two Isotov turboshafts engines. This is an armed assault helicopter which is being produced in large numbers. The Soviet Airforce has 800 and it is being exported to Eastern block countries, the Middle East and Africa.

MI-26 HALO - powered by two Lotarev turboshaft engines. First introduced in 1977. This 8-bladed helicopter is the heaviest in the world. It can carry 70 troops or 44,000 pounds of payload.

3.6.32 Kamov Helicopters - U.S.S.R.

Kamov is a civil/military helicopter manufacture in the U.S.S.R. Its helicopters are used extensively by the Soviet Navy.

KA-25 HORMONE - powered by two Glushkov turbo-shaft engines. Used as a navy ship-board survey helicopter.

KA-26 HOODLUM - powered by two Vedenoev piston engines. Introduced in 1956. Is used as as light transport or agricultural helicopter.

KA-32 HELIX - two turboshasft engines. Introduced in 1981 as an antisubmarine and assault helicopter for the Soviet Navy.

3.7 SUMMARY OF HELICOPTER MANUFACTURERS

The largest helicopter manufacturer in both the number of units manufactured and revenues earned from manufacturing is Bell Helicopter Textron. In 1980, this one firm manufactured over 36 percent of all the world's military and civilian helicopters. There were some 864 helicopters manufactured with a value of $556 million in that year. Bell Helicopter has consistently been the largest helicopter manufacturer since Larry Bell introduced the Bell 47 model in 1946. The company's growth has been steady and was particularly active during the Vietnam war when it produced thousands of military helicopters. In 1970, its peak year, over 1,800 military helicopters were produced, particularly UH-13 and UH-1A military models. It is forecast that Bell Helicopter Textron will increase the number of units produced by 7 percent per annum, nearly double the number of units manufactured in 1980. It also projected that the average value of the helicopters will increase. In 1980, the average helicopter value was $640,000. In 1990, in constant dollars, the average value is projected to be $1,020,000.

Aerospatiale Helicopter Corporation ranked second in the number of helicopters produced in 1980, but third in terms of revenue after Sikorsky. Aerospatiale manufactured 405 military and civil helicopters with a value of $320 million in 1980. Most of Aerospatiale's units have been military until the late seventies. It is expected it will increase its production by 5.8 percent per annum in the next decade to produce 715 units by 1990. The average value of an Aerospatiale helicopter is now $790,000 and will likely increase to $2,040,000 in constant dollars by 1990.

Hughes Helicopters Ltd. ranks third in the number of helicopter units produced. In 1980, some 370 units were built but the revenue earned was only $76 million. Hughes experienced rapid growth in the late sixties due to the Vietnam war and then a sharp decrease in production. In the late seventies the manufacturing totals built up again, primarily from the civil Hughes 500 sales. In the eighties, growth is expected particularly from military sales in the later part of the decade. An average annual growth rate of 3.7 percent is forecast to increase the number of units by 1990 to 530. The average value of Hughes helicopters in 1980 was $205,000. In 1990, the average value in constant dollars is predicted to be $1,045,000. This significant increase is because of the level of sophistication of the Apache military helicopter whichn is now being manufactured.

Sikorsky Aircraft ranks fourth in the number of units manufactured but is second in terms of revenue. Historically, Sikorsky has fluctuated in the number of units built and revenue. In the sixties, it experienced high numbers of military helicopters followed by relatively few in the seventies. In 1980, the Company experienced both peak military and civil helicopter sales. Prospects look good for continued military and civil sales in the eighties. It is forecast that Sikorsky will experience an overall annual growth rate of 4.3 percent to raise the 1990 production total to 271 units. In 1980, the average value of a Sikorsky helicopter was a high $2,400,000 due to the complexity and size of the helicopters manufactured. By 1990 it is expected that an average Sikorsky helicopter will be valued at $6.0 million, in constant dollars.

Agusta Aviation Corporation Inc. ranks fifth in terms of the number of helicopter units manufactured. In 1980, this company built 162 military and civil units valued at $227 million. By 1990, its production is expected to reach 205 units. The average value of the helicopters is expected to remain stable in constant dollar terms.

Westland Helicopters in 1980 manufactured 75 helicopters valued at $281 million. It is expected that this helicopter firm will experience growth in the mid-eighties, particularly from military sales and the Westland 30 civil model. In the late eighties, the number of units is expected to decrease.

MBB in 1980 manufactured 56 helicopters at a value of $49 million. Like Westland, MBB is forecasted to achieve growth rates in the number of units in the early eighties, then remain stable, and then by the end of the decade should decrease in the number of units produced.

Boeing Vertol has experienced flucuating production due to the limited market for the heavy tandem design helicopter they manufacture and the dependence on military sales for its helicopters. In 1980, it manufactured 15 units at a value of $72 million. This is an average of $4.8 million per helicopter. In the next decade, manufacturing is expected to be relatively static.

Tables 3.11 and 3.12 show the historical number of units of helicopters built by the major manufacturers and their value in current dollars for civil and military helicopters. The tables also present a forecast to 1990. It is recognized that since these forecasts were prepared by Bell Helicopter Textron in 1981, there has been a substantial reduction in production due to the economic recession. Most of the reduction, however, has affected civil helicopter sales, not military. Those firms which manufacture military helicopters have not been seriously impacted upon and, in fact, one company (Sikorsky) has actively increased its employment and earnings to record levels in 1982 and 1983. Those manufacturers which rely on civil helicopter manufacturing to a large extent have experienced reductions of about 30 percent in terms of the number of units built and sold.

Table 3.11

HELICOPTER PRODUCTION BY MANUFACTURER
CIVIL PRODUCTION

(No. of Units in $ Millions)

	AERO-SPATIALE		AGUSTA		BELL		BOEING		HUGHES		MBB		OTHER		SIKORSKY		WESTLAND	
	No.	$	No.	$	No.	$	No.	$	No.	$	No.	$	No.	$	No.	$	No.	$
1970	58	10	44	5	248	32	0	0	122	8	0	0	64	7	11	5	0	0
1971	92	18	51	11	229	33	0	0	123	10	10	0	35	4	18	12	0	0
1972	58	18	41	7	284	54	1	0	121	13	22	0	65	7	32	13	1	0
1973	111	32	29	7	414	84	0	0	178	18	23	8	186	20	99	31	0	0
1974	93	39	19	5	380	100	0	0	229	24	36	14	120	10	34	38	1	2
1975	67	29	40	15	400	125	0	0	203	24	16	6	111	14	25	46	0	0
1976	67	29	12	5	356	121	0	0	190	22	21	9	141	15	16	37	0	0
1977	95	76	16	9	311	107	0	0	200	29	16	10	103	15	14	43	0	0
1978	104	88	36	18	365	139	0	0	189	25	24	18	102	19	15	44	3	15
1979	229	142	42	28	547	219	0	0	283	54	15	12	197	24	37	71	0	0
1980	335	154	62	61	679	341	0	0	305	58	40	35	200	22	80	136	0	0
1981	362	210	57	60	728	482	1	10	350	74	30	28	223	50	100	184	0	0
1982	370	230	62	72	790	610	3	32	360	83	34	35	233	60	100	198	0	0
1983	391	275	62	77	881	741	3	43	375	95	39	43	243	70	100	214	0	0
1984	408	319	62	85	974	844	4	64	385	106	40	47	248	77	100	231	0	0
1985	424	370	67	100	1071	992	4	91	400	121	50	63	253	84	100	250	0	0
1986	445	434	67	108	1171	1170	4	98	410	135	50	68	240	54	100	270	0	0
1987	462	497	72	127	1262	1393	4	106	430	155	50	74	245	60	105	329	0	0
1988	479	566	72	137	1318	1555	4	114	440	173	50	80	250	66	112	413	0	0
1989	499	657	72	148	1410	1835	4	123	455	195	50	86	255	72	118	499	0	0
1990	516	745	77	172	1505	2166	4	133	465	217	50	93	260	80	118	538	0	0

Source: Based on Bell Helicopter Textron Study.

Table 3.12

HELICOPTER PRODUCTION BY MANUFACTURER
MILITARY PRODUCTION

(No. of Units in $ Millions)

	AERO-SPATIALE No.	AERO-SPATIALE $	AGUSTA No.	AGUSTA $	BELL No.	BELL $	BOEING No.	BOEING $	HUGHES No.	HUGHES $	MBB No.	MBB $	OTHER No.	OTHER $	SIKORSKY No.	SIKORSKY $	WESTLAND No.	WESTLAND $
1970	217	109	92	22	1801	787	75	172	70	11	0	0	221	215	113	245	23	23
1971	220	125	74	27	1267	540	46	104	14	1	0	0	113	82	48	97	26	31
1972	76	57	109	38	1204	468	14	35	16	1	0	0	113	95	23	51	29	36
1973	127	84	126	42	795	292	4	11	17	1	14	5	206	262	44	117	30	30
1974	127	96	153	59	323	227	31	92	19	2	0	0	207	167	49	149	17	36
1975	174	131	105	49	485	429	14	45	7	1	24	10	198	252	23	76	33	84
1976	184	40	79	94	389	383	26	89	14	3	18	8	157	188	10	36	24	69
1977	182	134	108	119	320	349	22	80	18	4	2	1	129	166	9	23	32	60
1978	152	165	76	118	234	272	4	16	105	16	23	18	88	93	13	44	85	327
1979	94	105	69	108	177	223	2	9	38	6	0	0	138	516	37	86	95	404
1980	72	168	100	166	185	215	15	72	65	18	16	14	44	25	99	292	75	281
1981	83	266	105	190	92	99	18	94	40	12	73	137	67	202	85	275	87	258
1982	105	386	99	171	125	185	3	17	40	13	76	148	61	87	93	321	77	241
1983	114	463	104	192	111	214	3	18	37	24	76	160	63	92	112	668	37	116
1984	127	556	109	236	123	271	3	20	73	249	60	131	65	187	128	1201	30	122
1985	141	663	109	257	146	361	3	21	122	628	50	143	87	244	133	1315	130	464
1986	150	775	118	320	149	412	3	23	126	708	50	154	77	253	135	1471	110	467
1987	163	909	118	346	145	466	3	25	116	759	50	167	88	324	135	1589	74	577
1988	176	1061	123	384	167	582	3	27	121	862	50	180	88	323	138	1730	75	617
1989	186	1217	128	520	175	671	3	29	131	1065	12	47	74	296	185	2081	75	661
1990	199	1405	128	562	180	753	3	31	65	501	10	42	69	280	153	2038	50	476

Source: Based on Bell Helicopter Textron Study.

The Aerospace Industries Association of America Inc. (AIA) monitors United States aircraft production. Their figures indicate that, in 1980, U.S. helicopter manufacturers delivered 1,366 civilian helicopters at a total value of $656 million. Over 38 percent of these deliveries (e.g., 525 units at $299 million) were exported from the United States. In 1981, the number of civil helicopters delivered decreased to 1,072, a reduction of 293 units from 1980. These civil units in 1981 were valued at $597 million. The number of units exported out of this total were 453, valued at $347 million or 69 percent of total deliveries. In 1982, the economic recession was in full effect. In 1982, the number of civil helicopters delivered dropped to 577 helicopters valued at $365 million. (Military sales in comparison were $2,035 million, a record year.) Exports were expected to account for about 270 units out of the total deliveries.

Although the effects of the recession are still apparent in 1983, it is expected that the number of surplus used helicopters will be consumed by the market and that new helicopter deliveries in 1983 should be higher than 1982. The AIA forecasts that, in 1983, some 780 civil helicopters valued at $530 million will be delivered. The helicopter industry expects that by the second quarter of 1984, growth rates for the delivery of civil helicopter units will be similar to that experienced in 1979 and 1980. Average growth rates of 3-4 percent are then expected to continue throughout the 1980's.

4.0 REGIONAL MARKET DEMAND

The regional market which British Columbia based helicopter-related overhaul, repair and servicing companies could effectively serve is Western Canada and the U.S. Pacific Northwest. This geographic market encompasses an area in which operators of helicopters could be expected to transport helicopters and to ship helicopter components for overhaul and repair-providing the cost and quality of work is competitive. The geographic scope, however, can be expanded to include Central Canada and the U.S. Southwest for overhaul and repair work of a more specialized nature or for maintenance on lesser known or unique helicopters. In some cases, the market could be expanded to all of North America and beyond for certain low volume components. Indeed, some Western Canadian helicopter maintenance firms have already established a reputation in South America and Southeast Asia for their specialized overhaul and repair work. On the other hand, in the case of routine maintenance, where most large operators have their own in-house capabilities and smaller helicopter operators rely on local maintenance firms close to their own geographic location, the market area may be limited. Thus, the market scope in the case of routine maintenance may be narrowed to British Columbia or even only a portion of British Columbia.

For the purposes of this study, the potential geographic market area was divided into a Primary Market Area and a Secondary Market Area.

The Primary Market Area includes:

British Columbia
Alberta
Yukon Territory
Washington
Oregon
Idaho
Alaska

For the British Columbia market area, the examination of market potential included classifying helicopters into separate geographic locations within the province. Helicopters were also classified as to those holding valid certificates of airworthiness (C of A) as well as normal registration to confirm active use. This detail was required to determine the market potential for routine helicopter maintenance services.

The Secondary Market Area includes:

Saskatchewan	Manitoba
Northwest Territories	Wyoming
Nevada	Colorado
Utah	New Mexico
Arizona	Montana
California	

The main data source for the location of the helicopter operator and the fleet composition was the "Directory of Helicopter Operators in the United States, Canada, Mexico and Puerto Rico" published by the Aerospace Industries Association of America (AIA) in 1983. This inventory lists helicopters registered in 1982 by owner and address. It does not indicate whether the helicopter has a valid certificate of airworthiness or whether the helicopter operated from the location noted in the listing (e.g., helicopters registered in British Columbia may be operating in Southeast Asia on long term contracts). The AIA publication also only lists civil helicopters. The location of military helicopters is generally not noted in published references.

In 1982, the AIA lists a total of 8,884 helicopters owned by some 2,688 operators in North America including Mexico and Puerto Rico. The following summarizes the helicopter ownership by category.

	Operators				Helicopters			
	US1/	Canada	Mexico	Total	US	Canada	Mexico	Total
Commercial	1060	125	3	1188	4627	1215	32	5874
Corporate	1055	100	-	1155	1572	153	—	1725
Government	318	19	-	337	1179	96	—	1275
	2433	244	3	2680	7378	1464	32	8874

1/ Includes Puerto Rico.

Table 4.1, overleaf, provides the details.

Table 4.1

CIVIL HELICOPTER FLEET 1982

COUNTRY	COMMERCIAL		CORPORATE		GOVERNMENT		TOTAL	
	OPER- ATORS	HELI- COPTERS	OPER- ATORS	HELI- COPTERS	OPER- ATORS	HELI- COPTERS	OPER- ATORS	HELI- COPTERS
UNITED STATES								
Alabama	13	24	20	29	11	280	44	333
Alaska	27	311	8	10	6	8	41	329
Arizona	39	143	25	42	7	26	71	211
Arkansas	8	19	5	8	3	5	16	32
California	159	495	122	199	49	210	330	904
Colorado	30	130	34	54	9	24	73	208
Connecticut	2	6	13	20	0	0	15	26
Delaware	2	2	4	4	1	2	7	8
Dist. of Columbia	1	1	0	0	6	22	7	23
Florida	72	355	59	89	37	94	168	538
Georgia	14	31	9	9	9	31	32	71
Hawaii	17	40	3	6	1	2	21	48
Idaho	18	59	16	20	6	12	40	91
Illinois	24	77	18	48	10	23	52	148
Indiana	20	43	16	21	10	22	46	86
Iowa	11	15	8	9	5	13	24	37
Kansas	9	19	7	11	3	8	19	38
Kentucky	10	26	35	43	2	5	47	74
Louisiana	28	763	20	55	10	22	58	840
Maine	4	10	4	6	1	4	9	20
Maryland	7	33	6	6	3	16	16	55
Massachusetts	12	24	10	28	2	3	24	55
Michigan	22	43	23	29	11	25	56	97
Minnesota	17	34	15	17	1	4	33	55
Mississippi	5	11	3	3	6	14	4	28
Missouri	13	51	8	13	6	16	27	80

Table 4.1 (Cont'd)

CIVIL HELICOPTER FLEET 1982

COUNTRY	COMMERCIAL		CORPORATE		GOVERNMENT		TOTAL	
	OPER-ATORS	HELI-COPTERS	OPER-ATORS	HELI-COPTERS	OPER-ATORS	HELI-COPTERS	OPER-ATORS	HELI-COPTERS
UNITED STATES (Continued)								
Montana	16	44	4	4	5	10	25	58
Nebraska	6	16	11	16	2	2	19	34
Nevada	12	35	10	18	5	9	27	62
New Hampshire	5	12	4	8	0	0	9	20
New Jersey	23	70	37	46	6	15	66	131
New Mexico	7	15	12	15	2	5	21	35
New York	31	148	54	83	11	33	96	264
North Carolina	6	21	12	14	3	12	21	47
North Dakota	14	29	3	3	0	0	17	32
Ohio	28	75	43	44	7	19	78	138
Oklahoma	18	94	19	32	2	15	39	141
Oregon	50	323	36	46	4	17	90	386
Pennsylvania	37	110	69	88	1	10	107	208
Rhode Island	4	11	1	2	1	1	6	14
South Carolina	5	30	12	13	5	6	22	49
South Dakota	3	4	2	5	3	3	8	12
Tennessee	17	50	25	27	9	34	51	111
Texas	88	381	104	207	15	50	207	638
Utah	17	141	6	9	1	1	24	151
Vermont	0	0	3	3	0	0	3	3
Virginia	12	24	16	18	7	16	35	58
Washington	46	127	32	38	7	17	85	182
West Virginia	10	16	34	39	4	8	48	67
Wisconsin	6	46	7	7	3	5	16	58
Wyoming	14	39	8	8	0	0	22	47
Puerto Rico	1	1	3	3	5	7	9	11
	1060	4627	1055	1572	318	1179	2441	7388

Table 4.1 (Concluded)

CIVIL HELICOPTER FLEET 1982

COUNTRY	COMMERCIAL		CORPORATE		GOVERNMENT		TOTAL	
	OPER-ATORS	HELI-COPTERS	OPER-ATORS	HELI-COPTERS	OPER-ATORS	HELI-COPTERS	OPER-ATORS	HELI-COPTERS
MEXICO	3	32	0	0	0	0	3	32
CANADA								
Alberta	25	242	27	44	2	8	52	286
British Columbia	33	398	38	55	4	4	75	457
Manitoba	7	42	1	1	0	0	8	43
New Brunswick	3	9	3	3	1	1	7	13
Newfoundland	4	62	3	3	0	0	7	65
Northwest Territ.	2	7	0	0	0	0	2	7
Nova Scotia	2	4	5	5	2	6	9	15
Ontario	26	209	15	31	5	54	121	294
Prince Edward Isl.	0	0	0	0	1	1	1	1
Quebec	17	202	6	9	3	22	26	233
Saskatchewan	4	26	0	0	0	0	4	26
Yukon	2	24	0	0	0	0	2	24
	125	1215	100	153	19	96	244	1464

It can be noted from Table 4.1 that the State of California has the largest number of helicopters, some 904. Louisiana ranks second with 840, followed by Texas with 648 helicopters. Florida ranks fourth with 538 and British Columbia is fifth with 457. The largest market areas are as follows:

California	904	Ontario	294
Louisiana	840	Alberta	286
Texas	638	New York	264
Florida	538	Quebec	233
British Columbia	457	Arizona	211
Oregon	386	Colorado	208
Alabama	333	Pennsylvania	208
Alaska	329		

Out of the largest market areas in terms of helicopter numbers, the Primary Market Area has four provinces or states which are in the top 15 market areas. The Secondary Market Area contains three additional states (California, Arizona and Colorado) which are in the top 15 market areas.

4.1 PRIMARY MARKET AREA

Table 4.2 shows the Primary Market Area by geographic area and helicopter manufacturer and model. In some cases where there are a variety of models, they have been grouped together (e.g., Bell 47 series). As noted, these are registered civil helicopters and not all necessarily have valid certificates of airworthiness. The table shows the Primary Market Area has 1,763 helicopters of which British Columbia has 444 or 25.1 percent of the total.

Table 4.2

PRIMARY MARKET AREA 1982

HELICOPTER TYPE	B.C.	ALBERTA	YUKON TERRIT.	WASH.	OREGON	IDAHO	ALASKA	TOTAL
Bell 47	23	11	3	38	29	10	5	119
Bell 47 Soloy	5	–	–	5	5	3	–	18
Bell 204	8	11	3	2	4	–	4	32
Bell 205	12	6	–	–	19	–	18	55
Bell 206	221	131	10	42	71	40	110	625
Bell 206 L	27	6	–	2	9	2	14	60
Bell 212	20	6	–	4	–	4	20	54
Bell 214	9	–	–	–	3	1	–	13
Bell 222	–	1	–	–	2	–	–	3
Bell 412	3	2	–	–	2	–	13	20
Bell	328	174	16	93	144	60	184	999
Hughes 300	2	9	–	8	4	2	2	27
Hughes 500	31	54	5	13	27	6	71	207
Hughes	33	63	5	21	31	8	73	234
Hiller UH-12	5	1	1	15	28	8	19	77
Hiller UH-12 Soloy	–	–	1	16	40	2	2	61
Hiller FH 1100	3	3	–	6	8	–	8	28
Hiller	8	4	2	37	76	10	29	166
Aerospatiale Lama	1	–	–	8	14	2	–	25
Aerospatiale Dauphin 1	–	–	–	–	–	–	–	–
Aerospatiale Alouette	1	5	–	2	26	4	14	52
Aerospatiale Gazelle	1	7	1	2	1	–	2	14
Aerospatiale AStar	24	22	–	3	12	1	18	80
Aerospatiale Twin Star	–	11	–	–	–	–	1	12
Aerospatiale Puma	2	–	–	–	1	–	–	3
Aerospatiale	29	45	1	15	54	7	35	186

Table 4.2 (Cont'd)

PRIMARY MARKET AREA 1982

HELICOPTER TYPE	B.C.	ALBERTA	YUKON TERRIT.	WASH.	OREGON	IDAHO	ALASKA	TOTAL
MBB BO 105	-	1	-	1	4	-	15	21
MBB BK 117	-	-	-	-	5	-	2	7
MBB	-	1	-	1	9	-	17	28
Sikorsky S-51	-	-	-	-	-	-	-	-
Sikorsky S-55	8	-	-	-	-	-	-	8
Sikorsky S-58	5	-	-	1	2	-	1	9
Sikorsky S-61	15	1	-	-	3	-	-	19
Sikorsky S-64	2	-	-	-	5	-	-	7
Sikorsky S-76	12	3	-	-	22	-	-	37
Sikorsky	42	4	-	1	32	-	1	80
Boeing Vertol 107	-	-	-	-	12	-	1	13
Boeing Vertol 234	-	-	-	-	1	-	-	1
Boeing	-	-	-	-	13	-	1	14
Others								
Enstrom	-	1	-	11	14	5	4	35
Robinson R-22	4	1	-	4	9	-	-	18
Brantly Hynes	-	-	-	-	-	-	-	-
Westland 30	-	-	-	-	-	-	-	-
Agusta 109	-	-	-	-	2	-	-	2
Kaman	-	-	-	-	-	1	-	1
TOTALS	444	293	24	183	384	91	344	1763

The table shows that, in the Primary Market Area, Bell Helicopter Textron helicopter products have the largest market share. Nearly 60 percent of all the helicopters in the Primary Market Area are Bell Helicopter products. The Bell 206 Jet Ranger alone accounts for 36 percent of all the helicopters in the region.

Hughes Helicopter products rank second in terms of number of total helicopters (13.5 percent), followed by Aerospatiale Helicopter products (10.7 percent) and Hiller products (9.6 percent).

The following lists the most popular helicopter types in the Primary Market Area:

Most Popular Types in Primary Market Area	Number
Bell 206	625
Hughes 500	207
Bell 47	119
Aerospatiale AStar	80
Hiller UH-12	71
Hiller UH-12 Soloy	61
Bell 206L	60
Bell 205	55
Bell 212	54
Aerospatiale Alouette	52

4.1.1 British Columbia Market Area

A special analysis of the British Columbia market area within the Primary Market Area was undertaken to determine the market size for routine maintenance opportunities.

The data source was the Transport Canada Civil Aircraft Register (March 31, 1983). The register lists 408 helicopters which are owned by British Columbia operators. There were, however, 55 helicopters (14.5 percent) which did not have a valid certificate of airworthiness and therefore are inactive. The following shows the geographic location of the registered helicopters in British Columbia.

Table 4.3
BRITISH COLUMBIA GEOGRAPHIC LOCATIONS 1982

	VAN. AREA	VICTORIA AREA	VAN. ISLAND	NORTH B.C.	INTERIOR	N/A N/A*	TOTAL
Bell 206	107	9	5	34	13	7	175
Bell 47	21	8	7	10	5	5	54
Hughes 500	28	-	3	4	2	1	38
Sikorsky Prod.	31	1	-	-	1	1	34
Bell 206L	14	5	-	1	2	-	22
Aerospatiale Prod.	8	-	-	3	5	-	16
Bell 212	13	-	-	-	1	1	15
Hiller Products	7	2	4	-	-	1	14
Bell 204/205	6	1	-	3	3	-	13
Hughes 300	6	-	1	-	1	-	8
Robinson	5	-	2	-	-	-	7
Bell 214	6	-	-	-	-	-	6
Enstrom	1	-	-	1	1	-	3
Brantly Hynes	1	-	-	-	-	-	1
	254	26	22	56	34	16	408

* Unknown - sales reported and address of owner not registered.

The table shows that over 60 percent of all the registered helicopters are in the Vancouver area of the province. Northern British Columbia (i.e., Prince George and north) ranks second with 13.7 percent of the total. Vancouver Island, including the Victoria area, accounts for 11.7 percent of the total.

In order to establish the historical trend of helicopters in British Columbia, an analysis was done of helicopters with a valid certificate of airworthiness in the 1976-1981 time period, including total hours flown by type.

Table 4.4 shows that the number of helicopters with a valid certificate of airworthiness has more than doubled in the five year period. This is an annual growth rate in excess of 15 percent. The utilization has increased faster than the number of helicopters. In terms of the number of hours flown, it has grown by 2.6 times or about 21 percent per annum. While the number of helicopters with a valid certificate of airworthiness increased to 353 helicopters, in 1982, it is likely that productivity was significantly reduced due to the economic recession in British Columbia.

4.2 SECONDARY MARKET AREA

The Secondary Market Area, as noted, covers Central Canada and the U.S. Southwest regions. These markets are more difficult for British Columbia firms to effectively compete due to their distance. There could be, however, a market for services and products if British Columbia companies can compete

Table 4.4
BRITISH COLUMBIA HELICOPTER TREND

	1976		1977		1978		1979		1980		1981	
	NO.	HOURS	NO.	HOURS	NO.	HOURS	NO.	HOURS	NO.	HOURS	NO.	HOURS
Aerospatiale Alouette	2	672	1	607	1	636	2	1,242	2	936	1	367
Aerospatiale AStar	-	-	-	-	-	-	-	-	7	2,363	13	6,942
Bell 204/205/212	8	4,827	8	5,821	9	9,220	12	9,729	20	15,631	24	17,427
Bell 206	72	37,951	76	42,750	91	53,342	124	76,380	150	84,540	155	94,902
Bell 206L	-	-	-	-	1	487	6	3,178	17	11,464	17	11,588
Bell 214	-	-	-	-	1	826	3	518	5	2,499	4	2,660
Bell 47	41	13,368	37	11,677	40	12,636	41	12,038	41	14,259	31	9,547
Enstrom	-	-	-	-	-	-	1	55	1	370	1	5
Hiller FH1100	2	310	2	458	2	130	2	154	1	77	2	179
Hiller UH-12	7	2,094	6	1,852	4	1,158	5	1,248	6	1,211	7	1,632
Hughes 300	2	323	1	324	-	-	-	-	5	1,273	3	1,559
Hughes 500	12	4,309	13	5,341	14	8,826	22	11,548	29	14,675	32	14,878
Robinson	-	-	-	-	-	-	-	-	-	-	4	770
Sikorsky S55/58	6	3,479	7	1,993	9	4,085	8	1,386	11	2,737	10	2,209
Sikorsky S61	-	-	5	2,581	4	4,104	8	10,364	8	10,182	6	7,232
Sikorsky S76	-	-	-	-	-	-	2	701	7	3,092	8	4,666
	155	67,362	158	73,434	178	95,471	237	128,515	310	165,309	318	176,563

on price and quality. Table 4.5 shows the numbers and models of helicopters in the Secondary Market Area. It can be seen that, in terms of the number of helicopters, the Secondary Market Area is nearly equal to the Primary Market Area. It should be recognized that one state, California, accounts for over half of the helicopters in the Secondary Market Area.

The Secondary Market Area table again shows the dominance of Bell Helicopter Textron products, with 50 percent of the helicopter products being Bell. Hughes Helicopter are significant in the Secondary Market Area with 17.5 percent of the total. Aerospatiale and Hiller hold about the same market share (11.3 percent and 10.4 percent, respectively) as they do in the Primary Market Area. The Bell 206 Jet Ranger is not as dominant a helicopter type as in the Primary Market Area, but it still commands 22 percent of the total. In terms of the most popular helicopter types in the Secondary Market Area, the ranking is as follows:

Most Popular Types in Secondary Market Area	Number
Bell 206	383
Bell 47	300
Hughes 500	194
Hiller UH-12	147
Hughes 300	110
Bell 206 L	77
Aerospatiale Lama	60
Aerospatiale Alouette	54
Enstrom	51

Table 4.5

SECONDARY MARKET AREA 1982

HELICOPTER TYPE	SASKATCHEWAN	MANITOBA	NWT	WYOMING	NEVADA	COLORADO	UTAH	NEW MEXICO	ARIZONA	MONTANA	CALIFORNIA	TOTAL
Bell 47	3	4	-	5	11	27	11	11	18	20	190	300
Bell 47 Soloy	-	-	-	1	1	7	3	1	1	4	16	32
Bell 204	3	-	-	-	-	17	-	-	-	-	18	38
Bell 205	-	-	-	-	-	4	1	-	-	-	24	29
Bell 206	8	27	3	13	18	43	31	15	37	23	165	383
Bell 206 L	-	-	-	-	-	15	13	-	18	1	29	77
Bell 212	-	-	-	-	-	-	1	-	7	1	11	20
Bell 214	-	-	-	-	-	-	2	-	-	-	1	3
Bell 222	-	-	-	-	1	-	-	-	-	-	1	2
Bell 412	-	-	-	-	-	-	1	-	-	-	-	1
Bell	14	32	3	19	31	113	63	26	80	49	455	885
Hughes 300	-	2	-	4	5	4	1	-	13	3	78	110
Hughes 500	-	1	-	9	15	28	24	4	21	1	91	194
Hughes	-	3	-	13	20	32	25	4	34	4	169	304
Hiller UH-12	2	-	-	7	1	8	1	-	35	-	93	147
Hiller UH-12 Soloy	-	-	-	3	4	3	-	-	2	-	13	25
Hiller FH 1100	2	-	-	-	-	1	-	-	-	-	6	9
Hiller	4	-	-	10	5	12	1	-	37	-	112	181
Aerospatiale Lama	-	-	-	-	-	15	33	-	3	2	7	60
Aerospatiale Dauphin	-	-	-	-	-	-	-	-	-	-	2	2
Aerospatiale Alouette	-	1	2	3	-	17	22	-	5	1	3	54
Aerospatiale Gazelle	-	-	1	-	-	-	-	1	2	-	10	14
Aerospatiale AStar	3	-	-	1	1	11	6	-	11	-	20	53
Aerospatiale Twin Star	-	-	-	-	-	4	-	-	6	-	5	15
Aerospatiale Puma	-	-	-	-	-	-	-	-	-	-	-	-
Aerospatiale	3	1	3	4	1	47	61	1	27	3	47	198
MBB BO 105	-	-	-	-	5	-	-	-	-	-	7	12
MBB BK 117	-	-	-	-	-	-	-	-	-	-	-	-
MBB	-	-	-	-	5	-	-	-	-	-	7	12

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Table 4.5 (Cont'd)
SECONDARY MARKET AREA 1982

HELICOPTER TYPE	SASKATCHEWAN	MANITOBA	NWT	WYOMING	NEVADA	COLORADO	UTAH	NEW MEXICO	ARIZONA	MONTANA	CALIFORNIA	TOTAL
Enstrom	-	-	-	1	-	2	-	4	6	2	36	51
Robinson	-	-	-	-	-	-	-	-	4	-	25	29
Brantly Hynes	-	-	-	-	-	2	-	-	-	-	-	2
Westland 30	-	-	-	-	-	-	-	-	-	-	3	3
Agusta 109	-	-	-	-	-	-	-	-	1	-	-	1
Sikorsky S-51	-	-	-	-	-	-	-	-	-	-	1	1
Sikorsky S-55	3	-	1	-	-	-	-	-	19	-	6	29
Sikorsky S-58	2	-	-	-	-	-	-	-	6	-	25	33
Sikorsky S-61	-	-	-	-	-	-	-	-	-	-	7	7
Sikorsky S-64	-	-	-	-	-	-	-	-	-	-	2	2
Sikorsky S-76	-	-	-	-	-	-	-	-	-	-	4	4
Sikorsky	5	-	1	-	-	-	-	-	25	-	45	76
TOTALS	28	36	7	47	62	208	150	35	214	58	899	1742

4.3 COMBINED MARKET AREAS

When the Primary Market and Secondary Market Areas are combined, there are over 3,500 helicopters which are potentially customers of British Columbia based helicopter overhaul and repair companies. This is about one-third of the North American civil helicopter fleet.

The Bell 206 Jet Ranger turbine powered helicopter dominates both the Primary and Secondary Market Areas with a total of 1,008 units or 29 percent of the total fleet. The Bell 206L, Long Ranger, the larger version of the Bell 206, adds another 137 units to this total. British Columbia has the largest number of Bell 206's in the two market areas with 221 units. California ranks second with 165 units, Alberta third with 131 units, and Alaska, with 110 units is fourth. The Bell 206 and Bell 206L therefore represent a very large market potential. It is expected, according to Bell Helicopter, that the Bell 206 will be still in production in 1990.

The Bell 47 piston helicopter, which was in production from 1946 to 1974 is the second largest helicopter market. There are some 419 units in the Primary and Secondary Market Areas. When the Soloy turbine conversions are included the total increases to 469 units. The Primary Market Area, however, includes only 29 percent of the total number of Bell 47's, most of which are used in Washington and Oregon. California has the largest concentration of Bell 47 helicopters, with 206 units including the Soloy conversion or some 44 percent of the total

Bell 47's in the two market areas. These older helicopters are used now primarily in the agriculture sector. Due to the age of the Bell 47 and higher operating costs, the number of Bell 47's is expected to decrease in number, particularly those in use with commercial operators. However, due to the number of units, they, perhaps, represent a unique market for overhaul and repair such as has been established by Soloy Conversions of Olympia, Washington. It would be likely difficult, however, to compete in the California market due to the distance.

The Hughes 500 also represents a sizeable market opportunity when the Primary and Secondary Market Areas are combined. There are 401 units in the two markets, divided equally between the two. California has the largest concentration of the turbine powered helicopter with some 91 units. Alaska, with 71 units, ranks second and Alberta with 54 units, ranks third. The Hughes 500 has about 11.5 percent of the total helicopter fleet in the two market areas. The Hughes 500 series will be in production for several more years.

The Hiller UH-12 piston helicopter also is a large potential market for overhaul and repair in terms of the number of helicopters. The two market areas have 224 units. When the Soloy turbine powered conversions are added, the total increases to 310. The Hiller UH-12, like the Bell 47, represents older technology since this helicopter was first certified in 1948. It, like the Bell 47, may represent a unique opportunity due to the number of Hiller UH-12's which are still in the helicopter fleet. Hiller Aviation also still produces the UH-12 and a turbine version, UH-12T.

The piston powered Hughes 300 has a strong market position in the Secondary Market Area, again, particularly in California. There are 137 units in both markets but nearly 57 percent are located in California. As in the case of the Bell 47, there may be some market opportunities. Since most are located in California, the market competition is expected to be intense.

The Aerospatiale AStar is another market possibility. Since this helicopter was certified in 1977, it has been increasing its North American market share. It represents new technology in the use of composite material, including in the rotor head design. The total number of units in the Primary and Secondary Market Areas is 133 units. AStars are concentrated in British Columbia (22), Alberta (22), California (20), and Alaska (18). The AStar and the twin-engine version, the Twin Star, represent a market size which may be sufficient to support a British Columbia overhaul and maintenance facility if a significant volume of business can be attracted.

There are a number of Aerospatiale Alouette series helicopters in the two market areas. There are 106 units registered, of which Oregon has the largest number (26), followed by Utah (22), Colorado (17) and Alaska (14). This presents about half of the North American total. The Alouette helicopter is no longer produced by Aerospatiale; however, due to the number of units in the two market areas, there may be some market potential for overhaul and repair of this helicopter.

Table 4.6 combines the two market areas to show the total number of helicopters in the Primary and Secondary Market Areas. The table also presents a projection to 1990, broadly based on growth rates developed by the Bell Helicopter Textron study. The average annual growth rate projected is 3.0 percent for this table, less than the 4.0 percent average growth rate used in the Bell Helicopter Textron study.

As noted the geographic location of military helicopters within the two market areas is not available. It is likely that between 25 - 30 percent of the Canadian and U.S. military helicopters are in Western Canada and Western U.S. States. This represents some 2,000 to 2,500 helicopters.

Table 4.6

MARKET AREA HELICOPTER INVENTORY AND PROJECTION

HELICOPTER MANUFACTURER	1982			1990		
	PRIMARY	SECONDARY	TOTAL	PRIMARY	SECONDARY	TOTAL
Bell 47 1/	137	332	469	90	220	310
Bell 204/205	87	67	154	74	57	131
Bell 206	625	383	1008	920	525	1445
Bell 206 L	60	77	137	88	114	202
Bell 212	54	20	74	74	27	101
Bell 214	13	3	16	20	25	45
Bell 222	3	2	5	5	3	8
Bell 412	20	1	21	27	4	31
Bell 400	-	-	-	18	22	40
Bell	999	885	1884	1316	997	2313
Hughes 300	27	110	137	36	175	211
Hughes 500	207	194	401	305	285	590
Hughes	234	304	538	341	460	801
Hiller UH-12 1/	138	172	310	160	200	360
Hiller FH 1100	28	9	37	32	10	42
Hiller	166	181	347	192	210	402
Aerospatiale Lama	25	60	85	20	50	70
Aerospatiale Dauphin	-	2	2	-	-	-
Aerospatiale Alouette	52	54	106	45	45	90
Aerospatiale Gazelle	14	14	28	12	12	24
Aerospatiale AStar	80	53	133	137	85	222
Aerospatiale Twin Star	12	15	27	20	26	46
Aerospatiale Puma	3	-	3	4	1	5
Other Aerospatiale	-	-	-	3	5	8
Aerospatiale	186	198	384	241	224	465

1/ Including Soloy Conversions.

Table 4.6 (Cont'd)
MARKET AREA HELICOPTER INVENTORY AND PROJECTION

HELICOPTER MANUFACTURER	1982 PRIMARY	1982 SECONDARY	1982 TOTAL	1990 PRIMARY	1990 SECONDARY	1990 TOTAL
MBB BO 105	21	12	33	36	19	55
MBB BK 117	7	-	7	12	3	15
MBB	28	12	40	48	22	70
Westland 30	-	3	3	2	5	7
Westland (other)	-	-	-	-	1	1
Westland	-	3	3	2	6	8
Sikorsky S-51	-	1	1	-	-	-
Sikorsky S-55	8	29	37	6	25	31
Sikorsky S-58 2/	9	33	42	7	28	35
Sikorsky S-61	19	7	26	16	5	21
Sikorsky S-64	7	2	9	5	1	6
Sikorsky S-76	37	4	41	47	6	53
Sikorsky (Other)	-	-	-	2	1	3
Sikorsky	80	76	156	83	66	149
Boeing Vertol 107	13	-	13	12	-	12
Boeing Vertol 234	1	-	1	2	1	3
Boeing Vertol	14	-	14	14	1	15
Agusta 109	2	1	3	3	2	5
Brantly Hynes (all)	-	2	2	-	2	2
Enstrom (all)	35	51	86	41	58	99
Kaman	1	-	1	-	-	-
Robinson R-22	18	29	47	28	50	78
Other Helicopter Manufacturers	-	-	-	2	1	3
TOTALS	**1763**	**1742**	**3505**	**2311**	**2099**	**4410**

2/ Includes turbine versions.

5.0 HELICOPTER MAINTENANCE DOCUMENTATION

This chapter briefly outlines the documentation, publications and historical records required in order to attest to the aero mechanical airworthiness of a helicopter.

5.1 GOVERNMENT REGULATIONS

In Canada, helicopter maintenance is regulated by Transport Canada and in the United States by the Federal Aviation Administration. In many instances, the same regulations by these two agencies cover both fixed wing and helicopter maintenance requirements. However, in other instances, the helicopter has additional requirements.

