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The Use and Potential of Helicopters In Forest Pest Management

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FORWARD

This report was originally prepared under DSS Contract OGR6-0265 for the Chemical Control Research Institute, now part of the Forest Pest Management Institute of the Canadian Forestry Service. It was submitted in December, 1976 and made available, on a limited circulation basis, to the various federal and provincial government agencies responsible for forest pest management and related research in Canada. The high level of interest in the original report and the demand for copies ultimately led to a decision to publish the information in the present, abridged format.

ABSTRACT

The purpose of this study was to explain the contemporary state of the art in Canada of forest spraying by helicopter, and to evaluate the feasibility of a proposed research program to optimize treatment results through the development of specialized helicopter spraying equipment, techniques and operational guidelines.

The study involved a review of available literature relating to the experimental or operational use of helicopters for forest spraying in Canada and the United States, publications concerning aircraft and spray system performance, and technical data and aircraft ownership and operator licensing in Canada. The work included a survey of operators, pilots and resource managers in both Canada and the United States to document relevant experience, opinion and comment.

The study concluded that the helicopter has a high-potential as a forest spray aircraft. Its three major stumbling blocks in this role are lack of information on rotary-wing aerodynamics as they relate to spray cloud behavior, lack of understanding of operational logistics, and lack of an aerial dispersal system which is both helicopter-specific and forestry-specific. These technological gaps appear to be a source of great concern to the majority of those reached by the survey.

It was recommended that the proposed research program be implemented and that it include the investigation of the helicopter rotor wake as an aerial applications tool to optimize deposit, and the establishment of flight parameters and operational guidelines to fully exploit the helicopter's unique aerodynamic characteristics and flight capabilities; in addition, that a light-weight, economical, helicopter-compatible, spray delivery system be developed for use in conjunction with electrically-powered, rotary, atomizing devices. It was further recommended that the work initially be conducted in the field of high-value stand pest management where the need for this technology is great and where the characteristically higher development costs are more easily tolerated.

RÉSUMÉ

Le but de cette étude consistait à expliquer l'état actuel de l'arrosage de forêts par hélicoptère au Canada, puis à évaluer la possibilité de réaliser un programme de recherche proposé pour optimiser les résultats du traitement, en développant un équipement spécialisé d'arrosage par hélicoptère, des techniques et des directives opérationnelles.

L'étude impliquait une revue de la littérature spécialisée relative à l'usage opérationnel ou expérimental d'hélicoptères pour l'arrosage aérien au Canada et aux États-Unis, des publications concernant la performance des appareils et du système d'arrosage, puis des données techniques et de la possession et des permis de pilotage des aéronefs au Canada. Le travail comportait une enquête auprès des opérateurs, des pilotes et des gestionnaires de ressources tant au Canada qu'aux États-Unis, en vue d'une documentation pertinente étayée sur leurs expériences, opinions et commentaires.

L'étude a abouti à la conclusion que l'hélicoptère présente de grandes possibilités comme appareil d'arrosage aérien des forêts. Ses trois inconvénients principaux pour jouer ce rôle consistent en un manque de renseignements sur l'aérodynamique des hélices, quant à leur rapport au comportement du nuage d'arrosage, un manque de connaissances en logistique opérationnelle, et enfin l'absence d'un système aérien de dispersion qui serait à la fois spécifiquement applicable à la forêt et à l'hélicoptère. Ces lacunes technologiques semblent être une source de sérieuse inquiétude pour la majorité des gens touchés par l'enquête.

On a recommendé de mettre en oeuvre le programme de recherches proposé, et qu'il comprenne l'étude du sillage produit par la rotation des hélices de l'hélicoptère, en tant qu'instrument potentiel d'optimisation du dépôt; ainsi que d l'établissement de paramètres de vol et de directives d'opération permettant d'exploiter à fond les caractéristiques aérodynamiques et les capacités de vol uniques à l'hélicoptère; en plus, qu'un système d'arrosage léger, économique et compatible avec l'hélicoptère soit mis au point pour servir conjointement avec des dispositifs atomiseurs rotatifs mûs à l'électricité. On a de plus recommandé que les travaux soient conduits tout d'abord dans le domaine de la répression des ravageurs des peuplements de grande valeur, où le besoin de cette technologie est de rigueur et où les coûts de plus amples développements peuvent être plus facilement absorbés.