The requirements of airworthiness are outlined in Part 1, Chapter III, Paragraph 3.1 of the Air Regulations in Canada. A Certificate of Airworthiness is issued by Transport Canada only after it is satisfied that an aircraft conforms to approved design in all respects, including methods of construction, materials, equipment, weight and balance. To ensure that a product is airworthy, a system of supervision and inspection at every operation from raw materials to finished product is involved in the certification system. It is required by regulation that companies and persons which are engaged in the business of manufacture, maintenance, repair, and overhaul; supply of aircraft, aircraft accessories, aero engines and accessories, and materials for use in aircraft nominate qualified individuals to act as inspectors. These nominated inspectors will examine and certify the eligibility of products under their control for use in aircraft. Each certificate signed by an inspector is dependent upon a certificate from the immediately preceding unit in the chain. The Chief Inspector of the company is directly responsible to the directors of the firm for the organization and control of the inspection staff as well as for adequate facilities and equipment to enable them to perform their duties effectively. The inspection organization is to be maintained at the standard originally approved, and any changes have to be notified to the Regional Airworthiness Inspector and approved by the Chief Aeronautical Engineer of Transport Canada.

The authority for certifying items at manufacturers, repair and overhaul shops and supply houses is vested as follows:

a) **Licensed Aircraft Maintenance Engineer (AME).** Certification by an engineer is limited to those items for which his license is endorsed (e.g., rotory wing and specific helicopter types). In the case of manufacturing, repair, and overhaul, an engineer's license in Category "B" is required for airframe work, and a Category "D" is needed for engine work. For a complete helicopter manufacture or overhaul, certification by a Category "R" licensed AME is required. AME license qualification standards are set by the government authorities as well as the years of practical experience.

b) **Authorized Representatives.** Authorized representatives are those employees of a company which has been approved by a governmental licensing agency for the manufacture, repair, overhaul, maintenance, servicing and certification. A licensed AME may not necessarily be an authorized representative of a company unless approved by the licensing agency.

A company may be approved for the fabrication of only parts, or it could include the manufacture, repair, overhaul, maintenance and servicing of all items up to the complete aircraft. Normally such companies must have a complete inspection staff, together with the required quality control systems. The company itself will be held responsible for the certification and will not be under the authority of an A.M.E. license, even though an A.M.E. may be on staff. The company must provide a list of all persons, together with their qualifications, whom the company will be authorizing to certify on their behalf and must be prepared to show proof of their fitness to undertake the duties required. Companies wishing to be approved have to supply particulars of:

i) The type or types of aircraft for which they request authority to certify airworthy after repair, modification, overhaul and inspection;
ii) Their facilities, equipment and tools;
iii) Engineering services (if any);
iv) Inspection organization;
v) Quality Control Committee who will be responsible for the airworthiness of all aircraft dealt with;

vi) Personnel qualifications;

vii) Manuals and similar data pertaining to all work for which they are requesting approval.

c) **Approved Inspection Staff.** Individuals can be nominated to be responsible inspectors for a company based on the scope of responsibility and their qualifications.

No material, part, component or accessory requiring certification can be installed in a Canadian registered civil aircraft without having been inspected, tested and certified airworthy. This applies to any new, overhauled, or repaired items and covers such items as generators, undercarriages, floats, propellers, rotors, up to and including complete wings, etc. The acceptable forms of certification are as follows.

a) Parts, components or accessories will normally be certified on a properly completed provided a Certificate Tag A.1.99 attached to each item.

b) Parts, received from any source, which have been certified airworthy under any system of approved inspection and certification, such as on Export Certificate of Airworthiness, British Release Note, Airworthiness Approval Tag FAA Form 186, or a certification on the invoice for Class III items, need only be retagged with Tag A.1.99.

c) Raw materials, such as aircraft wood, sheet metal, plastic composites, tubing, extrusions, etc., may be certified by the general form of certification.

d) Standard parts made to general aircraft specifications, such as AN, SAE, MIL, AGS, etc., do not require certification other than on the invoice which states the manufacturer's certification or specifications to which the item was manufactured.

e) Items imported from the United States as Class I units must have an Export Certificate of Airworthiness, while Class II units require an Airworthiness Approval Tag, FAA Form 186, to be attached. Class III units require either FAA Form 186 or certification on the exporter's invoice that the unit:

   i) was manufactured in accordance with a particular specification;
   ii) was manufactured in accordance with accepted products, methods, processes and procedures; and that,
   iii) by inspection, it was determined that the parts or materials described were airworthy.

Federal Aviation Regulation (FAR) Part 21 and Advisory Circular 21-2 contain procedures which are acceptable to Transport Canada with regard to the importation of aircraft products from the United States. Aircraft products are classified as follows:

a) A Class I product is a complete aircraft, aircraft engine, or propeller (rotor blade) which has been type certified in accordance with the applicable Federal Aviation Regulations and for which Federal Aviation Specifications or Type Certificate Data Sheets have been issued.

b) A Class II product is a major component of a Class I product and the failure of which would jeopardize the safety of a Class I product; or any part, material, or appliance approved and manufactured under the Technical Standard Order (TSO) system.

c) A Class III product is any part of component which is not a Class I or Class II product and includes standard parts, i.e., those designated AN, NAS, SAE, etc.

The Federal Aviation Administration requirements for helicopter airworthiness are covered in the Federal Aviation Regulations (FAR) Part 27 (Normal Category Rotorcraft) and Part 29 (Transport Category Rotorcraft). In addition, other FARs which are familiar to fixed wing aircraft, such as 43, 91, 135 and 137, refer to both fixed wing and rotorcraft. FAR 43 in particular, contains information applicable to rotorcraft. These sections refer to inspections of a rotorcraft, following the maintenance manual of the manufacture, concerning:

- Driveshafts or similar systems
- Main rotor transmission gearbox for defects
- Main rotor and centre section, and
- Auxiliary rotor on helicopters

In addition to the FARs, type certification information is contained in the Aircraft Specification Sheets or Aircraft Specification Data Sheets issued by the FAA which outline requirements such as maximum rotor limits, retirement time of various components and references to the maintenance manual.

Airworthiness directives and inspection and airworthiness certificates are similar to those of Transport Canada but are subject to the various FARs.

5.2 OPERATOR MAINTENANCE RECORDS

The operator of a helicopter is required to have a maintenance retirement schedule that is a historical record of the critical parts which have a finite life. The record indicates that certain parts are to be scrapped after the flight-hour requirement has been reached. The service life of these components depends upon the continual stresses imposed upon them and the service record of the like component. In many instances, these lives have been extended or shortened as information about the part has been obtained. The record is the responsibility of the operator but is usually kept up to date by a maintenance technician.

In addition to a retirement schedule, an overhaul or major inspection record is kept on the rotory components of the helicopter. The information as to the life of the component is obtained from either the Aircraft Specification Sheet or the Manufacturer's Maintenance Manual. The helicopter operator also keeps Service Bulletins and an Airworthiness Directive Record for the helicopter.

Logbooks are another source of maintenance records. Maintenance trends and life expectancies can be determined from the logbooks, as well as information on logistical support of the helicopter.

There are several computer software programs now available to assist helicopter operators in keeping up-to-date maintenance records.

5.3 MANUFACTURERS' PUBLICATIONS

The helicopter manufacturer issues publications to assist helicopter operators in maintenance requirements. These include Operator's Manuals (Flight Manuals), Maintenance Manuals, Service Bulletins, Overhaul Manuals, Advisory Letters and Inspection Manuals. There is no standardization between manufacturers as to these publications but efforts are being made by all aircraft manufacturers to standardize the maintenance and parts manuals with the Airline Transport Association (ATA) system format. Most of the newer helicopters now use the

ATA system. The quality of the manufacturers' manuals also are not standardized and differ from one helicopter manufacturer to another.

5.4 SUPPLEMENTAL TYPE CERTIFICATES

The Supplemental Type Certificate (STC) is for a part or component not available from the original aircraft manufacturer. A supplemental manufacturer or an operator will have developed an item or modified a helicopter, and will have obtained approval for the STC from the government regulators. The STC could include a number of items including baggage racks, skid gear modifications, different engine installations or aerial ambulance configuration. Some are available in kit form while others are only information on the specifications to make the modifications.

5.5 BILATERAL AIRWORTHINESS AGREEMENT

The current Canada/United States civil bilateral airworthiness agreement does not permit work to be performed by one country's technicians on aircraft components that are removed from foreign registered aircraft and shipped across the border. For example, Canadian helicopter engine components cannot be removed from the helicopter and shipped to the United States for repair and overhaul then returned to Canada for installation. Technically, the helicopter must also be delivered to the United States at the same time. It is recognized that the conditions of the existing agreement have not been strictly enforced.

The Canadian and United States governments are currently working on a modification to the agreement to recognize repair and certification of aircraft components. With respect to the more complex situation regarding the issuance of a Supplemental Type Certificate (STC) a new agreement is likely required. It is expected that a new agreement will be issued in the future which could eliminate the extra stringent engineering procedures expected of Canadian firms when they perform work on United States aircraft. A new agreement could mean increased business for well-equipped Canadian repair and overhaul shops.

The existing bilateral airworthiness agreement does not apply to military aircraft and/or components shipped to the other country for repair and overhaul work. Military aircraft have been exempt from airworthiness agreements.

6.0 HELICOPTER MAINTENANCE

This chapter reviews basic helicopter maintenance to provide an understanding of the maintenance requirements of helicopters. The review is intended for the non-technical reader to understand the major helicopter maintenance systems and their components.

6.1 MAIN ROTOR SYSTEM

The main rotor is the wing of the helicopter. In addition to aerodynamic stresses, it is subject to centrifugal force. This force is coupled with motion which induces vibration, twisting movements and flexing, and generally places the rotor system under continuous stress during the entire operation. Through continuous efforts in research and development, many improvements have been made in rotor systems. New improvements have increased the finite life of the components, decreased the maintenance, and increased performance in both lift and speed.

6.1.1 Rotor Heads

There are two basic types of rotor heads: the fully articulated and the semi-rigid rotor. The fully articulated rotor head has provisions for independent flapping of the rotor blades using a hinge mechanism for each blade. There is also a means to allow the blades to lead and lag independently for equalization of lift of the advancing and retreating blades. Lead and lag are accomplished by using a mechanism and a dampener to control the amount of lead and lag of the blade. The head must also provide a pitch change for each blade. The rotor head may also be classified as to the type of lubrication system used--grease/oil system (wet) or no lubrication (dry). The newer technology requires no lubrication (i.e., dry).

The rotor head is usually made of steel and aluminum alloy. As a result, many of the parts are time-life limited because of the stresses imposed on the 'head' components. Aerospatiale has a rotor head made of fibreglass that does not have a retirement life. Examples of helicopters which use a fully articulated head include: Sikorsky S-58, Hughes 500 C&D, Sikorsky S-76, Aerospatiale AStar 350 (fibreglass) and the MBB BO 105. The BO 105 is (close to a rigid rotor system) and is unique in that it uses a one-piece titanium forging and reinforced glass fiber blades for fully articulated interaction.

The semi-rigid rotor head is a two bladed type and is usually underslung. The major portion of the head is below the top of the mast to increase stability. The head has a seesaw action or flapping axis using a gimbal or a pillow block trunnion arrangement at the top of the rotor. This equalizes the lift forces of the advancing and retreating blades. The head also has a feathering axis for changing pitch which is provided for by movable blade grips. Examples of helicopters which use a semi-rigid rotor heads include: Bell 47, Hiller UH-12, and Bell 206. The Bell 206 is a more modern semi-rigid rotor head and later models have a dry lubrication system. It requires a tension-torsion strap, made of fine wire wrapped around two spools thousands of times to retain the rotor head and to absorb the force stress of rotation.

6.1.2 Rotor Blades

The first rotor blades were made of laminated wood and were used on several of the earlier production type of helicopters. A steel core was placed near the leading edge of the blade during the lamination process which acted as a mass balance. The main disadvantage of wooden blades is the requirement for matched pairs due to the variations of the wood and the effect of moisture on the blade. It has some advantage over metal blades in retirement life.

Metal rotor blades have been in use for over twenty years. Metal blades are generally of bonded construction using aluminum alloy, and are used on most helicopters now in production. A distinct advantage is the ability to greatly control the blade construction and single blades may be changed without the use of matched sets. Like other metal components exposed to stresses induced in flight, the metal blade must be time life limited. Grip plates and doublers are added at the root of the blade to spread the attachment stresses over a wide area of the blade.

Fibreglass is the newest material for rotor blades. The blade is manufactured using several types of material and then covered with fibreglass. There are two types of fibreglass blades used on production-type helicopters: the fibreglass spar-type blade and metal spar blade.

The fibreglass spar blade uses a precured roving spar. The rovings are strings or strips of glass material which is impregnated with epoxy resin. The metal spar blade is a composite blade where a metal spar is used and fibreglass materials are used to build the remainder of the blade.

The major advantage of fibreglass over metal is the life of the blade. The fibreglass blade is also less susceptible to notch damage due to the threads of the roving. Corrosion is non-existent and bonding can often be repaired by epoxy resin injections. The Sikorsky S-76, Aerospatiale AStar, and MBB BO 105 are examples of helicopters using fibreglass blades. It is expected that most helicopter manufacturers will offer fibreglass blades in the 1980's and by 1990 nearly all rotor blades will be fibreglass.

6.1.3 Rotor Head Maintenance

The rotor head, since it is a highly stressed unit of the helicopter, usually has many time-change and mandatory retirement items. Some manufacturers will allow the major inspections and overhaul to be performed by the operator while others have exchange programs or certain authorized repair stations that do the work. It is a complex procedure and requires specific expertise. Often, the tolerance dimensions are in 10th of thousands rather than thousands. Checks taken require that the parts of ferrous metal be magnafluxed and the non-ferrous parts be zygloded and other non-destructive tests (NDT) be undertaken to locate any cracks. In reassembling the rotor head, the blades have to be balanced (static and dynamic) and excessive vibration has to be eliminated. Blade tracking is also required to ensure all blades are travelling within the same tip path plane. Other procedures include blade sweeping for semi-rigid rotor systems to ascertain clockwise dynamic balance, electronic balancing to solve vibration problems, dampener maintenance to position the advancing and retreating blade, and autorotation adjustments. As can be seen rotor head and blade maintenance require expertise in a number of areas and specialized facilities and equipment.

6.2 MAST AND FLIGHT CONTROLS

6.2.1 Mast

The main rotor is attached to the mast assembly which is a tube like structure attached to the helicopter's transmission. It absorbs torsional and tension loads received from the engine torque and the weight of the helicopter in flight. The mast is a critical item and usually has a finite life. Some masts support only the head assembly while others, such as the Bell system, support the stabilizer bar assembly and the rotor head. The mast also holds the swashplate (star assembly) through which the flight controls operate. All masts are made of machined steel forgings, making them susceptible to corrosion, stresses, scratches, and other damage associated with steel parts. The masts are plated with cadmium to prevent corrosion from forming on the steel. Masts used on semi-rigid rotors are also susceptible to damage from mast bumping due to the underslung head striking the mast.

At overhaul, masts are checked dimensionally, magnafluxed and may require a check for concentricity. Most masts contain a main mast bearing. A failure of this single bearing will result in possible shearing of the mast or stoppage of the main rotor.

6.2.2 Stabilizer Bar

Several models of the Bell helicopter use a stabilizer bar system that is mounted either on the mast or on the trunnion cap of the rotor. If the helicopter rotor is disturbed by wind forces in hover, the stabilizer bar tends to remain in its same plane of rotation due to the gyroscope action of rigidity. Since the stabilizer bar is connected by linkage to the feathering axis of the rotor, the relative movement between the mast and the stabilizer bar will cause the blades to feather. The feathering of the blades causes the rotor to return to its original position. The balancing of the stabilizer bar is considered a routine item at the major inspection periods when the components are torn down and built up. Other maintenance performed include bearing changes, and shimming of the mixing levers. At overhaul, magnetic inspection and dye penetrant inspection is done.

6.2.3 Dampers

Hydraulic damper units are used in conjunction with the stabilizer bar. The dampers restrict the travel rate of the stabilizer bar in both directions. They are usually attached to the mast by a frame assembly below the rotor head. Maintenance of dampers is limited to field level checks and timing checks to return to a neutral position.

6.2.4 Swashplate

This device transfers the movement of the cyclic and collective control from stationery push-pull to rotating push-pull movements that are transferred to the rotor system. When the collective is applied, all the rotor blades collectively change pitch, which requires the swashplate to move up and down as it rotates. The cyclic movement requires a universal joint movement of the swashplate to tilt the whole rotor system left, right, fore, and aft.

The maintenance procedures are to keep the movable surfaces of the swashplate clean to prevent injury to the bearing surfaces. The tension inspection of the gimball and rotating plate are other maintenance items that need to be performed, as well as changing bearings. The overhaul procedures include dimensional checks, magnetic particle inspection, dye penetrant inspection and other NDT procedures. The swashplate assembly normally has parts that have finite lives due to metal fatigue.

6.2.5 Flight Control Systems

The controls are usually made of push-pull tubes, torque tubes, bellcranks, mixer boxes, gradient springs, magnetic brakes, bungee springs, counterweights, hydraulic services and timing mechanisms. The larger the helicopter, the more complex the control system.

a) Collective Stick. This control lever in the cockpit is raised and lowered to raise and lower the helicopter. A twist grip is incorporated to control the throttle on a piston engine or the compressor RPM on a turbine engine. A switch box is often placed on top of the collective in a turbine powered helicopter. The box contains the trim switches for the engine, landing lights, and search lights as well as the starter button.

b) Cycle Control. This control lever in the cockpit is used to tilt the rotor in all directions as the control is moved. Like the collective, switches are usually provided on the cycle grip such as the microphone switch and trim switches for the helicopter.

c) Push-Pull Tubes. These are used in the collective and cyclic systems for control movement. Rod ends may be a high usage item on some helicopters and in some operations, depending on the operating environment and the vibration level.

Replacement of worn rod ends and/or spherical bearings is the maintenance requirement. Most push-pull tubes require close tolerance bolts and cotter pins for safety.

d) Torque Tubes. These are used in a flight control system for several different purposes in a system. Torque tubes are usually attached to each end of the structure by a bearing so that partial rotation of the shaft may take place. The type of bearing used varies considerably: oilite bronze bushings, teflon bearings, or sealed pre-lubricated ball bearings.

Torque tubes are inspected periodically for bearing wear and cracks, especially at the rod attachment point which may be worn.

e) Bellcranks. The bellcrank is mainly used to change direction with a push-pull tube, like the function of the torque tube. The bellcrank may not be used to change direction, but will always change the travel of the tube and the mechanical advantage.

f) Mixer Box. Usually all helicopters use a mixer for the cyclic and collective inputs prior to being transmitted to the swashplate. The purpose of the mixer is to prevent the collective input from affecting the cyclic input as they move together or in relation to each other.

g) Gradient Unit. In hydraulically boosted controls, a gradient unit is installed to provide artificial feel of the movement of the control which has been removed by the hydraulic boost. Gradient units are used in all cyclic inputs, as well as in some tail rotor and collective systems.

h) Control Boosts. Helicopters not using hydraulics for boosted controls may make use of bungee springs to assist moving the controls. Hydraulic boost systems for the controls, however, are used in most helicopters. In addition to assisting in moving the rotor, most of the hydraulic actuators are built to absorb rotor feedback which improves the smoothness of the controls and eliminates vibration.

i) Hydraulic System. The system normally is composed of a hydraulic pump, reservoir, relief valve, filters, accumulators and actuators. Maintenance of the components is usually limited to removal and replacement of tubing, hoses, valves, and pumps. Components such as pumps, valves, and actuators require special equipment for rebuilds. Most hydraulic components do not have a finite life but most have recommended overhaul times.

j) Control Rigging. It may be necessary after removal and replacement of components that the particular system be rigged, that is, adjusted so that the correct amount of pitch is present on the collective, and the cyclic travel is within tolerances. Special equipment is required for control rigging such as jigs and rigging pins.

6.3 MAIN ROTOR TRANSMISSIONS

The main rotor turns at speeds of three to four hundred RPM on most helicopters while, at the same time, the engines that power these rotors are turning at about ten times higher RPM on a reciprocating power plant and more than twenty times higher RPM on turbine helicopters. Engines produce the greatest amount of power at high RPM but the rotor cannot operate at high RPM because of the tip speed and retreating blade stall. Helicopters, therefore, require a transmission to reduce the engine speed to a speed that can be handled by the main rotor.

6.3.1 Transmissions

Early light helicopters, such as the Bell 47, had a reciprocating engine mounted vertically and coupled directly to the transmission which drove the rotor. Shafting later allowed the engine and transmission to be located separately and today many turbine powered helicopters often have the engines and transmissions in different locations. There are a number of different ways the power from the engine can be transferred to the transmission depending on the location of the engine and the transmission.

Most turbine helicopters make use of a short shaft system to deliver power to the transmission. These short drive shafts vary in design but all have some way to correct for misalignment and for movement of the transmission. In terms of maintenance, coupling parts may have to be replaced as a result of wear. Some shafts also require alignment procedures between the engine and transmission. This is repeated when major components are changed. Clutches may be automatic, belt tighteners, hydromechanical or sprag. The most popular is the sprag clutch. A sprag clutch is used on a Bell 206. The clutch is necessary to unload the engine during starting operation because the inertia required to move the rotor system would be too great. The free shaft turbines will not require a clutch since the engine does not have a direct drive between the compressor and the power turbine. Clutches are located between the power plant and the gear reduction of the transmission.

One unit related to the clutch is the free wheeling unit. It is found on all helicopters, regardless of the power plant. The purpose of the unit is to allow the engine to drive the transmission and prevent the rotor from driving the engine. Without this unit, the engine would be driven by the rotor any time an autorotation is attempted.

A torquemeter may be included between the engine and the transmission drive system. This system is usually located within the turbine and measures the power output of the engine. It may be a limiting factor for the transmission on some helicopters since the engines are capable of producing more power than the transmission can absorb. The Aerospatiale Gazelle is an example of a helicopter which has a torquemeter.

Some helicopters have a rotor brake located between the engine and transmission to stop the rotor on shutdown after the engine has ceased to power the rotor. These brakes are normally a disc type attached to the input side to the transmission and may be either hydraulic or manually operated. There are wear factors to the unit which confine most operators only to use the unit when necessary.

The maintenance practices applied to these components located between the engine and transmission are as varied as the varients. The clutch engagement and the free wheeling unit are critical to flight. If the units are used properly, they will normally last from major inspection to major inspection or recommended overhaul. The units are subject to overhaul unless the manufacturer provides exchange units. A wear factor is created between the sprags, the driver, and driven races of these units, and usually these parts are replaced during the overhaul.

The transmissions are normally mounted to the fuselage on semi-flexible mounts to help dampen vibration that is transmitted from the main rotor system to the fuselage. If vibrations are not controlled, they may start harmonic or sympathetic vibrations in the fuselage and components. This may lead to fatigue and wear factors if the vibrations are not isolated or reduced by the transmission mounting. Although the mount has some flexibility, it must also possess high strength ratios because the helicopter is actually suspended from the transmission mounts and is absorbing the torsional loads of the rotor system.

6.3.2 Transmission Design

The trend in transmission design is to simplify the transmission as much as possible. This, in turn, will reduce the operating and manufacturing costs. The transmission on the Bell 206 is a good example of a simple transmission design. This transmission is mounted in front of the engines receiving the engine power through a short shaft from transmission input. The engine used is a free turbine and, therefore, no clutch is necessary. A sprag unit is mounted at the engine output, therefore, no free wheeling unit is necessary in the transmission.

The transmission case is made up of a main case and a top case. The main case provides a housing for the input quill, accessory drive quill, transmission oil pump, and supports the spiral bevel gear and shaft. The lower mast bearing and support mount are in the bottom of the lower case and serves as a reservoir for transmission oil.

The input quill transmits engine power to the transmission. The quill consists of a steel pinion gear supported by a set of tri-plex thrust bearings and one radial alignment bearing. A spiral bevel gear and shaft then mesh with the input gear reducing the RPM and change the direction of the power train 90°.

Only one accessory drive quill is used in the Bell 206 transmission and this quill is mounted in the lower case under the spiral bevel gear. The accessory gear is driven from this bevel gear and turns the transmission oil pump, hydraulic pump, and rotor tachometer generator.

The transmission has its own separate oil system to supply lubrication to the various components of the transmission.

The Bell 206 transmission for maintenance purposes may be disassembled in the field for major inspection and parts replacement. Because of fewer parts than older transmissions, the procedure is simpler but the same NDT checks are made of the ferrous and non-ferrous parts.

Although the transmissions vary considerably in construction, most of them use the same basic principles. This includes input pinion rotating bevel gears, planetary gear reductions and accessory gears. The number of accessories driven is the biggest variation in the different transmissions. This is usually in direct relationship with the complexity of the helicopter in regard to electrical systems, hydraulic power and other systems.

6.3.3 Transmission Maintenance

The maintenance inspections of the transmission are also quite varied from major inspections of the transmission where a complete teardown and rebuilding is done, to a simple removal and exchange of a unit. On many transmissions a great number of special tools and equipment are needed to perform an overhaul. In most cases, transmission overhaul is beyond the capability of a small operator to conduct. All manufacturers have recommended overhaul or exchange times on transmissions.

6.4 POWERPLANTS

The powerplants used in early helicopters were adaptations of existing fixed wing powerplants. These adaptations included mounting the engine vertically (lubrication system needed to be changed as a result), increasing the speed due to the horsepower requirement of the helicopter, installing a fan to develop the airflow for cooling, changing the method of controlling power due to constant RPM of the rotor and establishing transient ranges of RPM due to harmful vibration ranges in the airframe components.

Often, the life of these engines was shortened as a result of modifications, and due to the high power setting at which the helicopter is required to operate. Some helicopter engines have a time before overhaul (TBO) in the range of less than 1000 hours. Fixed wing turbine engines, in comparision, have TBO's of 5000 hours.

6.4.1 Reciprocating Engines

Reciprocating piston engines include horizontally opposed engines and radial engines. All these engines have to have cooling, and since these are usually air cooled, they receive their cooling air from a fan. In all cases, the fan is powered by the engine and air is ducted around the cylinders to dissipate the heat. The cooling fans are subject to balance problems and resulting vibrations. Cooling fans have recommended overhaul periods and may have finite lives on some of the items.

6.4.2 Turbo Shaft Engines

Although there are reciprocating engine helicopters still being manufactured, most helicopters are now turbine powered. The turbine engines used in helicopters vary in size from 300 to 3,000 or more horsepower. It was not until the turbine-engine was developed that an engine was specifically designed for helicopter application. The turbine engines used in helicopters are termed "turboshaft" because the power extracted from the engine is used to turn a shaft. The shaft then turns the transmission, main rotor and tail rotor of the helicopter. The shaft turbine may produce some thrust but the turbine wheel absorbs most of the power of the escaping gases of combustion to produce shaft horsepower. The turboshaft engine may also contain a gear reduction to reduce the speed of the turbine which may exceed 30,000 RPM on some engines.

There are two types of turboshaft engines: direct shaft turbine and free shaft turbine. The free turbine is the most popular in application.

6.4.2.1 Components

The basic components of a turboshaft engine are a compressor, diffuser, combustor, turbine wheel(s), and exhaust. The free turbine derives its power from a separate turbine not connected to the compressor. The direct drive turboshaft engine, on the other hand, runs at a constant speed, with the compressor and the power output attached to the same shaft. The free turbine advantage is that it can vary the speed of the compressor as required to maintain the power turbine.

Compressor designs vary but a combination axial and centrifugal compressor, where the first stages of compression are axial and the last stage centrifugal, is common in most shaft turbines. This design reduces the number of stages of the axial compressor and, therefore, the size of the engine may be reduced in length without an appreciable change in diameter. With a centrifugal compressor, only the diameter of the engine would increase. The combination design reduces foreign object damage (FOD) by eliminating the smaller stages of the axial compressor. The combination design also increases the speed of the airflow through the engine.

The axial compressor is made up of stages, each stage consisting of one stator and one rotor. The rotor is a multi-bladed disc with each blade being an airfoil. The rotory airfoils speed up the airflow and force air through the stator. This converts the airflow velocity into pressure by reducing the area in which the air flows. The process is repeated at each stage of the axial compressor.

The centrifugal compressor is a curved disc with blades. The blades are larger at the inlet than at the outlet. The air is picked up by the inlet and forced into a smaller area as the compressor rotates.

The air is then directed to the diffuser section where it is straightened and enters the combustion area of the engine where some is used to support combustion and the rest is used for cooling purposes.

The annular combuster, using reverse flow, is the most common combuster. At the combuster, fuel is added to the air and ignited. The heated air rapidly expands and passes through a nozzle assembly and is directed to the turbine wheel. The wheel is rotated by the gases passing over it and turns the compressor which generates more air to repeat the process.

In the free turbine, another turbine is placed behind the compressor turbine and is called the power turbine. This turbine drives a shaft to power the helicopter. The direct drive turbine wheel, on the other hand, is fixed to the compressor and drives a power shaft to power the helicopter or a separate turbine. Some engines drive from the compressor end (cold end) while others drive from the combusters end (hot end). The main advantage of driving from the hot end is that less shafting is required, however, the gear reduction is exposed to more heat in this area.

6.4.2.2 Power Output Measurement

With a reciprocating engine, a weight ratio of one pound per horsepower is achieved. In a turbine, ratios in excess of four horsepower per pound are common. The power is measured in horsepower and is usually expressed as shaft horsepower (SHP) or equivalent shaft horsepower (ESHP), which takes into consideration the additional thrust power generated.

Since engine performance will deteriorate with increases in atmospheric conditions such as density altitude, many turbines are flat rated whereby a given horsepower may be reached at a given temperature (.e.g., 450 SHP at 30^{o}C).

The power the engine delivers to the transmission may be limited and is termed torque limited. If all the power is not used, additional power in emergencies may be available because of the torque limitations.

Power on a reciprocating engine is measured by the manifold pressure while the power output on the turbine engine is measured by a torquemeter. The torquemeter measures the force produced by the engine and is usually expressed in foot-pounds of torque.

RPM measurement is also required to determine power output in conjunction with torque. To measure RPM on a shaft turbine, a tachometer is used. In a free shaft turbine, two tachometers are used. One tachometer is used for the compressor (N_1 or N_g) and the other for the power turbine (N_2 or N_f). Due to the speed at which the turbine operates, some tachometers often read in percent of maximum RPM. If RPM cannot be maintained or lags, it is an indication of an overloaded helicopter, incorrect adjustment or a worn engine.

Another instrument in the operation of the turboshaft engine is the exhaust gas temperature (EGT). It measures the temperature of the gases passing through the turbine area. If these gases are too hot, the metal of the hot section of the engine may be damaged, particularly in the areas of the nozzles and turbine wheels.

6.4.2.3 Particle Separators

One of the most critical requirements of a turboshaft engine is to eliminate foreign objects in the inlet airflow. This can be difficult in helicopter operations where operations are conducted in unimproved areas with dust and sand being blown into the air by the downwash of the main rotors.

Often a particle separator is located at the air inlet of the engine. One design uses centrifugal force to cause the particles to drop to the bottom of the filter unit and the compressor bleed air scavanges the particles overboard through holes in the filter unit. A second design is a separate duct system for inlet air particle separation and engine cooling. The heavy particles move aft through a particle separator valve into an ejector. The remaining air, with finer particles, enters the compressor through a wire mesh screen and is consumed by the engine.

On many other helicopters, an inlet screen is used with no particle separation. The screen prevents large foreign objects from entering the engine.

6.4.2.4 Compressor Damage

Small turboshaft compressors are subject to damage from a number of factors, including:

- F.O.D. Damage: Foreign object damage (FOD) may be caused by anything other than air passing through the compressor. Dust and sand are common foreign objects but may be quite varied, as is the damage caused from foreign objects.

- Erosion: If damage is caused by sand the compressor components will erode, allowing the engine to continuously ingest sand particles with the rapid airflow. Material will be removed from the compressor blades and stators as if the compressor was sandblasted. The removal of metal from the components will eventually change the shape of the airfoil sections of the blades. Once the efficiency is changed, the compressor cannot supply the required air flow and higher temperatures result. Eventually, the problem will result in a compressor siege or stall whereby, the combustor pressure is greater than the compessor pressure creating a reverse flow.

- Nicks, Scratches, and Blade Deformation: Larger items passing through the compressor can result in severe damage such as nicks and scratches. This may result in blades breaking off, passing through the compressor and doing still more damage. The loss of blades will also cause off-balance problems resulting in total failure of the engine. The ingestion of safety wire clippings and cleaning rags used by maintenance personnel are the most common causes of damage.

- Dirt: Like erosion, dirt will change the shape of the airfoils and reduce the efficiency of the compressor and increase the operating temperatures. Dirt build-up may be accelerated by the area of operation and by any oil that may be on the compressor blades.

- Blockage: Airflow blockage is critical. If enough of the airflow is restricted, stall and flameout of the engine may result. This blockage may be the result of several factors including ice, weeds, grass and leaves collecting in the inlet area of the engine. Deflectors and compressor discharge air can prevent ice buildup at the inlet guide vanes.

6.4.2.5 Fuel Controls

Fuel metering systems are becoming increasingly complex. The purpose of fuel control is to direct the correct proportion of fuel to the engine in order to meet the demands of that engine. The amount of fuel is governed by several factors that ensure that the correct ratio of fuel and air are obtained. These include: temperature compensator; barometric pressure compensator; N_1 governor (free turbine); N_2 governor; power control actuator; and a 3-D cam and are correlated by computer control. New fuel controls are microprocessor controlled and use electronic measuring devices combined with digital read-out display instruments.

6.4.2.6 Ignition Systems

The ignition system of turbine engines is only used during starting. Once combustion occurs, the system is not in use. Most systems are high capacitance discharge systems and consist of an exciter, igniter, and appropriate wiring. Many have an automatic relight system in the event of a flameout.

6.4.3 Turboshaft Maintenance

Most of the maintenance work performed on turbine engines is routine servicing, inspection, removal and replacement maintenance. Additional requirements are needed if the helicopter operation involves different environments such as salt water. With a salt water environment, the cleaning requirements are higher due to corrosion problems.

The life of turbine engines is not only based on time of operation but on cycles of the engine. Turbine wheel life in particular may be limited to cycles. Items on the engine are generally given overhaul or replacement times.

Many turbine engines are maintained on a modular concept as to their overhaul procedure whereby the hot section will have one life, the compressor another, and the gear reduction assembly still another life. Any of the modules can be removed and overhauled separately and, in some instances, the module may be exchanged. In other cases, the whole engine is exchanged or a rental engine is used while the other engine is rebuilt due to the finite life of components.

Large helicopter operators will have spare engines for exchange and may do their own major components work. Other operators have to have major work done by an authorized repair station, the manufacturer or his representative. Repair work is only done by a few factory authorized dealers or the engine manufacturer due to the expertise and equipment needed.

Engine alignment is a requirement at an engine change if the helicopter has been structurally damaged or driveshaft wear is excessive. Special tools are needed for an engine alignment.

Control rigging is one of the most difficult tasks in an engine installation. A preliminary rigging of the controls is needed, followed by adjustments after the engine is in operation and flight tests can be made. Controlling rigging will also include the droop compensator to maintain and stabilize pre-selected N_2 RPM as power is increased. The engine may also need trimming adjustment after the installation of an engine.

6.5 TAIL ROTORS

The tail rotor is used for the directional control of single main rotor helicopters. The majority of helicopters are equipped with tail rotors. Even though the tail rotor has disadvantages, it is relatively simple in design compared to the complexity of the tandem main rotor. The tail rotor, like the main rotor, must be able to perform in much the same manner with the blades being able to change pitch and flap either independently or as a unit. The blades must have a negative and positive pitch capability to supply directional control under powered conditions and autorotation. Directional control is done by foot pedals in the cockpit.

6.5.1 Tail Rotor System

The drive for the tail rotors is supplied from the transmission of the helicopter. It is necessary for the tail rotor to rotate at all times during flight, even if the engine is not operational.

6.5.1.1 Tail Rotor Drive Shaft

The tail rotor is driven through shafting from the transmission down the length of the tail boom. Since tail booms generally have some flexibility, the shafting must also have some ability to move in a fore-and-aft direction. This movement may be supplied by splined shafts or flexible couplings. The shafting is supported and aligned by hanger bearings along the length of the tail boom. Alignment is important to reduce vibration. At times, it may be necessary to divert the shaft if the tail rotor is mounted at the top of a tail boom pylon. In this type of situation, an intermediate gear box is used to change direction but not the speed.

6.5.1.2 Tail Rotor Gearbox

The tail rotor gearbox changes direction and increases or decreases the speed. The tail rotor, nevertheless, turns faster than the main rotor.

6.5.1.3 Tail Rotor Blades

The tail rotor blades are made of a number of different materials and designs. Many of the newer blades are composites with metal blades still common. Composite material blades will dominate the industry by 1990. The blades may be a two-bladed system or multi-bladed system.

6.5.1.4 Pitch Change Mechanism

To change the tail rotor pitch, most of the newer helicopters utilize push-pull tubes. A few use cable for the pitch change mechanism. It may also have a hydraulic boost on the control system operated from the same system used for the cyclic and collective.

6.5.1.5 Tail Rotor Maintenance

- Temperature: Impending failure of any bearing will be indicated by a rise in the temperature of the bearing package which may result in high frequency vibration.

- Driveshaft: The shafts are very sensitive to corrosion, scratches, and bends. The driveshafts are hollow and usually made of aluminum alloy. The ends of the shafts in an area of heavy stress and the coupling attachment are critical. Removal and replacement of the drive shafting requires special attention to avoid damage.

- Couplings: The couplings are indexed, stainless steel discs. Once the coupling stock is used, it should not be restocked and should be replaced.

- Alignment: The alignment of the tail rotor drive-shaft is important. When the alignment is incorrect, the vibration level increases, resulting in an increase in the wear factors, especially in the bearing areas.

- Intermediate Gearboxes: Gearboxes usually only require nominal servicing of lubricating oil. The gearboxes have recommended periods of overhaul designated by the manufacturer. Some gearboxes may be overhauled in the field, while other will require exchange or overhaul at designated repair stations.

- 90° Gearbox: Maintenance of the 90° gearbox is similar to the intermediate gearboxes in regard to servicing. The overhauls will be much the same with set time schedules for the overhaul. Some gearboxes cannot be overhauled in the field, while others may be completely disassembled and rebuilt in the field.

Rebuildable boxes requiring the change of components may require a lash and pattern check to determine the gear mesh.

- Tail Rotors: Many parts used in the tail rotor are assigned a finite life due to the stresses placed on them. Typical time change items may include yokes and blades. Bearing replacements are quite common when conventional type bearings are used. Replacement of parts of the tail rotor can be performed in the field.

- Tail Rotor Vibrations: Tail rotor vibrations are always of a high frequency type. It is difficult to determine the source of the vibration as to the pitch change, drive shaft or the tail rotor itself.

- Balancing: The shafts are balanced by the manufacturer but this is normally only a static balance. Tail rotors after overhaul will still require a static balance both spanwise and chordwise and will require dynamic balance as well. Universal balancing equipment is available for a number of tail rotors designs.

- Tail Rotor Track: Some times the balance may be solved only after the tail rotor is back in place. The track is established manually or electronically in a pre-flight test.

- Tail Rotor System Rigging: Most use a push-pull tube system for pitch control. In addition, hydraulic servos may be used. Cables are used on older, light helicopters. Some tail rotor systems are more difficult to rig than others and may require rigging pins, protractors and jigs to position the controls.

6.6 AIRFRAMES AND RELATED SYSTEMS

The airframes of helicopters cover a wide range of materials and, for the most part, the materials used in helicopter manufacture are similar to fixed wing aircraft.

6.6.1 Tubular Construction

Early helicopters used tubular fuselage construction with trusses. This type of construction has a high strength-to-weight ratio but it is very costly to manufacture. Each tube is cut, fitted and welded into place. It is also difficult to hold dimensions to a close tolerance. Tubular construction, however, has an advantage in that it can be repaired in the field unless there is severe airframe damage which requires jigging in order to hold the alignment. The Bell 47 is an example of tubular construction.

6.6.2 Sheet Metal Construction

Aluminum monocoque and semi-monocoque design sheet metal construction is a common structure for most helicopters. This construction type has a high strength-to-weight ratio and, in fact, can be higher than tube construction for the same size. Sheet metal construction has some advantages in the manufacturing process. Parts can be stamped out and compound curves made at a rapid rate. Construction in jigs also has closer tolerances than those of the tubular fuselage construction.

In the field, few additional tools are needed for repairs; however, the structure is slightly more delicate than a tubular structure. If large repairs are needed, the fuselage requires specialized jigs to obtain proper alignment for the various sections.

6.6.3 Bonded Construction

The third type of construction used in helicopter fuselages is the use of fibreglass, honeycomb and bonded structures. All of these materials and methods are of high strength-to-weight ratios. Honeycomb and bonded structures also have reduced construction costs. The bonding eliminates some of the riveting and welding. Most helicopters use a combination of various materials and methods of construction to obtain the greatest advantage of each.

6.6.4 Stress and Loads

The helicopter fuselage carries both the lift and thrust forces at the same point. The centre area of the helicopter must be built to carry and propel the vehicle from this point. The lift and thrust area have the highest load factors applied in flight because the main rotor is both the wing and propeller.