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INTRODUCTION

The aerial spraying of liquid insecticides has provided a principle means of forest pest control in Canada for three decades. Fixed-wing aircraft equipped with various boom-and-nozzle dispersal systems have constituted the basic approach to aerial applications throughout this period, although mechanical spray atomizers have begun to enjoy increasing utilization during recent years.

Most contemporary spray equipment is inherently reliant on aircraft speed and, hence, on the velocity of the inflight relative wind to provide some degree of spray atomization or to turn the fans which power pesticide pumps and mechanical atomizers.

The helicopter did not make its debut until the mid-1940's, and only began to come into its own after 1950. One of its earlier uses was as a spray aircraft in agricultural operations, a role in which it came to earn an excellent reputation for superior droplet penetration of the canopy and coverage of foliage. The spraying equipment employed for this work has usually been of the boom-and-nozzle type, developed for agricultural use on aeroplanes and modified to permit installation on helicopters.

In operational forest spraying, helicopter utilization has been very limited. Results have occasionally been outstanding but often no better than those of the aeroplane in spite of the helicopter's demonstrated effectiveness for treating field crops.

It has become increasingly apparent that the aerial applications environments of forestry and agriculture respectively are radically different, each requiring its own set of operational guidelines for optimization of treatment results. Unfortunately, too little is known concerning the effects of rotary-wing aerodynamics on spray clouds to establish such guidelines for forestry. We simply do not know how high a level of treatment effectiveness can be expected of the helicopter, much less how to achieve such results consistently.

The problem is compounded by the fact that agricultural spraying equipment is generally unsuitable for forestry application by helicopter, and the helicopter-specific, forestry-oriented, aerial spray system has yet to be developed.

During 1976, in response to the growing conviction that a tool of great possible benefit to forest pest management was being overlooked, the Chemical Control Research Institute of the Canadian Forestry Service decided to initiate an investigation into the helicopter's real potential as an aerial spray vehicle. An independent study was commissioned to thoroughly evaluate this potential and, hence, the feasibility of a research program to evolve specialized and practical helicopter spraying techniques and equipment for use in Canadian forestry.

The stated objectives of the feasibility study were several in number:

1. To review all available literature which directly relates to forest spraying by helicopter and obtain the opinions and comments of pilots, operators and resource managers with significant experience in this field on the problems and potential of the helicopter in an aerial applications role;

2. To explore the history of forest pest control in Canada, and explain the contemporary state of the art as the result of past and present influences on related research and development, the trends followed, and the evolution of today's attitudes and operational policy in terms of the aircraft, equipment, systems and techniques in use;

3. To document information on aircraft performance capabilities, Canadian aircraft ownership and operator licencing, and aerial applications equipment types and availability, and to investigate the types, importance and extent of high-value forest stands in Canada in which helicopter spraying would be feasible at the present level of technology;

4. Based on the foregoing, to make recommendations concerning the feasibility and (if feasible) the directions of the proposed comprehensive, CCRI research program to evaluate the use of helicopters for forest pest control, to develop related, specialized equipment, systems and techniques and, ultimately, to evolve operational guidelines for the effective use of rotary-wing aircraft as aerial spray vehicles in Canadian forestry.

The original report presented, in both graphic and tabular form, a large volume of technical and numerical data on the performance and capacities of aircraft, aerial dispersal systems, and related equipment. Most of this was published in the United States and Canada during or prior to 1976, and all of it employed British units of measurement to specify or define terminology and performance criteria peculiar or basic to standard aviation vocabulary not only in this country, but in the United States where virtually all of the equipment and aircraft discussed are manufactured. Metrification of these values would have been both complicated and confusion-producing under the circumstances. The original report thus used the various data as they were received and, consequently, employed British units of measurement throughout. The same is true of the present version which is simply an abridgement of the original document submitted to Chemical Control Research Institute in December, 1976.