Another load factor in the fuselage is in landing. The helicopter does not require forward speed to maintain flight and, therefore, the helicopter will usually carry the load in one direction. Emergency autorotation landing stresses require appropriate construction to protect against this impact stress.

The vibration level is different from a fixed wing aircraft. The helicopter has the highest level of vibration due to the use of so many rotating components. These vibration levels are transferred throughout the entire airframe.

The tail sections of the helicopter are different from fixed wing aircraft. A side load from the tail rotor is present on the tail boom during all modes of flight. In addition to the side load, many helicopters have a horizontal stabilizer which is pushing downward in cruise flight conditions.

6.6.5 Fuselage Maintenance

Fuselage maintenance may include simple sheet metal repairs or may include major fuselage rebuilding. When major repairs are required, jigs will often be necessary because alignment is quite critical to ensure a minimum of vibration from the rotating components. These types of vibrations caused by misalignment will not only shorten the life of the components but will also be detrimental to the airframe itself with loose rivets and fatigue cracks in the structure.

Other detrimental items to the fuselage structure include hard landings. Due to the stresses placed on the components at the time of a hard landing, the airframe, tail boom, transmission, engine and landing gear may incur damage. Some of the rotating components may also be damaged such as transmission cases, gearbox cases and mast bearings.

Sudden stoppage of the main rotor will cause the force to be transmitted throughout the system, not only at the point of impact. Damage to a blade from striking an object may also cause secondary damage to the root area of the blade and rotor head. Sudden stoppage of the tail rotor can also lead to secondary damage such as twisting of the tail boom structure, and structural damage to the hanger bearing mounts and the tail boom attachment points.

6.6.6 Airframe Systems

Other systems, in addition to the basic airframe and rotating components, are incorporated into the airframe and include:

- Fuel System: The fuel system is usually made up of one or more tanks. They are usually force feed systems as opposed to a gravity feed systems used in fixed wing aircraft.

- Electrical System: Electrical systems are similar to light fixed wing aircraft. The turbine powered helicopters will utilize starter-generators and often two batteries. A nickel cadmium (Ni-Cad) battery is used almost exclusively by helicopters.

- Environmental Systems: Environmental control units (ECU) are now installed in most helicopters. These are air conditioning machines which may furnish either hot or cool air.

6.6.7 Special Purpose Equipment

Special equipment is often needed to perform some tasks. These items are available from the manufacturer as optional equipment or from companies that have items certified by a Supplemental Type Certificate (STC). Some of the more common special purpose equipment includes the following:

- Avionics and other electronic equipment
- High skid gear for ground clearance
- Floats (stationery and pop-out)
- Rescue hoists and load measuring devices
- Cargo hooks and nets
- Medivac litter installations
- Light installations/search lights
- Spray equipment and other aerial application equipment
- Stabilization devices (IFR Operations)

7.0 FUTURE HELICOPTER TECHNOLOGY

New technology use in helicopter design and manufacturing is rapidly changing the helicopter industry. These changes are already affecting helicopter methods of overhaul, servicing and parts manufacture. Standard maintenance practices for the last two decades are becoming outdated as newer helicopters are entering the market each year. Newer technology requires that helicopter maintenance capabilities include skills in composite materials, metal alloys, electronic test equipment as well as new maintenance procedures and up-to-date maintenance equipment. In the near future, helicopter technology is expected to advance rapidly. This chapter briefly outlines some of the expected technology which may be incorporated in helicopters of the 1980's and 1990's. A substantial amount of helicopter technology research is being undertaken by the U.S. Army's Aviation Research and Development Command (AVRADCOM) in St. Louis, Missouri. This agency is directing advaced helicopter research for the U.S. Army's defense requirements in cooperation with other research agencies and the manufacturers.

7.1 DIGITAL SYSTEMS INTEGRATION

Digital avionics are now being incorporated into helicopters. The next generation of helicopters will offer digital systems integration between the various avionic equipment by using multiplexing techniques. The U.S. Army Helicopter Improvement Program (AHIP) and the U.S. Coast Guard's Short Range Rescue and Recovery Aircraft (SRR) studies already has begun research and development in this technology area. Advanced avionics components and systems such as the Integrated Avionics Control System (IACS) and Digitally Integrated Avionics System (DIAS) are being tested by the military. Improvements in navigation will be achieved through integration of lightweight Doppler Navigation Systems, the NAVSTAR Global Positioning System, digitally stored maps, and positioning radar systems operating in the millimeter wave region.

Improved communications will be enhanced through multi-band radios and digital voice processing. Introduction of micron scale electronics, and output of the Very High Speed Integrated Circuit (VHSIC) program, will enhance the capability and reliability of electronic components while simultaneously reducing size, weight and cost.

The man-machine interface control will be enhanced through utilization of "by exception" controls and displays, and many on-board systems will be assessed and controlled through the crew-member's voice. Shieldings and coatings will protect aircraft systems from radio frequency interference, and wide use will be made of fibreoptic data links for high speed information transfer rates.

7.2 ADVANCED COCKPIT TECHNOLOGY

Studies are underway to determine the medium which will be used for cockpit displays including cathode ray tubes (CRT's), plasma displays and flat panel units. The kind of information that must be presented, the type of information required, and the safety issues of advanced instrumentation are also being addressed by the military and helicopter manufacturers.

One of the major advances being made in cockpit systems is the development of the Subsystem Status Monitor (SSM) System, which reduces the pilot visual and decision making work load during the monitoring of helicopter subsystems by automatically displaying only what the pilot needs to know, when he needs to know it. Another development for the cockpit is the Aircraft Performance Indicator System (APIS), which is an on-board computer that provides the pilot with detailed information such as lift margin, fuel management and cruise capability. A Voice Interactive System (VIS) is a development which will provide the pilot with the capability of "talking to the helicopter" and having it respond by either displaying the information requested, turning off and on systems, or warning him of pending problems. All these cockpit systems use new control system technologies.

In the area of cockpit control, two, three and four axes controllers reduces pilot work load and frees one hand and both feet of the pilot. The pilot now has to sit forward holding both the collective and cyclic, as well as using both rudder pedals at all times during flight.

Hughes Helicopters has a forward-looking infrared (FLIR) System for the AH-64 Apache helicopter that enables the pilot to manoeuver at night at low levels. Bell Helicopter is developing a miniature head-up-display (HUD) that will project into the pilot's night-vision goggles flight data, such as altitude, air speed and heading.

7.3 IMPROVED HANDLING QUALITIES

The spectacular advances in microprocessors, optical transmission and advanced control concepts offer many opportunities for handling qualities improvement and better aeromechanical performance. The potential for digital microprocessors to provide task automation along with one hand control, will result in a substantial reduction in pilot work load. Projected improvements made available by near term digital, optical control technologies, and new control ways such as velocity vector control, will also reduce work load significantly and provide excellent flying qualities. Pilot work load relative to current augmented helicopters could be reduced by as much as 70 percent.

Microprocessors will also be integrated to provide orthogonal control, automate systems operations and to provide enroute flight management.

The new control technologies offer the potential to improve ride qualities, in particular, vibration and gust suppression. This can have an impact on the reliability of aircraft equipment and comfort of the occupants.

Articulated rotor head helicopters already provide a smoother ride but still are rougher than high altitude fixed-wing transport aircraft. New helicopters will have gust suppression, with automatic feedback derived from body sensors or blade degrees of freedom, to improve the ride significantly.

7.4 VIBRATION SUPPRESSION

Using higher harmonic control, vibration suppression is another possibility for improving ride comfort. Model tests have been done by Hughes Helicopters but not test flights. If harmonic control works, the result will be a smoother flight and gross weight savings of one or two percent from the elimination of vibration control devices.

Bell Helicopter now isolates the entire rotor system, including transmission and mast, from the airframe using a Nodal Beam System (NBS), which is a tuned-beam suspension system. Bell is also developing a Liquid Inertial Vibration Elimination (LIVE) System. It is predicted to weigh half as much as th Nodal Beam System.

7.5 FLY-BY-WIRE

Fly-by-wire or fly-by-light technology offers the opportunity of eliminating all the weight and complexity of mechanical control systems with their mixers, coupling linkages and boost services. The optical or electronic replacement of mechanical control is largely independent of vehicle size. Weight savings will be considerable, particularly for complex helicopters which now require redundancy in mechanical controls.

The U.S. Army is now evaluating a Digital Optical Control System (ADOOCS) in a Sikorsky Black Hawk. This is a fly-by-wire system which eliminates the control rods and bell cranks now required to control the helicopter.

7.6 COMPOSITES

Extensive use of composite materials in secondary structures is apparent on all recent helicopter designs. By the beginning of 1990, all the rotor blades on U.S. Army helicopters will be made of composite materials. Several Aerospatiale helicopters and the U.S. Army's AHIP helicopters use composite main rotor hubs. The Army's Advanced Composites Airframe Program (ACAP) also will bring composite technology to primary airframe structures.

In addition to the advantages of field repairability, low manufacturing cost and inherent serviceability, the use of composite materials in primary structures affords great design flexibility and weight savings of 20 percent. Beside glass graphite, Nomex, Kevlar, and expoxy, there is a wide variety of stronger and more exotic materials including metal matrix composites which could be used in transmissions, landing gears, and other highly stressed components. Advanced manufacturing technology will automate the production of helicopter components making them more affordable. (eg. production cost reductions of 15 percent will be possible due to lower labour content.) Advanced resins are already being employed. The leading edge of the Boeing Vertol CH-47C/D fiberglass rotor blade, for example, is protected by a resin from the effects of rain, sand and spark discharge. Crashworthiness and ballistically tolerant structural concepts are another advantage of new composite materials. All the major manufacturers are now using composite materials in production of helicopters or testing the suitability of composite components.

7.7 EMPENNAGE SIZE

Empennage size reduction is another trend. As helicopters go faster, they need more tail surface for stability. The empennage in a helicopter, however, presents a problem. It gets into the main rotor downwash in transition and picks up periodic loadings from blade vortices in forward flight that add to the vibration problem. The empennage has resonant tendencies of its own that produce structural concerns, and, as in the fixed-wing aircraft, this adds to drag. Since helicopters do not need aerodynamic surfaces for control power and relatively little surface for altitude turn in cruise, the helicopter can take advantage of active control for stabilization. A reduced tail size therefore will provide a lighter, smoother, simpler, more compact helicopter that will go faster with the same amount of power. The tailless Sikorsky Advancing Blade Concept (ABC) research designs are an example of this concept.

7.8 ENGINE DEVELOPMENT

As fuel consumption becomes an increasingly important issue for all rotorcraft operations, new fuel efficient engines will be developed. The U.S. Army's 800 horsepower Advanced Technology Demonstration Engines (ATDE) have demonstrated the relation between fuel consumption and engine design. This engine may be used in the Light Helicopter Program (LHX). The

Small Turbine Engine Program (STEP) of Pratt & Whitney of Canada Ltd. is another example of a new engine design which will be available in the late 1980's. Lower engine weights and regeneration (recuperator) may also reduce fuel use. New engine technology is expected to reduce fuel consumptions by 15 percent.

Major engine improvements are being made in inlet protection, electronic fuel controls, improved bearings and seals, and advanced drive system concepts. A National Aeronautics and Space Administration (NASA) research and development transmission design now employs both gears and rolling contact surfaces to transmit torque with much reduced transmission noise. The concept is less complex than current transmissions and, therefore, could be less costly. Transmission weight reductions of 15-20 percent are predicted, along with better efficiency, lower noise, and increased time between overhauls. The use of ceramics for bearings and other selected engine components will increase with attendant life improvements.

It is probable that syn-fuel based engine fuel stocks could be used in the future. Some changes will be required to accommodate different starting characteristics and different types of impurities that are not governed by the fuel specifications now in place.

If higher speed becomes a requirement, then renewed emphasis will be placed on convertible fanshaft engine technology. Options for advanced anti-torque control elements may require changes in the transmission design approach and selection of engines. The no-tail rotor (NOTAR) technology currently being demonstrated by a Hughes Helicopters contract with the U.S. Army may be the start of innovative tail rotorless configurations with more power available for forward flight.

Better materials for engines and transmissions are a certainty. There is already high hardness steel for improved gear life, and advanced manufacturing technologies are being examined to ensure the high temperature capacity of turbine engines can be met with the life cycle fatigue strength needed. Increasing use of ceramic coatings for temperature barrier protection and control of engine clearance should provide significant increases in the overall efficiency of engines.

7.9 ROTOR SYSTEM DESIGN

Rotor system design already employs tip-shaping, advanced airfoils, and higher rates of twist on the main rotor sections of all recently developed and/or modernized helicopters. The concept of a completely bearingless main rotor has been tested to show the attendant reduction in maintenance and component cost. Bell Helicopter has experimented with a bearingless hub-absorber using a centrifugal mercury pendulum absorber on a Bell 206L and Bell 412. The response of higher harmonic control inputs to the rotor system are now being tested. Model tests have also shown that appropriate multicyclic pulsing of the rotor can attentuate undesirable vibration characteristics. Other concepts being examined include aeroelastic conformability which would permit the rotor to respond to control inputs or gusts in such a manner as to always seek an optimum loading distribution, thereby maximizing performance throughout the flight envelope.

A test program between the U.S. Army's Aeromechanical Laboratory and the French Office National D'Etudes Et De Recherches Aerospatiales (ONERA) have provided insight into the mechanisms which generate rotor noise and advances are expected in understanding these factors to result in reduced noise.

In the case of higher speed capability, the performance of both the Sikorsky Advancing Blade Concept (ABC) and the Bell XV-15 Tilt Rotor have shown that a combination of low speed and agility, as well as high speed cruise capability, are possible. Cruising speeds are predicted to increase by about 15 percent in the next generation of helicopters.

7.10 MAINTENANCE

One of the largest impacts of the new technologies may be the cost effectiveness payoff in the maintenance area. It is predicted that, within a decade, control systems will be essentially self rigged, or perhaps rigged by a cassette tape that accommodates and fine tunes the helicopter rigging to a specific mission requirement. In addition, the extension of built-in microelectronic diagnostics and systems monitoring (already in digital automatic flight control systems) to full control systems, offers very large possible maintenance cost savings.

8.0 HELICOPTER MAINTENANCE RELIABILITY

There is a sparcity of information regarding the reliability of civil helicopters. Helicopter and engine manufacturers do not regularly release data on the subject. The FAA's or Transport Canada's helicopter malfunction or defect (M or D) reporting systems do not have the detailed data needed for an analysis of maintenance problems. In recent years, helicopter operators have organized the collection and dissemination of information on helicopter maintenance issues. British Airways, for example, disseminates maintenance information on its Sikorsky S-61 and S-76 fleet to other operators. It is anticipated, as the information is assembled and a statistical data base determined, the operators will be able to address common maintenance problems in conjunction with the manufacturer. The military, on the other hand, do have a substantial repository on helicopter maintenance and reliability. This data base stems primarily from the Vietnam war where combat conditions dictated high maintenance reliability of military helicopters. Government agencies such as the Defense Advanced Research Projects Agency (DARPA), U.S. Army Aviation Research and Development Command (AVRADCOM) and the National Aeronautics and Space Administration (NASA) continually monitor helicopter reliability under the reliability, availability and maintainability (RAM) program to evaluate Maintenance Man Hours per Flight Hour (MMH/FH). These agencies work closely with the helicopter manufacturers using defense research contracts to develop new techniques to improve the RAM capability of military helicopters. NASA, on occasion, has examined civil helicopter maintenance reliability and has compared civil and military maintenance reliability.

The following outlines the main maintenance problems of civil and military helicopters based on the research of these U.S. government agencies.

8.1 MAINTENANCE COSTS

The maintenance costs associated with operating helicopters is significantly more expensive than comparable fixed-wing aircraft. The hourly maintenance costs, including maintenance burden for the Sikorsky S-76 is about $270 per block hour as compared to about $126 per block hour for the Beechcraft King Air. A cost figure of two to three times to comparable fixed-wing maintenance costs is normal for most helicopters.

Direct maintenance costs for component part repair/overhaul maintenance constitute 35.5 percent of the total cost, followed by service labour for refueling, washing and handling the helicopter at 23.6 percent of the total cost. When examining maintenance labour, fuel, wash and ground handling, take about 47.2 percent of the total maintenance man hours followed by inspections (20.8%) and on-aircraft fix repairs (20.3%). The following table shows the direct maintenance costs and direct maintenance man hours by cost component.

Direct Maintenance Costs		Direct Maintenance Man Hours	
Part Repair/Overhaul	35.5%	Fuel, Wash, Ground Handle	47.2%
Fuel,Wash, Ground Handle	23.5%	Inspections	20.8%
Aircraft Fix	15.3%	On-Aircraft Fix	20.3%
Inspections	10.4%	Replacement Action	7.8%
Time Between Overhaul	9.4%	No Defect	3.9%
Erroneous Removal	5.1%	Erroneous Removal	0.9%
No Defect	0.7%	Remove/Install	0.6%
	100.0%		100.0%

Source: Million, Daniel J., K. T. Research, Requirements to Reduce Maintenance Cost of Civil Helicopters, NASA, Feb., 1978

Unscheduled maintenance costs form a significant portion of maintenance costs (i.e., averages about 20 percent of total maintenance).

Civil helicopter operators indicate the following ranking of unscheduled maintenance man hours and cost problems.

Table 8.1

RELATIVE HELICOPTER MAINTENANCE REQUIREMENTS AND COSTS

RANK	RELATIVE MAN-HOUR REQUIREMENTS	RANK	RELATIVE REPAIR PARTS COSTS
1	Transmission bearing spall	1	Compressor failures
2	Airframe cracks	2	Transmission bearing spall
3	Fuel control	3	Turbine failures
4	Compressor failures	4	Transmission housing crack
5	Transmission housing cracks	5	Tension-torsion assembly failures
6	Tension-torsion assembly failures	6	Blade cracks & corrosion
7	Float leaks	7	Fuel governor
8	Fuel governors	8	Gearscuffing & spalling
9	Gear scuffing & spalling	9	Hub bearing failure
10	Actuator/servo leaks	10	Main rotor mast retainer nut
11	Hub bearing failure	11	Hub/swashplate crack
12	Tail rotor gearbox mount cracks	12	Tail rotor grip bearing
13	Hub/swashplate support cracks	13	Tail rotor transmission mount
14	Main rotor mast bearing retainer nut	14	Swashplate bearing failure
15	Turbine failure		
16	Blade corrosion & cracks		
17	Tail rotor grip bearing		
18	Main rotor mast corrosion		
19	Hanger bearing failure		
20	Swashplate bearing failure		

Source: Ibid, NASA.

8.2 ELEMENTS IMPACTING HELICOPTER MAINTENANCE

The magnitude of maintenance varies with size of the helicopter and/or operational environment, but the distribution of maintenance and support by helicopter type remains relatively constant. A distribution of aircraft maintenance and support for light, medium and heavy U.S. Navy helicopters is shown in Table 8.2. Preventative maintenance includes aircraft inspections and replacement of TBO components. Support actions relate to aircraft handling, servicing, and general activities associated with aircraft maintenance. The magnitude of support actions is primarily dependent on operator activity and does not relate to helicopter design. It should be noted that the U.S. Navy example shown below indicates relatively high maintenance man-hours per flight hour in comparison to civil operations but the maintenance distribution is similar to civil operations.

Table 8.2
DISTRIBUTION OF OPERATION MAINTENANCE MAN HOURS

	MEDIUM TRANSPORT Boeing Vertol Sea Knight (CH-46F)		LIGHT ASW Kaman Seasprite (SH-2F)		MEDIUM ASW Sikorsky Sea King (SH-3G)		HEAVY TRANSPORT Sikorsky Sea Stallion (CH-53D)	
	MMH/FH	%	MMH/FH	%	MMH/FH	%	MMH/FH	%
Preventative	4.1	27.0	5.3	29.1	5.4	28.9	6.6	27.8
Corrective	4.7	30.9	6.0	33.0	6.7	35.8	7.5	31.6
Support	6.4	42.1	6.9	37.9	6.6	35.3	9.6	40.6
TOTAL	**15.2**	**100.0**	**18.2**	**100.0**	**18.7**	**100.0**	**23.7**	**100.0**

* ASW - Anti-Submarine Warfare
Source: U.S. Navy 3-M Aviation Utilization and Readiness Reports.

An operator survey undertaken by the University of Virginia indicated that unscheduled maintenance averages about 20% of total maintenance. The causes of unscheduled maintenance are as follows:

Vibration	31.0%	
Vehicle Design	29.4%	
Operational Environment	23.4%	
Engine Failure	11.8%	Mean unscheduled maintenance is 18.6% of total maintenance.
Avionics	2.4%	
Hard Landings	2.0%	
	100.0%	

The same operator survey noted scheduled maintenance by major helicopter subsystem.

Engine	27.3%	
Drive System	18.6%	
Airframe	18.3%	Mean scheduled maintenance is 78.0% of total maintenance.
Rotor	13.7%	
Avionics	9.1%	
Other	13.0%	
	100.0%	

8.3 FACTORS IMPACTING MAINTENANCE COSTS

The most cost-significant maintenance actions are replacement of repairables and preventative maintenance (inspections). This is due to the high material costs associated with repairables, including their attrition, and the relatively high frequency of preventative maintenance.

Associated with both these costs and probably the most significant, is unnecessary maintenance which represents wasted dollars. Erroneous removals and repairs, as well as unnecessary inspections, are in the same category. Controllable factors contributing to maintenance costs are the following:

- Vibration
- Scheduled time between overhauls (TBO's)
- Foreign-object damage (FOD)
- Inspection policy
- Diagnostics
- Technical publications and training

8.3.1 Vibration

Vibration impact on maintenance is usually a causal factor. Assessments of subsystem failure rates and the resulting maintenance man hour impacts indicates that incorporation of vibration absorbers can be equated to reduced maintenance expenditures of varying magnitude. It is particularly noted in the airframe, drive and flight control subsystems. The susceptibility to vibration and subsequent failure varies widely with types of components. A vibration failure usually is noted as a functional or visible defect that is readily apparent and is fixed and the item returned to service. However, in many cases, the vibration that caused the first failure also weakens other components and interface connections. When the mean time to failure after repair is much shorter than the mean time to first failure of a component, then the cost-effectiveness of the repair action is diminished.

Vibration measuring equipment is widely available, and more effective use of such equipment would permit rapid isolation of troublesome components.

8.3.2 Scheduled Time Between Overhauls (TBO's)

A large contributor to helicopter operating costs is the policy of scheduled removal and overhaul of components. The concept of a TBO interval requires that the component be removed from service at a predetermined time. It is based on the premise that undesired events can be precluded if a time-phased removal is imposed. The TBO intervals were increased on components until some intuitively acceptable balance was struck between the frequency of unscheduled removals encountered and the TBO duration itself. Based on the industry's increased evaluation knowledge to predict, measure and demonstrate failure rates, the TBO intervals are becoming realistic. Many specifications are now calling for an on-condition (OC) removal criterion for components which formerly had TBO intervals. Engines and transmissions for some new helicopter programs are now included in this OC category. A decision to implement an on-condition maintenance need is based on consideration of cost, mission effectiveness, and safety. When compared with operating with a TBO, on-condition is less expensive. The objective is to reduce costs by elimination of the TBO without endangering the mission or increasing the hazard rate of safety risks.

8.3.3 Foreign-Object Damage (FOD)

FOD is a major concern to maintenance cost. The highest off-aircraft maintenance cost is engine repair and overhaul. U.S. military data indicate that 12 percent of power plant replacements were caused by FOD. Maintenance procedures were the common sources of FOD on turbine engines. The following shows the most common source of FOD on military helicopters:

Maintenance Procedures		
Hardware (tools, lockpins, etc.)	24%	
Rags, clothing, etc.	19	
	43%	
Operational Environment		
Ground debris	14%	
Ordinance	10	
Birds	9	
	33%	
Aircraft Design		
Miscellaneous components	17%	
Inlet components	7	
	24%	
		100%

8.3.4 Inspection

As in the case of TBO's, many inspection requirements were based on a premise that undesired events could be precluded if a time-phased inspection philosophy was imposed. The cost of routine inspections is about 10 percent of the direct maintenance cost. Continued development of diagnostic and prognostic techniques should assist to develop reliable failure warning levels and thereby reduce inspection time and costs.

8.3.5 Diagnostics and Erroneous Maintenance

Unnecessary maintenance such as erroneous removals, no defect, and remove and install actions account for between 12-15 percent of the direct maintenance costs. In addition to wasting time and contributing to helicopter unavailability, it induces other maintenance through removal, installation, and handling errors. These erroneous maintenance actions can also be related to improper diagnostics, as well as lengthy and/or repetitive maintenance.

8.3.6 Technical Publications and Training

The best design, supported by the most effective support system, is not effective without an adequate man-machine interface. This interface is affected by the training the helicopter mechanic receives, coupled with technical publications. Civil operators do not have the training facilities of the military and must rely on individuals to possess basic skills and licenses prior to being hired, and on helicopter manufacturers to include special training as a part of new helicopter purchases. The training quality of a manufacturer, however, is usually related to the sales revenue of the manufacturer. Technical publications are again the responsibility of the manufacturer and the quality of technical manuals can be poor, leading to higher costs of maintenance due to errors made in maintenance procedures.

8.4 TECHNOLOGICAL DEFICIENCIES

In this subsection, the technological deficiencies which contribute to the high costs of helicopter maintenance are discussed.

8.4.1 Compressor Failures

Turbine engine compressor failures are the number one reliability problem, from a cost standpoint, considering the failure rate, man hours and parts cost. A study of engine compressor failures by the U.S. Army noted the following as the major compressor failures: corrosion/erosion-induced vane failures, blade/disk fatigue failures, diffuser cracking and leaking, compressor lining wear and cracking, and variable stator and bleed air problems. It is projected that normal reliability growth will reduce unscheduled engine removals due to compressor problems by about 20 percent within the next decade.

8.4.2 Fuel Control Problems

The fuel control portion of the free turboshaft turbine engine fuel system provides the fuel management during engine starting and, up to the flight range of the power turbine, approximately 85 to 100 percent of the normal flight RPM. Common malfunctions of the fuel control system are improper starting and fluctuations of speed in the lower ranges. The following failure modes of fuel control units are commonly noted: contamination from actuating media or from fuel itself; leaking of valves and clogged orifices; wear found on contacting elements; springs, bellows and retention devices problems due to misadjustment; and erroneous troubleshooting. Erroneous removal problems occur in as many as 65 percent of the military helicopter fuel controls removed in the field and which showed no defect when tested in the shop. Normal reliability growth projections indicate an 8 percent reduction in the unscheduled engine removal rate due to fuel problems over the next decade.

8.4.3 Tension-Torsion Assembly Failures

The tension-torsion assembly strap retains the blade against centrifugal forces while permitting the torsional movements required for blade control. Catastrophic blade loss has resulted from wirepack tension-torsion assembly failures in current turbine helicopters (e.g., a recent Bell 212 accident in the Middle East reduced the TBO on the strap on this helicopter and similar models to 1200 hours and frequent inspections). As the function of the strap assembly is critical to safe operation and as strap deterioration cannot be readily observed, the straps are replaced when any deterioration is found at overhaul time, regardless of how serious.

Two forms of deterioration of the strap have been observed, first, the polyurethane cover deteriorates from hydraulic, oil, or other field contamination, and second, broken wires protrude through the cover causing further deterioration. Although the strap consists of multiple wire windings, the assembly shows little sign of redundancy and acts as a single load path for blade retention.

8.4.4 Transmission Bearing Spalling

Spalling (or flaking) of a bearing is the result of fatigue failure of the contacting surfaces. If the bearing is properly made, mounted and lubricated, and if the loads are not excessive, bearing spalling should occur only infrequently. Common problems are the following.

- Unanticipated loads, in excess of the design load spectrum;
- Lack of cleanliness of the bearing materials (inclusions or flaws act as origins for incipient failure);
- Misalignment or other assembly conditions such as to cause an unanticipated distribution of load;
- Improper surface finish of the ball, roller, or raceway paths such that lubrication breakdown occurs;
- Contamination of the lubricant.

Bearing spalls are the cause of 19 percent of all military helicopter transmission unscheduled removals. Only one civil helicopter model is noted as having a serious problem of spalling of the upper shaft support bearing, and the problem appears to be one of design execution. The reason for the high military failure rate may be due to standard lubricant specifications used by the military and use of these lubricants may be inappropriate for specific helicopters and specific missions.

8.4.5 Turbine Failures

A study of U.S. Army turbine engines to determine repair and maintenance factors noted the following as major turbine failure modes: and nozzle bond cracking, nozzle support structure wear/cracking, nozzle erosion, burning and sulfidation. Blade/wheel cracking is noted as an infrequent failure mode. The problems, in turn, are caused by thermal stresses, thermal weakening and the abrasive effects of the hot gases. The inevitable use of higher turbine pressure ratios and operating temperatures, and the trend to increase power-to-weight ratios, have contributed to the problem areas.

The use of cast nozzles and slotted inner/outer nozzle bonds, along with the development and application of improved materials, directional solified alloys and improved coatings to resist sulfidation, helps to reduce the magnitude of turbine failure problems. It is expected that normal reliability growth will permit a 19 percent reduction in the unscheduled engine removal rate due to turbine problems. About half of the reduction could be achievable with existing technology; the other half will be developed within the decade.

8.4.6 Metal Blade Cracking and Corrosion

The problems of metal blades have been documented in earlier sections, and the advent of composite blade technology may eliminate the problems associated with metal blades within a decade.

The metal blade consists of an aluminum extruded spar with an aluminum sheet metal forming bonded to the trailing edge. Common failure modes are cracking (predominantly in the bond areas) and corrosion. It is difficult to repair the metal blade and, therefore, a large number of damaged blades are scrapped. The blade is also susceptible to FOD. Repair of dents makes the blade susceptible to further cracking of the dented area, resulting in subsequent scrapping.

The fibreglass composite blade is much less susceptible to bonding cracks, denting, FOD or corrosion. Repair is simple and inexpensive, resulting in low life-cycle costs. A Boeing Vertol study of the U.S. Navy's H-46 modification program using fibreglass blades indicates a potential blade operating cost reduction in the order of 83 percent over metal blades. MBB similarly calculates that the composite rotor system experience of the BO-105 has a fatigue life of 22,000 hours for that blade. This compares to 4,800 hours for a metal blade on the Bell 206.

9.0 HELICOPTER MAINTENANCE FACILITIES

This chapter discusses the helicopter repair and overhaul maintenance facilities and services which are available in British Columbia. An outline of those British Columbia companies which provide spare parts and those which have the capability to manufacture original equipment parts or components is included. It also examines those facilities and services in the two market areas which compete with British Columbia companies for the helicopter repair and overall maintenance market. Competing spare parts organizations and original equipment manufacturers are also included.

9.1 BRITISH COLUMBIA REPAIR AND OVERHAUL FACILITIES AND SERVICE

There are a number of firms in British Columbia which provide repair and overhaul services. Some specialize in complete overhauls of helicopters, others only handle certain helicopter jobs. Many firms are also helicopter operators who have built up in-house repair and overhaul expertise and contract to other operators, while still others are independent repair stations with no helicopter operations. There are also firms which have the capability to sell and service spare parts and even to manufacture original equipment, as well as to do repair and overhaul. Other companies specialize only in spare parts or in being a component or spares manufacturer. The following discusses those organizations in British Columbia which offer helicopter-related maintenance services.

9.1.1 Okanagan Helicopters Ltd. - Richmond, B.C.

This is the third largest operator of helicopters in the world after Petroleum Helicopters Inc., New Orleans, Louisiana (392 helicopters) and Bristow Helicopters Ltd., Redhill, Surrey (159 helicopters). Okanagan has some 140 helicopters and its subsidiary companies; Associated Helicopters Ltd. of Edmonton and Universal Helicopters (NFLD) Ltd. of Gander have 21 and 15 helicopters respectively. It and its subsidiary companies has about 20 percent of the total Canadian market in terms of the number of hours flown by its fleet. Okanagan is active in international off-shore petroleum exploration support activities, particularly in Southeast Asia.

Okanagan is controlled by the Resource Service Group of Calgary who acquired full control of the company early in 1982. Recently, the Resource Service Group attempted to sell 49 percent of Okanagan to Bristow Helicopter Ltd. of England for about $21 million. The Canadian Transport Commission, in its Decision 7791, denied the transfer of shares.

Okanagan employs some 550 persons of which some 172 are maintenance engineers. Sixty-six are licenced AME engineers. The company operates two helicopter maintenance facilities in Richmond; one located at Vancouver International Airport for general service maintenance, and the other located in an industrial park on Viking Way which is used for component repair and overhaul. The Viking Way facility was originally developed to meet the repair and maintenance demands of the rapidly growing Okanagan helicopter fleet in the late seventies, but the recent economic recession has prompted Okanagan to actively seek third party contracts from other helicopter operators to more effectively utilize the available facilities and services. Okanagan is capable of offering nearly a complete helicopter repair and overhaul service, including a large number of associated components and accessories.

As can be noted in Table 9.1, Okanagan provides a wide variety of repair and overhaul expertise; in particular for Bell Helicopter Textron products (Bell 206) and the Sikorsky S-61. Okanagan is an approved Bell service centre.

It should be noted in the case of turbine engine repairs, Okanagan is certified to conduct component repair and overhaul support for the Allison 250 series and the General Electric CT-58. Eleven of its maintenance personnel are in the engine shop. It has currently the expertise to conduct the following work for the Allison 250 series:

	Series C 20/C 20 B	Series C 28/C 30
Compressor Overhaul	x	x
Turbine - Midpoint Overhaul	x	
Turbine - Major Overhaul	x	x
Gearbox - Major Inspection and Rebuild	x	x

Currently, Okanagan does not offer major turbine parts repair nor special processes such as plasma, plating or coatings but Okanagan is reportedly interested in expanding its capabilities to conduct major repairs for the Allison 250 engine.

Table 9.1
OKANAGAN ENGINEERING SUPPORT DIVISION CAPABILITY

	HUGHES 500	BELL 206	BELL 205	BELL 212	BELL 214	AS 350	AS 332	SIK-ORSKY S-76	SIK-ORSKY S-61
Accessory Shop:									
Hydraulic Services		x	x	x					x
Starters/Genrators		x	x	x		x			x
Class III Repairs		x	x	x				x	x
Battery Maintenance		x	x	x	x	x	x	x	x
Fans/Blowers		x	x	x					x
Small Electro-Mechanical		x							
Component Shop									
NDT Inspection		x	x	x	x	x	x	x	x
Dynamic Component Repairs			x	x	x	x			x
Dynamic Component Overhauls			x	x	x	x			x
Dynamic Component Inspections			x	x	x	x			x
Engine Shop									
Component Repairs		x	x					x	x
Component Overhauls		x	x					x	x
Component Inspections		x	x					x	x
Accessory Repair/ Overhaul (Limited)		x	x					x	x
Class III Repairs		x	x					x	x
Balancing		x	x					x	x
Sheetmetal Shop:									
Airframe Repairs			x	x	x	x	x	x	x
Special Installations			x	x	x	x	x	x	x
Attachable Component Repairs			x	x	x	x	x	x	x
Landing Gear Repairs			x	x	x	x			

Table 9.1 (Continued)

OKANAGAN ENGINEERING SUPPORT DIVISION CAPABILITY

	HUGHES 500	BELL 206	BELL 205	BELL 212	BELL 214	AS 350	AS 332	SIK-ORSKY S-76	SIK-ORSKY S-61
Avionics Shop:									
Airframe System Repairs (Electrical)		X	X	X	X	X	X	X	X
Airframe Rewiring		X							X
Special Installations			X	X	X	X	X	X	X
Black Box Repairs		X							
Hangar									
Flight Line Maintenance		X	X	X	X	X	X	X	X
Component Changes		X	X	X	X	X	X	X	X
Scheduled Inspections		X	X	X	X	X	X	X	X
Structural Repairs/ Rebuilds		X	X	X					X
Interior Refurbishing	X	X	X					X	
Special Installations	X	X	X	X	X	X	X	X	
Modifications/ Upgrades		X	X	X	X	X	X	X	X

Source: Okanagan Helicopters

It would need an engine test cell and other equipment and skills for this type of work. Okanagan can lease engine components while customers use Okanagan's facilities for re-certification of their units. It can also supply Allison 250 - 20/C 20B compressors, turbines and gearboxes. It is reported that Okanagan has reached an agreement to represent Standard Aero for Allison 250 overhauls in Southern British Columbia.

In the case of General Electric CT 58 engine support, Okanagan has upgraded their facilities to full overhaul capability. This upgrading includes the following facilities:

- Schenk RSN Dynamic Balancing Unit
- Mobile Engine Test Cell
- Complete NDT Facilities
- Hot Chemical/Vapour Cleaning Line

Okanagan has Transport Canada approval of 'D' Licence status for its engine shop which allows development of support programs for other General Electric CT-58 operators. This has allowed Okanagan to increase the mid-point inspection from 1500 hours to 2000 hours and the 3000 hour TBO overhaul to 4000 hours.

The avionics shop is also authorized by Transport Canada for major installations of airframe avionics systems. There are 12 employees in the avionics shop. The avionics shop has capabilities in the field of NAV/COM, H/F, VHF-FM, ADF and radar (Bendix 1200, 1400 series). Currently, they are considering inclusion of the VLF Omega and Loran C navigation systems into their avionics capability.

Since Okanagan has a large in-house capability for repair and overhaul, it is noteworthy to examine those components which are sent to others for repair and overhaul. It should be recognized that the use of outside accessory and overhaul depends on Okanagan's own expertise, in-house shop utilization, quality of outside repairs and overhaul and, of course, the cost to Okanagan.

A. Biederman Inc., Glendale, California
Vertical Gyro AFCS (Automatic Flight Control System)

Aero Instruments and Avionics - North Tonawanda, N.Y.
Fuel Pressure/Transmitter
Transmitter/Oil Pressure
Gyro/Rate
Gyro Synchronizer
Gyro/3 Axis
Transmitter/Press.Trans. Hyd.Oil
Indicator/Altitude
Indicator/Altimeter
Transmitter/Press.Engine Torque
Transmitter/Press. Engine Oil
Transmitter/Oil Pressure

Aviatron Inc., Montreal, P.Q.
Engine/Tach Generator
RPM Sensor
Tach. Generator/Rotor Trans.
Motor Generator
Fuel Pressure/Oil Switch
Power Supply/Anti Collision Light
Pump Heater Fuel
Blower, HT/VT System

Bendix Aviation Electric, Montreal, P.Q
Indicator/Horizon Situator
Indicator/Altitude-IFR
Gyro/Roll and Pitch
Indicator/Turbine Outlet Temp.
Fuel Control Unit/Manual
Out Fuel Control
Gyro/Vertical Standby
Hydraulic Transmitter
Gyro/Twin

Evergreen Air Centre, Inc., Marana, Arizona
Filter Assay/AF Fuel

Flight Accessory Services, Sun Valley, California
Damper Assembly
Pump/Hydraulic

L.J. Walch Company, Inc., Oakland, California
Activator/Liner
Control/Dimmer
A/C Generator
Volt Reg.
Relay
Reverse Curent Relay

Lori (NORDHAM), Tulsa, Okalahoma
Engine Oil Cooler

Pacific Aero Products Inc., Burbank, Calif.
Starter

Pacific Avionics and Instruments Ltd., Richmond, B.C.
Gyro/Directional

Precision Aero Instrument Ltd., Richmond, B.C.
Fuel Pump Boost
Activator/Anti-Icing
Indicator/Gas Producer
Ignition Unit
Blower Assy/Heater Vent
Ignition Unit

Rotor Blades Inc., Stockton, Calif.
Main Rotor Blade

Simmonds Precision Product Support, Miami, Florida
Activator

Spar Aerospace Limited, Toronto, Ontario
Barfield Tester ST.

Standard Aero Limited, Winnipeg, Manitoba
Bleed Assembly
Combustion Liner
Case-Compressor
Valve Assembly
Turbine Assy
CECO Govenor and Fuel Central Unit
Bendix Fuel Control
SUNSTRANDS Fuel Pump

Aviall, Dallas, Texas
Bendix Fuel Controls
Govenor
Engine Instruments

Hamilton Standard, Windsor Locks, Connecticut
GE CT58 Fuel Controls

General Electric, Lynn, Maine
CT58 Fuel Pumps
Flow Divider

Aviation Electric Ltd. (Bendix), Montreal, P.Q.
Starter Generator

Sari Instrument Ltd. (SIL), Richmond, B.C.
Various Instruments and Electrical

Composite Technology Canada Ltd., Winnipeg, Manitoba
Main Rotor Blades

Innotech, Richmond, B.C.
Avionics and Radar

Pratt and Whitney Canada Ltd., Montreal, P.Q.
PT6-T3B Turbine Engine Overhauls

Lord Precision Machining, Erie, Pennsylvania
Torsion Straps

9.1.2 Helicopter Welders of Canada Ltd. - Richmond, B.C.

This firm was established some twenty years ago by its owner Croft Wilkinson and has since established an international reputation for quality helicopter airframe repairs. The firm now employs 17 people in its 27,000 square foot building. The firm's capabilities include helicopter airframe repair and overhauls, conversions and modifications for nearly every helicopter model. In addition, it manufactures repair jigs (a 205/212 jig was delivered to the Phillipine Air Force recently), handles honeycomb and bonded metal repairs and does precision machining. It has, in particular, developed major airframe repair expertise for the Hiller UH-12E, Bell 47, Bell 205, Bell 206, Bell

212, Aerospatiale 315 Lama, 318 Alouette, 341 Gazelle, 350 AStar, and 355 Twin Star helicopters. In 1981, the firm did $1.7 million of helicopter airframe repairs and overhauls, of which 65 percent was from United States customers. The firm is considering developing expertise in composite materials and has established a corporate link with Composite Technology (Canada) Ltd., a composite rotor blade firm located in Winnipeg. The firm also does exhaust systems and engine mounts for fixed wing aircraft. Apparently, Helicopter Welders did make exhaust stacks for Bell 212's at one time as original equipment parts.

9.1.3 Meridian Heliflight Inc. - Prince George, B.C.

This firm is one of the 120 approved Bell service centres in North and South America. The firm employs about 15 persons.

The company has expertise in general maintenance, component overhaul and helicopter modification services for the Bell 205, Bell 206 and Bell 212/412. It is also an Aerospatiale service centre. Meridian is authorized to conduct engine repairs on the Bell 206. It is one of the 77 authorized Aviall agencies in North and South America to conduct engine component teardowns and rebuilds for the Allison 250 engine series. Aviall provides the necessary expertise and parts at a discount to its authorized agencies. Meridian, as an Aviall agent can arrange for complete engine repair and overhaul at an Aviall Regional turbine shop (e.g., Evergreen at McMinnville, Oregon, is the closest) or at one of the main Aviall centres (Dallas, Texas, Burbank, California or Frederick, Oklahoma). It is also part of a turbine engine exchange program for the Allison 250. Meridian is also a service centre for the Lycoming LTS 101 engine used in the AStar. It was recently reported that Meridian Heliflight has reased an agreement to represent Standard Aero inplace of Aviall for Allison 250 overhauls in Northern British Columbia.

Meridian Heliflight also has facilities for helicopter painting, avionic repairs, some instrument repairs and nickel cadmium (Ni-Cad) battery maintenance.

9.1.4 E.M. Heli-Logistics Ltd. - Langley, B.C.

The company has specialized in Hughes 500 series repair and overhaul at its hangar facilities at Langley Airport. It is an authorized Hughes Helicopter service centre and can undertake airframe rebuilds of the Hughes 500 and overhaul of component parts, and distributes Hughes Helicopter parts. In terms of airframe rebuilds, it has the facilities for the fuselage and tail boom and the necessary alignment tools. Component overhauls include: transmission, gearbox, main rotor assembly, tail rotor, etc.

Recently, E.M. Heli-Logistics has started also to overhaul Sikorsky S-55 and S-58 models. It is anticipated that one Sikorsky a month will be repaired and overhauled. In order to have the necessary facilities, the company will double its size by moving into adjacent space and constructing a new hangar.

9.1.5 Deltaire Industries Ltd. - Richmond, B.C.

This was, up to very recently, one of the largest repair and overhaul companies specializing in helicopters in Western Canada. The company, however, went into receivership due to the decreased volume of repair and overhaul business in the economic slow-down. It is reported that Delta Rotorcraft Ltd. has purchased the assets from the Receiver and plans to resume helicopter maintenance operations in the near future. Delta Rotorcraft has the same ownership as Quasar Helicopters Ltd.

When Deltaire Industries was in operation, it provided complete rotory maintenance, overhaul and service. It was authorized for component overhaul (including dynamic component overhaul), modifications and general service for the following helicopter models.

Bell	205, 206, 212, 412
Aerospatiale	SA 315, SA 316, SA 318, SA 319, SA 341
Hiller	12E, 12T, FH 1100
Sikorsky	S-55, S-55T, S-58, S-58T

In addition, Deltaire Industries performed painting on helicopters up to S-61 size, nondestructive testing (NDT), and tungston inert welding (TIG). It also offered a complete avionics repair and modification shop for custom avionic installations and transmission test standards for all helicopter types except Hiller products.

It also conducted some limited engine maintenance such as engine module replacement for the Allison 250 series.

9.1.6 Western Heli-Craft Ltd. - Delta, B.C.

The firm specializes in rebuilds of the Bell 206 Jet Ranger, Aerospatiale AS 350 AStar, and Hughes 500. It is an authorized Bell service centre for the Bell 206 for spare parts, general maintenance, component overall and helicopter modifications. Western Heli-Craft also has a paint shop.

9.1.7 Highland Helicopters Ltd. - Richmond, B.C.

This company operates 38 Bell 206's and a Bell 212 located at bases throughout British Columbia and Western Alberta. Highland which has the same owner as Executive Aircraft Ltd., a large Shell Aero Centre and aircraft servicing base at Vancouver International Airport and Canada Learjet Ltd., an executive jet charter company operating from the same facilities, provides some helicopter overhaul and maintenance to other helicopter operators at its Vancouver International Airport headquarters. It is a Bell Helicopter service centre for the Bell 206 and is authorized for spare parts sales, general maintenance, component overhaul and helicopter modification. All components of the Bell 206 can be overhauled except for the Allison 250 engine.

9.1.8 Falcon Helicopter Maintenance Ltd. - Delta, B.C.

This firm is owned by a former Okanagan maintenance employee. It provides maintenance and overhaul for the Bell models 204, 205, 206, 212 and 214, as well as the Sikorsky S-58. The company is not listed as an authorized Bell Helicopter service centre. It also has some capabilities with Sikorsky transmissions.

9.1.9 Frontier Helicopters Ltd. - Abbotsford, B.C.

This company is a charter helicopter firm which operates five Bell 205's, five Bell 206's, one Bell 206L and two Aerospatiale AS 350 AStars. It is a subsidiary company of Conair Ltd., a large aerial tanker forest fire suppression firm. Frontier Helicopter does maintenance for other helicopter operators. It has 16 maintenance personnel, of which 14 have AME licenses. It is authorized by Bell Helicopter to conduct component overhauls, general maintenance and spare parts sales for the Bell 206 and Bell 47.

9.1.10 H.J. Aero Copters Maintenance Ltd. - Delta, B.C.

H.J. Aero Copters leases three Bell 206's and does some limited maintenance and overhaul for helicopter operators. The firm has two AME's and an apprentice on staff. It is not an authorized Bell Helicopter service centre.

9.1.11 Quasar Helicopters Ltd. - Abbotsford, B.C.

Quasar is a large helicopter charter firm which has bases in the Northwest Territories as well as British Columbia and Alberta. It operates the following fleet:

Bell	two 205's, sixteen 206's, four 206L's, two 212's, two 214's, two Bell 47's
Hughes	six Hughes 500

The company does conduct maintenance for other helicopter firms and has 21 licensed AME's and 5 apprentices on staff. It is both an authorized Hughes and Bell Helicopter service centre.

Bell has authorized Quasar to perform component overhaul, avionics repair and modifications, as well as general maintenance and spare parts sales, for the Bell 205, Bell 206, Bell 212/412 and the Bell 214.

9.1.12 North Delta Copters Ltd. - Delta, B.C.

The company provides helicopter maintenance and overhaul primarily for the Hiller UH 12E and FH 1100 helicopters. It can provide airframe rebuilding for these Hiller models as well as the Bell 47. It also stocks spare parts for Hiller and is a distributor for Perkins Plastics Inc. (windows). The firm also has capabilities in sheet metal repairs and helicopter welding.

9.1.13 Transwest Helicopters (1965) Ltd. - Port Coquitlam, B.C.

The helicopter charterer has 10 helicopters including five Hughes 500's; three Bell 47's, a Bell 206 and an Enstrom 28C. It operates a Bella Coola base in addition to its Vancouver area headquarters. Its maintenance staff consists of two licensed AME's and one apprentice. It is an authorized Hughes Helicopter service centre for spare parts, component overhaul and general maintenance.

9.1.14 Rototech Helicopters Ltd. - Surrey, B.C.

The helicopter charter company operates four Bell 206's and four Hughes 500's from its main Delta Air Park base and also from Chetwynd. It has six AMEs and two Apprentices on staff to undertake limited helicopter maintenance for other helicopter operators.

9.1.15 Pacific Helicopters Ltd. - Delta, B.C.

This helicopter charter firm operates two Bell 212's, two Bell 206's, a Bell 206L and three Hughes 500's. It provides maintenance inspections on Bell and Hughes helicopters.

9.1.16 Vancouver Island Helicopters - Sidney, B.C.

The company has it base of operations at Victoria International Airport and has charter bases on Vancouver Island and the North Coast region. It operates eight Bell 206's, five

Bell 206L's, a Bell 204 and a Bell 47. It is an authorized Bell Helicopter service centre for spare parts sales, general maintenance, component overhaul, avionics and modifications for the Bell 47 and Bell 206. The company has eight engineers on staff for helicopter overhaul work. It actively does maintenance work for other helicopter operators and annually overhauls 25-30 machines. The company does all component work including the engine gearbox. Engines are sent to Standard Aero in Winnipeg. Vancouver Island Helicopters has limited avionics capability and usually uses Victoria Avionics for this type of repair. It also does not have its own non-destructive testing facilities and uses Viking Air Ltd. in Victoria or F.C. Propulsion and Aero Systems (1980) Ltd. in Vancouver for NDT work.

9.1.17 Canadian Gas Turbine (CGT) Ltd. - Richmond, B.C.

This is a new firm which plans to establish an authorized heavy maintenance service centre for the Allison 250 turbine engine at Vancouver International Airport. The firm is being started by three former Okanagan Helicopter employees who have experience in Allison 250 overhauls. Aviall has an agreement with CGT to appoint the new firm as an authorized Allison 250 service centre. When in operation in late 1984, the company will be capable of overhauling turbines, compressors and gearboxes.

9.1.18 Pacific Vocational Institute - Richmond, B.C.

Pacific Vocational Institute (PVI) has a 29,000 square foot facility on Sea Island for Aircraft Maintenance Technical Training. The campus graduates about 90 students each year and provides training courses and practical experience towards the obtaining of an Aircraft Maintenance Engineer (AME) licence. Helicopter maintenance is included in the core curriculum program as well as specialized courses for credit towards receiving an "R" license. In addition to the Aircraft Maintenance Program, there is an Aircraft Sheet Metal, Avionics and Composite Structures programs. There are also applied technology training courses rated to computer programs, advanced electronics/avionics, ground support systems, major and minor systems component overhaul and metals and materials testing.

PVI plans to build a new 130,000 square facility at a cost of $15 million close to the present facilities. The larger space will permit additional programs to be offered as well as improved facilities and equipment. Helicopter maintenance will be an important part of the new facility with special courses and equipment planned to be established. The Applied Technology Laboratories as well as the Learning Resource Centre facilities will be available for both learning activities as well as a support resource for those sectors of the aerospace industry who could benefit directly as well as indirectly.

9.2 BRITISH COLUMBIA ASSOCIATED MAINTENANCE FACILITIES

This subsection briefly outlines those British Columbia companies which provide associated support facilities and services to those companies which undertake helicopter repair and overhaul work. In addition, Aerospatiale Helicopters, Sikorsky Aircraft of Canada, and Hiller Aviation Corporation have representatives in British Columbia for product sales and product support. Due to budget limitations information could not be obtained from every firm listed.

A. Sheet Metal

Cam Air Service Centre	Delta, B.C.
Fred's Aero Maintenance Ltd.	Langley, B.C.
Pacific Aircraft Salvage Inc.	Richmond, B.C.
Viking Air Ltd. (Specializes in amphibian aircraft and de Havilland aircraft repairs)	Sidney, B.C.

B. Upholstery and Interiors

Daken Upholstery Corp. (Specializes in aircraft upholstery)	Richmond, B.C.
Innotech Aviation Ltd.	Richmond, B.C.
Joe's Upholstery	Vancouver, B.C.
Pacific Aircraft Salvage Inc.	Richmond, B.C.
Viking Air Ltd.	Sidney, B.C.

C. Welding

A.R. Technologies	Richmond, B.C.
Aeromaker Service Ltd.	Sidney, B.C.
Shoreline Metal Craft Ltd.	Sidney, B.C.
V.W. Aero Flite Ind. Ltd.	Richmond, B.C.
Viking Air Ltd.	Sidney, B.C.

D. Painting

Aero Mechanical Refinishers — Richmond, B.C.
Painting and fibreglass work

Fred's Aero Maintenance Ltd. — Langley B.C.

Innotech Aviation Ltd. — Richmond, B.C.

Vancouver Aero Services Ltd. — Richmond, B.C.
Specializes in painting and has done a number of helicopter repainting assignments. Owned by Peter Van Gruen "Pete the Painter".

Viking Air Ltd. — Sidney, B.C.

Western Heli-Craft Ltd. — Delta, B.C.
Has done repainting of a number of helicopters.

E. Parts and Supplies

AFC Air Fix Corp. — Maple Ridge, B.C.
Hughes helicopter component parts and supplies.

Aviation Electric Ltd. — Richmond B.C.
Bendix subsidiary for rotory wing avionics and instrument maintenance and overhaul. Services include electrical, electronic, electro-mechanical hydraulic and pneumatic components, instruments, accessories, ignition systems and fuel controls. Repair and overhaul of fuel controls for PT6-3B engines, Allison 250-C18 to C30 engines, and Lycoming LTS101-350 and 600 engines, Bendix RSA injectors also repaired. Dealer for the following companies:

Bendix Aerospace & Electronic Group
Sunair
Hydraulic Research
United Industries
Lewis Engineering
AIM Instruments
Daniels Electronics

Cougar Industrial Ltd. — Burnaby, B.C.
Supplier of pumps, meters, fitters, hoses and nozzles and special fittings

H.S. Tool and Parts Inc. — Vancouver, B.C.
Precision parts, specialty tool die making.

Lucas Industries Canada Ltd. — Richmond, B.C.
Distributors of hydraulic equipment from the following manufacturers:

Char Lynn	UCC Products
Parker Hamnifin	Von Ruden Mfg.
Brand Hydraulics	Gresen Hydraulics
Warner Motive	Husco Valves

Northwest Heli Pro, Inc. — Richmond, B.C.
Distributors of engine accessory parts and other helicopter spare parts.

Progressive Air Ltd. — Richmond, B.C.
Distributor for instruments and accessories. Work closely with local Aviall representative for engine component overhaul of Allison 250 series.

Standard Aero Ltd. — Richmond, B.C.
This is a Vancouver distributor for the large Winnipeg based aero engine overhaul company. Its Vancouver office has a technical representative for the Allison 250 and other engines but its main function is a parts supplier. Standard Aero is a distributor for the following helicopter parts:

Airborne fuel pumps & cartridges
Facet fuel filters & separators
Allison engines
SAFT batteries
Eastern rotorcraft cargo hooks
David-Clarke headsets
Janitorial heater parts
Champion ignitors
Whelen lamps
Randolf paints
Klixon circuit breakers
General Electric lamps
It also distributes cargo hooks, slings and all helicopter accessories.

Star Teck Aviation Industries Inc. — Richmond, B.C.
Manufacture/repair and distribute fuel, oil and hydraulic hose lines.

IMI Aerospace Ltd. — Richmond, B.C.
Specializes in helicopter parts and supplies

F. Avionics and Instruments

Aviation Electric Ltd., Pacific Div. — Richmond, B.C.
Avionic sales and service for Bendix avionics, Bendix Flight Systems and Bendix Guidance Systems.

Griffiths Avionics Ltd. — Sidney, B.C.
Represents the following for sales and service:

Collins	Narco
Edo-Aire	Wulfsberg
King	

Innotech Aviation Ltd. — Richmond, B.C.
This firm represents a number of avionic companies including:

Bendix	Sunair
Collins	Brelonix
King	Flight Tronics
RCA	Radair
Edo-Aire	Smith Audio Systems
Wilcox/Sperry	Sundstrand
Bonzer	Spilsbury & Tindall

Pacific Avionics and Instruments Ltd. — Richmond, B.C.
This firm specializes in avionics sales and service. In addition to its Vancouver International Airport location, it has a branch office at Abbotsford Airport. It is reported to be the largest avionics and instrument centre in Western Canada. Its sales and services for avionics include weather radar, radar altimeters, compass/HSl/flight directors, RMl, solid state invertors, airborne FM, and flight phones.

Manufacturers represented include:

David Clarke	
Bendix	Davtron
Canadian Marconi	Dayton
Cessna (ARC)	Edo Aire
Collins	Flitetronics
Commadore	Genave
Communications Component	King
Narco	Plantronics
Radair	Radone
Sperry Flight Systems	Sperry/Wilcox
Spilsbury	Sunair
Texas Instruments	Wulfsberg

The company presently employs 20, down from twice that number 2 years ago. It is estimated that the company has over $1 million invested in its test labs, clean room, library and computerized inventory. There are about $300,000 of avionic and instruments parts on hand at all times. It is particularly strong in support of Collins avionic products and is one of only 11 world-wide authorized Collins service centres. Pacific Avionics maintains a small research & development program for the development of special avionic products which could be possibly manufactured in the future. The firm now assembles electricity harnesses for Canadian Aircraft Products.

Precision Aero Instruments Ltd. — Richmond, B.C.
This company provides and repairs flight instrument and engine accessory instruments.

SIL Industries Ltd. — Richmond, B.C.
Specializes in the sale, service and overhaul/repair of instrument accessories and hydraulics for helicopters.

Victoria Avionics Ltd. — Sidney, B.C.
This avionics sales and service company is qualified to repair and install navcom equipment, automatic direction finders,

transponders, and HF communication equipment. It represents Collins, Wulfsberg, Narco, ARC and Genave Avionics equipment.

Northern Airborne Technology Ltd. — Pr. George, B.C.

This company is a British Columbia based avionics manufacturer specializing in helicopter installations. It is also a dealer for avionics equipment. A field maintenance facility is maintained in the Spar Aerospace hangar in Calgary, Alberta. The company was established in late 1979 and has rapidly established a dealer/distributor network throughout Canada and the United States.

Its research and development activities include: avionics systems & components; systems integration; airborne data collection and computers; interfacing and audible noise suppression.

Northern Airborne has the following in-house facilities:

- Transport Canada avionics facility including VHF, UHF, pulse, VOR/ILS, HF, Autopilot, and tactical FM.
- Full circuit board design and assembly capability
- Machine shop with metal and plastic capability
- Full-size helicopter wiring jigs for the Bell 206, Bell 206L and Aerospatiale AS350 AStar
- Hot-stamping with marking facilities
- Computer-aided design, drafting and manual system
- Engraving equipment
- Full colour photo laboratory

In addition to the above facilities, full environmental test facilities are under construction at the Prince George facility. The company has manufactures the following:

- Avionics equipment
- Aircraft wiring harnesses
- Lighted panels, including night vision compatible panels
- Intercommunication systems
- Custom control systems
- Test equipment

The most noteworthy products it manufactures are the AA90 audio control and intercom system, the HSA70 stress monitor system which provides voice advisory information on critical performance limits and running updates of enroute information, a retrofit auto-ignition system for the Bell 206, a crashworthy ELT antenna system and solid-state lighting for night vision capability.

Sales and service for the following equipment are provided:

Wulfsberg	Collins	Televideo
King	Ohio Scientific	

Spilsbury Communications Ltd. — Vancouver, B.C.

This is a manufacturer and distributor of navigation and communication equipment ncluding non-directional beacons. It provides for helicopter installation including HF SSB radio communication equipment as well as other broad band radio equipment.

G. Engine Overhauls

Aero Power Inc. — Sidney, B.C.

This company has reciprocating engine overhaul maintenance capabilities and engine exchange experience. Most of the maintenance experience is with fixed wing aircraft.

Pacific Aero Engines Ltd. — Richmond, B.C.
An approved Transport Canada overhaul facility for helicopter piston engines up to 450 HP.

Pratt & Whitney Aircraft of Canada Ltd. — N. Vancouver B.C.
This is a branch office to provide technical support for Pratt & Whitney engines including the PT6-3T Twin Pac used in helicopter engines. Support will also be provided for the Pratt & Whitney STEP engines when they are introduced in the late 1980's. The turbine engine overhauls, however, are done at Pratt & Whitney's Longueuil, Quebec facility (Pratt & Whitney Aircraft of Canada have three U.S. service centres and another eight in Europe, Asia, Australia and Mexico).

Progressive Air Ltd. — Richmond, B.C.
The firm has the capability to overhaul reciprocating engines as well as to provide engine exchanges.

Aviall — Richmond, B.C.
Aviall, which is a large U.S. engine overhaul company headquartered in Dallas, Texas, established a Vancouver office and a technical representative in March 1983 to offer sales and services. Its services are directed at Western Canadian helicopter operators with Allison 250 turbine engines. To date, most of the local activities have been to promote the technical capabilities and parts distribution aspects of the company. Overhauls for the Allison 250 are conducted at the Dallas facilities of Aviall. It will, in the future, work closely with the newly established Canadian Gas Turbine (CGT) Ltd., a proposed Aviall service centre at Vancouver International Airport.

Valley Aero Engines Ltd. — Langley, B.C.
This firm does engine overhauls for reciprocating engines including Lycoming, Pratt & Whitney and Continental products.

Standard Aero Ltd. Richmond, B.C.

Standard Aero Ltd. maintains a technical representative and a parts distribution centre at Vancouver International Airport. The representative based in Vancouver is qualified on the Allison 250 series turbine engines used in many helicopters. He is qualified to conduct a teardown and inspection to determine the problem area, whereas a non-authorized person would void the warranty. The cost of erroneous repair may also be avoided.

Standard Aero is a wholly-owned subsidiary of Federal Industries Ltd. with head offices and overhaul facilities in Winnipeg, Manitoba. Field service and sales representatives are located in Vancouver, Montreal, Quebec, Van Nuys, California and Atlanta, Georgia. Standard Aero International covers parts distribution in most North American cities. European sales are handled through an office in London, England and Far East sales are handled from an office in Bellevue, Washington.

The company was established in 1938 and employs 500 in its 200,000 sq.ft. plant in Winnipeg. Its sales for 1983 are forecast at $75 million. It handles, by computerized inventory, 60,000 different parts valued at about $22 million. It annually overhauls more than 650 turbine engines and piston engines including the Allison 250 series, General Electric T58 and Lycoming T53/T55 engines. Two test cells with separate consoles and a common control room and preparation area are outfitted for turbine engine tests of fuel and oil pressure, engine temperatures, airflow pressure, vibration, horsepower (dynomometer) and electrical systems. The engine overhauls are supported by the following facilities:

Cleaning (solvent, chemical, mechanical ultrasonic)
Welding (plasma, TIG, arc, spot, MIG, etc)
Protective Coatings (Enamel, ceramic, black oxide, anodizing)
Non-Destructive Testing (MPI coil, FPI dip tanks, ultrasonic, eddy current)
Machining (lathes, mills, drills, grinders planers)
Metalizing (thermospray, flame spray of bronze, brass, steel, aluminum, nickel, etc.)
Balancing
Tool and Gauge

H. Manufacturing and Engineering

Canadian Aircraft Products Ltd. — Richmond, B.C.

This firm is a manufacturer of aircraft components for large aerospace manufacturers. It is currently building components for the DeHavilland DHC-7 and DHC-8 and the Canadair Challenger. It owns one large building and leases another in an industrial park in Richmond. Employment was at 160 a year ago but is now down to 60 and will likely remain at that level unless there is additional work contracted out by the major aerospace manufacturers.

The company has its own in-house engineering capability and can design and manufacture complex airframe components. DeHavilland and Canadair have given Canadian Aircraft Products complete authority and responsibility for the components it makes.The company is currently investigating CAD/CAM computer drafting to assist in its engineering capabilities. It now uses an in-house computer but it is for work scheduling, inventory control and administration purposes.

It has the facilities for bending and shaping of sheet metal, milling, bonding, chemical etching, anodizing, painting and other processes. The company also has complete NDT facilities.

Canadian Aircraft Products has also built its own jigs to assemble major components such as complete elevators, rudder assemblies, leading edge wings, fuel cells, wing tip sponsons and floats.

The major machinery Canadian Aircraft Products has includes a hard rubber parts press, a 850 ton press, an automatic drill, a Bridgeport Series 1 CNC numerical control machine with 3 axis contouring and a Burgemaster VTC325-330 numerical control machine with the equivalent of 4 axis contouring. A five axis numerical contour machine has been examined for subcontracting to U.S. military specifications but the cost is too high in relation to the business risk.

In addition to its metal working capabilities, Canadian Aircraft Products has been rapidly developing expertise in composite technology. It is using fibreglass, Kevlar and Nomex materials from Dupont for applications. It has built its own molds, enheat treatment facility (20 ft length), special cutting room and other special facilities to use composite materials. It is currently manufacturing the leading edge wing, including the pneumatic de-icer area, of the DeHavilland DHC-8 with composite materials.

Canadian Aircraft Products does not now manufacture component parts for the helicopter industry. They have, however, designed an external fuel tank for the military for use on the Bell Huey 109. Some tail booms for the Bell 206 were also made. They are currently examining the engineering feasibility of a STC for an ambulance carrier for the Hughes 500.

Canadian Aircraft Products also recently met with Bell Helicopter Textron in Fort Worth, Texas to promote the possible use of its engineering and manufacturing capabilities in conjunction with the Bell 400 series to be built in Canada in the late 1980's.

H.S. Tool and Parts Inc. — Vancouver, B.C.
This company is Transport Canada approved to manufacture precision parts, and to do specialty tool diemaking and design services.

Viking Air Limited — Sidney, B.C.
This firm has been engaged in the rebuilding of Grumman amphibian aircraft for some years and has built up a reputation in its sheet metal fabrication abilities. Recently, the company acquired the tools, jigs and spare parts to rebuild the DeHavilland DHC-2 Beaver and DHC-3 Otter. To date, the firm has not undertaken a significant amount of helicopter re-building work. The facilities and services offered by Viking Air include:

Sheet metal	Plating
Al heat treatment	Welding
Cable swaging NDT	
Upholstery & Int.	Machining
Electrical	Painting

Engineering & manufacturing of certain airframe components.

CNC Precision Machining Corp. — N.Vancouver, B.C.
CNC Precision is a small machine shop which does numerical control machining of aerospace parts. It has two 3-axis contouring NC machines (Excello 604, Shizuoka AN5). It also does machining work for the electronic industry.

Decade Industries Ltd. — Richmond, B.C.
It does some machining of aerospace parts. It has two numerical controlled machines capable of three axis contouring (Excello Machine Centre and OKK MCV-500).

Ebco Industries Ltd. — Richmond, B.C.
Ebco is a large metal working company which does most of its work for the forest and mining industries. It has done aerospace machining. It has a Cincinatti CIM-X 2 axis contouring numerical control machine and a Giddings and Lewis planer with 3 axis profiling.

Heli-Craft Enterprises — Westbank, B.C.
The firm manufactures bleed air heaters for the Bell 206.

9.3 COMPETING FACILITIES AND SERVICES

As can be expected there are a number of firms outside of British Columbia, but within the study area, which offer repair and overhaul of helicopters and other helicopter related facilities and services. As well, there are parts distributors and original equipment parts and component manufacturers in the study area outside of British Columbia. This subsection discusses the major competing facilities and services by location in the Primary and Secondary Market Areas.

9.3.1 Alberta

This adjacent province has a well developed helicopter repair and overhaul industry which competes directly with British Columbia firms for the market.

Bell Helicopter Textron - Calgary, Alberta

Bell Helicopter provides product support for all Bell Helicopters in Canada from their Calgary supply depot.[1] In addition to its Fort Worth headquarters facilities, Bell has supply support facilities in Montgomeryville (Pennsylvania); Van Nuys, California; Amsterdam, Netherlands; Brisbane, Australia and Calgary, Alberta.[2] In addition to these Bell supply support centres there are 12 field support representatives of which 4 are located within the study area at Kirkland, Washington; Aurora, Colorado; Van Nuys, California and Calgary, Alberta. There are an additional 12 international supply support representatives in most industrialized countries. There are also some 165 customer service facilities throughout the world. These service facilities are approved by Bell Helicopter for certain types of maintenance on specified Bell Helicopter products.

The following summarizes these customer service facilities which are located in the study area:

1/ Having a supply support centre in Alberta does provide Alberta repair and overhaul firms with some advantages over similar British Columbia firms.

2/ There was a supply support centre in Ottawa but it was recently closed except for a sales office. There are some rotor blades stored in Montreal for Eastern Canadian helicopter users.

Authorized Bell Helicopter Service Centres

Primary Market		Secondary Market	
British Columbia	7	Saskatchewan	1
Alberta	5	Manitoba	2
Yukon Territories	1	Northwest Territories	-
Washington	2	Wyoming	2
Oregon	5	Nevada	1
Idaho	3	Colorado	3
Alaska	6	Utah	3
	29	New Mexico	-
		Arizona	4
		Montana	-
		California	11
			27

Source: Bell Helicopter

All Bell Helicopter supply support centres, such as Calgary, were recently linked to an on-line computer system for parts inventory control. This system automatically locates the desired part, arranges for its delivery to the customer, invoices the customer and re-orders the part for inventory. The part may be located in any of the supply support centres and shipped to the customer.

Bell Helicopter, prior to the on-line computer system, was achieving a 92 percent completion fill rate of delivering the part on time to the customer. This is the best it has been in 10 years. With the computer, it is anticipated the completion fill rate will be close to 100 percent.

There was a time in 1980 and 1981 when there were severe supply parts shortages due to heavy demand for new helicopters and new spare parts.

There was also a problem with quality control. Some of the sub-component manufacturers, which Bell had contracted to ease the the shortage, were not qualified to manufacture parts to the high tolerances needed on the helicopter parts. These shortages and the poor quality led to unsatisfactory delivery and very poor customer relations. Bell Helicopter recognized the seriousness of the problem and completely changed their customer service system to ensure adequate inventory and spare parts support. The Calgary supply support centre, for example, carries now about $3 million in spare parts inventory. Of this total, $1 million is on the shelves, $1 million is being delivered to customers and the remainder is being ordered from Fort Worth and other locations for delivery to Calgary. The Calgary inventory is turned over about 3.5 times a year. The value of the inventory has been steadily increasing but the number of items in the inventory, however, has been relatively static.

The Calgary supply support centre is located relatively close to the airport and is essentially a large warehouse. There is considerable space for inventory but Bell Helicopter has an option to take over a adjacent facility should the need arise. There are only six employees at the centre who are responsible for helicopter sales, spare parts control and clerical work.

Bell 206B's are expected to be the main helicopter in use in Western Canada and Bell Helicopter will continue to actively support spare parts for this machine. Spare parts for the Bell 206L and even the Bell 204, are expected to also remain strong for several years.

Field Aviation Company Ltd. - Calgary, Alberta
The company operates extensive aircraft maintenance facilities in Toronto and Calgary. The Calgary facility since it was established in 1952, has established an international reputation for quality helicopter airframe repairs. It has become particularly expert in major repairs for the Bell 206 and Bell 206L. Field Aviation has frame jigs for both the fuselage and tail boom for the Bell 204/205, Bell 206/206L and the Bell 212. It also has the tail boom jig for the Aerospatiale AS 350 AStar.

Field Aviation has the capability to do the all the repair work in its own hangar except for engine overhauls. The work includes structural repairs, painting, upholstery and interiors, sheet metal and machining, hydraulics and instrument repair. It has also developed a knowledge of helicopter salvage and has operated throughout the world to repair damaged helicopters. Avionics is sub-contracted to a company in the same hangar.

The Field Aviation hangar at Calgary is 232,000 sq. ft. but helicopter repair and overhaul constitutes only about 15-20 percent of the total aircraft business of the firm. The helicopter division has now only four AME's which reflects roughly 50 percent of the helicopter division's capacity. About 75 percent of the customers are from the United States (Alaska, Kentucky, Utah and Louisiana) and are attracted to Field Aviation based on its reputation and value of the U.S. dollar in comparison to the Canadian dollar. A significant amount of the work is for commercial helicopter operators or insurance adjusters for repairing damaged helicopters. In the past, Alberta Forestry has been a major client. Bell Helicopter itself is even a customer for repairs on its demonstrators and other helicopters.

Field Aviation has found in the economic slowdown that commercial helicopter operators are having Field Aviation only do the airframe jig work where the tolerances are critical. The remaining work is then done in-house due to the spare labour resources now available. In busier operating times, Field Aviation would have done all the work since the in-house customer staff would be kept busy with operational aircraft. There are a number of completed airframes in Field Aviation's hangar which have not been picked up by customers because there is no demand to use the helicopters. Insurance companies, in comparison to commercial operators, still prefer Field Aviation to do the complete repairs including upholstery, painting, windshields, electrical, radio and so forth.

In terms of spare parts, Field Aviation normally uses Bell Helicopter parts from the Calgary supply centre and normally has about $80,000 of parts in inventory. At the present, the inventory is down to $50,000. Field Aviation is an authorized Bell Helicopter customer service facility and receives a 20 percent discount from Bell Helicopter for parts. Field Aviation notes that this discount is freely applied and therefore not a great advantage in competitive price quotes. Service from Bell Helicopter is good, with deliveries in less than ten days if the part is not stocked in Calgary.

Field Aviation rates Bell Helicopter support as the best in the industry but it was at one time poor. Aerospatiale spare parts support is considered poor in terms of delivery and parts are expensive. The Hughes Helicopter spare parts delivery is also rated very poor. Hughes 500 helicopter has an advantage in being repaired in that it does not need special jigs due to its egg shaped design. However, it needs more airframe panels from the factory unless they can be shaped in a sheet metal shop. Field Aviation jigs were made in-house for about $50,000. Commercially made jigs are over $100,000.

Field Aviation estimates a Bell 206 major airframe repair will take 5-6 weeks, of which two weeks are needed to assemble the necessary parts. A Bell 212, due to its complexity, will take 8-10 weeks to repair. The helicopter division is normally working on five fuselage repairs and three tail boom repairs at any one time.

The company has had discussions with Bell Helicopter regarding manufacturing parts for Bell and it is aware that Bristol Aerospace in Winnipeg makes parts for the Bell 206. Field Aviation also had discussions with a German helicopter manufacturer and the Government of Alberta regarding helicopter component manufacturing.

The Copter Shop - Calgary, Alberta

The Copter Shop is a subsidiary company of Spar Aerospace Ltd., a Toronto, Ontario firm with 2,000 employees. Spar, the parent company, had some $177 million in sales revenue in 1982. This large aerospace company is engaged in the design, development, manufacturing and servicing of systems and products for the aerospace, aviation, communications, defense, manipulator and mapping markets. Half of its sales are international and 20 percent of its domestic sales are to the Canadian Government.

Spar Aerospace is actively engaged in helicopter sub-component manufacture. It is currently a component manufacture for Sikorsky Helicopters. Its Gears and Transmission Division in the Toronto area is manufacturing all the dynamic transmission parts for the Sikorsky UH-60 Blackhawk military helicopter. Each of the transmission systems is comprised of a main transmission, intermediate gearbox and a tail rotor gearbox. Spar has been contracted to build 1,167 transmission systems through to 1993. It also recently signed a $40 million contract with General Electric of Fairfield, Connecticut to manufacture accessory gear boxes and other components for GE turboshaft engines starting in March 1984 and ending February 1987.

The Copter Shop at Calgary Airport was purchased some years ago by Spar Aerospace to provide repair and maintenance service for Western helicopter operators. Currently, the total staff is down to 15 employees, of which most are helicopter repair and overhaul maintenance engineering personnel. The Copter Shop provides repair and maintenance, maintenance contracts, field service, component overhauls, non-destructive testing (zyglo and magnaflux), and spare parts sales. It has an association with Northern Airborne Technology Ltd. which allows Northern Airborne to use its facilities for avionics field installation and repairs. The Copter Shop is authorized by Transport Canada to inspect, repair, overhaul and modify the following helicopters:

Aerospatiale 350, 355
Aerospatiale 315, 316, 318
Bell 47, 204/205, 206/206 L, 212, 412
Enstrom
Hiller
Hughes 300, 500
Sikorsky S-55, S-58
MBB BO 105

The Copter Shop is also an authorized Bell Helicopter customer service centre. It also offers an exchange service for Aerospatiale 315, 316, 318 and 350 and the Bell 206 for components and accessories.

The main expertise of the Copter Shop is in hydraulic controls, dynamic components, avionics (in association with Northern Airborne) and general airframe maintenance. Spar Aerospace, the parent company, did investigate the possibility of the Copter Shop providing engine overhauls in competition to Standard Aero Ltd. but has decided against the investment at this time.

The Copter Shop's international market has been increasing, particularly in countries which are politically para-military and where military and commercial helicopters are jointly operated. Many of these countries also are engaged in off-shore exploration and are active in helicopter operations to support exploration. In a number of these countries, the helicopter repair and overhaul work cannot be done internally and there are political reasons for not having the work done by U.S. companies. South and Central America and South Asian countries are where half of the Copter Shop's business is currently derived, with the other half from the United States and Canada. The sales revenue in 1983 is expected to be between $3.6 to 4.8 million, down by 30-40 percent from the 1980-1981 period.

In terms of helicopter parts, the Copter Shop feels that its international business could be affected if, for example, Bell Helicopter parts were to be restricted from re-sale to third party countries which were not in the best interests of the United States government. Bell Helicopter deliveries are very reliable, particularly with the supply support centre located close by. The Copter Shop is concerned about the cost of the parts and feels the mark-up only encourages the manufacture of bogus parts. Bell Helicopter have been very successful in court actions against manufacturers which make helicopter parts without Bell Helicopter's authority (which is difficult to obtain). Bell Helicopter have full time staff to check bogus part manufacturers. The Copter Shop receives a 20 percent discount on parts from Bell Helicopter but the high price does not provide a competitive advantage.

Aerospatiale parts delivery is slow and parts are also expensive despite the devaluation of the French franc. Aerospatiale set the prices some time ago to provide stability but the lowering of the franc has made it difficult and expensive to obtain parts. Aerospatiale insists that the parts be shipped first to Grande Prairie, Texas where a 5 percent handling fee is added as well as the extra transportation and time costs. In order to get service and a discount on spare parts, however, it is necessary to negotiate directly with

Aerospatiale in France. It is, however, the larger firms which have been successful in direct negotiations in France.

Hughes Helicopter spare parts delivery is considered poor and part prices are also too high. Efforts, however, are being made to improve the delivery of spare parts.

The Copter Shop is also a representative for the following parts and accessories:

Tedeco	Brion Leroux Aeronautics
Astronautics	General Electric
Auxilec Inc.	Gill
Badin Crouzet	Sfena
JET	Jaeger
Leyland	U.S. Gauge

Eagle Copters Ltd. - Calgary, Alberta

This company is a specialized helicopter repair and overhaul, helicopter parts distributor and aircraft leasing firm. It was established in 1973. It has a modern hangar designed specifically for maintenance and has leased the adjacent land to eventually build another maintenance hangar. The number of employees is eleven, most of whom are qualified AME's.

Eagle Copters is an authorized Bell Helicopter customer service facility and is capable of providing component repairs, maintenance and spare parts for the Bell 205, Bell 206 and Bell 212/412. The company's specialty is the Bell 204B. Eagle Copters owns and leases the world's largest fleet of these single engine, medium weight helicopters and does all its own work on the fleet. These helicopters have proven to be a good investment due to their low capital cost and performance but spare parts and maintenance would be expensive if not done in-house by Eagle Copters. In addition to Bell Helicopter products, Eagle Copters has repair and overhaul experience on Aerospatiale, Agusta and MBB products. The company usually does 5-6 major re-builds each year and can readily increase or decrease its services to meet demand since its overhead costs are kept low.

Eagle Copters' market area is mostly Canadian and, of this, a large percentage come from Quebec (Quebec Hydro is a large client). The United States is a growing market for Eagle Copter and represents about 10 percent of their total revenue. Helicopters used by the U.S. Forestry Department are a large customer for the repair and overhaul services of Eagle Copters. International customers are not many in number but there have been some. The overseas market has not been aggressively addressed by Eagle Copters due to the cost of marketing and servicing these customers.

The company also provides trained maintenance personnel to helicopter customers under contract or as employees of the customer. These maintenance people are hired to conduct daily maintenance in the field and co-ordinate with Eagle Copters when major work is required.

Associated Helicopters Co. Ltd. - Edmonton, Alberta
This is a charter helicopter operator firm and is a subsidiary of Okanagan Helicopters. It has bases at Calgary, Fort McMurray and Grande Prairie but also operates extensively in the Arctic and East Coast for petroleum companies conducting off-shore exploration. The current fleet size is 21 helicopters; these are Bell 47 (2), Bell 206B (11), Bell 212 (1), Aerospatiale AS 350 AStar (5) and an Aerospatiale AS 332 C Super Puma. Maintenance for other helicopter operators is conducted at their Edmonton Municipal Airport facilities. There are 24 maintenance personnel on staff. Associated Helicopters recently transferred to new hangar facilities at the airport. It is a Bell Helicopter customer service facility and is authorized to provide spare parts, general maintenance, component overhauls, and avionic repairs for the following Bell products: Bell 47, Bell 205, Bell 206, Bell 212/412 and Bell 214. Associated Helicopters have an avionics test centre for repair of navigation and communication equipment.