CHAPTER I: HISTORICAL REVIEW

1. Background

During the past 30 years, the science of aerial pesticide application has become an indispensable tool in the effective management of the Canadian forest resource.

Throughout this period, aerial applications technology has continued to evolve. For obvious reasons, the directions followed were shaped by the contemporary state of the art of civil aviation in general and of agricultural aviation in particular, while both these interests were periodically subject to strong influence by the military sector as various systems and methods became declassified and surplus aircraft were made available for private purchase. More recently, public concern over environmental quality, combined with increasing demands on the forest, rapid spread of certain insect infestations and rising treatment costs, have accelerated the search for improved spray equipment and for more ecologically acceptable pesticides and application techniques.

It is thus readily apparent that to fully appreciate the contemporary state of the art of aerial forest spraying in Canada, it is essential that its technological development be reviewed against the fluid background of an ever-changing social, political and economic climate and an evolving civil aviation industry. This chapter will attempt, briefly, to highlight and explain the course of this development to the present day.

2. Evolution of Forest Spray Aircraft

From its earliest beginnings in Canada until after the outbreak of World War I, aviation was taken seriously by only a few, including the small group of private experimenters whose activities then comprised the total aviation program in this country.

Following the outbreak of hostilities in 1914, however, many military authorities began to recognize the aeroplane's strategic potential. The ensuing conflict thus maintained a traditional role of war as a catalyst of technological achievement by greatly accelerating development in the field of aviation to produce a practical means of transporting personnel and material. The war also set a trend which was to influence many aspects of civil aviation, including both the agricultural and forestry sectors, for more than four decades when, at its close, large numbers of military aircraft were declared surplus and made available for sale to the general public. The price of these machines was usually very minimal and they quickly became the backbone of the fledgeling civil aviation industry, usually crewed by recently-returned, military-trained airmen.

During the seven years which followed World War I, the air transport industry suffered severe growing pains, both in Canada and elsewhere. Commercial air services of various types continued to spring up but most managed to survive only briefly. This situation was largely due to the combined effects of the post-war recession and the stagnation in aircraft development which resulted from relaxation of the military requirement. Consequently, civil aviation was both unable to realize potential markets, and was deprived of technological advancement in aircraft, its primary tool and an obvious prerequisite to any significant expansion of the industry itself (Molson 1974).

By 1926, however, the aircraft manufacturing industry had begun to gain momentum and the 'new generation' machines had begun to appear. Civil aviation benefitted, and expanded accordingly.

By the mid-1930's, the bush-flying era was in full swing across Canada and, in 1935, Noorduyn Aviation Limited of Montreal flew the first prototype of the Norseman. This machine, specifically designed for remote-area operations in Canada, continued in production until 1959 and became one of the best-known aircraft ever designed and manufactured in this country.

The close of the 1930's was marked by the eruption of World War II in Europe, and any question if the aircraft's strategic importance was rapidly and emphatically dispelled. World War II followed, but vastly exceeded, the developmental catalysis traditions of its 1914-18 predecessor, giving rise to an almost staggering acceleration of the evolution of aircraft and aviation-related technology, as the adversary nations strove for superiority in the skies.

Revolutionary aerodynamic and structural concepts, materials and aero engines were developed and applied in the field, and aircraft performance and reliability standards improved dramatically and steadily. Support and maintenance techniques kept pace together with instrumentation, avionics and pilot training.

With the end of hostilities, those returning airmen who wished to pursue careers in aviation faced brighter prospects than had their counterparts in 1918. The same was true of the civil aviation industry which was already an established entity, and which could now benefit from many of the technological advancements which the war had produced.

Technical achievement, however, was not the only spin-off benefit of World War II to affect civil aviation after 1945. As was the case in 1918, the reduction in armed forces activity and the declassification of certain equipment and systems soon began to make large numbers of surplus military aircraft available to civilian interests, usually at relatively minimal costs.

Many of these surplus machines were acquired by commercial operators and assigned a variety of peace-time missions which ranged from general air transport to aerial surveys and high-altitude photography, and which soon came to include the aerial application of chemical pesticides to agricultural crops and forest lands both in the United States and in Canada.

3. Development of the Aerial Applications Concept

3.1 Origins

It is virtually impossible to establish the earliest date on which aircraft were used to disperse pesticides. However, in 1911, a German forester patented the concept of using aircraft for forest pest control (Molson 1974), and there are stories of their experimental use for agricultural purposes in the United States during 1918 and 1919.

The first well-documented such activity was carried out in Ohio during 1921 against the catalpa sphinx (Doane et al. 1936) when a plantation was dusted with lead arsenate, using a hopper attached to the side of a Curtis J.N. 6 (Balch et al. 1955/56).

Following the success of the catalpa sphinx program in 1921 (Molson 1974), the Huff Daland Company of Ogdensburg, New York began to produce 'specialty-design' aircraft for aerial applications, and created the Huff Daland Dusters to carry on commercial dusting activities. Within a few years, this company was succeeded by the Keystone Aircraft Corporation, manufacturers of the 'Keystone Puffer'. With these and other aircraft, dusting operations continued throughout the 1920's, primarily for protection of the cotton crops in the southern United States (Nigam 1975).

Anderson (1960) states: "Aerial forest dusting and spraying have been experimented with at various times since 1925, but this method became practical only after the extremely effective insecticide, DDT, was developed."

In 1927, the Civil Operations Branch of the Royal Canadian Air Force bought two Keystone Puffers. One was used for experimental dusting of wheat stem rust in Manitoba, and the other for calcium arsenate dusting experiments against spruce budworm on Cape Breton Island, Nova Scotia (Randall 1975).

As summarized in Table 1, calcium arsenate dust was employed in Canada from 1928 to 1930 inclusive to control spruce budworm and eastern hemlock looper in Ontario and Quebec, and western hemlock looper in British Columbia. Results were excellent against the looper but very limited in relation to spruce budworm (Nigam 1975; Randall 1975). This, plus excessive treatment cost per acre and numerous technical problems, caused aerial dusting to be abandoned as a means of forest insect control in Canada and, in fact, no further aerial applications of any kind were undertaken in Canadian forestry until 1944.

Table 1: Calcium arsenate dust application, 1927-1930[1]

Insect Species	Prov.	Period	Acreage	Dosage (lb./ac.)	Total Used (lb.)
Spruce budworm	N.S.	1927	2,550	15-30	56,000
	Ont.	1928-29	1,400	10-40	40,000
E. hem. looper	Ont.	1928-29	1,005	30-35	30,175
	Que.	1929	1,500	18	27,000
W. hem. looper	B.C.	1929-30	1,645	20-26	33,170

[1] P.C. Nigam, 1975.

Probably the most significant work carried out during the 1930's in the United States was a series of experiments aimed specifically at the improvement of aerial applications technology for forestry (Randall 1975). This work led to the design of boom and nozzle systems for dispersing pesticides in liquid form rather than as dusts. Interestingly, this concept which constitutes the basic approach to nearly all modern forest pest management was, for many years, used very little in the United States, and not at all in Canada.

3.2 The Modern Era

By the mid-1940's (Nigam 1975; Randall 1975), outbreaks of western hemlock looper and spruce budworm, in British Columbia and Ontario respectively, had created a vital need for protective action. Fortunately, Canadian foresters and entomologists now had more effective tools at their disposal in the form of better aircraft, and the new chlorinated hydrocarbon compound, DDT. The advent of this chemical, and proof of its effectiveness against a wide spectrum of insect pests, had led to its use for the protection of military personnel during World War II. Related spraying equipment and techniques had also been developed.

Experimental work was undertaken in 1944 against the spruce budworm in Ontario, spraying a solution of DDT and aromatic oil from the White Standard biplane and the Pitcairn Autogyro. The following year, this method was employed operationally to treat budworm infestations in Ontario and Quebec, and in 1946 against the western hemlock looper in British Columbia.