Alpine Helicopters Ltd. - Calgary, Alberta

This helicopter charter firm has its corporate headquarters in Kelowna, B.C. but its maintenance centre is located at Calgary International Airport. It also has bases at seven locations in B.C., Alberta and the Northwest Territories. It operates a fleet of twenty-four helicopters including: Bell Soloy 47 (4), Bell 206 B (12), Bell 206 L (1), Bell 204 (2), Bell 212 (3) and a Bell 412 (1).

Alpine is a Bell Helicopter customer service facility. It is authorized to conduct overhauls of components, modifications and general maintenance for the Bell 47, Bell 205, Bell 206, Bell 212/412 and the Bell 214.

Kenting Helicopters - Calgary, Alberta

This charter operator has a fleet of eighteen helicopters including Hughes 500 (3), Aerospatiale AS 355 Twin Star (4), Bell 206 B (9) and Bell 412 (2). Kenting is controlled by Trimac Ltd., a large truck transport and oil field service company. It is authorized by Bell Helicopter to provide spare parts, general maintenance, component overhaul, avionics repair and modifications to the Bell 206. Work on the Bell 212/214 authorized by Bell includes spare parts, general maintenance and avionics repair, but component repair is not authorized nor modifications on this Bell model.

Alberta Aircraft Overhaul Ltd. - Calgary, Alberta
This firm does maintenance and overhauls for both fixed wing and rotory aircraft. Helicopter work is limited to airframe repairs, major modifications and replacement of parts.

Astra Welding Ltd. - Calgary, Alberta
Astra has experience in welding (aluminum, stainless steel, magnesium and general welding) and sheet metal fabrication.

Action Helicopter Maintenance and Consulting Ltd. - Calgary, Alberta
Action Helicopters provides helicopter maintenance and overhaul. It is particularly capable of undertaking Hughes 500 rebuilds, modifications, inspection and providing spare parts for this helicopter model.

Airborne Precision Instruments Ltd. - Calgary, Alberta
The firm provides sales and service of engine instruments, gyro instruments, flight instruments, navigation instruments, solid state inverters and autopilots. Airborne is a warranty authorized service centre for Bendix Avionics Division, King, Edo-Aire, and Aviation Instrument Manufacturing (AIM).

Calgary Aero Accessories Ltd. - Calgary, Alberta
This firm sells, repairs and overhauls electrical, electronic, fuel, hydraulic, bleed air and vacuum components as well as starters and generators for both

fixed wing and rotory aircraft. It also provides dynamic balancing and has equipment for armatures and rotors.

O'Dowds Aircraft Sheet Metal Shop Ltd. - Calgary, Alberta

The company provides custom sheet metal work for rebuilds and modifications to fixed wing and rotory aircraft.

Canairmo Supplies Ltd. - Calgary, Alberta

Canairmo is a distributor of helicopter accessory equipment including rotor balance and track systems, cargo nets and helicopter windows.

Western Rotorcraft Ltd. - Calgary, Alberta

Western Rotorcraft provides repair and maintenance on the Bell 47, Bell 204/205, Bell 206, Aerospatiale Gazelle and Alouette, Hughes 500 and the Sikorsky S-55. The firm has sheet metal and fibreglass capabilities.

Western Avionics Ltd. - Calgary, Alberta

This company provides helicopter avionics sales and service for Collins, King, Sperry, Bendix, Narco and Canadian Marconi Avionics products.

Custom Aviation Works Ltd. - Edmonton, Alberta

The firm provides welding, machining and metal work for both fixed wing and rotory wing aircraft.

K.R Aircraft Sheet Metal Ltd. - Edmonton, Alberta
K.R. Aircraft specializes in all types of sheet metal work for fixed wing and rotory aircraft, including salvage repairs.

Ducey Avionics Ltd. - Edmonton, Alberta
Ducey is a well established avionics sales and service company. The company, in addition to repairs and servicing, does custom design installations. It represents many avionic manufacturers including Canadian Marconi, King, Collins, Sperry Bendix, Narco, RCA, Genave, Brelonex, Sunair and Edo Aire.

HARV Air - Edmonton, Alberta
This firm provides helicopter custom painting as well as fixed wing painting.

Northwest Industries Limited - Edmonton, Alberta
This is a large aerospace company and is a subsidiary of CAE Industries Ltd. (Toronto). CAE Industries, the parent company, is engaged in the development of aircraft flight simulators, air traffic control systems and aircraft repair and overhaul. Northwest Industries activities include aircraft repair, overhaul and modification of airframes. They also design, install and repair avionics and instruments. They are also equipped to manufacture aircraft components, and to design, fabricate and install structural and systems modifications. Northwest Industries also has complete non-destructive testing equipment. The company does a

substantial business in the repair of military aircraft and has manufactured engine ducting for the Lockheed 1011. Northwest Industries is not currently actively engaged in the helicopter repair and overhaul field but has the capability and the equipment to do so in the future.

International Radiography & Inspection Services (1976) Ltd. (IRIS) - Edmonton, Alberta

IRIS provide specialized non-destructive testing inspections including x-ray, ultrasonic and eddy current methods of testing.

Avialta Helicopter Ltd. - Edmonton, Alberta

Avialta is a new approved Bell Helicopter customer service facility. The company specializes in the overhaul of Bell 206 and Bell 47. It also operates an upholstery division for refurbishing aircraft interiors. In conjunction with HARV Air it can also provide aircraft painting.

9.3.2 Yukon Territories

Trans North Turbo Air Ltd. - Whitehorse, Yukon Territories

This is a fixed wing and rotory wing charter company. In addition to its headquarters at Whitehorse Airport, Trans North has nine bases throughout the Yukon Territories and Northern Alberta. It operates twenty helicopters including: Hughes 500 (4), Aerospatiale 316 (1), Bell 47 (2), Bell 204 (2) and Bell 206 (11). Trans

North is an authorized Bell Helicopter customer service facility for spare parts, general maintenance and component overhauls for the Bell 47 and Bell 206.

9.3.3 Washington State

Aero-Copters, Inc. - Seattle, Washington

Aero-Copters is a charter helicopter company which operates from Boeing Field with three Bell 206 helicopters. It is a certified FAA repair station and is an Aviall agency for Allison 250 series engine overhauls. It is authorized by Bell Helicopter to provide maintenance component overhaul and avionics repair for the Bell 47 and Bell 206. On the Bell 206, Aero-Copters can also provide engine overhauls. Aero-Copters also provides electrical services and Ni-Cad battery service.

Weyerhaeuser Company Corporate Aircraft - Tacoma, Washington

This is the corporate flight department of a large forest industry company. It operates seven Bell 206's and three Bell 212's for forest fire protection, aerial ambulance and corporate travel. It provides repair and maintenance to other helicopter operators from its Sea-Tac Airport facilities. It is a Bell Helicopter customer service facility and is authorized to provide spare parts, general maintenance and component overhauls for the Bell 206 and Bell 212/214 models.

Air Lab, Inc. - Seattle, Washington

Air Lab is an authorized FAA repair station for rotory wing instrument/avionics repair services and a warranty representative for a number of instrument and avionic component manufacturers.

Soloy Conversions Ltd. - Olympia, Washington

This company has designed, engineered and installed Allison 250 turbine engines to replace the original reciprocating Lycoming TVO engines in the Hiller UH 12E and the Bell 47G. Over 100 Hiller UH-12E's had been converted before Hiller recently purchased the rights from Soloy. In the case of the Bell 47G, there are about 150 with the Allison 250 engine installed. Soloy can do the installation or provide a STC kit to be installed by a qualified maintenance shop in about 350 man-hours of labour. The kit is available at $135,000 U.S. The conversion doubles the payload of the helicopter and trebles the engine life over the original piston engine. Soloy also make a conversion for the Cessna 206 fixed wing aircraft.

Soloy also provide turbine conversion accessories such as a particle separator and mist eliminator system, hydraulic reservoir assembly, hydraulic drive assembly, dual collective controls, cargo hook assembly, external load support system, cabin heater and floatation landing gear. Also available are aerial application accessories, weighing systems, oil filter systems and avionics.

American Avionics Inc., Seattle, Washington
This firm provides sales and service of fixed wing and rotory aircraft radio, electronics and instruments. At its Boeing Field facilities it repairs, modifies and overhauls nav/com systems, radio magnetic indicators, radar, flight computers, Omega VLF Loran and other avionics, instruments and accessories. It also provides engineering and installation services.

Northwest Aero Industries, Inc. - Tacoma, Washington
They are distributors of helicopter hardware and components of original equipment manufacturers.

Standard Aero International - Bellevue, Washington
This is the Far East Sales Division of Standard Aero Ltd. of Winnipeg, Manitoba. It is principally a spare parts distributor for Standard Aero but also is a representative for engine overhaul services. Standard Aero International is a recent merger of SPAD Aircraft Parts and IMI Corporation to allow Standard Aero increased market penetration in the United States.

Measurement Systems International, Seattle, Washington
This firm manufacturers the MS1-150 Sky Weight which is an external load recording system for weighing the sling payload carried by helicopters. It has an STC for use on most helicopter models.

SGC Inc. - Bellevue, Washington
This avionics manufacturing firm markets the Model SG-715 and SG-712EX, both HF SSB radios for installation in helicopters, and other mobile equipment. The units are designed for standard aviation rack dimensions. SGC also makes antenna couplers and aviation remote control accessories for their radios.

Heath Tecna Precision Structures Inc. - Kent, Washington
They are manufacturers of fibreglass, Kevlar and graphite reinforced plastic and metal bond structures, components and assemblies for fixed wing and rotory aircraft.

Northern Radio Company, Redmond - Washington
They are manufacturers of communication systems for fixed wing and rotory aircraft.

Tyee Aircraft Inc. - Everett, Washington
This is a manufacturer of flight controls and structural tubes for helicopters.

9.3.4 Oregon State

Columbia Helicopters, Inc. - Aurora, Oregon
This helicopter charter firm specializes in helicopter logging, aerial construction, and off-shore exploration support. It operates the world's largest commercial fleet of Boeing Vertol 107-11 (12). It also has two

Sikorsky S76's, two Bell 205's, three Bell 206's, six Hiller UH 12E's and a Hughes 500. Until recently, it also operated, under contract, a Boeing Vertol 234 Chinnook for ARCO in Alaska. Columbia Helicopters operates its helicopters in the Western U.S. and Canada, U.S. Gulf Coast, Southeast Asia and the Middle East. Its Aurora, Oregon facility has a complete repair and overhaul capability. It is particularly qualified on BV107 maintenance, including General Electric engine overhaul and rotor blade repairs. Facilities include non-destructive testing (zyglo, magnaflux), engine overhaul shop, avionics shop, hydraulics shop, painting and interior shop. It also has an engine test stand installation. It is an Aviall agency for engine repairs and is also a Bell Helicopter customer service facility. Bell Helicopter authorization includes spare parts, general maintenance and component overhaul for the Bell 205 and Bell 206. For the Bell 206, the firm also has the additional authorization for engine overhaul and helicopter modifications. Columbia Helicopters also has an in-house research and development department which has designed special equipment, particularly in heavy lift operations and helicopter logging (e.g., external load weighing, quick release hooks, viewing windows, component breakdown and built-up modules for field repairs).

AAR Western Skyways Inc. - Troutdale, Oregon

This company is a full service FBO for jet turbine and piston maintenance of both fixed wing and helicopters. It also owns AAR Aviation Supply which has eight distribution offices in the United States and Asia. It can conduct engine inspections for Pratt & Whitney, Lycoming and the Allison 250 series. It is an Aviall agency for the Allison 250 overhauls. It conducts avionics and instrument repairs for ARC, King, Collins, Sperry, Bendix and Wulfsberg. It manufactures fuel metering test stands, hydraulic power pac and pressurization test units. Bell Helicopter has authorized AAR Western Skyways to provide spare parts, general maintenance, component overhauls, engine repairs, and avionics repair and modifications to the Bell 206.

Evergreen Helicopters, Inc. - McMinnville, Oregon

This is a large helicopter charter company active in helicopter logging, aerial construction and other helicopter activities. It also has operations in the U.S. Gulf Coast area. The company also owns Rotor-Aids Inc. in Ventura, California and Evergreen Helicopters of Alaska Inc. in Anchorage, Alaska. It operates a Sikorsky S-64E "Crane" designed for heavy lift operations. In addition, it has the following equipment:

Bell 212	12
Bell 205	12
Bell 206	20
Aerospatiale 316	15
Aerospatiale 315	29
Aerospatiale 350	6
Aerospatiale 335	2

Evergreen is authorized by Bell Helicopter to provide spare parts, general maintenance and component overhaul for the Bell 47, Bell 205, Bell 206 and Bell 212. It is also an Aviall agency for the repair and exchange of turbine engines. Evergreen also has the facilities to repair and overhaul most Aerospatiale products and Sikorsky S-64, S-55 and S-58 helicopters.

Heli-Jet Corporation - Eugene, Oregon
Heli-Jet operate five Bell 205's that generally work in connection with the forest industry for fire support, helicopter logging and aerial ambulance activities. It is a Bell Helicopter customer service facility for the repair and overhaul of the Bell 205, not including engine repairs.

Paramount Helicopters, Inc. - Bend, Oregon
This is a helicopter charter operator which operates Bell 214B (3), Bell 206 (1), Hiller 12E (1), Bell 212 (1), Bell 47G (2) and an Aerospatiale 332C Super Puma. Its operations include logging, aerial construction, off-shore exploration and other general activities. It is an FAA repair station and is authorized by Bell Helicopter to provide maintenance and repair on the Bell 47, Bell 206 and Bell 214 including components and avionics, but not engine overhauls.

Rambling Rotors, Inc. - LaGrande, Oregon
The firm is a charter operator which operates a Bell 204, Bell 206 and a Bell 206L. It is an FAA repair station and is authorized by Bell Helicopter to provide maintenance, component overhaul and modifications to the Bell 206.

Transwestern Helicopters Inc. - Scappoose, Oregon
Transwestern is a charter company with Bell 206 (7), Hughes 500 (4), and Hughes 300 (2) helicopters. It is an Aviall agency for engine overhauls and exchanges. Transwestern Helicopters is also a Bell Helicopter customer service facility for repair and overhaul of the Bell 206 including component overhaul, engine repair, avionics repair and helicopter modifications. It is also a Hughes Helicopter service centre.

Pendleton Aircraft Service - Pendleton, Oregon
Pendleton offers limited helicopter maintenance services. It is not an authorized factory service centre.

Flightcraft International Ltd. - Portland, Oregon
The firm is a distributor of rotory wing spare parts including Bendix avionics, Canadian Marconi Omega VLF, Collins radio, Hughes Helicopter spare parts, Janitorial heaters, King radios, Sperry flight systems, Lear Siegler electrical, and Teledyne-Gill batteries.

Astro Tool Company Inc. - Beaverton, Oregon
This company is a manufacturer of electrical connector tools used in rotory wing aircraft.

FLIR Systems, Inc. - Lake Oswego, Oregon
This firm manufactures infrared imaging systems for helicopters. The Forward Looking Infrared (FLIR) system is used in military applications and is now being marketed for civil uses such as night security surveillance, search and rescue, forestry management, pipeline patrol and other industrial uses. The company has an STC for installation of the device on the Bell 206 and Hughes 500.

Arnav Systems Inc. - Salem, Oregon
Arnav manufactures Loran navigation systems. It manufactures four models: Arnav 20, Arnav 50, Arnav 60 and the ANA-1000. The Arnav 60 is specifically designed for helicopter installations where the panel mounting depth may be limited. This model can track two hundred way points in its computer storage, and displays the information in alpha and/or numeric outputs. Arnav is distributed by Van Dusen Air Incorporated, Gemco Sales Inc. and Avionic Associates, Inc.

9.3.5 Idaho State

Helicopter Maintenance Corporation - Boise, Idaho
The firm provides helicopter repair services and is authorized by Bell Helicopter to provide spare parts, general maintenance, component overhauls and modifications for the Bell 206. It also provides Ni-Cad battery service. Helicopter Maintenance Corporation is a National Airmotive Corp. agency for engine overhauls. National Airmotive is an Oakland, California engine repair and overhaul facility for the Allison 250 and 501/T56 turbine engines. It is similar to Aviall, Airwork Corp., and Standard Aero in providing complete engine overhauls, exchange of engines, modules and accessories.

Hillcrest Aircraft Co., Inc. - Lewiston, Idaho
Hillcrest operates both fixed wing and rotory aircraft charters. The rotory wing fleet includes the Bell 206 (11) and Aerospatiale 315 (1). It is an FAA repair station for helicopter maintenance. Other services include battery, electrical and hydraulic repairs and it is an Aviall agency for engine overhauls. Bell Helicopter authorizes Hillcrest Aircraft to offer complete maintenance service for the Bell 206 including component repair, engine repair and modifications.

Nampa Valley Helicopters - Boise, Idaho
Nampa is a small maintenance firm which specializes in Hiller Helicopter service, parts and overhaul.

Western Aircraft Maintenance, Inc. - Boise, Idaho
This large repair and overhaul centre is owned by Morrison-Knudsen, a diversified construction, forestry and building products company. It is a certified FAA repair station. It employs 65 people and utilizes four hangars with a total of 70,000 sq.ft. The company maintains repairs and modifies both fixed wing and rotory aircraft. It also staffs an avionics/instrument shop, part sales department and a land two-way radio communications division.

Western Aircraft Maintenance is an authorized Bell Helicopter customer service facility to repair and overhaul the Bell 206 including component overhaul, engine repair, avionics repair and modifications. It is also an authorized service centre for Aerospatiale (350 AStar, 355 Twin Star, 315 Lama, 318 Alouette and 341 Gazelle) and Hiller UH 12E. Western Aircraft Maintenance is an Aviall agency for engine overhauls of the Allison 250 series turbine. It specializes in dynamic component overhaul for major components such as the main rotor shaft and main gearbox assembly. It also offers exchange units on most components. Western Aircraft Maintenance mechanics and technicians are available on a 24-hour basis for unscheduled maintenance and can be dispatched to a project site to carry out field repairs. The avionics/instrument shop is a service centre for Bendix, Collins, King, Sperry and others. The instrument technicians test, repair or overhaul all instrument types from encoding altimeters to flow indicators.

Western Aircraft Maintenance has non-destructive testing facilities using magnaflux, x-ray, and fluorescent penetrant. It has a Chadwick Vibrex System for rotor blade tracking and balancing. Other services include welding, electroplating (brush cadmium plating), Ni-Cad battery service and a large parts inventory.

9.3.6 Alaska State

Air Logistics of Alaska, Inc. - Anchorage, Alaska
This company is a division of Offshore Logistics, Inc., a large Lafayette, Louisiana based helicopter firm with 145 helicopters in the fleet. The Alaska Division operates both fixed wing and rotory wing aircraft. Bell Helicopter has authorized the Alaska Division to provide parts, general maintenance and modifications for the Bell 205, Bell 206 and Bell 212/214. Component repairs for the Bell 206 are also offered. It has bases at Anchorage Airport and Metro Field, Fairbanks Airport, Alaska.

Alaska Helicopters, Inc. - Anchorage, Alaska

This company is a subsidiary company of Columbia Helicopters Inc., based in Aurora, Oregon. Alaska Helicopters operates thirteen Bell 206, four Bell 206L, two Bell 204, two Bell 205, two Hiller FH 1100 and a Boeing Vertol 107.

Alaska Helicopters is an authorized Bell Helicopter customer service facility for the Bell 205, Bell 206, and Bell 212/412. The authorization includes component overhaul for the Bell 205 and Bell 206, engine repairs for the Bell 206, avionic repairs for all models and modifications to all models.

Alaska Helicopters is an Aviall agency for the Allison 250 series turbine engine overhauls. It also provides electrical repairs and battery re-cycling.

ERA Helicopters, Inc. - Anchorage, Alaska

This is the largest Alaskan helicopter charter firm with 103 helicopters in the fleet, including the following: Bell 206 (24), Bell 206L (14), Bell 212 (16), Bell 412 (13), Bell 205 (6), Aerospatiale 350 AStar (13), Aerospatiale 355 Twin Star (1), and MBB BO 105 (15).

ERA Helicopters is an authorized Bell Helicopter customer service facility for the Bell 205, Bell 206 and Bell 212/412 including component overhaul, avionics repair and modifications. Engine repairs are also authorized for the 206. It is also an Aerospatiale service centre for the AStar and Twin Star and it is also a MBB BO 105 service centre. ERA is an Aviall agency for the Allison 250 series engine overhauls. It also provides electrical and electronic instrument repair and repair of communication, navigational and radar equipment. Battery re-cycling services are provided as well. ERA Helicopters also own the ERA Aviation Centre and Jet Alaska, an executive jet charter service. It also operates helicopter divisions in Houston, Texas and Lake Charles, Louisiana.

Kenai Air Alaska, Inc. - Kenai, Alaska

Kenai operates three Bell 206, two Bell 206L, two Bell 205 and a Bell 212 in its helicopter charter operations. It is a FAA certified repair station. Kenai Air Alaska is a Bell Helicopter customer service facility for the Bell 205, Bell 206 and Bell 212/412. It is also authorized to provide spare parts, general maintenance, component overhaul and modification service to these Bell models.

Sea Airmotive, Inc. - Anchorage, Alaska

This firm is a charter operator with five Bell 206, three Bell 205 and a Bell 212. It is a certified FAA repair station and a Bell Helicopter service centre. It is authorized to repair and overhaul the Bell 205, Bell 206 and Bell 212/412. In addition to general maintenance, component overhaul, avionics repair and modifications are authorized. Sea Airmotive also has a Ni-Cad battery shop. It is also a part of the Airwork

Corporation service centre network for the overhaul of the Allison 250 series engines. Airwork Corporation of Millville, New Jersey has complete overhaul and repair services for the Allison 250 series engine, Pratt & Whitney PT6 and Pratt & Whitney jet engines.

Trans-Alaska Helicopters, Inc. - Anchorage, Alaska
This is a helicopter charter firm which operates seven Bell 206, one Bell 206L and one Bell 205. Bell Helicopter authorizes Trans-Alaska to perform maintenance on the Bell 205 and Bell 206 including component overhaul, avionics repair and modifications. Trans-Alaska is located at Merrill Field in Anchorage.

Wingnut Aviation - Sitka, Alaska
Wingnut provides helicopter and fixed wing aircraft limited maintenance. It is not a manufacturers' service centre.

Airglas Engineering Co. Inc. - Anchorage, Alaska
The firm is a manufacturer of fixed wing and rotory aircraft skis.

9.3.7 Secondary Market Area

In the Secondary Market Area, there are competing repair and overhaul facilities and other helicopter related facilities and services. California, in particular, has numerous companies which provide helicopter related facilities and services due to the large helicopter market in the southwest and the development of the California aerospace industry in general. This subsection does not provide a detailed review of all facilities but only highlights those companies which have established reputations in the field.

9.3.7.1 Manitoba

Bristol Aerospace Limited. - Winnipeg, Manitoba

Bristol Aerospace, since 1964, has been a subsidiary of Rolls Royce Holdings Canada Ltd. Bristol Aerospace has full engineering capabilties and manufactures and overhauls a number of aerospace products including gas turbine components, sounding rockets, JATO solid propellant, payload instrumentation and weapon systems. Its annual revenue is about $75 million, 60 percent of which is military work. It also repairs and overhauls fixed-wing aircraft and helicopters. Bristol Aerospace have a metalurgical lab, metal plating shop, paint shop, sheet metal shop and other facilities. It also has complete non-destructive testing facilities.

Bristol Aerospace is a Bell Helicopter customer service centre for the Bell 205, Bell 206 and Bell 212/412. It can provide spare parts, general maintenance, component overhaul and modifications to these Bell products.

Bristol Aerospace has developed and manufactured a helicopter wire strike protection system that is now being widely distributed. The company has expressed an interest in expanding its component manufacturing expertise for the helicopter industry and is doing some sub-contract work for Bell Helicopter in making exhaust stacks for the Bell 206. It is also manufacturing some turbine engine parts. The firm anticipates becoming involved with work on the new Bell 400 program with Bell Helicopter. Bristol employs 1,250 persons in a 500,000 sq.ft. plant on 23 acres.

Standard Aero Ltd. - Winnipeg, Manitoba

This company was discussed in the British Columbia facilities and service subsection as Standard Aero, and has a field office and parts distribution facility in British Columbia. As noted earlier, Standard Aero is a leading repair and overhaul company of turbine engines in North America. It has over 200,000 sq.ft. of floor space on a 7 acre industrial site. It offers complete aviation overhaul services for piston and turbine engines, engine and airframe accessories and support services.

Piston engines overhauled encompass all Continental and Lycoming models including the Teledyne-Continental 0-470 and 0-200 series, as well as the Pratt & Whitney R985, R1340 and R1830 radial engines.

Since 1960, Standard Aero has been overhauling turbine engines. Their experience is on the Allison 501/T56, 501K and the popular Allison 250 series used in a large number of helicopters. They also overhaul General Electric T58 and Lycoming T53/T55 used in many helicopters. Other engines include the Lycoming ALF-502 and AiResearch (GARRETT) auxiliary power units (APU) and ground power units (GPU).

Accessory overhaul capabilities include fuel, oil, pneumatic and electrical systems plus a wide range of airframe components including wheels, brakes, actuators, valves and hydraulics.

StandardAero at present does most of the engine and accessory overhaul repairs for Canadian helicopters.

Boeing of Canada Ltd. - Winnipeg, Manitoba
This firm is a Division of the Boeing Airplane Company in Seattle, Washington. The Winnipeg facility was developed to manufacture fibreglass aerospace components and other fibreglass products. It now manufactures advanced composite metal and plastic structures for helicopters, noteably components for Boeing Vertol helicopters.

Composite Technology (Canada) Ltd. - Winnipeg, Manitoba
This rotor blade overhaul facility is associated with Composite Technology Inc. of Stockton, California and Composite Technics Inc. of Dallas, Texas. The Canadian facility was established in 1982 and is the first rotor blade overhaul and repair facility in Canada. It has a 20,000 sq.ft. building where overhauls, repairs and exchanges of metal and composite blades are done. Composite Technology does custom tooling for blade repairs;

maintains quality control by testing bonds, x-rays and ultrasonic inspection and uses special processes such as honing machines, vacublast equipment and painting. Each main and tail rotor blade is balanced to factory approved master blades. Composite Technology is an approved rotor blade repair facility for Bell, Hughes, Aerospatiale, MBB and Agusta helicopter products.

9.3.7.2 Arizona

Evergreen Air Centre - Marana, Arizona

This is a major FAA repair station for the maintenance, modification, repair and overhaul of commercial, military rotory and fixed wing aircraft. It is an Aviall agency for the Allison 250 series turbines. Evergreen has a full range of support shops, an Allison 250 test cell, hydraulic and servo overhaul, fuel control overhaul and test and a complete on-site and mobile NDT. It is an authorized Bell Helicopter service centre for the Bell 47, Bell 205, Bell 206 and Bell 212/412 for component overhaul, avionics repair and modifications. It is approved for engine components overhaul on the Bell 206.

Sperry Corporation - Phoenix, Arizona

The Flight Systems Avionics Division of Sperry designs and manufactures a variety of flight control systems and airborne weather radar used in helicopters. Service is also conducted on Sperry products at the Phoenix facility. Sperry has recently purchased the ARC Avionics

Company from Cessna Aircraft Company. Sperry plans to relocate the ARC Avionics Division from Boonton, New Jersey to Phoenix, Arizona.

9.3.7.3 California

Flight Accessory Services Inc. - Sun Valley, California
This firm provides overhaul and repair of helicopter accessories and is a certified FAA repair station. It is particularly skilled in hydraulic accessories such as servcs, pumps, accumulators, valves and fittings. Parts for Bell, Hughes, Aerospatiale and Sikorsky helicopter products are maintained.

Bell Helicopter Textron Inc. - Van Nuys, California
Bell Helicopter has a large facility in California to provide maintenance for all Bell Helicopter products. No engine repairs are conducted but component overhaul, avionics repair and modifications are carried out for most models. For the Bell 206, there are airframe repair fixtures for the tail boom. Bell has non-destruct testing facilities. It also does cabin fixtures for the Bell 205, Bell 206 and Bell 212.

Rotor Blades Inc. - Stockton, California
This is a certified FAA repair station for modifications and overhaul of helicopter rotor systems. It is capable of repairing root end separations, replacing root doubles and plates and replacing erosion strips on the

main and tail rotor. The facilities are approved by Bell, Hiller, Hughes and Enstrom helicopter companies for rotor blade work.

Abex Corp. - Oxnard, California
Abex manufacturers and overhauls hydraulic pumps/motors and flight control servo values for helicopters. The overhaul and repair facilities are located at Santa Monica, California.

Chadwick-Helmuth Company Inc. - El Monte, California
The firm designs and manufactures Vibrex track and balance equipment for helicopters. The system dynamically tracks and balances helicopter rotors and can be used to balance other rotating components for vibration analysis and troubleshooting. The device is available for nearly every helicopter model. In Canada, the distributor is Canadian Airmotive Ltd. located in Ottawa, Ontario.

Western Helicopters Inc. - Rialto, California
This company is a subsidiary of Rocky Mountain Helicopters Inc. based at Provo, Utah, which operates some 67 helicopters. Western Helicopters, at its California facility, provides overhaul of helicopters, and repairs engines and rotor systems. It is an Aviall agency for engine repairs of the Allison 250 series. It provides track and balancing using Chadwick equipment, electrical repairs, overhaul of hydraulic components, non-destructive testing and helicopter interiors and

painting. It is an authorized Aerospatiale service centre as well as a Bell Helicopter customer service facility. Bell Helicopter authorizes Western Helicopters to conduct component overhaul, avionics repair and modification to all Bell models except for the Bell 222. It is also authorized to conduct engine repairs on the Bell 206.

Tracor Aviation Inc. - Santa Barbara, California
Tracor is a large rotory and fixed wing modification, completion and repair company. It has a 120,000 sq.ft. facility and specializes in aircraft completions including engineering, avionics, paint, furniture fabrication and interior installations. Its maintenance and modifications include major modifications and structural repair projects.

A. Biederman, Inc. - Glendale, California
The firm is a certified FAA repair station for the sale, service and repair of rotory wing instruments.

Accessory Service Inc. - Valencia, California
This firm specializes in the overhaul and repair of hydraulic accessories. It is a licensed manufacturer of Bell Helicopter hydraulic servos for the Bell 205 and Bell 206. It is also a Bell service centre for hydraulic system components. Accessory Service has its own hydraulic research and development division.

Heliflight Systems (West), Inc. - Long Beach, California

This is the California division of Heliflight System Inc. of Houston, Texas which is, in turn, a subsidiary of Offshore Logistics, Inc., a large charter helicopter operator. Heliflight Systems (West) is an Aviall agency for Allison 250 series overhauls. It has an electrical shop, avionics shop and a paint and interior shop. It also does hydraulic overhauls and battery service. Bell Helicopter have authorized Heliflight Systems (West) to undertake complete overhaul and repair of the Bell 206 including engine overhauls. It is also authorized to conduct maintenance, avionics repair and modification to the Bell 222, one of the few stations with this capability.

Aviall - Burbank, California

Aviall maintains a large facility in California, in the former Aviation Power Supply company facilities. In 1981, the owners of Aviation Power Supply purchased Cooper Airmotive of Dallas, Texas, which was established by Edward Booth in 1932 as an aircraft repair and overhaul centre. Aviall was the name selected for the two merged companies. The total Aviall company has 2,100 employees and occupies 1.3 million sq.ft. of factory and offices in three centres (Dallas, Texas, Frederick, Oklahoma and Burbank, California). Annual sales revenue is $330 million and there is $80 million in parts inventory and $100 million in capital equipment. The helicopter portion of the business accounts for about $35-40 million in annual revenue.

The following are the helicopter engines serviced by Aviall:

Allison 250-C18	Bell 206A
Allison 250-C20	Bell 206B, Bell 206L, Agusta 109, Hiller FH 1100, Hughes 500, MBB 105, Bell/Soloy 47 and Hiller/Soloy 12E
Allison 250-C28	Bell 206L-1
Allison 250-C30	Bell 206L-3, Sikorsky S-76
Avco Lycoming T53	Bell 204 and Bell 205
Rolls Royce Gem	Westland 30

It also has experience in overhaul of the Turbomeca Artouste and Astazou turbine engines used in some Aerospatiale products.

The Burbank facility can not only overhaul turbine engines but can re-manufacture parts and accessories which are factory approved. These remanufactured parts include:

Case assembly	Compressor
Case assembly	Gearbox
Housing assembly	Gearbox
Liner assembly	Combustion
Nozzle assembly	1st, 2nd, 3rd and 4th Stage
Diffuser assembly	Turbine

As noted earlier, Aviall has established Aviall agencies throughout North and South America. Aviall provides these centres with spare parts, exchange components and technical information. The Aviall agencies are particularly experienced in Allison 250 series overhauls.

Global Systems Inc. - Irvine, California
Global manufacture the GNS-500 Omega VLF navigation system used in helicopters operating in off-shore operations. It also makes the NDB-2 navigation data bank.

Davtron Inc. - Redwood City, California
The firm is a manufacturer of digital instruments and flight instruments (VOR, DME, TAS and VNE) for helicopters.

Ensign Aircraft Company - Lakewood, California
Ensign is a manufacturer of helicopter assemblies including control pulleys, bulk heads, engine panels and hoists.

H.R. Textron Inc. - Valencia, California
Textron is manufactures hydraulic flight controls, electro-hydraulic servo valves and fuel accessories. The company is a certified FAA repair station for instrument overhaul, repair and exchange services.

Litton Industries Inc. - Calabasas, California
This is the aero products division of Litton Industries. The division manufactures inertial and Omega navigational systems.

ITT General Controls - Glendale, California

This is the aerospace product division of ITT which designs and manufactures pneumatic, fuel and hydraulic controls for helicopters.

Menasco, Inc. - Burbank, California

This is a subsidiary of Colt Industries. It designs and manufactures flight controls, actuators and rotor components for helicopters.

Scientific Atlanta, Aviation Group - San Diego, California

This firm manufactures helicopter tracking/balancing equipment and vibration monitoring equipment.

Silver Instruments Inc. - Oakland, California

They manufacture digital display fuel management computers and fuel measurement systems for helicopters.

Semco Industries Inc. - North Hollywood, California

Semco design and manufacture temperature sensors, turbine control systems and signal condition equipment for rotory wing aircraft.

Vard Newport - Santa Ana, California

Vard Newport are manufacturers of helicopter assemblies, rotor assemblies, gearboxes, pulleys and pumps for the helicopter industry.

Western Gear Corporation - City of Industry, California

The firm is a manufacturer of helicopter hoists, transmissions, control actuators, accessory devices, AC/DC electric motors and on-board cargo winches.

Universal Technology International - Santa Clara, California

This firm is a distributor of Bell Helicopter parts and components. It also handles Lycoming LTS-101 engine series parts and it distributes engines, nav/com and electronic equipment.

Weco Inc., Aerospace Systems - Burbank, California

Weco are suppliers of accessories and accessory parts for helicopters. They also handle electrical and electronic parts, and have an overhaul and repair facility to service accessories sales.

National Airmotive Corp. - Oakland, California

This is a complete overhaul and repair facility for the Allison 250 series of engines and has been mentioned in earlier sub-sections. It, like Aviall, has franchised distributor agencies where National Airmotive provides spare parts, exchange programs and technical knowledge. In addition to the Allison 250 series, National Airmotive also does the complete overhaul of the Allison 501/T56 turbine engines.

Airwork Corporation - Burbank, California

This company is based in Millville, New Jersey and has extensive operations in the Eastern and Southern United States to overhaul and repair Allison 250 series engines (Millville, New Jersey; Miami, Florida and Dayton, Ohio). It also has 70 members of a service centre network in North America. Airwork Corporation is similar to Aviall, National Airmotive and Standard Aero for engine overhauls and repairs. On the West Coast, Airwork operates Pacific Airwork Corporation which specializes in full overhaul and test of the Pratt & Whitney Canada Ltd. PT6T engine series including the Twin Pac helicopter engines and gearbox. It also repairs and overhauls the Lycoming LST 101 engine. Pacific Airwork Corporation also has a small facility at Portland, Oregon for inspection and minor engine repairs.

10.0 HELICOPTER MAINTENANCE REQUIREMENTS

The purpose of this chapter is to examine the maintenance requirements of the major helicopter models and to estimate the maintenance costs which are generated from providing such helicopter-related maintenance. The maintenance cost estimates are both for 1982 and 1990.

The information sources used to develop specific maintenance requirements and costs include material from the helicopter manufacturers, engine and accessory manufacturers, helicopter repair and overhaul companies and published literature information. It should be noted the information obtained varied considerably from helicopter model to helicopter model as to detail depending on the manufacturer and the popularity of the helicopter model. The existing maintenance experience record also varied. There are also variations on cost calculation methods which may make direct comparison difficult between helicopter models. Helicopter operator and repair and overhaul firm experience with a manufacturer's published Time Between Overhaul (TBO) hours and Retirement Life hours, while steadily improving, does not necessarily meet these targeted hours. Most operators and repair and overhaul firms note that 75-80 percent of the targeted hours is the normal experience. Unscheduled maintenance, therefore, is relatively high. The costs used, represent in most cases, approximate values and should be used only as a general cost guide. The average annual hours flown are based on FAA and Aviation Statistics Centre data for 1982 for the specific helicopter model.

For each of the most popular helicopter models in the study area, the major scheduled maintenance requirements and the maintenance costs have been documented. Maintenance requirements have been divided into two categories; component overhaul and limited life. Component overhaul maintenance items are those which are removed from the helicopter at specific time intervals for overhaul and repair and then replaced back on the helicopter. The limited life item, on the other hand, when it is removed is replaced with a new item. Metal fatigue is the reason why limited life items are not overhauled and replaced on the helicopter. In recent years, however, particularly with the use of composite materials, limited life has ben replaced by the term "on condition" (OC) whereby the item does not have a set limited life time period but is subject to continual inspection. Should there be evidence of a problem, a limited life time period is set by the manufacturer or government agencies. Air worthiness directives, if applicable, are also noted as to maintenance needs.

An estimate of the manpower labour needs to overhaul an item and the cost of materials for the overhaul of the item has been developed. In the case of the limited life items, an estimate of the cost to replace the item is calculated. The limited life replacement cost normally includes the labour of replacing the item.

Based on the manufacturer's scheduled maintenance requirements and the average number of hours flown in 1982 by the helicopter model, an estimate of the number of helicopters in the study area which will need maintenance of a particular item is calculated for 1982. A 1990 projection is developed based on the helicopter model forecast in Chapter 4.0 and assuming that helicopter utilization and scheduled maintenance time requirements remain relatively stable over the 1980's.

A total value for component overhaul and limited life items is calculated based on the unit price, labour costs, and the number of helicopters requiring the specified maintenance for 1982 and 1990. Those maintenance items which are frequent maintenance items or relatively high value items are noted for each helicopter model.

10.1 BELL 47

Maximum Gross Weight - 2,850 lbs.
Maximum Load - 1,194 lbs.
Engine Model - Lycoming TVO Piston in models since 1956
Soloy Conversion Allison 250-C20B available
Stopped Production in 1974
Average Annual Hours Flown - 365

Market

1982			1990		
Primary	Secondary	Total*	Primary	Secondary	Total
137	332	469	90	220	310

* Includes 50 Soloy Conversions in 1982

Component Overhaul

Component	TBO	Estimated Manhours	Unit Price ($U.S.)	1982 No. Units	1990 No. Units
Main Transmission 47-620-600	1200	24	12,000	143	95
Main Rotor Head 47-120-184	1200	24	2,800	143	95
Swash Plate Assembly 47-150-259-7	1200	13	1,600	143	95
Mast Assembly 47-130-114	1200	3	600	143	95
Engine Mount Assembly 47-612-171	1200	8	800	143	95
Engine Mount Adaptor Plate 47-612-800	1200			143	95
Tail Rotor Gearbox 47-641-159	1200	16	2,000	143	95
Tail Rotor Assembly 47-641-159	1200	8	900		
Tail Rotor Shaft	1200	7	240	143	95
Engine Fan Assembly 47-661-All	1200	12	1,000	143	95
Engine Overhaul Lycoming TVO 435	1000	100	12,000	171	113

Limited Life

Component	Hours	Unit Price ($U.S.)	1982 No. Units	1990 No. Units
Main Rotor Blade 47-110-250-23	5000	14,134	34	22
Main Rotor Hub Yoke 47-120-177-1	5000	6,545	34	22
Main Rotor Blade Grips(2) 47-120-177-1	5000	1,940	34	22
Tail Rotor Hub Yoke 47-641-126-5	2500	1,518	69	46
Tail Rotor Blade 47-642-117-1	2500	2,350	69	46
Engine Mount Assembly 47-612-171-123	2500	1,940	69	46

Air Worthiness Directives
A.D. No. CF-83-06 FAA-AD 80-10-04 Bell 47 all series Action: Removal from service of Tail Rotor Blades (PN 47-642-102 [all numbers] with more than 300 flight hours.

Component Overhaul Value
(Can. 1982/83 Dollars) (Based on a shop labour rate of $40/hr.)

	1982	1990
Main Transmission	$2,247,576	$1,483,400
Main Rotor Head	629,388	415,396
Swash Plate Assembly	355,576	234,680
Mast Assembly	186,344	122,987
Engine Mount Assembly	186,344	122,987
Engine Mount Adapter Plate		
Tail Rotor Gearbox	443,044	292,409
Tail Rotor Assembly	204,061	134,680
Tail Rotor Shaft	82,142	54,214
Engine Fan Assembly	244,338	161,263
Engine Overhaul (depends on replacement parts)	2,682,680	1,770,569
	$7,197,795	$4,750,544

Limited Life Value*
(Can. 1983 dollars) (U.S. unit prices converted at 1.23 percent)

	1982	1990
Main Rotor Blade (Set)	$ 594,567	$ 392,414
Main Rotor Hub Yoke	275,310	181,705
Main Rotor Blade Grips	163,202	107,713
Tail Rotor Hub Yoke	127,890	84,407
Tail Rotor Blade	198,034	130,702
Engine Mount Assembly	163,441	107,871
	$1,522,444	$1,004,812

* Labour installation values are generally reflected in component overhaul.

It can be noted that the 1990 values are expected to be a third less than 1982 due to the fewer number of Bell 47 helicopters which will likely be in operation. The number of Bell 47G31B1 and Bell 47G3B2 are expected to decline due to the higher cost of spare parts. Bell increased its spare parts cost by 50-100 percent in 1983 over the 1982 price list. The Bell 47G2 is expected to remain a popular pilot trainer but it too is affected by high spare parts cost. Many Bell 47's are still used by the agricultural industry, particularly in the U.S. Southwest.

The higher value overhaul components are engine overhauls, main transmission overhauls, main rotor head overhauls and tail gearbox overhauls. The higher value limited life components are the main rotor blades, main rotor hub yokes and tail rotor blades.

10.2 BELL 204/205

Maximum Gross Weight - 9,500 lbs.
Maximum Load Bell 204 - 4,800 lbs.
Bell 205 - 4,300 lbs.
Engine Model - Lycoming T53 turbine in most models.
General Electric T58 in some Bell 204's.
Stopped Production in 1981
Average Annual Hours Flown 575

Market

1982			1990		
Primary	Secondary	Total	Primary	Secondary	Total
87	67	154	74	57	131

Component Overhaul

Component	TBO	Manhours	Unit Price ($US Approx)	1982 No. Units	1990 No. Units
Main Transmission	1000	155	20,000	88	75
59-141	2500	25	4,000	35	30
59-131	1500	18	2,500	59	50
Input Drive Shaft	3000	11	1,500	30	25
Main Rotor Mast	1000	17	3000	88	75
Stabilizer Bar	3000	26	4000	30	25
Main Rotor Head	2400	70	11,000	24	20
Swash Plate and Support	3000	40	6,000	30	25
Scissors and Sleeve Assembly	3000	30	4,800	30	25
Tail Rotor Hub	2,500 (or 4 yrs.)	20	3,000	38	33
Tail Rotor 90° Gearbox	3,000 (or 4 yrs.)	18	2,500	38	33
Tail Rotor 42° Gearbox	3,000 (4 yrs.)	20	3,200	38	33
Tail Rotor Blade	5000	12	2,000	18	15
Engine Overhaul (approximate)					
Light Overhaul	1500	50	20,000	59	50
Major Overhaul	3000	300	60,000	30	25
Engine only not accessories					

Limited Life

Component	Hours	Unit Price ($U.S.)	1982 No. Units	1990 No. Units
Main Rotor Head				
Pitch Horn	3000	550	30	25
Torsion Tension Straps	1200 (or 3 yrs.)	2500	51	43
Outboard Strap Fitting	3600	700	25	21
Inboard Strap Fitting-5	1200	650	74	63
Inboard Strap Fitting-7	2400	650	37	31
Strap Pins (4)	2400	110	37	31
Yoke	3600	5100	25	21
Swash Plate and Support				
Drive Link	9000	380	10	9
Outer Ring	9000	1400	10	9
Support	1000	725	89	76

Mast Bearing				
204-9 Bearing	1000	1500	89	76
205-1 Bearing	2500			
Main Rotor Blades (set)	4000	23500	22	19
Tail Rotor Blades (set)	5000	4000	18	15
Tail Rotor Yoke				
744-5 Assembly	1000	800	89	75
704-1	4000	2500	22	19
744-1	4000	2500	22	19
Tail Rotor Drive Shaft				
Bearing Hangers - 9	1000	75	89	75
Bearing Hangers - 5	2500 (or 4 years)	100	39	33
Hydraulic Servos (2)	2400	250	37	31
Engine Oil Cooler Blower Bearings (4)	1000	12	89	75

Airworthiness Directives
Incorporated into current inspection and overhaul manuals.

Component Overhaul Values
(Can. 1982/83 Dollars) (Based on a shop labour rate of $40/hr.)

	1982	**1990**
Main Transmission	$2,710,400	$2,303,840
59-141	207,200	176,120
59-131	223,905	190,319
Input Drive Shaft	68,550	58,268
Main Rotor Mast	384,560	326,876
Stabilizer Bar	178,800	151,980
Main Rotor Head	391,920	333,132
Swash Plate and Support	269,400	228,990
Scissors and Sleeve Assembly	213,120	181,152
Tail Rotor Hub	170,620	145,027
Tail Rotor 90° Gearbox	144,210	122,578
Tail Rotor 42° Gearbox	179,958	152,973
Tail Rotor Blade	79,488	67,565
Engine Overhaul (Approximate)		
Light Overhaul	1,569,400	1,333,990
Major Overhaul	2,574,000	2,187,900
(Engine overhaul depends on replacement parts needed)	$9,365,531	$7,960,710

Limited Life Value*
(Canadian 1983 Dollars) (U.S. Unit prices converted at 123 percent)

	1982	1990
Main Rotor Head		
Pitch Horn	$ 16,500	$ 14,025
Torsion Tension Straps	156,825	133,301
Outboard Strap Fitting	21,525	18,296
Inboard Strap Fitting-5	59,163	50,288
Inboard Strap Fitting-7	29,582	25,144
Strap Pins (4)	20,024	17,020
Yoke	156,825	133,301
Swash Plate and Support		
Drive Link	4,674	3,973
Outer Ring	17,220	14,637
Support	79,366	67,460
Mast Bearing		
204-9 Bearing	164,205	139,525
Main Rotor Blades	635,910	540,524
Tail Rotor Blades	88,560	75,276
Tail Rotor Yoke		
744-5 Assembly	87,576	74,440
704-1	67,650	57,503
744-1	67,650	57,503
Tail Rotor Drive Shaft		
Bearing Hangers-9	8,210	6,979
Bearing Hangers-5	4,797	4,077
Hydraulic Servos	22,755	19,342
Engine Oil Cooler Blower Bearings (4)	5,255	4,466
	$1,714,272	$1,457,080

* Labour installation values are generally reflected in component overhaul.

The 1990 values are expected to be about 15 percent lower than those shown for 1982 due to a slowly decreasing number of these models which will continue to be operated in the late eighties. They will likely be replaced by twin engine, light and medium helicopters. There is a high percentage of the total Bell 204/205 production in the study area and they are popular due to their low capital cost and payload carrying ability.

The higher value overhaul components are main transmission overhaul, engine overhauls (both light and major), main rotor head overhauls, and main rotor mast overhauls. High replacement value parts include the main rotor blades, main rotor head yokes, torsion tension straps and the main mast bearing assemblies.

10.3 BELL 206*

Maximum Gross Weight - 3,200 lbs.
Maximum Load - 1,630 lbs.
Engine Model - Allison 250 (C20/C20B)
(Bell 206A has 250-C18 series engine)
Average Annual Hours Flown 600.

Market

1982			1990		
Primary	Secondary	Total	Primary	Secondary	Total
625	383	1008	920	525	1445

*Includes both Bell 206A and Bell 206B models.

Component Overhaul

Component	TBO	Estimated Manhours	Unit Price	1982 No. Units	1990 No. Units
Main Rotor Hub Assembly	1200	33	5500	504	720
Main Rotor Mast Assembly	2400	6	1000	252	360
Swashplate Assembly	2400	18	3000	252	360
Transmission	2400	31	5000	252	360
Freewheeling Assembly	3000	6	1200	202	288
Hydraulic Servo Actuator	2400	5	800	252	360
Hydraulic Pump and Reservoir	2400	5	800	252	360
Tail Rotor Gearbox Assembly	2400	20	3600	252	360
Tail Rotor Hub Assembly	2400	10	1600	252	360
Engine Overhaul Allison 250	3000	230	50,000	202	288

Limited Life

Component	Hours	Unit Price ($U.S.)	1982 No. Units	1990 No. Units
Collective Idler Link 206-010-407-1	4800	395	126	180
Servo Activator Support 206-001-566-01	4800	4,590	126	180
Collective Lever 206-010-467-1	4800	630	126	180
Collective Tube (Lower) 206-001-194-1	4800	310	126	180
Main Rotor Blade (2) 206-010-200-33	4800	10,475	126	180
Main Rotor Trunnion 206-011-113-103	4800	760	126	180
Main Rotor Grip (2) 206-011-132-9	4800	2,200	126	180
Main Rotor Retention Straps (2) 206-011-147-7	1200	1,740	504	720
Retention Strap Fitting (2) 206-011-124-1	2400	590	252	360
Retention Strap Pin (2) 206-010-125-1	1200	115	504	720
Swashplate Bearing 206-010-443-1	2400	640	252	360
Swashplate Sleeve Assembly 206-010-454-5	4800	1280	126	180
Swashplate Support Assembly 206-010-452-5	4800	1065	126	180
Tail Rotor Blade (2) 206-016-201-1	2400	2300	252	360
Tail Rotor Yoke 206-011-811-9	4800	1450	126	180

Airworthiness Directives
AD 82-17-04 Bell 206A, B and L Action: Inspection of tail rotor blades and repair or replacement as necessary to prevent loss of blade tip block and balance weight. (25 hour repetitive inspections required).
AD 82-24-05 Bell 206 all Action: Bendix fuel control and governor inspection
AD 82-13-03 Allison C20 engine. Action: High Pressure Filter mods.
AD 81-18-01 Bell 206 all Action: Rotor head trunnion inspection and replacement.
AD 83-03-02 DDA-250 C20/C20B/C20C Action: Remove and inspect third stage turbine wheels for blade and/or sheared separation.

Component Overhaul Value
(Can. 1982/83 Dollars) (Based on a shop labour rate of $40/hr.)

	1982	**1990**
Main Rotor Hub Assembly	$ 4,074,840	$ 5,827,021
Main Rotor Mast Assembly	370,440	529,729
Swashplate Assembly	1,111,320	1,589,188
Transmission	1,862,280	2,663,060
Freewheeling Assembly	346,632	495,683
Hydraulic Servo Actuator	298,368	426,666
Hydraulic Pump and Reservoir	298,368	426,666
Tail Rotor Gearbox Assembly	1,317,456	1,883,962
Tail Rotor Hub Assembly	596,736	853,332
Engine Overhaul	14,281,400	20,422,402
	$24,557,840	$35,117,709

Limited Life Value*
(Canadian 1983 Dollars) (U.S. unit prices converted at 123 percent)

	1982	1990
Collective Idler Link	$ 61,217	$ 87,540
Servo Actuator Support	711,358	1,017,242
Collective Lever	97,637	139,621
Collective Tube (Lower)	48,044	68,703
Main Rotor Blade (2)	3,246,830	4,642,968
Main Rotor Trunnion	117,785	168,432
Main Rotor Grip (2)	681,913	975,134
Main Rotor Retention Strap (2)	2,157,321	3,084,970
Retention Strap Fitting (2)	365,753	523,026
Retention Strap Pin (2)	142,582	203,892
Swashplate Bearing	198,374	283,675
Swashplate Sleeve Assembly	198,374	283,675
Swashplate Support Assembly	165,054	236,027
Tail Rotor Blade (2)	1,425,816	2,038,917
Tail Rotor Yoke	224,721	321,351
	$9,842,778	$15,050,307

* Labour installation values are generally reflected in component overhaul.

It can be seen that the Bell 206 series represents a very large market potential for repair and overhaul. It is estimated that the 1982 value is approximately $34 million and is expected to raise to over $50 million by 1990 as more Bell 206's are added to the fleet. The growth rate in the future is expected to decrease due to competition from the Aerospatiale 350 AStar and Hughes 500. There will also be competition for the Bell 206L and the new Bell 400 series when it is introduced in the late 1980's.

The higher value overhaul components are the main rotor hub assemblies, transmissions, tail rotor gearbox assemblies and the swashplate assemblies. In terms of limited life parts, the main rotor blades are the highest value, followed by the main rotor retention straps and tail rotor blades. The servo actuator supports and the main rotor grips are also significant in terms of total value.

10.4 BELL 206-L LONG RANGER

Maximum Gross Weight - 4150 lbs.
Maximum Load - 1947 lbs.
Engine Model - Allison 250-C28B
Average Annnual Hours Flown - 730

Market

1982			1990		
Primary	Secondary	Total	Primary	Secondary	Total
60	77	137	88	114	202

Component Overhaul

Component	TBO	Estimated Manhours	Unit Price ($U.S.)	1982 No. Units	1990 No. Units
Main Rotor Hub Assembly	1200	35	5,600	83	122
Main Rotor Trunnion Assembly	1200	8	1,300	83	122
Swashplate Assembly	2400	20	3,200	42	62
Cyclic Pivot Support	1200	5	800	83	122
Hydraulic Actuators	2400	5	800	83	122
Transmission	1800	35	5,800	55	80
Freewheeling Assembly	1200	8	1,300	83	122
Tail Rotor Gear Box Assembly	1800	22	3,600	55	80
Engine Overhaul Allison 250	3000	235	55,000	33	48

Limited Life

Component	Hours	Unit Price ($US)	1982 No. Units	1990 No. Units
Main Rotor and Control				
Retention Strap Fitting (2) 206-011-124-1	2400	590	42	62
Retention Strap Pin (2) 206-011-125-1	1200	115	83	122
Retention Strap (2) 206-011-147-7	1200	1,740	83	122
Grip (2) 206-011-132-9	4800	2,200	20	30
Blade (2) 206-015-001-1	3600	12,200	28	40
Mast 206-040-535-101	5000	5,800	20	29
Latch Bolt (2) 206-011-260-101	1200	300	83	122
Cyclic Tube (2) 206-001-193-1	4800	810	20	30
Main Rotor Trunnion 206-011-120-103	2400	1,070	42	62
Swashplate and Support				
Duplex Bearing 206-010-443-1	2400	640	42	62
Collective Lever Idler 206-010-407-1	4800	400	20	30
Swashplate Support 206-010-452-15	4800	1,060	20	30
Swashplate Sleeve 206-010-454-5	4800	1,280	20	30
Collective Lever 206-010-467-1	4800	630	20	30
Miscellaneous Bolts	1000	725	100	147
Tail Rotor and Gearbox Components				
Tail Rotor Blade (2) 206-016-201-1	2400	2300	42	62
Gearbox Duplex Bearing 206-040-410-3	1200	485	83	122
Tail Rotor Yoke 206-011-819-401	5000	1650	20	29

Airworthiness Directives
Same as Bell 206 and AD 83-03-04, Bell 206 L, 206 L-1 Action: Inspection to determine whether float valve assembly has been damaged by incorrect installation.

Component Overhaul Value

(Can. 1982/83 Dollars) (Based on a shop labour rate of $40/hr.)

	1982	1990
Main Rotor Hub Assembly	$687,904	$1,011,219
Main Rotor Tunnion Assembly	159,277	234,137
Swashplate Assembly	198,912	292,400
Cyclic Pivot Support	98,272	144,460
Hydraulic Actuators	49,728	73,100
Transmission	469,370	689,974
Freewheeling Assembly	159,277	234,137
Tail Rotor Gearbox Assembly	291,940	429,152
Engine Overhaul	2,542,650	3,737,770
	$4,657,330	$6,846,349

Limited Life Value

(Canadian 1983 Dollars) (U.S. Unit Prices Converted at 123 Percent)

	1982	1990
Main Rotor and Control		
Retention Strap Fitting (2)	$60,958	$89,608
Retentin Strap Pin (2)	23,480	34,515
Retention Strap (2)	355,274	522,253
Grip (2)	108,240	159,113
Blade (2)	840,336	1,235,294
Mast	142,680	209,740
Latch Bolt (2)	61,254	90,043
Cyclic Tube (2)	39,852	58,582
Main Rotor Tunnion	44,940	66,062
Swashplate and Support		
Duplex Bearing	33,062	48,062
Collective Lever Idler	9,840	14,465
Swashplate Support	26,076	38,332
Swashplate Sleeve	31,488	46,287
Collective Lever	15,498	22,782
Miscellaneous Bolts	89,175	131,087
Tail Rotor and Gearbox Components		
Tail Rotor Blade (2)	237,636	349,324
Gearbox Duplex Bearing	49,514	72,785
Tail Rotor Yoke	40,590	59,667
	$2,209,893	$3,248,541

*Labour installation valves are generally reflected in component overhaul.

Component Overhaul

Component	TBO	Estimated ManHours	Unit Price ($U.S.)	1982 No. Units	1990 No. Units
Main Rotor Hub Assembly	2400	70	11,500	25	34
Main Rotor Mast Assembly	1500	18	3,000	40	55
Swashplate and Support	1000	40	6,500	61	83
Scissors and Sleeve	1000	30	5,000	61	83
Transmission Assembly	2500	155	26,000	24	33
Hydraulic Cylinders	2400	20	3,500	25	34
Driveshaft Assembly	1000	15	2,500	61	83
Starter Generator	1000	15	2,200	61	83
Tail Rotor Hanger Assembly	2500	18	3,000	24	33
42^{o} Gearbox Assembly	2500	22	3,500	24	33
90^{o} Gearbox Assembly	2500	18	3,000	24	33
Tail Rotor Hub Assembly	2500	25	4,000	24	33
Engine Overhaul	3000	200	60,000 (Can.)	20	28

(Reduction gearbox 2750 hrs. Rotor components on flight cycles above 10,000 hrs. - Fuel control and accessories at engine overhaul time.)

Limited Life

Component	Hours	Unit Price ($U.S.)	1982 No. Units	1990 No. Units
Main Rotor				
Blade (2) 212-015-501-5	4000	23,410	15	21
Inboard Strap Fitting (2) 212-010-102-7	2400	665	25	34
Outboard Strap Fitting (2) 204-012-103-5	3000	710	20	28
Pins (4) 204-012-103-5	2400	115	25	34
Strap (2) 204-012-122-5	1200	1,865	51	70
Pitch Horn (2) 204-011-120-5	3000	550	20	28
Yoke 204-011-120-5	3600	5,100	23	31

Main Rotor Mast/Controls				
Collective Sleeve 204-011-408-3	9000	1,180	7	9
Drive Link (2) 204-011-407-1	9000	385	7	9
Gimbal Ring 204-010-404-1	9000	910	7	9
Mast Bearing 204-040-136-9	1000	1,445	61	83
Mixing Lever 212-010-302-1	9000	550	7	9
Swashplate Outer Ring 204-011-403-1	9000	1,370	7	9
Pitch Link (2) 204-011-403-1	9000	1,275	7	9
Scissors Hub 204-011-127-3	9000	715	7	9
Scissors Tube (2) 212-010-404-5	9000	1,715	7	9
Stabilizer Bar Tube (2) 204-011-328-11	5000	415	12	17
Stabilizer Bar Frame 204-011-307-1	10000	1,665	6	8
Swashplate Support 204-011-404-121	1000	1,665	6	8
Pitch Link (2) 204-011-127-3	9000	1,275	7	9
Scissors Hub 204-011-405-13	9000	715	7	9
Scissors Tube (2) 212-010-404-5	9000	1,715	7	9
Stabilizer Bar Tube (2) 204-011-328-11	5000	415	12	17
Stabilizer Bar Frame 204-011-404-121	1000	725	61	82
Control System Bolts	1000	725	61	82
Tail Rotor Components				
Blade (2) 212-010-750-9	5000	3,820	12	17
Yoke Assembly 212-010-704-5	5000	2,600	12	17
Shaft Hangers Bearings (4) 204-040-623-5	1000	75	61	83
Power Plant and Related System				
Oil Cooler Blower Bearing (2) W 202 PP	1000	10	61	83
Oil Cooler Blower Bearing (2) 9104 PP	1000	10	61	83

Airworthiness Directives
CF-83-03 P&W PT6T-3B Twin Pac: Action: Improved P3 oil filter.

Component Overhaul Value
(Canadian 1982/83 Dollars) (Based on a shop rate of $40/hr.)

	1982	1990
Main Rotor Hub Assembly	$ 423,625	$ 576,130
Main Rotor Mast Assembly	205,400	279,344
Swashplate and Support	585,295	796,000
Scissors and Sleeve	448,350	609,756
Transmission Assembly	916,320	1,246,195
Hydraulic Cylinders	127,625	173,570
Drive Shaft Assembly	224,175	304,878
Starter Generator	201,666	274,265
Tail Rotor Hanger Assembly	105,840	143,942
42° Gearbox Assembly	124,440	169,238
90° Gearbox Assembly	105,840	143,942
Tail Rotor Hub Assembly	142,080	193,229
Engine Overhaul (Depends on replacement parts	1,360,000	1,849,600
	$4,970,656	$6,760,089

Limited Life Value

	1982	1990
Main Rotor		
Blade (2)	$ 863,829	$1,174,807
Inboard Strap Fitting (2)	40,898	55,621
Outboard Strap Fitting (2)	28,400	38,624
Pins (4)	14,145	19,237
Straps (2)	233,982	318,217
Pitch Horn	27,060	36,802
Yoke	144,279	196,219
Main Rotor Mast/Controls		
Collective Sleeve	10,160	13,817
Drive Link (2)	6,630	9,016
Gimbal Ring	7,835	10,656
Mast Bearing	108,418	147,449
Mixing Lever	4,736	6,440
Swashplate Outer Ring	11,796	16,042
Pitch Link (2)	21,956	29,859
Scissors Hub	6,156	8,372
Scissors Tube (2)	29,532	40,164
Stabilizer Bar Tube (2)	12,251	16,661
Stabilizer Bar Frame	12,288	16,711
Swashplate Support	28,136	38,265
Control System Bolts	54,397	73,980

Tail Rotor Components		
Blade (2)	112,766	153,362
Yoke Assembly	38,376	52,191
Shaft Hangers Bearings (4)	22,509	30,612
Power Plant and Related Systems		
Oil Cooler Blower Bearing	750	1,020
Oil Cooler Blower Bearing	750	1,020
	$1,842,035	$2,505,164

* Labour installation values are generally reflected in component overhaul.

The number of twin-engine Bell 212's is expected to increase at abour 4 percent per annum and therefore the value of component overhead and limited life parts will also increase. The Bell 212 is subject to competition from other Bell products, particularly the Bell 412, the four-bladed version of the 212. The Bell 212 also competes with the Aerospatiale Twin-Star and the BK 117.

The higher value component overhaul items on the Bell 212 include the engine overhauls, transmission assemblies, swashplates and supports, scissors and sleeves, and main rotor hub assemblies. Similarly, the higher value limited life parts include the main rotor blades, main rotor straps, yokes, tail rotor blades and the main rotor mast bearings. It can be noted that a number of the parts used are common to the Bell 204. There are also parts which are common with the Bell 412, the four-bladed version of the 212. The Bell 412 analysis follows.

10.5 BELL 412

Maximum Gross Weight - 11,600 lbs.
Maximum Load - 5,433 lbs.
Engine Model - Pratt & Whitney PT6T-3B, Twin Pac
Average Annual Hours Flown - 700

Market

1982			1990		
Primary	Secondary	Total	Primary	Secondary	Total
20	1	21	27	4	31

Component Overhaul

Component	TBO	Estimated ManHours	Unit Price ($U.S.)	1982 No. Units	1990 No. Units
Main Rotor Hub Assembly	2500	80	12,800	6	9
Main Rotor Mast Assembly	2500	25	4,000	6	9
Swashplate and Support	2500	45	7,200	6	9
Hub and Sleeve	2500	30	5,000	6	9
Flight Controls Hyd. Cylinder	2500	10	1,800	6	9
Transmission	2500	175	28,000	6	9
Hydraulic Drive Quill	2500	15	2,500	6	9
Input Quill Assembly	2500	10	1,600	6	9
Rotor Brake	2400	6	1,000	6	9
Tail Rotor Hub Assembly	2500	25	4,000	6	9
Tail Rotor Gearbox 90°	2500	20	3,200	6	9
Tail Rotor Gearbox 42°	2500	25	4,000	6	9
Tail Rotor Driveshaft Hangers	2500	15	2,400	6	9
Tail Rotor Hydraultic Cylinder	2500	10	1,600	6	9
Tail Rotor Drive Quill	2500	6	960	6	9
Engine Overhaul	3000	200	60,000 (Can.)	5	7

Limited Life

Component	Hours	Unit Price ($U.S.)	1982 No. Units	1990 No. Units
Main Rotor Hub and Blade				
Yoke Assembly (longflex) 412-010-101-113	5000	24,130	3	4
Spindle (4) 412-010-156-105	5000	11,630	3	4
Pitch Horn (4) 412-010-149-105	5000	2,410	3	4
Retention Bolt (4) 412-010-124-105	5000	610	3	4
Retention Bolt (4) 412-010-137-103	5000	900	3	4
Damper Bridge (forging) (8) 412-010-185-101	10000	290	1	2
Pivot Bearing (4) 412-010-106-101	5000	4,845	3	4
Fitting (4) 412-010-111-103	5000	1,410	3	4
Damper Set (4) 412-010-145-101	5000	1,710	3	4
Blades (fibreglass over 10,000 hrs.)				
Main Rotor Controls				
Pitch Link Assembly (long) (2) 412-010-425-101	5000	2,720	3	4
Pitch Link Assembly (short) (2) 412-010-425-121	5000	2,025	3	4
Swashplate Link Assembly (2) 412-010-406-111	5000	3,700	3	4
Swashplate Link Assembly 412-010-406-113	5000	3,150	3	4
Drive Hub Assembly 412-010-445-101	10000	2,420	1	2
Rephasing Lever Assembly (4) 412-010-403-113	5000	2,150	3	4
Drive Link Assembly 412-010-405-101	5000	3,335	3	4
Swashplate Outer Ring 412-010-407-105	10000	2,760	1	2
Swashplate Support Assembly 412-010-443-101	5000	2,400	3	4
Gimbal Ring Assembly 412-010-404-001	9000	910	2	2
Collective Sleeve 412-011-408-003	9000	1,180	2	2
Collective Lever Assembly 412-010-408-101	10000	2,435	1	2
Control System Bolts 412-704-112-101	1500	745	10	14

Propulsion and Drive System				
Main Rotor Mast Assembly 412-040-101-109	10000	8,300	1	2
Cap Assembly 412-010-171-101	10000	890	1	2
Nut 412-010-172-101	10000	380	1	2
Cone 412-010-165-101	10000	865	1	2
Drive Pin 412-010-166-101	10000	180	1	2
Upper Cone Seat 412-010-186-101	10000	1,205	1	2
Splined Plate Assembly 412-010-177-101	10000	2,800	1	2
Lower Cone Seat 412-010-178-101	10000	1,910	1	2
Cone 412-010-174-101	10000	1,215	1	2
Tail Rotor Installation				
Tail Rotor Assembly (2) 212-010-750-009	5000	3,820	3	4
Tail Yoke Assembly 212-011-702-001	5000	4,330	3	4
Rotor Brake				
Quill Bearing 204-040-425-001	600	230	24	36

Airworthiness Directives
PT6-T-3B engine AD, the same as Bell 214. AD T82-26-51 Bell 412. Action: Retirement life of the main rotor yoke reduced to 700 hours. (inspection)

Component Overhaul Value
(Canadian 1982/83 Dollars) (Based on a shop rate of $40/hr.)

	1982	1990
Main Rotor Hub Assembly	$ 113,664	$ 167,086
Main Rotor Mast Assembly	35,520	52,214
Swashplate and Support	63,936	93,986
Hub and Sleeve	44,100	64,827
Flight Controls Hydraulic Cylinder	15,684	23,055
Transmission	248,640	365,500
Hydraulic Drive Quill	22,050	32,414
Input Quill Assembly	14,208	20,886
Rotor Brake	8,820	12,965
Tail Rotor Hub Assembly	30,000	44,100
Tail Rotor Gearbox 90°	28,416	41,772
Tail Rotor Gearbox 42°	35,520	52,214
Tail Rotor Driveshaft Hangers	21,312	31,329
Tail Rotor Hydraulic Cylinder	14,208	20,886
Tail Rotor Drive Quill	8,525	12,532
Engine Overhaul (depends on replacement parts needed)	340,000	499,800
	$1,044,603	$1,535,566

Limited Life Value	1982	1990
Main Rotor Hub and Blade		
Yoke Assembly (longflex)(2)*	$178,079	$ 261,777
Spindle (4)	171,659	252,338
Pitch Horn (4)	35,572	52,290
Retention Bolt (4)	9,004	13,235
Retention Bolt (4)	13,284	19,527
Damper Bridge (forging)(8)	2,854	4,195
Pivot Bearing (4)	71,512	105,123
Fitting (4)	20,812	30,593
Damper Set (4)	25,240	37,102
Main Rotor Controls		
Pitch Link Assembly (long)(2)	20,074	29,508
Pitch Link Assembly (short)(2)	14,945	21,968
Swashplate Link Assembly (2)	27,306	40,110
Swashplate Link Assembly	11,624	17,086
Drive Hub Assembly	2,977	4,376
Rephasing Lever Assembly (4)	31,734	46,649
Drive Link Assembly	12,306	18,090
Swashplate Outer Ring	3,395	4,990
Swashplate Support Assembly	35,424	52,073
Gimbal Ring Assembly	2,239	3,291
Collective Sleeve	2,903	4,261
Collective Lever Assembly	2,995	4,403
Control System Bolts	9,164	13,470
Propulsion and Drive System		
Main Rotor Mast Assembly	10,209	15,007
Cap Assembly	1,095	1,609
Nut	467	687
Cone	1,064	1,564
Drive Pin	221	325
Upper Cone Seat	1,482	2,179
Splined Plate Assembly	3,444	5,063
Lower Cone Seat	2,349	3,453
Cone	1,494	2,197
Tail Rotor Installation		
Tail Rotor Assembly (2)	28,192	41,442
Tail Yoke Assembly	15,978	23,487
Rotor Brake		
Quill Bearing	6,790	9,981
	$777,887	$1,175,552

* Assume AD T82-26-51 re main rotor yoke reduction as to retirement life only temporary.

The Bell 412 is expected to experience an increase in the value of component, overhaul and limited life replacement parts as more Bell 412's are introduced to the market. The Bell 412 competes with the two-bladed Bell 212 and also with the higher performance, longer range, Bell 214ST. It also competes with the Aerospatiale AS 355 Twin Star, MBB BK 117 and the Sikorsky S-76 to some extent.

The higher value overhaul components are the engine overhauls, transmissions and main rotor hub assemblies. The high value limited life replacement parts are the yoke assemblies and the spindles which are very high cost items in relation to the rest of the limited life replacements.

10.6 BELL 214 (Including ST Model)

Maximum Gross Weight - 16,000 lbs. (ST 17,500 lbs.)
Maximum Load - 5,973 lbs. (ST 7,886 lbs.)
Engine Model - Lycoming T55
(ST-twin General Electric CT7-2)
Military T-700 version
Average Annual Hours Flown - 635
(ST Average Hours Flown - N/A)

Market

1982			1990		
Primary	Secondary	Total	Primary	Secondary	Total
13	3	16	20	25	45

Component Overhaul

Component	TBO	Estimated ManHours	Unit Price ($U.S.)	1982 No. Units	1990 No. Units
Main Rotor Hub Assembly	2500	80	14,000	4	11
Swashplate and Support	2500	50	8,000	4	11
Scissors and Sleeve	2500	35	5,600	4	11
Transmission	2500	180	32,000	4	11
Main Rotor Mast Assembly	2500	30	5,000	4	11
Main Drive Shaft	2500	50	8,000	4	11
Combining Gearbox	2500	30	5,000	4	11
Hydraulic Activators (3)	2500	45	7,200	4	11
Tail Rotor Hub	2500	30	4,800	4	11
Gearbox 90° Assembly	2500	25	4,000	4	11
Gearbox 42° Assembly	2500	30	5,000	4	11
Engine Overhaul (depends on cycles) (2)	(est.) 2500	200	75,000	4	11

Limited Life

Component	Hours	Unit Price ($U.S.)	1982 No. Units	1990 No. Units
Main Rotor Hub and Blades				
Blade Assembly (2) 214-015-300-105	5000	97,940	2	5
Yoke 214-010-105-001	5000	26,140	2	5
Trunnion 214-010-220-101	5000	6,030	2	5
Spindle (2) 214-010-103-003	5000	11,995	2	5
Grip Assembly (2) 214-010-104-113	2500	5,610	4	11
Barrel Drag Brace (2) 214-010-120-003	5000	965	2	5
Clevis Drag Brace (2) 214-010-121-001	5000	4,395	2	5
Strap Fitting (2) 214-010-115-001	5000	4,395	2	5
Strap (2) 214-010-179-003	1,250	3,965	8	22
Pin (2) 214-010-117-001	2,500	165	4	11
Pitch Horn Assembly 214-010-200-103	5000	10,795	2	5
Pillow Block Bearing Bolts (2) 20-057-12-50D	1,250	35	8	22
Pillow Block Bearing Bolts (2) 20-057-12-48D	1,250	35	8	22

Main Rotor Controls				
Pitch Link Assembly (2) 214-010-410-011	5000	2,350	2	5
Scissors Assembly (2) 214-010-506-105	5000	2,145	2	5
Scissors Hub Assembly 214-010-505-101	5000	2,425	2	5
Swashplate Outer Ring 214-010-503-105	5000	2,850	2	5
Collective Lever Assembly 214-010-474-109	5000	1,160	2	5
Collective Sleeve 214-010-411-001	5000	4,120	2	5
Collective Idler Link 214-010-558-001	5000	4,120	2	5
Swashplate Inner Ring 214-010-402-113	5000	7,180	2	5
Swashplate Support 214-010-504-101	5000	2,765	2	5
Drive Link Assembly (2) 214-010-536-101	5000	3,280	2	5
Housing (3) 214-010-538-101	5000	920	2	5
Hydraulic Actuator (3) 214-076-161-001	10000	42,150	1	2
Trunnion 214-010-539-101	5000	2,045	2	5
Rod End Bearing 214-001-051-007	10000	1,270	1	2
Rod End Bearing 214-001-051-009	10000	1,270	1	2
Rod End Bearing 214-001-051-013	10000	1,315	1	2
Tail Rotor Hub and Blades				
Tail Rotor Blade Assembly (2) 214-015-700-103	2500	7,990	4	11
Grip Plate Set (2) 214-010-822-101	5000	1,570	2	5
Yoke Assembly 214-010-702-107	5000	8,440	2	5
Elevator and Controls				
Elevator Spar 214-021-101-111	5000	1,555	2	5
Elevator Actuator (2) 214-001-970-101	5000	10,000	2	5
Elevator Assembly 214-021-100-103	5000	4,570	2	5
Elevator Assembly 214-021-100-104	5000	4,570	2	5
Drive System				
Transmission Restraint Case 214-040-063-109	1500	13,250	6	19
Main Rotor Mast 214-040-090-109	5000	12,380	2	5
Tail Rotor Mast 214-040-404-101	5000	5,855	2	5
Nodalized Pylon				
Transmission Spindle (2) 214-030-606-103	5000	2,275	2	5
Fore and Aft Restraint (2) 214-031-612-115	5000	2,990	2	5

Airworthiness Directives
AD 82-26-07 Bell 214 ST Action: Reinforcement modification of the attachment longeron on the upper left tail boom.

Component Overhaul Value
(Can. 1982/83 Dollars) (Based on a shop rate of $40/hr.)

	1982	1990
Main Rotor Hub Assembly	$ 88,080	$ 247,505
Swashplate and Support	47,360	113,082
Scissors and Sleeve	33,152	93,157
Transmission	186,240	523,334
Main Rotor Mast Assembly	29,400	82,614
Main Drive Shaft	47,360	133,082
Combining Gearbox	29,400	82,614
Hydraulic Actuators (3)	42,624	119,773
Tail Rotor Hub	28,416	79,849
Gearbox 90° Assembly	26,616	74,791
Gearbox 42° Assembly	29,400	82,614
Engine Overhaul	802,000	2,253,620
	$1,390,048	$3,886,035

Limited Life Value*

	1982	1990
Main Rotor Hub and Blades		
Blade Assembly (2)	$ 391,760	$1,100,846
Yoke	64,304	180,694
Trunnion	14,834	41,683
Spindle (2)	59,015	165,833
Grip Assembly (2)	55,202	155,119
Barrel Drag Brace (2)	4,748	13,341
Clevis Drag Brace (2)	21,623	60,762
Strap Fitting (2)	6,691	18,802
Strap (2)	78,031	219,268
Pin (2)	1,624	4,562
Pitch Horn Assembly	2,866	8,053
Pitch Horn Assembly	26,556	74,621
Pillow Block Bearing Bolts (2)	560	1,574
Pillow Block Bearing Bolts (2)	560	1,574

Main Rotor Controls		
Pitch Link Assembly (2)	11,562	32,489
Scissors Assembly (2)	10,553	29,655
Scissors Hub Assembly	5,965	16,763
Swashplate Outer Ring	7,011	19,701
Collective Lever Assembly	2,853	8,019
Collective Sleeve	10,135	28,480
Collective Idler Link	6,716	18,871
Swashplate Inner Ring	17,663	49,632
Drive Link Assembly (2)	16,138	45,347
Housing (3)	6,790	19,079
Hydraulic Actuator (3)	155,533	437,049
Trunnion	5,031	14,136
Rod End Bearing	1,562	4,389
Rod End Bearing	1,562	4,389
Rod End Bearing	1,617	4,545
Tail Rotor Hub and Blades		
Tail Rotor Blades (2)	78,622	220,927
Grip Plate Set (2)	7,724	21,705
Yoke Assembly	20,762	58,341
Elevator and Controls		
Elevator Spar	3,825	10,749
Elevator Actuator (2)	49,200	138,252
Elevator Assembly	11,242	31,590
Elevator Assembly	11,242	31,590
Drive System		
Transmission Restraint Case	97,785	274,776
Main Rotor Mast	30,455	85,578
Tail Rotor Mast	14,403	40,472
Nodalized Pylon		
Transmission Spindle (2)	11,193	31,452
Fore and Aft Restraint (2)	14,711	41,337
	$1,348,593	$3,785,158

The Bell 214, particularly the ST (Super Transport) version, is a relatively low production volume helicopter due to its size and cost. It is an 18-place helicopter and its VFR price is $4.3 million U.S. However, it is proving to be a popular helicopter in operations where its payload and range can be used such as off-shore exploration. It is expected that the number of Bell 214 ST's will increase substantially, particularly for off-shore operations in Alaska, Beaufort/Arctic and Southern California (Santa Barbara Channel). The value of component overhaul and replacement limited life parts on a unit-basis are relatively high since maintenance is relatively sophisticated on this complex helicopter.

The higher value overhaul components are the engine overhauls which is expected of twin, 1600 horsepower turbo-shaft engines. The transmissions are also a relatively high value components. The higher value limited life replacement components are the rotor blades and the hydraulic actuators. The drive systems, transmission restraint cases, the tail rotor blades and the main rotor straps are also relatively high value components.

10.7 HUGHES 500/369*

Maximum Gross Weight - 3550
Maximum Load - 1660
Engine Model - Allison 250-C20B
Average Annual Hours Flown - 510

Market

1982			1990		
Primary	Secondary	Total	Primary	Secondary	Total
207	194	401	305	285	590

* Includes all models of the Hughes 500/369 Series

Component Overhaul

Component	TBO	Estimated ManHours	Unit Price ($U.S.)	1982 No. Units	1990 No. Units
Main Transmission 369D 25100	3000	45	7,200	68	100
Tail Rotor Transmission 369D 25400	4800	12	1,800	42	62
Overrunning Clutch 369A 5350-603	1800	6	980	114	167
Swashplate 369B 27609	3770	5	750	54	80
Main Rotor Hub Assembly 369D 212 000) overhauled at Hughes only)	2770	80	12,600	72	108
Engine Overhaul Allison 250	3000	230	50,000	68	100

Limited Life

Component	Hours	Unit Price ($U.S.)	1982 No. Units	1990 No. Units
Main Rotor Blade (2) 369D 2110-505	2500	5,390	82	120
Main Rotor Blade (2) 369D 21100-509	2500	5,490	82	120
Main Rotor Hub 369D 21201	5700	3,900	36	53
Main Rotor Vertical Hinge Link 369H 1203	2960	280	69	101
Retention Straps (2) 369D 21210-501	2770	1,415	74	108
Lead/Lag Damper 369D 21400-503	6060	2,055	34	50
Main Rotor Drive Shaft 369D 255 10	3000 (on condition)	3030	68	100
Main Transmission Drive Shaft 369A 5510	3790	3,915	54	79
Tail Rotor Drive Shaft 369D 25518	4190	1,850	49	72
Main Transmission Drife Shaft Coupling 369H 5660	3790	385	54	79
Tail Rotor Drive Shaft and Flex Coupling 369A 5501	4980	1,575	41	60
Tail Rotor Hub Assembly 369A 1725-5	2440	995	84	123
Tail Rotor TT Straps (2) 269A 1706-501	5100	585	40	59
Tail Rotor Blade 369D 21613-11	5140	1,855	40	58
Horizontal Stabilizer 369D 230601-511	3800	5,965	54	79
Vertical Stabilizer 369D 23600-50B	3500	6,220	58	86
Sprague Overrunning 369A 5364	1800	480	114	167

Airworthiness Directives
AD 83-03-02 DDA-250 C20/C20B/C20C Action: Remove and inspect third stage turbine wheels for blade and/or sheared separation.
AD 84-01-02 Action: Inspection for mising part on main-rotor swashplate.