Thus began Canada's modern era in forest pest management. Over the intervening three decades, a wide variety of aircraft have been used for aerial forest spraying, while dispersal systems and applications technology have continued to improve. Appendix 'E' summarizes this period of development year by year to 1975 in terms of the province, insect pest and treatment involved, together with type of aircraft, spray system, acreage, chemical and, in some cases, cost per acre.

In 1952, the New Brunswick International Paper Company launched what has since become the sustained spruce budworm control program in that Province. An organization known as Forest Protection Limited was established to carry on this program as a joint venture of forest industry and government in New Brunswick. The main aircraft employed in this program have always been converted, ex-military machines, initially the Boeing A75 Stearman and, after 1957, the Grumman TBM 'Avenger'.

By 1960, commercial aircraft manufacturers had begun to introduce modern machines specifically designed and built for spraying and dusting operations, such as the Thrush (Snow) Commander, the Grumman G164 Ag-Cat, and the Piper PA-25 Pawnee. The Cessna 188 AgWagon followed in 1966. Although primarily intended for agricultural applications, these machines have also found a place in forest spraying.

Larger, faster aircraft with greater spray capacity have a number of obvious advantages over smaller machines. They are able to remain over the work site for longer periods of time without returning to base for more fuel and pesticide, and can cover a greater area in less time. Fewer machines are thus required to treat a given acreage, and administrative problems are reduced. Further, such rapid, wide-area coverage facilitates treatment of relatively vast insect infestations, covering the entire area during the short period of maximum pest vulnerability. The ultimate aircraft of this type to date in terms of capacity, range, availability and economy are four-engine transports such as the Douglas DC-6B and Lockheed L-1049. These machines became available for such duties as fire suppression and aerial spraying when they were phased out by airlines in favour of turbine- and jet-propelled airliners. Used for the first time in Quebec during 1972, the transport class aircraft has since become a permanent element of the spruce budworm program in that province, and was instrumental in treating almost 9.9 million acres during 1973 (Blais et al. 1973).

Thus, we have seen the development of the fixed-wing spray aircraft and related technology from the early 1920's through to the present day. During the latter part of this period, however, an innovative approach to powered flight suddenly made its appearance, utilizing concepts which represented radical departures from accepted practice and aeronautical theory. This late arrival, considered preposterous and impractical by nearly everyone connected with contemporary aviation, employed a 'rotating wing' principle rather than the rigid, fixed, supportive airfoils of the aeroplane, and came to be called the 'helicopter'.

4. The Helicopter

4.1 Rotary-Wing Development

The fixed-wing aircraft was, of course, the first design concept to actually evolve into a workable, heavier-than-air flying machine. It has the advantage of simplicity and was a logical next step to the manned glider.

The helicopter, however, while simple enough in principle, proved to be an extremely complicated and difficult concept to put into practice. In a helicopter, the rotating wing or 'main rotor' is required to perform all the functions of an aeroplane's wing, propeller, ailerons and elevators, providing lift, propulsion, control of pitch and roll in the forward flight mode and control of travel direction in the hovering mode. The tail rotor, which is basically required to counteract the torque induced when power is fed to the main rotor by the engine, also fulfills the function of a rudder to control yaw. Needless to say, the engineering of the helicopter's main and tail rotors, power train, and control system was a complex and demanding task fraught with problems and frustrations.

In addition, the rotary wing pioneers Breguet, Sikorsky and Bell were confronted with an almost total lack of encouragement on the part of authorities and aviation experts, both civilian and military. The helicopter was, at best, considered interesting in concept but unworkable in practice. Even those who were willing to concede that such a contraption had even a remote chance of becoming airborne were unable to visualize any practical application for any such radical departure from conventional design.

The first well-documented flights of Sikorsky and Bell were made in 1941 and 1943 respectively. On March 8, 1946, the Bell Model 47 became the world's first commercially certificated helicopter. It is interesting to note that the very first such aircraft to be sold commercially by Bell, registration number NC 1H, is now the property of a prominent Canadian firm, Viking Helicopters Limited of Carleton Place near Ottawa, Ontario.