Component Overhaul Value

(Can. 1982/83 Dollars) (Based on a shop labour rate of $40/hr)

	1982	1990
Main Transmission	$ 724,608	$ 1,065,174
Tail Rotor Transmission	113,148	166,328
Overrunning Clutch	164,776	242,221
Swashplate	60,615	89,104
Main Rotor Hub Assembly	1,383,652	2,033,968
Engine Overhaul (depends on replacement parts needed)	4,807,600	7,067,172
	$7,254,399	$10,663,967

Limited Life Value*

(Can. 1983 Dollars) (U.S. unit prices converted at 123 percent)

	1982	1990
Main Rotor Blades	$1,087,271	$1,598,288
Main Rotor Blades	1,107,443	1,627,941
Main Rotor Hub	172,692	253,857
Main Rotor Vertical Hinge Link	251,215	369,286
Retention Straps (2)	257,587	378,652
Lead/Log Damper	85,940	126,332
Main Rotor Drive Shaft	253,429	372,541
Main Transmission Drive Shaft	260,034	382,250
Tail Rotor Drive Shaft	111,500	163,904
Main Transmission Driveshaft Coupling	25,572	37,590
Tail Rotor Drife Shaft and Flex Coupling	79,427	116,758
Tail Rotor Hub Assembly	97,637	143,527
Tail Rotor TT Straps (2)	57,564	84,619
Tail Rotor Blade	91,266	134,161
Tail Rotor Blade	100,122	147,179
Horizontal Stabilizer	396,195	582,407
Vertical Stabilizer	443,735	652,290
Sprague Overrunning	67,306	98,939
	$4,945,935	$7,270,521

* Labour installation values are generally reflected in component overhaul.

The Hughes 500 series helicopter is a popular light turbine helicopter and is expected to continue to experience growth rates in the 1982-1990 period. It is a relatively low cost helicopter and has good performance. Its cabin room is considered small but a is a good crash-resistant design. Its main competition is the Bell 206 and the Aerospatiale 350 AStar.

The maintenance is reported to be relatively straightforward for major components but ongoing daily maintenance needs are onerous. Spare parts delivery problems have been noted by several repair and overhaul shops and operators. Hughes Helicopter does not appear to have the same caliber of customer service as does Bell Helicopter or Aerospatiale based on discussions with operators.

The higher value overhaul components are, of course, the engine overhauls. Main rotor hub assemblies are also a high value overhaul component but it can only be overhauled and repaired by Hughes Helicopters. Overhaul of the main transmissions is also a high value item.

In terms of limited life replacement part values, the main rotor blades have the highest value. The Hughes 500 has horizontal and vertical stabilizers which are high value due to their unit cost and low retirement life hours. The retention straps, rotor drive shafts, transmission driveshafts and vertical hinge links are also high value items.

10.8 AEROSPATIALE 350 ASTAR

Maximum Gross Weight - 4,300 lbs.
Maximum Load - 1,968 lbs.
Engine Model - Lycoming LTS-101-600
(Turbomeca Arriel in European Version)
Average Annual Hours Flown - 680

Market

1982			1990		
Primary	Secondary	Total	Primary	Secondary	Total
80	53	133	137	85	222

Component Overhaul

Component	TBO	Estimated ManHours	Unit Price ($U.S.)	1982 No. Units	1990 No. Units
Main Gearbox					
Epicylic Gear B50A32-0100-01	2000	60	10,365	45	75
Reduction Gearbox 350A32-0300-02	2050	75	12,260	44	75
Oil Pump Assembly 350A32-0400-00	2050	8	1,265	44	74
Tail Rotor Gearbox 350A33-008-04	2450	35	5,600	37	62
But in Spare = 4 Servos 704A44-831-063	1800	10	1,570 (exchange)	50	84
T1 Senser (Temp Comp)	2400	2	250	38	63
Engine Overhaul Lycoming LTS-101	2400	240	38,000 (Can.)	38	63

Limited Life

Component	Hours	Unit Price ($U.S.)	1982 No. Units	1990 No. Units
Main Rotor Blades 350A11-0010-02 (3)	2400 (on condition)	44,550 (set)	38	63
Main Rotor Head 350A31-000-03				
Starflex Body 350A31-1901-01	2400	9,965	38	63
Thrust Bearing 704A33-633-28 (3)	2400 (on condition)	1365	38	63
Special Thrust Bearing Bolts (6) 350A31-2051-20	2000	60	45	75
Main Rotor Shaft 350A37-0003-04 704A3-652-006	2400 (on condition)	10,300	38	63
Bearing INF 47896W/47820	2400 (on condition)	395	38	63
Coupling Bolts (6) 350A37-1242-22	2200	25	41	69
Coupling Bolts (6) 350A37-1243	2200	30	41	69
Tail Rotor Blades 350A12-0030-01	4000	8,650	23	38
Blade Horn (2) 350A12-1268-03	unlimited	470	-	-
Main Gearbox 350A32-0010-00				
Engine to MGB Coupling 350A35-1101-0001	2400	1,110	38	63
Drive Belt 704A33-690-004	600	10	151	252
Coupling Housing 350A35-1104-02	unlimited	1,495	-	-
Cross Beam Assembly 350A38-1018-32	2400 (on condition)	745	38	63
Front Strut: MGB Mount (2) 704A33-633-036	1000	505	90	151
Rear Strut: MGB Mount (2) 704A33-633-035	1000	505	90	151
Pitch Change Driver Assembly 350A33-2009-01	2400 (on condition)	1,770	38	63
Pitch Change Link (2) 350A33-2121-01	1000	320	90	151
Tail Rotor Elastomeric (2) 704A33-633-061	2400 (on condition)	130	38	63
Tail Rotor Driveshaft 350A34-0100-02	2400 (on condition)	2,540	38	63
Flexible Coupling 350A34-1000-00	2400 (on condition)	530	38	63
Shaft Bearings (6) 704A33-651-010	1200	20	110	184
AC-64182 (3) 704A44-831-062	2400 (on condition)	2,000	38	63
Starter/Generator 2928-2/3	1200	4,680	110	184

* MGB Main Gearbox

Airworthiness Directives
AD 82-175-29(B) Aerospatiale 350 All Models. Action: Repetitive inspection of main gearbox - oil/monitoring.
AD 82-176-28(B) Aerospatiale 350 All Models. Action: Repetitive inspection of bolted junction (20 bolts) for tightness - bevel ring gear/vertical shaft of bevel reduction gear module on main gearbox.
AD 82-177-30(B) Aerospatiale 350 All Models. Action: Repetitive inspections of tail rotor blades spars for cracks.
AD 82-157-27(B) Aerospatiale 350 All Models. Action: Modification on repetitive inspection to improve fuel filter by-pass reliability.
AD 83-07 Aerospatiale 350 All Models. Action: Repair electrical wiring attached to air bottle prior to overwater flying.
AD 83-16-03 Lycoming LTS 101-600A2. Action: Installation of overspeed limitors.
AD 83-07-05 Aerospatiale 350 All Models. Action: Reduce inspection intervals and establish a life limit on the main rotor mast. Service life of the mast now limited to 450 hours.

Component Overhaul Value
(Can. 1982/83 Dollars) (Based on a shop rate of $40/hr.)

	1982	1990
Main Gearbox		
Epicyclic Gear	$ 681,702	$1,138,442
Reduction Gearbox	795,511	1,328,503
Oil Pump Assembly	82,542	137,845
Tail Rotor Gearbox	306,565	512,115
But in Spare = 4 Servos	116,555	194,647
Tl Sensor (Temp.Comp.)	14,725	24,591
Engine Overhaul (Leavens Services Overhaul Ltd. Toronto, Ont.)	1,808,800	3,020,696
	$3,806,491	$6,356,839

Limited Life Value

	1982	1990
Main Rotor Blades	$2,082,267	3,477,386
Starflex Body	465,764	777,826
Thrust Bearing (3)	191,400	319,639
Special Thrust Big Bolts (6)	19,926	33,276
Main Rotor Shaft	481,422	803,975
Bearing	18,462	30,832
Coupling Bolts (6)	7,565	12,633
Coupling Bolts (6)	9,077	15,159
Tail Rotor Blades	244,708	408,663
Engine to MGB Coupling	51,881	86,642
Drive Belt	1,857	3,102
Cross Beam Assembly	34,821	58,152
Front Strut: MGB Mount (2)	111,807	186,718
Rear Strut: MGB Mount (2)	111,807	186,718
Pitch Change Driver Assembly	82,730	138,159
Pitch Change Link (2)	70,848	118,317
Tail Rotor Elastomeric (2)	12,152	20,294
Tail Rotor Driveshaft	118,720	198,262
Flexible Coupling	24,772	41,370
Shaft Bearings (6)	16,236	27,114
AC-64182 (3) (Dunlop)	280,440	468,335
Starter/Generator	633,204	1,057,451
	$5,071,866	$8,470,023

* Labour installation values are generally reflected in component overhead.

The Aerospatiale 350 AStar is gaining a share of the light turbine market due to its lower capital cost, the value of the French franc and the use of composite components which reduces maintenance costs. It is reported, however, that the cost of spare parts and delivery delays may offset the lower capital cost. Aerospatiale customer service is apparently improving in North America. The reliability of the Lycoming LTS-101 engine is a concern for some operators of the AStar.

It is expected that the AStar will experience a growth rate average of about 4 percent per annum for the light turbine in the period 1982-1990. The value of component overhaul and replacement of limited life parts will reflect this higher than normal growth rate.

The higher value component overhaul items on the AStar are the engine overhauls, reduction gearboxes, epicyclic gears in the main gearboxes and the tail rotor gearboxes. In terms of limited life items, the main rotor blades have the highest value. The starter/generators, main rotor shafts, Starflex bodies, and the tail rotor blades are also high value. Note many limited life parts are "on condition" and therefore 2400 hours was selected as appropriate by Aerospatiale representatives for calculation purposes in this study.

10.9 AEROSPATIALE 355 TWIN STAR

Maximum Gross Weight - 5,070 lbs.
Maximum Load - 2,264 lbs.
Engine Model (2) Allison 250-C20F
Average Annual Hours Flown - 530

Market

1982			1990		
Primary	Secondary	Total	Primary	Secondary	Total
12	15	27	20	26	46

Component Overhaul

Component	TBO	Estimated ManHours	Unit Price ($U.S.)	1982 No. Units	1990 No. Units
Fuel Pumps P94C16-602 (2)	1200	10	1,275	12	20
Main Gearbox					
Epicyclic Reduction Gear 350A32-0100-05	2000	70	11,275	26	45
Coupling Gearbox 355A32-0200-02	2000	80	13,325	26	45
Bevel Reduction Gear 355A32-0600-01	2000	80	13,140	26	45
Oil Pump Assembly 355A32-0700-01	2000	8	1,265	26	45
Tail Rotor Gearbox 350A33-0200-04	2400	35	5,600	6	10
Tail Rotor Servo Dunlop	3000	9	1,560	5	8
FWD Servo (AC) 704A44-831-109	3000	10	1,900	5	8
L.H. Servo (AC) 704A44-831-109	3000	10	1,900	5	8
R.H. Servo (AC) 704-A44-831-110	3000	10	1,200	5	8
Starter/Generator (2) 150-SG-117-Q1	1200	12	2,070	12	20
Engine Overhaul Allison (2) 250-C20F	3500	250	63,450	4	7

Limited Life

Component	Hours	Unit Price ($U.S.)	1982 No. Units	1990 No. Units
Main Rotor Blades (3) 355A11-0020-00	2000	4,625 (repair)	7	12
Main Rotor Head 355A31-0001-00	2400	(on condition)	6	10
Starflex Body 350A31-1901-01	2400	9,965	6	10
Sleeve 350A31-1831-06(lower) (3)	8000	1,460	2	3
Sleeve 350A31-1831-07(upper) (3)	800	1,460	2	3
Spherical Brg. Bolt 350A31-2067-20 (6)	1000	60	14	24
Spherical Thrust Brg. 704A33-6400-31 (3)	1000	1,365	14	24
Frequency Adaptors 704A33-6400-31 (3)	2400 (on condition)	695	6	10
Anti-Vibrator Assembly 350A31-0033-01	2400 (on condition)	7,090	6	10
Rotor Shaft 350A37-003-14 704A33-652-006	2400 (on condition)	10,300	6	10
Bearing I.N.F. 47866W/47820	2400	400	6	10
Attach Bolts MRH 350A37-1242-22 (6)	2200	25	6	11
350A37-1243-22 (6)	2200	30	6	11
Main Gearbox				
Upper Fitting 355A32-2026-20	2400 (on condition)	45	6	10
355A32-2028-21 L/H	2400 (on condition)	30	6	10
Lower Fitting 355A32-2029-21 R/H	2400 (on condition)	15	6	10
Input Flange, Reduction Gear (2) 355A32-2095-21	1000	545	14	24
Engine Shaft Assembly (2) 355A35-2034-00	1000	310	14	24
Coupling Housing 355A35-2004-03 (4)	unlimited	790	-	-
355A35-2004-02	unlimited	-	-	-
Gimbal Ring Assembly 355A35-0510-03 (2)	1000	3,310	14	24
Liminate Bearing LAT704A33-633-012 (4)	2400 (on condition)	90	6	10
LONG704A33-633-069 (4)	2400 (on condition)	140	6	10

Airworthiness Directives
AD83-03-02 DDA-250 C20. Action: Remove and inspect third stage turbine wheels for blade and/or sheared separations.
AD 83-08-04 Aerospatiale 355. Action: Replacement of the epicyclic planet pinion cage in the main transmission as per new schedule.
AD 83-08-04 Aerospatiale 355. Action: Emergency AD to reduce the time in service of certain main transmission parts. Serious crack in less than 1000 hours noted.
AD 83-07-05 Aerospatiale 355. Action: Repetitive inspection intervals and establish a life limit on the main rotor mast. Mast cracks noted. Service life of the mast now limited to 450 hours.

Component Overhaul Value
(Can. 1982/83 Dollars) (Based on a shop rate of $40/hr.)

	1982	1990
Fuel Pumps	$ 47,238	$ 80,305
Main Gearbox		
Epicyclic Reduction Gear	433,375	736,739
Coupling Gearbox	477,354	811,502
Bevel Reduction Gear	503,417	855,809
Oil Pump Assembly	48,775	82,918
Tail Rotor Gearbox	49,728	84,538
Tail Rotor Servo	11,394	19,370
FWD Servo (AC)	13,685	23,265
L.H Servo (AC)	13,685	27,265
R.H. Servo (AC)	15,530	26,401
Starter/Generator	72,626	123,464
Engine Overhaul	704,348	1,197,392
	$2,391,155	$4,072,967

Limited Life Value*

	1982	1990
Main Rotor Blades (repair)	$119,464	$ 203,088
Main Rotor Head		
Starflex Body	73,542	125,021
Sleeve	10,775	18,317
Sleeve	10,775	18,317
Spherical Brg. Bolt	6,199	10,539
Spherical Thrust Brg.	70,516	119,877
Frequency Adaptors	15,387	26,158
Anti-Vibration Assembly	52,324	88,951
Rotor Shaft	76,014	129,224
Bearing	2,952	5,018
Attach Bolts, MRH (6)	1,107	1,882
(6)	1,328	2,258
Main Gearbox		
Upper Fitting	332	565
	221	376
Lower Fitting	111	188
Input Flange, Reduction Gear	18,770	31,909
Engine Shaft Assembly	10,676	18,150
Gimbal Ring Assembly	113,996	193,793
Liminate Bearing LAT	2,657	4,516
LONG	4,133	7,026
Tail Rotor Blade Assembly	31,918	54,261
Flexible Coupling 1st & 2nd	7,823	13,299
Flexible Coupling 3rd & 4th	7,823	13,299
Flexible Coupling 5th	2,509	4,265
Fan Unit Axial Wheel	68,191	115,925
Bearings	2,214	3,764
Control Plate Assembly	9,594	16,310
Non-Rotating Control Plate	2,288	3,890
Hub Assembly	6,089	10,350
Load Sensor	67,847	115,340
	$797,575	$1,355,876

The Aerospatiale 355 Twin Star is a relatively new addition to the medium twin helicopter market. It is expected to experience above average growth rates for the 1982-1990 period as operators are attracted to its twin engine performance, relatively low capital cost and state of the art technology. The value of component overhaul and limited life replacement parts will reflect the expected growth rate in the sale of the Twin Star.

The engine overhauls for the Allison 250's are the highest value overhaul components, followed by the main components of the main gearboxes (bevel reduction gear, coupling gearbox and epicyclic reduction gear). The starter/generators are also a relatively high value component.

In terms of replacement limited life parts, repairs to the main rotor blades, gimbal ring assemblies, rotor shafts, Starflex bodies, and the spherical thrust bearings are all high value component items. It can be noted that there are some common replacement parts between the Twin Star and the AStar.

10.10 SIKORSKY S-76

Gross Maximum - 10,000 lbs.
Maximum Load - 4,525 lbs.
Engine Model (2) Allison 250-C30
Average Annual Hours Flown - 550

Market

1982			1990		
Primary	Secondary	Total	Primary	Secondary	Total
15	4	19	25	6	31

Component Overhaul

Estimated ManHours and Unit Prices Not Available

Component	TBO	1982 No. Units	1990 No. Units
Minor Components			
Vertical Gyro	2000	5	8
Yaw Rotor Gyro	2500	4	7
AFCS Actuator Assembly	2500	4	7
Bifilar Weight	12000	1	1
Major Components			
D.C. Starter Generator	1000	10	17
Bleed Air Valve	4000	3	4
Main Gearbox	1500	7	11
Intermediate Gearbox	3000	3	5
Tail Rotor Gearbox	3000	3	5
Main Rotor Servos	3000	3	5
Tail Rotor Servos	1500	7	11
Engine Overhauls	3500	3	5
2 Allison 250-C30	1500 turbine assembly only		

Limited Life

Component	Hours	1982 No. Units	1990 No. Units
Pylon	9000	1	2
Spar Cap Angle			
Stabilizer Slot Damper			
Lead Slot Kit	150	70	113
Power Train			
Quill Shaft-103	2440	4	7
-104	4550	2	4
Spline Adapter Shaft - 105	1750	6	10
- 106	3000	3	6
Shaft and Spar Pinion	1500	7	11

Main Rotor			
Bifilar Spacer	1900	5	9
Main Rotor Blade	11750	1	1
Bearing Outer Race (KANA Approved)	1000	10	17
Pitch Horn	8000	1	2
Hub Assembly	4900	2	3
Rotating Scissors	500	21	34
Rotating Scissors Hub Bolt	500	21	34
Rotating Scissors Hub Bolt	500	21	34
Main Rotor Mast	4520	2	4
Spindle Caps Assembly	5000	2	3
Spindle Nut	5000	2	3
Transmission			
Spline Adapter Shaft - 105	1750	6	10
- 106	3000	3	6
Quill Shaft - 103	2440	4	7
- 104	4550	2	4
Shaft and Spur Pinion	1500	7	11
Tail Rotor Control Cables	1500	7	11
Tail Rotor Blade	20,000 (or 5 years)	4	6

Unscheduled Replacement Parts	
Main Rotor Blade	2000 - 3000 hours
Tail Rotor Blade	2000 - 3000
Main Gearbox	1000 - 1200
DC Starter/Generator	500 (brush changes)
Vertical Gyro	400 - 500
AFCS Actuator Assembly	400 - 600
Bifilar Weight	1000 - 1500 (bushing change)
Strobe Light Power Supply (Grimes)	300 - 500

Airworthiness Directives

AD 82-25-01 Sikorsky S-76A. Action: Inspection for cracks on left and right hand main landing gear position rod end fittings (PN KRI-OMEAK).

AD 82-17-03 Sikorsky S-76A. Action: Repetitive inspection of the rotor brake disk-to-disk clearance to prevent rotor brake malfunction.

AD 83-11 Sikorsky S-76A Action: Inspections of forward spar caps on the vertical pylons.

AD 84-06-02 Action: Inspection of tail-rotor plugs and addition of retaining pad.

The Sikorsky S-76 is a medium-weight twin-engine turbine that has been introduced to the market in the last few years. It has proven to be a popular helicopter for corporate operations and off-shore exploration operations where its twin-engine and range are an advantage. The average annual hours flown are relatively low to date which likely reflect the maintenance requirements of a new helicopter model (eg. Okanagan Helicopters'experience is 3.9 man hours of labour per flight hour as to compared to 2.1 man hours for the Bell 212). It is expected that the average hours should increase to the 800 -1000 range in a short time. There has been some concern by operators as to the high maintenance requirements of the helicopter and the lack of manufacturer support. Some express the opinion that since a large portion of Sikorsky's business is military, the manufacturer has not had to deal with civil operators which do not have large back-up maintenance facilities or their research and development sources to solve problems.

10.11 SIKORSKY S-61 L/N

Gross Maximum Weight - 22,050

Maximum Load - 5,323

Engine Models (2) General electric CT-58

Stopped Production in 1980 but still manufactured under licence by Agusta.

Average Annual Hours Flown - 840

Market

1982			1990		
Primary	Secondary	Total	Primary	Secondary	Total
16	7	23	14	5	19

Component Overhaul

Component	TBO	Estimated ManHours	1982 No. Units	1990 No. Units
Main Rotor Assembly	2250	400	9	7
Dampers	2250 (or 3 yrs.)		9	7
Hydraulic Servos	1000		19	16
Tail Rotor Assembly - 31500	1500	40	13	11
- 31400	1750		11	9
Transmission (Heavy Lift)	750 (500 Free Wheel Inspection)	450		
(General Operators)	2000 (1000 Free Wheel Inspection or 1550 TBO overhaul)		10	8
Gearbox 42°	3800	45	5	4
Tail Rotor Gearbox	3800	60	5	4
Tail Rotor Driveshaft				
#1, 2, 3, 4 Sections	3000		6	5
#5 Section	3500		5	4
Transmission Oil Cooler Blower (Heavy Lift Operations)	1500		13	11
Pitot Valve (Engine)	3000		6	5
Flow Divider	3000		6	5
Centrifugal filter	2000		10	8
Auxilliary Servo	2500		8	6
Primary Servo	2500		8	6
Hydraulic Pump (Auxilliary)	2000		10	8
Hydraulic Pump (Primary)	2000		10	8
AC Generator (bushless)	2000		10	8
(bushes)	1500		13	11
DC Generator	1000		19	16
Main Landing Gear Shock Strut	5000		4	3
Tailwheel Assembly Shock Strut	5000		4	3
Primary Hydraulic Manifold	2000		10	8
Auxiliary Hydraulic Manifold	2000		10	8
Ground Invertor	1000		19	16
Heater Fuel Shut-off Value	2000		10	8
AC Supervisor PNL	1200		16	13
Heater	2000		10	8
Vertical Gyro (Pilot to Pilot)	1500		13	11

Engine Overhaul GE CT-58				
Mid-Point Engine	2000	400	10	8
High Speed Flight	4000		5	4
Major Engine Overhaul	4000	850	5	4
Fuel Control(Hamilton Standard)	2000		10	8
Bleed Value	3000		6	5
Fuel Pump	3000		6	5

Limited Life

Component	Hours	1982 No. Units	1990 No. Units
Main Rotor Blades (early models)	3600	5	4
(later models)	9400	2	2
Barrel Nuts or Main Gearbox O/H	3000	6	5
Barrel Nuts or Tail Rotor Gearbox O/H	3800	5	4
Main Rotor Head			
Horizontal Hinge Pair	4000	5	4
Damper Assembly Tower	2850	7	5
Damper Assembly Lower Spacer	2850	7	5
Strut - Upper Bracket	3000	6	5
Damper Bracket - Upper	3000	6	5
Horizontal Hinge Pair	5300	4	3
Spindle	3000	6	5
Spindle Assembly - 041	6000	3	3
Damper Cylinder Head Assembly	2700	7	6
Damper Piston Rod	3300	6	5
Damper Piston Rod (with improved valve assembly)	7000	3	2
Damper Trunnion	3200	6	5
Damper Trunnion (with improved trunnion assembly)	5200	4	3
Lug, Upper Damper Mounting	4800	4	3
Lug, Lower Damper Mounting	4800	4	3
Tail Rotor Flapping Hinge Bolt - 1	1800	11	9
Tail Rotor Flapping Hinge Bolt - 2	4200	5	4
Spindle Main Rotor Head - 1	3000	6	5
- 101	6000	3	3

Unscheduled Component Removals (High)
Motorized Hydraulic Pump 167N-100
Retracting Cylinder S6125-63101-7
Tail Wheel
Primary Servo Assembly - Various
Auxiliary Servo Assembly S6165-61500 Services
Fuel Centrifugal Purifier 400T01PO3
Starter Motor 20069-010

Airworthiness Directives
AD 78-20-05 R4 Sikorsky S-61. Action: Further revision of AD by clarifying applicability decreasing inspection intervals and updating other information.
AD 83-17-04 Sikorsky S-61. Action: Reported Spur Gear failures requires repetitive inspections for steel particles in the main gearbox chip detector and scavenge screen. Inspection required every 10 hours.

The Sikorsky S-61 has been a limited civil production model due to its size, capital cost and operating cost. It is used mainly by operators for logging operations or off-shore exploration where its heavy payload and seating capabilities can be used. It is expected that this helicopter will be slowly phased out of operations due to competition from more technically advanced helicopters such as the Aerospatiale AS 332 Super Puma and, to some extent, the Bell 214 ST and even the larger Boeing Vertol Chinook. Operators, who have had the S-61 for many years and have heavy annual utilization, give it good marks for maintenance reliability. Others have not had the same maintenance reliability due to limited exposure to the helicopter and the inherent difficulties of working on a large, complex helicopter.

10.12 DETROIT DIESEL ALLISON 250-SERIES

There are over 18,000 Allison 250 series turbine engines. They are installed in a variety of helicopters including the Bell 206, Hughes 500, Aerospatiale 355, Hiller FH 100, MBB BO 105 and Sikorsky S-76. The following outlines the maintenance schedule for the Allison 250-C20.

Hot End Inspection	1750 hours	(Improved Turbine)
Overhaul	3500 hours	(Improved Turbine)
Overhaul	1000 hours	(Non-Improved Turbine)

Component Overhaul

Component	TBO
Fuel Pump Sundstrand (not-improved)	1500
Fuel Pump Sundstrand (improved)	2250
Fuel Pump Sundstand single element	2250
CECO Fuel Control Unit	4000
CECO Governor AC + All	2000
(early models Fuel Control Unit and Governor)	1000
Bendix Fuel Control	2000
Governor	1500
Fuel Nozzles	1500/2000

Limited Life Removals

Component	Hours	Cycles
Empeller Assembly original	2500	7500
Empeller Assembly relocated hub	3550	9150
Gas Producer Turbine Rotor		
1st stage wheel original	1550	3000
1st stage wheel thick rim	1775	3000
2nd stage wheel originals and conversion	1550	3000
2nd stage wheel charged contour	1775	3000
2nd stage wheel pilot diameter	1775	3000

Power Turbine			
3rd stage wheel	(15 parts)	4550	6000
	(12 not hour limited)		6000
3rd stage wheel	centre shaft scallop (5 part numbers)		6000
4th stage wheel	original	4550	6000
4th stage wheel	machined web	4550	6000

10.13 SUMMARY

The total expenditures for repair, overhaul and servicing of the principal helicopter models in the Primary and Secondary Market Areas is estimated to be $96.4 million in 1982, and is projected to increase to over $132.8 million by 1990. When other helicopter models such as all the Sikorsky series, Hiller, Enstrom, Agusta are included the expenditures would be well in excess of $100 million. In 1990, the value of maintenance expenditures is forecast to increase by one-third over the 1982 figure.

Engine overhaul expenditures are the largest expenditure item, with about one-third of the total repair and overhaul total in this category. Main transmissions, main rotor head assemblies, swashplate assemblies, and tail rotor gearboxes are also significant component overhaul expenditures.

In terms of limit life replacement parts, main rotor blades are the largest expenditures. Tail rotor blades and main rotor retention straps are also significant expenditures.

Table 10 summarizes the major expenditures (eg. over $200,000) in the total market area for 1982 and Table 10.1 shows similar expenditures forecast for 1990.

TABLE 10.1

MAJOR OVERHAUL AND LIMITED LIFE REPLACEMENT COMPONENTS BY HELICOPTER TYPE IN 1982

	B 47	204/205	206	206L	212	412	214	Hughes 500	AStar	Twin Star	Total
COMPONENT OVERHAUL											
Main Transmission	$2,247,576	$ 3,141,505	$ 1,862,280	$ 469,370	$ 916,320	$ 248,640	-	$ 724,608	$1,477,213	$1,414,146	$12,501,658
Main Rotor Head	629,388	391,920	4,074,840	687,904	423,625	-	-	1,383,652	-	-	7,591,329
Swashplate Assembly	355,576	269,400	1,111,320	-	585,295	-	-	-	-	-	2,321,591
Tail Rotor Gearbox	443,044	-	1,317,456	291,940	-	-	-	-	306,565	-	2,359,005
Main Rotor Mast	-	384,560	370,440	-	205,400	-	-	-	-	-	960,400
Freewheeling Assembly	-	-	346,632	-	-	-	-	-	-	-	346,632
Tail Rotor Hub	204,061	-	596,736	-	-	-	-	-	-	-	800,797
Scissors & Sleeve Ass.	-	213,120	-	-	448,350	-	-	-	-	-	661,470
Engine Overhaul	2,682,680	4,143,400	14,281,400	2,542,650	1,360,000	340,000	802,000	4,807,600	1,808,800	704,348	33,472,878
Engine Fan Assembly	244,338	-	-	-	-	-	-	-	-	-	244,338
Hydraulic Servo Actuator	-	-	298,368	-	-	-	-	-	-	-	298,368
Hydraulic Pump & Reservoir	-	-	298,368	-	-	-	-	-	-	-	298,368
Drive Shaft Ass.	-	-	-	-	224,175	-	-	260,034	-	-	484,209
Other	391,132	821,626	-	665,466	807,491	455,963	588,048	78,505	213,913	272,661	4,294,805
	7,197,795	9,365,531	24,557,840	4,657,330	4,970,656	1,044,603	1,390,048	7,254,399	3,806,491	2,391,155	66,635,848
COMPONENT LIMIT LIFE											
Main Rotor Blades	594,567	635,910	3,246,830	840,336	863,829	-	391,760	2,194,714	2,082,267	-	10,850,213
Main Rotor Retention Strap	-	-	2,157,321	355,274	233,982	-	-	257,587	-	-	3,004,164
Main Rotor Retention Strap Fittings	-	-	365,753	-	-	-	-	-	-	-	365,753
Servo Actuator Support	-	-	711,358	-	-	-	-	-	-	-	711,358
Main Rotor Grips	-	-	681,913	-	-	-	-	-	-	-	681,913
Tail Rotor Blades	-	-	1,425,816	237,636	-	-	-	-	244,708	-	1,908,160
Starflex Body	-	-	-	-	-	-	-	-	465,764	-	465,764
Main Rotor Shaft	-	-	-	-	-	-	-	-	481,422	-	481,422
Starter/Generator	-	-	-	-	201,660	-	-	-	633,204	-	834,864
Horizontal Stabilizer	-	-	-	-	-	-	-	396,195	-	-	396,195
Vertical Stabilizer	-	-	-	-	-	-	-	443,735	-	-	443,735
Tail Rotor Yoke	-	-	224,721	-	-	-	-	-	-	-	224,721
MR Vertical Hub	-	-	-	-	-	-	-	251,215	-	-	251,215
Main Transmission Drive Shaft		-	-	-	-	-	-	260,034	-	-	260,034
Other	927,877	1,078,362	1,029,066	740,647	542,564	777,887	956,833	1,142,455	1,164,501	797,595	9,157,787
	1,522,444	1,714,272	9,842,778	2,173,893	1,842,035	777,887	1,348,593	4,945,935	5,071,866	797,595	30,037,298
	$8,720,239	$11,079,803	$34,400,618	$6,831,223	$6,812,691	$1,822,490	$2,738,641	$12,200,334	$8,878,357	$3,188,750	$96,673,146

TABLE 10.2

MAJOR OVERHAUL AND LIMITED LIFE REPLACEMENT COMPONENTS BY HELICOPTER TYPE IN 1990

	B 47	204/205	206	206L	212	412	214	Hughes 500	AStar	Twin Star	Total
COMPONENT OVERHAUL											
Main Transmission	$1,483,400	$2,303,840	$2,663,060	$ 689,974	$1,246,195	$365,500	$523,334	$1,065,174	$2,466,945	$2,404,050	$15,211,472
Main Rotor Head	415,396	333,132	5,827,021	1,011,219	576,130	-	247,505	2,033,968	-	-	10,444,371
Swashplate Assembly	234,680	228,990	1,589,188	-	796,000	-	-	-	-	-	2,848,858
Tail Rotor Gearbox	292,409	-	1,883,962	429,152	-	-	-	-	512,115	-	3,117,638
Main Rotor Mast	-	326,876	599,729	-	279,344	-	-	-	-	-	1,205,949
Freewheeling Assembly	-	-	495,683	234,137	-	-	-	242,221	-	-	972,041
Tail Rotor Hub	-		853,332	-	-	-	-	-	-	-	853,332
Scissors & Sleeve Ass.	-	-	-	-	609,756	-	-	-	-	-	609,756
Engine Overhaul	1,770,569	3,521,890	20,422,402	3,737,770	1,849,600	499,800	2,253,620	7,067,172	3,020,696	1,197,392	45,340,911
Engine Fan Assembly	-	-	-	-	-	-	-	-	-	-	-
Hydraulic Servo Actuator	-	-	-	-	-	-	-	-	-	-	-
Hydraulic Pump & Reservoir	-	-	426,666	-	-	-	-	-	-	-	426,666
Drive Shaft Ass.	-	-	426,666	-	304,878	-	-	-	-	-	731,544
Other	554,090	1,245,982	3,697,924	744,097	1,098,186	670,266	861,576	255,432	357,083	471,525	9,956,161
	4,750,544	7,960,710	38,885,633	6,846,349	6,760,089	1,535,566	3,886,035	10,663,967	6,356,839	4,072,967	91,718,699
COMPONENT LIMIT LIFE											
Main Rotor Blades	392,414	635,910	4,642,968	1,235,294	1,174,807	-	1,100,846	3,226,229	3,477,386	203,088	16,088,942
Main Rotor Retention Strap	-	-	3,084,970	522,253	318,217	-	219,268	378,652	-	-	4,523,360
Main Rotor											
Retention Strap Fittings	-	-	523,753	-	-	-	437,049	-	-	-	960,802
Servo Actuator Support	-	-	1,017,242	-	-	-	-	-	-	-	1,017,242
Main Rotor Grips	-	-	975,134	-	-	-	-	-	-	-	975,134
Tail Rotor Blades	-	-	2,038,917	349,324	-	-	220,927	-	408,663	-	3,017,831
Starflex Body	-	-	-	-	-	-	-	-	777,826	-	777,826
Main Rotor Shaft	-	-	-	-	-	-	-	-	803,975	-	803,975
Starter/Generator	-	-	-	-	-	-	-	-	1,057,451	-	1,057,451
Horizontal Stabilizer	-	-	-	-	-	-	-	582,407	-	-	582,407
Vertical Stabilizer	-	-	-	-	-	-	-	652,290	-	-	652,290
Tail Rotor Yoke	-	-	321,351	-	-	-	-	-	-	-	321,351
MR Vertical Hub	-	-	-	-	-	-	274,776	369,286	-	-	644,062
Main Transmission											
Drive Shaft	-	-	-	-	-	-	-	382,250	-	-	382,250
Other	612,398	821,170	2,445,972	1,141,670	1,012,140	1,175,552	1,532,292	1,679,407	1,944,722	1,152,788	13,518,111
	1,004,812	1,457,080	15,050,307	3,248,541	2,505,164	1,175,552	3,785,158	7,270,521	8,470,023	1,355,876	45,323,034
	$5,755,356	$9,417,790	$53,935,940	$10,094,890	$9,265,253	$2,711,118	$7,671,193	$17,934,488	$14,826,862	$5,428,843	$137,041,733

Assuming that unscheduled maintenance accounts for 15 to 20 percent of scheduled maintenance requirements, some $15 to $20 million could be added to the overhaul and repair expenditure total.

In addition to the scheduled and unscheduled overhaul and repair expenditures for overhaul and replacement of components and parts, there are other helicopter-related expenditures.

General routine maintenance costs, based on the assumption that one hour of general maintenance is required for every flight hour, indicates total expenditures of $55-65 million for the study area. Complete rebuilding of damaged helicopters would likely contribute another $7 - 8 million in expenditures. Avionics servicing and repairs for helicopters is estimated to be about $4 - 5 million and flight and other instrument overhaul and repair would be a further $2 - 3 million. Interior upholstery and painting of helicopters is likely in the $2.5 - 3.0 million range.

Totalling these other helicopter-related expenditures indicates an additional $70 - 85 million is likely allocated to servicing of helicopters including materials, spare parts and labour, in the two market areas.

11.0 HELICOPTER-RELATED FACILITIES AND SERVICE MARKET OPPORTUNITIES

This chapter provides an overall assessment of the possible market opportunities for British Columbia based helicopter-related repair, overhaul and maintenance companies to strengthen existing services or to provide new services to the helicopter industry.

The chapter discusses eight different activity classifications which were inventoried and assessed to varying degrees depending on the information available for each category during the course of the study. These categories are as follows:

1) Routine Inspection, Repair and Maintenance
2) Complete Engine Overhaul
3) Major Airframe Repair and Rebuilding
4) Fabric Repair, Recovering and Upholstery
5) Avionics Repair, Installation and Sales
6) Instrument and Accessory Overhaul and Repair
7) Aircraft Refinishing and Painting
8) Other

Each of the activity classifications were divided into the three principal areas of investigation:

A) Repair, Overhaul and Servicing
B) Spare Parts
C) Original Equipment Parts or Components

It should be remembered that the analysis and evaluation of possible market opportunities discussed herein are only preliminary. As noted earlier, project budget limitations allowed for only a cursory examination of many of the activity areas. Direct information was also mainly restricted to local interviews with British Columbia repair, overhaul and maintenance companies. Correspondence and telephone interviews were conducted to obtain information from others. It is felt, however, based on the information collected and its subsequent analysis and evaluation, that there are a number of potentially interesting opportunities for British Columbia firms to examine more closely in order to expand their current market share of the total market or to establish new endeavours in the helicopter industry.

There are over 3500 helicopters identified in the Primary and Secondary Market Areas and this total is expected to rise by 1,000 units by 1990. The two market areas represent about one-third of the total North American civil helicopter market. There are opportunities to provide increased services for those firms which have the necessary facilities, equipment and skills. There is strong competition, however, from firms outside of British Columbia who will want to strive to maintain and increase their market share. Caution should be exercised by those British Columbia firms who do not have the necessary capabilities and/or experience to enter high risk markets related to helicopter servicing.

11.1 ROUTINE INSPECTION, REPAIR AND MAINTENANCE

A. Repair, Overhaul and Servicing

Most helicopter operators (commercial, corporate and government) now have some capability to conduct routine maintenance and have trained mechanics available. It is estimated that a single Bell Jet Ranger requires between $25,000 - 30,000 in capital investment for facilities, tools and parts for simple, routine maintenance. Normally a full-time mechanic is required to service the equivalent of three Jet Rangers. If the helicopter is more complex, such as Bell 212, there is a need for a mechanic for every machine. Servicing and maintenance of helicopters usually requires between .8 to 3.5 hours of direct maintenance for every flight hour. The more complex the helicopter, the more maintenance hours required.

Commercial helicopter operators, in particular, have the in-house capability to conduct most of their own maintenance and, in fact, many are available to conduct maintenance for third party operators, as noted in the inventory. Government operators normally have the capability also to do some of their own in-house maintenance. Those firms which use maintenance companies for routine inspections and maintenance tend to be small corporate operators or individuals who own their own helicopter. There are, nevertheless, occasions when commercial and government operators will use commercial maintenance services. These occasions are usually when their own in-house staff are committed on other maintenance needs, or the helicopter is relatively unique and the helicopter service firm has the special skills needed to conduct the needed maintenance. It is fairly common for inspection and troubleshooting of a new helicopter or a relatively complex machine to be done by a specialized helicopter maintenance firm. Even in these cases, the tendency is to use a local maintenance firm for general routine maintenance, if possible, due to the cost and time lost to transport the helicopter elsewhere.

If the helicopter, however, should need repairs in addition to normal maintenance, then the scope increases dramatically to have this additional work done by a specialized maintenance firm, particularly if the skills or equipment are not in-house to make the necessary repairs.

The facility and services inventory conducted indicates that the Primary and Secondary Market Areas are likely adequately serviced with regard to routine inspection and maintenance services. If there are any opportunities for routine maintenance, they are for smaller maintenance shops located in sub-regions of the market area close to a helicopter population which are not adequately served by an established maintenance shop. On the other end of the scale, there could be opportunities for larger repair and overhaul firms to provide general maintenance service to its customers if these services are not now being offered. Larger firms could also provide technical support to the smaller regional firms.

B. Spare Parts

Those firms which provide routine inspection, repair and maintenance require a limited number of spare parts to carry out their services. These spare parts are generally low cost replacement parts such as bearings, nuts and bolts, seals, hydraulic and engine oil and other consumable items. These spare parts are distributed through a variety of networks of dealers and distributors. However, the vast array of spare parts presents some difficulty as to identifying appropriate spare parts replacements due to changing manufacturers code numbers, the quality of the spare parts, current prices, and where they are available (e.g., distributor). It would appear that there may be a market opportunity for spare parts dealers/distributors to provide additional information on the spare parts available. An increase in the distributor network is also likely required, particularly in the smaller centres where helicopters are based and where there are not large commercial operators who have their own spare parts inventory.

C. Original Equipment Parts or Components

With respect to routine inspection, repair and maintenance activities, there were few opportunities for the manufacture of original equipment parts or components. There are some helicopter accessories which may be worth considering for manufacture. These items include cargo nets, helicopter skids, search lights, special plastic windows, canvas covers, heaters, cargo hoists and other products. Many of these are now available from the helicopter manufacturer directly or through distributors. False Creek Industries Ltd. of Vancouver, which makes cargo nets, is an example of a British Columbia manufacturer. Heli Craft Enterprises of Westbank, which makes a bleed air heater for the Bell 206, is another example. In order to compete, a British Columbia accessory manufacturer would have to develop a product which operators will use and he would have to sell it at a competitive price. Most commercial helicopter operators, however, do not use these accessories if they affect the helicopter's payload unless specifically requested by customers. Viable opportunities for accessory manufacturing will likely stem from an existing manufacturer, not necessarily related to the industry, which wishes to expand a product line. An example is a tent manufacturer who, at the same time, makes canvas covers for helicopter cabin windows and blades for weather protection.

11.2 COMPLETE ENGINE OVERHAUL

A. REPAIR, OVERHAUL AND SERVICING

This important repair, overhaul and servicing activity is one of the highest in terms of value. The repair and overhaul of the Allison 250 series turbine engine in the two market areas, for example, in 1982 accounted for some $25 million in overhaul value for labour and materials. By 1990, since many of the Allison 250 series are used in the new twin-engine helicopters, the repair and overhaul value of this engine series could increase to $60 million. The civil engine overhaul and repair business in North America by the four major firms is estimated to be well in excess of $100 million a year. It can be noted that this one turbine engine series (Allison 250), in the two market areas, is nearly one-quarter of the total estimated market size.

There are only a limited number of overhaul firms which can completely overhaul engines including engine repairs. Engine overhauls require elaborate facilities to maintain the close tolerances required and the necessary testing equipment. Very skilled personnel are also required. The capital investment to establish a facility is very high. It also may take years to establish a reputation in the business. Despite the limited number of firms in the business and the high degree of capital investment, engine overhauls are priced relatively competitively. The four large North American firms in the engine overhaul business are summarized below:

Aviall - Headquartered in Dallas, Texas with other major facilities in Burbank, California and Frederick, Oklahoma. It has a franchised agency network of 77 stations in North and South America. There are Aviall agencies in British Columbia and an Aviall field representative located at Vancouver International Airport. An Aviall service centre is proposed to be established by Canadian Gas Turbine (CGT) Ltd. in Vancouver.

National Airmotive - Headquartered in Oakland, California. The firm has a limited number of service centre agents in the United States.

Airwork Corporation - Headquartered in Millville, New Jersey. This subsidiary of Purex Industries also has facilities in Miami, Florida; Atlanta, Georgia; Dayton, Ohio; Houston, Texas; Wichita, Kansas and Burbank, California. It also operates a limited number of franchise agencies.

Standard Aero - Headquartered in Winnipeg, Manitoba. It is a subsidiary of Federal Industries Ltd. and has field representatives at various locations including Vancouver. It reportedly now has agency agreements with Meridian Heliflight and Okanagan Helicopters but all overhaul work is done in Winnipeg.

The engine manufacturers also repair and overhaul their own engines to varying degrees. Detroit Diesel Allison uses a dealer network (Aviall Airwork Corp., Standard Aero, etc.) for overhauls while Pratt & Whitney, on the other hand, does most of its own overhaul work, particularly for the Canadian market.

In Canada, due to the difficulty of transporting engines to and from the United States, exchange rates, custom requirements and the Canada - United States Airworthiness Agreement, most of the complete engine overhauls are done by Standard Aero in Winnipeg including Canadian military helicopter engines. Detroit Diesel Allison also, until recently, had an agreement with Standard Aero which provided Standard Aero with exclusive rights to all Allison engine overhauls in Canada.

In addition to the major firms which offer complete overhaul and repair of turbine engines, there are a number of firms which are termed maintenance service centres and can offer varying degrees of services. Nearly all restrict their services to component inspection and replacement. Very few have the test facilities or the equipment to make repairs and properly dynamically balance engines. Meridian Heliflight in Prince George, for example, is an authorized to inspect and replace components on the Allison 250 series but it cannot make repairs. Similarly, it is also authorized to inspect and replace engine components on the Avco Lycoming LTS-101 used on the AStar. Okanagan similarly has built up its own in-house expertise on the Allison 250 series engine and the General Electric CT 58 to the point where it is now doing engine maintenance for other operators. Okanagan, however, still needs additional facilities, equipment and skills to be able to offer complete overhaul and repairs on these engines.

The value of the engine overhaul and repair market is large enough to present possible market opportunities for British Columbia based firms. A number of operators have suggested there needs to be additional firms offering engine overhaul services. Standard Aero was cited as being too large and not responsive to the needs of the industry. Prices, delivery, and exchange problems were also noted. The following quote from "Canadian Civil Helicopter Market Analysis and Forecast", Department of Supply and Services, July 1982, sums up the position of the operators.

> ..."A number of operators have refused to purchase an aircraft based solely on the high cost to maintain the engine. As many of Canada's aircraft utilize the Allison engine, operators have the option to have the engine overhauled in Canada by Standard Aero. In fact, they don't perceive it as an option, given the barriers to overhaul their engines in the United States. It is argued that there should be another engine overhaul facility for this engine in Canada" p. 5-10.

There are the elements of an engine overhaul facility in British Columbia. As noted, Okanagan Helicopter and Meridian Heliflight now have some capabilities in the field which could possibly be expanded. There are also firms which have industrial turbine overhaul experience and there are several machine, milling and gear works in British Columbia. The possible scenarios for the development of expanded engine overhaul facilities could include the following:

o Establish a business venture with Standard Aero to have some overhaul work done in British Columbia, similar to the basis on which Aviall agencies have been established. The Allison 250 series would be specifically targeted. (It is understood that Standard Aero and Okanagan Helicopters have discussed a similar concept).

o Establish a business venture with Pratt and Whitney. There are no outside firms which overhaul Pratt and Whitney products (PT6-T) in Canada though there are a few in the United States. There have been over 22,000 PT 6 turbines built, including 2,550 PT 6 T-3 B Twin Pac units used in helicopters. A Pratt and Whitney overhaul facility in Western Canada would likely overhaul the PT 6 A engine used in the de Havilland Twin Otter, Beech King Air, Piper Cheyenne, Cessna Conquest, and Embraer Bandeirante in addition to the PT6 T - 3 B Twin Pac engine. Pratt and Whitney is also developing the STEP (Small Turbine Engine Program) (PW 209 T) for installation on the Bell 400A in 1988 and Bell 440 in 1989. A working agreement for engine overhauls of the PT 6 would allow the overhaul firm to move into the overhaul of the new turbine engine in the 1990's.

o Expand Okanagan Helicopter's Viking Way facility to include engine overhaul test facilities and repair capabilities in addition to the current component overhaul expertise for the Allison 250 series.

- Expand Meridian Heli-flight's Prince George capabilities to include more advanced engine component work as compared to inspection and replacement of components. Engines to be serviced would include the Allison 250 series and the Lycoming LTS-101.

- Develop with Aviall, National Airmotive or perhaps Airwork Corporation a Canadian subsidiary or franchised company in Western Canada of a calibre to undertake major component overhauls but not necessarily engine repairs. The proposed Canadian Gas Turbine (CGT) Ltd. agreement with Aviall is similar to this concept.

- Expand the Vancouver industrial turbine overhaul and repair expertise of Cullen Detroit Diesel Allison Ltd. to include aviation turbines. It should be noted, however, that aviation turbine overhaul requirements are more exacting than industrial turbines.

The scenario which is probably the most practical is to combine the Okanagan Helicopter facilities in a joint venture with a major engine overhaul firm such as Standard Aero. The new company would still require additional capital for facilities and equipment to allow fuel component overhaul, engine test and balance and some selected repair work to be done. Since Okanagan would not own the facility, but share it, the market potential to attract additional engine overhauls from commercial operators, in addition to Okanagan's own requirements, is enhanced. The major engine overhaul company, such as Standard Aero, would have the necessary engineering expertise and reputation. Okanagan Helicopters would benefit from employing its under utilized facilities and personnel, while the major overhaul firm would benefit from securing its market linkages in Western Canada for repair work and remanufactured parts which likely could not be done in British Columbia due to lower work volumes. The proposed establishment of an Aviall service centre by Canadian Gas Turbine (CGT) Ltd. may also be a viable scenario.

There also may be some market potential to provide turbine engine conversion in conjunction with Soloy Conversions Ltd. of Olympia, Washington. This firm has an established business in converting older, piston-powered helicopters to the Allison 250 series turbine. The Bell 47 G and Hiller UH 12 E are the two helicopters converted to turbine power. There have been about 150 Bell 47's converted and about 100 Hiller UH 12 E's. There is a specialized market for operators which need a small helicopter which has the higher payload carrying capacity, performance and the engine reliability of a turbine. Unfortunately, the cost of the conversion, including the turbine engine, is $100,000 more than the piston-powered Bell 47 or Hiller UH 12 E is currently worth in the market place. A technical agreement with Soloy Conversions by a British Columbia firm may provide an opportunity for some turbine conversions, particularly for Canadian helicopters. Canadian helicopters being exported back to the United States for agricultural purposes, which may justify the cost of the conversion could also be a market. It also may be possible to develop an STC turbine conversion for the Hughes 300 series and other popular piston helicopters.

Rotor Head, Transmissions and Gearboxes

The repair, overhaul and servicing of rotor heads transmissions, main rotor gearbox, tail rotor gearbox, intermediate gearboxes and the drive shaft are high maintenance requirement areas in terms of replacement spare parts and man hours of labour. In addition to normal maintenance, all these components are rotary and subject to vibration and therefore have to be balanced on replacement in the helicopter.

Most rotor heads, transmissions and gearbox assemblies are designed in modules to assist in component overhaul and maintenance. The facilities, equipment and skills needed are similar to the engine overhaul but do not require the same degree of capital investment or specialized equipment. Rotor head, transmission, and gearbox overhaul work is done by a number of firms for specific helicopter models, such as Bell Helicopter authorized customer service facilities or Aerospatiale and Hughes service centres which do component overhaul replacement. There are few which can do repairs, therefore, most maintenance firms replace with new or exchange parts rather than repair. There are also a limited number of maintenance firms which do dynamic component overhauls or have the non-destructive testing inspection equipment to determine part failure. There are some specialized shops which have been developed to do dynamic components and NDT but there is demand for service in this field.

In British Columbia, firms such as Okanagan Helicopters, E.M. Heli-Logistics, Highland Helicopters, Frontier, Quasar, Merician Heliflight and Vancouver Island Helicopters all have the capability to do rotor head, transmission and gearbox work. Deltaire Industries, before it went into receivership, also did transmission and gearbox overhauls.

The expansion of opportunities for British Columbia maintenance firms to increase their market share requires an increase in their capabilities to include more complex helicopters and additional helicopter models in their area of expertise. A maintenance firm which can demonstrate it has the necessary certification, equipment and skills to handle complicated work will attract business from a considerable distance. There is also a market in the repair and exchange of transmission and gearbox components. It should be noted that changes in design and materials (e.g. composite materials) now taking place will impose new overhaul and maintenance requirements to meet changing market conditions and British Columbia firms will have to obtain the necessary expertise to expand their market share.

Engine Accessories

These engine accessories include fuel control units, fuel pumps, starter/generators, tachometers, ignition units, bleed assembly, combustion liners, hydraulic pumps and so forth.

These engine accessories can be overhauled and repaired by a major engine overhaul firm which may also manufacture or re-manufacture certain parts (eg. Standard Aero remakes bleed valves, combustion liners, etc.). The engine accessories can be also installed at a component maintenance service centre which does engine component overhauls. Fuel control and other engine accessories are normally overhauled or replaced at the same time as engine overhauls.

Firms which have experience in engine component overhauls are the most competent also to do engine accessory troubleshooting replacement. In British Columbia, Okanagan Helicopter and Meridian Heliflight have these skills. Repairs to engine accessories are not done in British Columbia and may present a market opportunity. Engine accessories are now sent to Eastern Canada or the United States (California). Bendix Aviation Electric of Montreal has a Vancouver branch office which could form the nucleus of a more comprehensive engine accessory overhaul and repair facility in British Columbia.

B. Spare Parts

The market opportunity for British Columbia companies to develop increased business derived from engine overhauls is somewhat dependent on the development of an engine overhaul facility. If a comprehensive engine overhaul centre is developed, there will need to be an associated program of supplying spare parts. These parts would include turbine wheels, combusters, casings, turbines, compressors and so forth. Okanagan Helicopter and Meridian Heliflight now require some engine components and spares for the work they undertake for Allison 250 series, General Electric CT-58 and Lycoming LTS-101 engines.

Spare parts for rotor heads, transmissions, gearboxes and drive shafts are normally distributed through the authorized factory distributor network. Bell Helicopter distributes from its Calgary, Alberta and Burbank, California service centres in the study area. Aerospatiale distributes from Calgary, Alberta and Grande Prairie, Texas and Hughes Helicopter from its Culver City, California, plant and Sikorsky from its Stratford, Connecticut plant. Spare parts prices and delivery times are the critical items to access the market opportunities. If spare parts can be brought into British Columbia quicker and at a cheaper price, then increased spare part sales would result from increased business from British Columbia maintenance centres. An on-going liaison with manufacturers and other respective dealers/ distributors could also assist in developing an adequate local inventory of needed spare parts which would eliminate most time problems.

Engine accessory spare parts could present some market potential. Firms such as Bendix, CECO and Sunstrand market their products using dealers and distributors. Additional representation in British Columbia could assist in having these spare parts more readily available. Along with the sales would be a requirement for some servicing and limited repair of engine accessories in British Columbia. A new company, Northwest Heli Pro Inc., at Vancouver International Airport, carries an extensive line of engine accessory parts and other helicopter spare parts There are other distributors such as Standard Aero in British Columbia.

C. Original Equipment Parts or Components

There is likely very limited opportunities to manufacture original equipment parts or components for engines in British Columbia. There may be some demand for parts or component repairs if a comprehensive turbine engine overhaul facility were to be established.

Manufacturing of rotor heads, transmissions, gearboxes, divershafts or other related helicopter components is a difficult field to enter. It requires the major manufacturer to contract or license a firm to build the required parts. There have been some building of parts without the authorization of the manufacturer. These bogus parts become a serious problem for Bell Helicopter some years ago and they established a Bogus Parts division to stop their production. Bell Helicopter has been very successful in their legal court actions and have effectively eliminated most of the bogus parts. Some original equipment parts are, or have been manufactured in Canada (Bristol Aerospace, Haley Industries, Fleet Industries and Spar Aerospace) but no helicopter components are currently built in British Columbia.

Engine accessory component manufacture is also a specialized field. Fuel system and other accessory manufacturers, however, could be interested in some parts being manufactured under sub-contract. However, in order to demonstrate competence to manufacture, the British Columbia firms would likely first have to become established in the repair of accessories. Currently, repairs are done outside of British Columbia for most of the hydraulic accessories, fuel pumps, engine instruments, etc. SIL Industries Ltd. of Richmond, British Columbia does do overhaul and repair of some accessory instruments and, perhaps, could be expanded to repair a variety of engine accessories, particularly for those components which are in relatively constant demand.

11.3 MAJOR AIRFRAME REPAIR AND REBUILDING

A. Repair, Overhaul and Servicing

Major airframe repair and rebuilding is a specialized procedure which requires assembly jigs and tools. The jigs are for the fuselage section and the tail boom, and rebuilding of the two sections can be done separately. Rebuilding airframe companies may have both jigs or just one depending on their expertise and customer demand. Normally, a separate jig is required for each helicopter model. Each rebuilding jig, if commercially purchased, represents a capital investment of close to $100,000.

In British Columbia, Helicopters Welders of Canada Ltd., has an established reputation for helicopter airframe repairs, overhauls and modifications for many helicopter models including Bell Helicopter and Aerospatiale. Helicopter Welder's customers are located throughout North American (and some overseas) but, in particular, in the western United States. Its main competition is Field Aviation in Calgary which has also built up a sizable market in the helicopter airframe repair and rebuilding business. In addition to jigs and special tools, major airframe repair and rebuilding firms need to have expertise in sheet metal working, welding (all types), bonding metal, honeycomb structures and composite materials. Non-destructive testing is also a requirement. It takes about 250-500 hours to rebuild a Bell 206 fuselage and another 85-100 man hours to rebuild the tail boom.

There are a number of firms which can offer minor airframe repairs and which have sheet metal machining and milling, welding and other skills, but their repairs are usually non-structural. The repairs are usually restricted to torn door panels, dented fuselages panels or bent landing gear skids.

The market for repair, overhaul and servicing of major airframe repairs and rebuilding depends on the rate of helicopter accidents and, indirectly, the demand for helicopter services.

Since helicopters operate in difficult environments (e.g., helicopter logging, off-shore exploration, forest fire suppression, etc.), the accident rate is high as reflected by the very high accident insurance premiums for the helicopter industry. In 1981, due to the number of helicopter hours flown, the accident rate was one of the highest. In 1981, there were 126 helicopter accidents in Canada compared to 56 in 1982. Due to the high demand for helicopters in 1981, there was strong demand to rebuild damaged helicopters to return them quickly to active service. There are three main customers for major helicopter rebuilds: insurance companies, aircraft salvage companies and commercial operators. Insurance companies will have a helicopter repaired if the market value of the repaired helicopter meets or exceeds the "The Official Helicopter Blue Book" of current helicopter prices. Commercial operations and salvage companies will rebuild airframes that have been classed as insurance "write-offs". It is estimated that half of the insurance "write-offs" are, in fact, repairable, and that helicopters can be rebuilt by using scrapped airframes from two or three helicopters. During the 1981 period, a number of these damaged helicopters were rebuilt and re-sold in a period of inflating helicopter prices. In the current economic situation, major airframe rebuilding firms are still receiving work from insurance companies but business from commercial and salvage operators is slow. Many firms, which formerly had this work done "outside", are now making the repairs internally using the major rebuilder just for the use of the rebuilding jigs. There are also a number of repaired airframes which have neither been paid for nor picked up by the owners since there is little demand to return the helicopters to active service.

It would appear that Helicopter Welders have developed the market for major repairs and rebuilding to the extent possible given the current economic climate. However, there may be some additional opportunities in the future if Helicopter Welders or other arframe rebuilders could coordinate its operations with other firms to provide a more comprehensive service to customers. Field Aviation, for example, not only can do airframe rebuilding but component overhaul, upholstery and interiors, painting and so forth -- all in one hangar (e.g. one stop concept).

B. Spare Parts

The spare parts for a major airframe repair and rebuilding can be substantial for a heavily damaged helicopter. Major rebuilding of a Bell 206, for example, takes about six weeks, two of which are allocated to obtaining all the necessary spare parts. The spare parts could range from door panels, control tubes, frames, nuts and bolts, rivets, windows and materials such as sheet metal to complete components.

There may be market opportunities for those which now distribute spare parts to liaise closer with major repair and rebuilding firms to coordinate spare parts requirements. Most helicopter rebuilders now have to deal separately with a variety of individual suppliers. These coordinated service may present cost savings which, in turn, can be passed on to the customer. This, in turn, would make British Columbia major airframe repair and rebuilding firms more competitive.

C. Original Equipment Parts or Components

As noted earlier, the major helicopter manufacturers, for the most part, control the building of original equipment parts and components. It is possible to obtain sub-contract work but it is difficult, particularly in a slow economy when the major manufacturers want to retain as much of the production in their own facilities. Selection of the appropriate parts and components is also difficult since they must be able to be produced within the capabilities of the sub-contracting firm. They should also be parts or components which are replaced regularly and are relatively high value items. It is these same parts and components which the major manufacturer usually wants to retain. It is suggested, however, that there may be parts and components which could be built under sub-contract in British Columbia which could be used by the major manufacturers.

Canadian Aircraft Products Ltd. in Richmond, for example, does have the capability to work closely with a major manufacturer to produce airframe parts and components for helicopters. Canadian Aircraft Products recently approached Bell Helicopter for opportunities for design, engineering and manufacturing involvement with the new Bell 400 series to be built in Canada. Canadian Aircraft Products has experience with sheet metal, metal machining and milling and composite material components for a variety of aerospace products, and it would be one of the British Columbia firms which could be the focus for future endeavours in sub-contract manufacturing.

There may also be a manufacturing opportunity to build helicopter rebuilding jigs. Helicopter Welders has been quite successful in selling jigs to Pacific Rim countries.

11.4 FABRIC REPAIR, RECOVERING AND UPHOLSTERY

A. Repair, Overhaul and Servicing

This maintenance activity is not a high value activity. Most of the work is upholstery and interior work since fabric repair and recovering are not common in the helicopter industry. The upholstery and interior work in helicopters is relatively infrequent and is usually associated with a major helicopter rebuilding program or a general upgrading of the helicopter every 5-7 years. A Bell 206 interior upholstery completion using leather and fabric, is valued around $4,000 to $5,000. There are a few British Columbia firms which provide upholstery and interior restoration for helicopters. Most do not specialize and their services are for fixed wing aircraft as well. In fact, some are also for automotive and marine upholstery. Daken Upholstery Ltd. has been doing most of the upholstery work on helicopters in British Columbia but a management change may affect future business revenue.

There is possibly a need to coordinate upholstery and interior completion firms with the various helicopter maintenance companies to ensure customers a more complete range of services. Innotech Aviation in Vancouver does do upholstery and interior work, and could readily offer complete aircraft completions for fixed wing and helicopters similar to their Montreal facility. Corporate helicopter interiors likely offer a better market opportunity than commercial operators. The commercial operator will not add the weight or the expense unless his customers request it.

B. Spare Parts

Demand is not sufficient to offer spare parts in any volume. Most of the upholstery and interior work is custom work in which a variety of fabrics, leather, wood, carpentry and metal are used.

C. **Original Equipment Parts or Components**

As noted under spare parts, most of the upholstery and interiors are custom made. There could, however, be some limited market to manufacture cabin hardware such as strap handles, lighting fixtures, head restraints and head liners. These items would likely be in conjunction with an aircraft completion centre rather than the major manufacturer.

11.5 AVIONICS REPAIR, INSTALLATION AND SALES

A. Repair, Overhaul and Servicing

The sale, installation and service of avionics is a growing activity in the helicopter maintenance field. Navigation and communications equipment is now lighter, more compact and more reliable than equipment of a few years ago. Avionics installations are of two basic types, depending on the helicopter operations; these are VFR (Visual Flight Rules) or IFR (Instrument Flight Rules). The majority of helicopters are only equipped for VFR flights in terms of avionics and instruments. IFR helicopter flights, however, are becoming increasingly important for operators which have twin engine helicopters used in off-shore exploration or scheduled type of operations where high operational reliability is needed.

Avionics for VFR flights are usually restricted to a VHF transceiver for communication and VOR and ADF transponder for navigation. Cabin audio systems, audio switching panels, microphones, cockpit speakers and antenna are also included. A common VFR avionics package, as described, would weigh about 30 lbs. and would have an installed value of between $15,000 to $20,000. Avionics servicing is annually about 5 percent of the capital cost or about $750 - $1,000 for a VFR helicopter.

An IFR avionics package would include a radio altimeter, an additional VHF transceiver, DME, two VOR/LOC/glideslope, marker beacon, flight director/nav approach coupler, autopilot Omega/VLF navigation, radar, and so forth, will add over $1 million to the cost of a twin-engine helicopter such as the Bell 212.

The capabilities of firms which offer avionics sales, installation, services and repairs varies as does the avionic equipment. Standard VFR nav/com units made by King or Narco are sold and serviced by a number of companies. King Radio Corporation, for example, sells and services its standard Silver Crown nav/com through seven avionics sales and service centres in British Columbia. The number of avionics firms which handle the higher quality Gold Crown nav/com equipment, however, is only three. King flight control, weather radar, radar altimeters, etc., are sold and serviced only by one British

Columbia avionics dealer (Pacific Avionics). Similarly, higher value avionics equipment such as Collin's Pro Line or Sperry is serviced and repaired by only a few firms.

The capital investment in a full facility avionics centre is considerable. Even firms which service and repair standard VFR communication equipment will have a capital investment of approximately $100,000. Those which service and repair IFR avionics will likely have an investment of $1 million for the test equipment, tools, library and other facilities needed for servicing solid-state circuits, digital displays and microprocessor controllers now offered by the IFR avionics manufacturers.

In British Columbia, Pacific Avionics and Instruments, Helicom Avionics and Instruments, Okanagan Helicopter, Quasar Helicopters and Victoria Avionics have avionics repair capability for equipment currently used in helicopters. Pacific Avionics and Instruments is particularly well equipped and is experienced in the special vibration problems associated with avionics installations in helicopters. Vibration also causes more frequent need for maintenance than similar avionics equipment installed in fixed wing aircraft.

British Columbia is relatively well positioned to take advantage of growing market opportunities in the avionics field with respect to repair, overhaul and servicing. However, in order to remain competitive, there will have to be constant investments made in equipment and training to ensure that British Columbia firms are able to handle the services and repairs necessary for new sophisticated equipment being offered by the avionics manufacturers. Pacific Avionics and Instruments appears particularly well positioned to take advantage of market opportunities in the helicopter avionics area (e.g., electronic locator transmitters - ELT - now are repaired in the Toronto area but could be repaired in British Columbia).

B. Spare Parts

Avionics sales and service organizations do not experience serious problems in obtaining spare parts. Some avionics manufacturers were indeed cited for their support in spare parts inventory, technical literature and training courses offered. Collins and King, in particular, appear to have relatively good spare parts support. There may be, however, some improvements needed to coordinate spare parts to the smaller avionics centres in the province or to commercial operators which desire to do some of their own avionics repair work.

C. Original Equipment Parts or Components

There are now two manufacturers of avionics equipment in British Columbia.

Northern Airborne Technology specializes in electronic equipment for installation in helicopters. It is also sells and services for the Collins, King and Wulfsberg lines. This Prince George company manufactures audio controllers, channel controllers and loudhailer paging systems. One product, the HSA 70 voice advisory system is a unique device which provides a pilot with an analysis of 40 performance variables in speech format. It will provide real time advice on elapsed time, fuel remaining and critical airframe updates when enroute. It is also designed to accommodate a storage unit to record all critical flight data, such as start cycles, power cycles, operation outside of design limits and true elapsed flight time. The product should find a ready market for helicopter operators which need such information to reduce maintenance downtime on their fleets. Electronic self-test devices such as the HSA 70 will be common in the future.

Spillsbury Communications has been manufacturing HF SSB radios for some years, a two-way communication device which has extended range for operations in remote areas where fixed wing and helicopters operate. Spillsbury also makes ground navigation equipment.

There are market opportunities for new or improved avionics equipment. Market entries for specialized devices for helicopters which can sustain the vibration produced in a helicopter would likely have good market potential. Commercial operators are concerned about the weight of equipment affecting the helicopters payload; therefore, lighter weight, more versatile and rugged avionics equipment is desired. Cooler operating temperatures are also desired to reduce maintenance. High corrosion is also a problem experienced in helicopter avionics for helicopter operations near salt water and corrosion resistant materials would assist in improving reliability. New products which can incorporate these features will gain customers.

11.6 INSTRUMENT AND ACCESSORY OVERHAUL AND REPAIR

A. Repair, Overhaul and Servicing

The repair, overhaul and servicing of instruments and accessories is done by a number of companies but not many are British Columbia companies. Some repair and overhaul of flight instruments such as directional gyros, altimeters, turn and bank indicators are done by Pacific Avionics and Instruments but the firm does not seem to have developed a strong position in the market. Similarly, SIL Industries does overhauls and repairs of instruments, hydraulics and accessories but has not seemed to have gained a significant share of the available market. Precision Aero Instruments are also used by some operators for instrument servicing but, again, has not achieved a large market share. There have also been, in the past, British Columbia firms which repaired starters/generators, electrical accessories, hydraulic pumps, etc., but which are now out of business either due to a lack of financing, poor quality, lack of expertise and equipment or insufficient market size.

Aviation Electric in Montreal, Quebec, is increasing its share of the instrument and accessory work. Wright Instruments of Mississauga, Ontario; Aviatron, Montreal, Quebec; Standard Aero, Winnipeg, Manitoba, Flight Accessory Services, Sun Valley, California and A. Biederman, Glendale, California, are also firms which are used by British Columbia helicopter companies for instrument and accessory overhaul and repair. Some of the larger helicopter operators like Okanagan Helicopters can also do a limited amount of instrument and accessory repair work in-house.

It would appear that since operators now use repair and service firms in Eastern Canada and the Southern United States, there should be a market opportunity for a British Columbia company. Aviation Electric, which is a division of Bendix, has a branch office in Vancouver. Since this firm appears to have an increasing share of the market, there may be a possibility of expanding the Vancouver sales office into an instrument and accessory repair centre. This type of development would then be able to provide the study market area with the needed technical expertise and spare parts at a relatively minimal capital investment. Use of the facilities of SIL Industries or Precision Aero Instruments may be another possible means to expanding the instrument and accessory overhaul and repair business in British Columbia.

B. Spare Parts

Improvement in the availability of instrument and accessory spare parts is linked to the development of instrument and accessory repairs. The expansion of the Aviation Electric facility to handle repairs would undoubtedly increase the sales of Bendix and other spare parts. It would appear that, even without an expansion of repair services, spare parts distribution could be improved with more representation in British Columbia. There may also be a need for more instrument and accessory exchanges just as there is with engine components.

C. Original Equipment Parts or Components

The opportunities for manufacturing instruments and accessories seem remote unless it can be demonstrated there is a viable market for the overhaul and repair of such products in the first place.

11.7 AIRCRAFT REFINISHING AND PAINTING

Helicopter refinishing and painting is required after rebuilding the airframe as a result of an accident or every five to seven years depending upon the helicopter's use and operating environment. It is also frequently done in conjunction with upholstery and interior work. Paints which are used are normally a polyurethane base which is chip-resistant and hard wearing which reduces the intervals between refinishing and painting. A Bell 206 refinishing and painting job including masking, sanding, undercoating/primer and a polyurethane finish, for example, will be approximately $3 to $4 thousand dollars. Most companies which do aircraft painting offer their service for both fixed-wing and helicopters. The larger helicopter operators usually have their own paint shop but will on occasion, use specialized paint firms. The British Columbia companies which are noted for helicopter refinishing and painting are Vancouver Aero Services Limited (Peter van Gruen), Innotech Aviation Limited and Western Heli-Craft Limited.

Innotech Aviation, to some extent now coordinates its upholstery and interior completions with its refinishing and painting capabilities. There may be, however, a need for increased coordination between those firms which offer refinishing and painting with airframe repair companies, upholstery and interior firms, as well as general helicopter overhaul and maintenance firms.

11.8 OTHER

There are some miscellaneous areas which may present market opportunities.

Rotor Blades

Main rotor blades and tail rotor blade overhaul, repair and servicing represents a potential market opportunity. Blade repair is done in the study area by three firms: Rotor Blades Inc., Stockton, California; Composite Technology Inc., also of Stockton, and recently Composite Technology (Canada) Ltd. in Winnipeg, Manitoba. Composite Technology (Canada) is a sub-division of Composite Technology Inc. The largest market share is now apparently being achieved by Rotor Blades Inc. because of its lower price and high quality. Composite Technology (Canada), a new firm, is getting some work but operators comment that price is higher than the United States competition.

Rotor blade technology is changing. Metal blades which are subject to metal fatigue from the rotory torque on the blade are subject to a limited life and therefore have to be replaced. Repair work is usually restricted to nicks and cuts but not cracks and major structural repairs. Other metal blade repairs are the replacing of root end separations, root plates and erosion strips. Blade tip shaping can also be done as well as dynamically balancing the blades. Composite blades, on the other hand, do not have a limited life and can be structurally repaired if damaged. Most helicopter manufacturers estimate that, by 1990, all helicopters will have composite main rotor and tail rotor blades. In addition to repairing blades, there will be more blades on each helicopter. Four and five blades are used on Hughes and Aerospatiale helicopters and even Bell Helicopter now produces four bladed helicopters. Bell Helicopter plans to have a four bladed rotor on the new Bell 400 series.

It would seem that, with the growing trend to the use of composite blades and the fact that more helicopter designs are incorporating multi-blades, there may be a market opportunity to have a rotor blade overhaul and repair facility in British Columbia.

Tension Torsion Straps

A number of Bell Helicopter products (eg. Bell 206) use main rotor tension torsion straps. It is a strap made of thousands of turns of steel wire used to absorb tension of centrifugal loads between the blade and the hub, and also the torque of blade pitch change. Bendix Aircraft brake and strut division in South Bend, Indiana and Lord Kinematics of Erie, Pennsylvania make the straps for Bell under sub-contract. These retention straps have a limited life of only 1200 hours and the unit price is $2,140 (Canadian), making this product one which could qualify for a possible original equipment part to be made in British Columbia (e.g., large numbers at a relatively high unit price). It is not a technically complex product but it is subject to considerable stress and therefore subject to metal fatigue which may deem certification standards very high. The retention strap fittings and pins also are possible items of manufacture.

Blade Tracking and Balancing

In order to reduce vibration, which could create a mechanical malfunction if not corrected, the rotor blades should be tracked and balanced. Blade tracking and balancing is a mechanical procedure used to bring the blades of the rotor in satisfactory relationship with each other under dynamic conditions so that the blades rotate on a common plane. There are electronic balancing and tracking devices available, but the Chadwick-Helmuth Co. VIBREX product is the most common. These devices can be used for the main rotor and tail rotor and also for fixed wing aircraft propellors. The cost of the basic equipment including a balancer, strobex blade tracker, accelerometer, caliberator, magnetic pick-ups, cables, etc. is about $5,500 Canadian. The rotor blades should be balanced periodically and after any repair work; therefore, there could be a market opportunity to provide a track and balancing service to smaller helicopter operators which do not have such equipment or perhaps to manufacture a similar device (or under licence from Chadwick) for sale in the study area. The present Canadian distributor is Canadian Airmotive Ltd. of Ottawa, Ontario.

Bearings

There are a variety of bearings which are used in helicopters and which frequently need replacing.

Ball bearings are used extensively in helicopter construction. Many carry an airframe manufacturer's part number which must be adhered to with no substitutions made because of the closer tolerances required than for standard ball bearings. Roller bearings are the second most commonly used bearings. Normally, they carry radial loads but by tapering the races they can also carry thrust loads. Spherical bearings are used on control tubes and rods and are commonly called rod ends. They are also used on the pitch change in tail rotors and other areas where some side movement is required.

Elastomeric bearings are used in oscillating loads where complete rotation is unnecessary, and they are commonly used in new rotor heads. This type of bearing uses an elastomer (rubber) as the lubricating surface between two or more surfaces. The most common elastomeric bearing types are:

o Cylinderical bearings - absorb high radial loads and provide movement in radial oscillation.

- Spherical bearings - provide movement about the three axes and absorb heavy torsional loads.

- Conical bearings - absorb high radial and axial loads with some movement in both directions.

There may be a market opportunity for a British Columbia bearing manufacture such as B.C. Bearing Engineers Ltd. to develop bearings under license to the airframe manufacturers. Kaman, which is a major helicopter parts sub-contractor, has a division, Kaman Bearing Canada Ltd. with a sales office in Vancouver. The possibility of this sales office being expanded to handle helicopter bearings may be another possibility.

Chip Detectors and Boroscopes

Electronic chip detector and boroscope manufacture in British Columbia may be a possible opportunity. Foreign object damage (FOD) is a leading cause of turbine failure. Electronic chip detectors and boroscopes are devices which are used to locate metal fines, sand and other foreign particles which may become injested in the engine. Technical Development Corp. of Glenalden, Pennsylvania, make the "Zapper", a pulsed electronic chip detector. Machida America, Inc. of Norwood, New Jersey make flexible boroscopes for visual inspections. These are typical of available products and could be manufactured in British Columbia.

Nickel-Cadmium Batteries

Ni-cad batteries are used extensively in helicopters but none are manufactured in Canada. Ni-cad batteries not only are rechargeable but are usually lighter in weight and can start a turbine engine faster without heat build-up. SAFT America Inc. of Valdasta, Georgia manufacture a ni-cad battery which is popular for rotary wing installation. A licencing agreement may be possible to build a similar battery in British Columbia.

Improved Cockpit Displays

Custom cockpit displays for helicopters may offer a marketing opportunity as the trend to increased avionics and instruments in the cockpit requires additional space and layout for their installation. Sfena Corporation, a French company with facilities in Grande Prairie, Texas, has been successful in developing IFR cockpit display panels for Aerospatiale and Bell Helicopter products, and also designs for the U.S. Navy. A similar cockpit display panel may appeal to IFR or corporate helicopter operators in the study area to be done by a British Columbia firm.

12.0 SUMMARY AND CONCLUSIONS

There are approximately 3,500 civil helicopters in the Primary and Secondary Market Areas identified in the study. It is anticipated that over the next decade the number of units will increase by 1,000. Military helicopters, particularly the U.S. Army helicopters, are not identified by geographic area but could be a substantial number in the study area. The Primary Market Area which includes British Columbia, Alberta, the Yukon, Alaska and the U.S. Pacific Northwest has about half of the total number of identified helicopters. Bell Helicopter products now account for 54 percent of the total and, by 1990, is still anticipated to have 52 percent of the total market. One helicopter model, the Bell 206, accounts for about 30 percent of the total market and is expected to retain this market share over the decade.

Maintenance requirements of helicopters are considerably more than fixed wing aircraft due to higher stress factors on rotating components and parts. Overhauls are more often and limited life component hours are generally lower than for comparable fixed wing maintenance. The facilities and skills needed to maintain, overhaul and repair helicopter components is considerable and the capabilities increase with the complexity of the helicopter design.

British Columbia now has a number of firms which are capable of undertaking helicopter general maintenance including some which can provide specialized overhaul and repair. A number of British Columbia firms have even established international reputations in the field.

There are also a number of firms which compete with British Columbia firms for the maintenance, overhaul and repair of helicopters. Alberta in the Primary Market Area and California in the Secondary Market Area are particularly capable in certain areas of expertise.

It is estimated in Chapter 10.0 that civil helicopter maintenance for overhaul and repair of engines and major helicopter components is some $96.4 million and that by 1990 that the figure will increase to $132.8 million. Routine maintenance, refurbishing, avionics and instrument servicing and other helicopter related expenditures could add another $70 - $85 million to the total. Military helicopter maintenance is in addition.

A number of possible market opportunities have been identified for British Columbia companies. Some of these include:

- Develop major overhaul facilities for the Allison 250 series and perhaps the Pratt and Whitney PT6 turbines;
- Expand British Columbia supplier capabilities to overhaul main rotorheads, transmissions and gearboxes and engine accessories for additional helicopter models, particularly the newer, more complex-designed helicopters. There are some opportunities for spare parts manufacturing and repair of these components as well;
- Expand local overhaul and repair of avionics and instrument capabilities, particularly for the more technically advanced products;
- Repair and overhaul of composite rotor blades.

While there is a substantial amount of helicopter-related maintenance, overhaul and repair capability in British Columbia there is a need to coordinate the various activities. These activities are presently in various locations throughout the Vancouver Lower Mainland (Vancouver International Airport, Richmond, Vancouver, Delta, Langley, Abbotsford) and other locations throughout the province (Prince George, Victoria, and so forth). Prospective helicopter customers usually are only aware of a particular firms skills, qualifications and costs from previous experience or reputation. Customers from out of the province, in particular, need to be made aware of the abilities of British Columbia firms. It would appear that a helicopter maintenance association of British Columbia helicopter-related firms, which could coordinate the industry, would assist in the marketing of the members' various capabilities throughout the Primary and Secondary Market Areas.

There is also a need for coordination in the use of British Columbia helicopter facilities and equipment. In order to maintain, overhaul and repair new types of helicopters there will be a continual need for capital investment for new equipment which often cannot be economically justified for the use by any one company. As the costs increase, there may be a need for a common maintenance centre where special equipment and testing facilities can be jointly used on a "user pay" basis. It is suggested that the planned new facilities for the Pacific Vocational Institute could form the nucleus for such a specialized maintenance equipment and test centre. The Pacific Vocational Institute's new Aviation/Aerospace Campus Training Facility would have, in-house, the latest technology to train

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