The early model helicopter's numerous shortcomings, including low speed, limited range, small payload and complex maintenance requirements, and the technological and marketing problems faced by their builders, are well-illustrated by a September, 1947 report of the Research Branch, Ontario Department of Lands and Forests, entitled "Report on Experimental Use of a Helicopter in Port Arthur District."

This helicopter, probably the first in Canada, was equipped with inflated rubber pontoons, and appears to have been a Bell Model 47B-3 owned by Photographic Survey Company Ltd., of Toronto, Ontario. According to the report, the helicopter carried a pilot and one passenger. Powered by a 178 h.p. Franklin engine, it flew at 65 to 75 miles per hour, and had a range of up to 150 miles. With only the pilot on board, it could carry 350 pounds of cargo, or "...400 pounds ...if good take-off space was available." The helicopter was on hand for 21.5 days during which it actually flew only eight days, or 37 percent of the time. The remaining 13.5 days, or 63 percent of the total, the ship was grounded for maintenance, repairs, weather (4.75 days), or awaiting supplies (presumably for the helicopter). It required inspections every 25 flight hours, each requiring at least one day to accomplish, and a complete, tear-down inspection at 100 flight hours. The report goes on to say, "A jeep trailer with supplies, tools and spare parts is pulled by a truck wherever the helicopter goes." Obviously, maintenance costs must have been extremely high.

To keep the foregoing in proper perspective, it must be remembered that, during the same year, 1947, one of the smallest fixed-wing aircraft commercially available was the Piper Model J3 'Cub', and it is interesting to compare its performance with that of the Bell 47B-3. Like the helicopter, the Cub carried a pilot and one passenger. On wheeled landing gear, it had a top speed of 87 miles per hour, or 12 miles per hour better than that of the helicopter. The J3 was equipped with a 45-or a 60-h.p. engine, compared with the helicopter's required 178 h.p., and consumed one-third of the fuel per hour. Assuming full fuel tanks and a 150-pound pilot, the Cub's 'cargo' capacity was only about 35 pounds less than the helicopter's, but it had a 55-mile advantage in range. In 1947, the new factory list price of the J3 Cub was $2,195 while, according to the Aircraft Blue Book (First Quarter, 1976), the equivalent price for a Bell Model 47B-3 was approximately $25,000.

The helicopter's unique ability to hover at zero ground speed and to take off vertically from a confined landing area was extremely advantageous in many situations. However, such capabilities were costly to the operator, and involved complicated and troublesome maintenance schedules.

Nevertheless, helicopters continued to be produced and purchased in growing numbers by organizations with specialized requirements. The armed forces of the United States ultimately recognized the potential strategic value of the helicopter, and began quite early to support its research and development. Such support was largely responsible for the speed with which rotary wing technology evolved, as new modifications, designs, materials and systems were developed, tested and put into service. A benefit not to be underrated, of course, was that the military provided a major market for the final product.

Increasing production combined with better designs, greater reliability, higher payloads, and maintenance requirements which were both standardized and much less exacting, ultimately resulted in an aircraft whose special abilities were no longer offset by all its earlier disadvantages. Other helicopter manufacturers began to appear, including Boeing (Vertol), Hiller, Hughes and the French Aerospatiale (Appendix 'B': Table 1). Gas turbine engines with their high power-to-weight ratio and small size, were introduced in military helicopters during 1956, and in commercial machines during 1962. Today, some turbine helicopters boast speeds in the order of 200 miles per hour, with others capable of lifting loads ranging from 1,500 pounds to nearly 17 tons.

4.2 Helicopters in Aerial Applications

The date on which helicopters were first used for aerial applications is uncertain, but there is little doubt that their debut in this role was made in agricultural operations rather than forestry. The Bell Helicopter Company has reported that its first commercial helicopter sale, a Model 47, was involved in agricultural work a few months after delivery in 1946.

The earliest reported helicopter dusting operation in Canada was carried out during 1947, when a Bell Model 47 (probably Series B-3) was used to apply rotenone to an aphid infestation of a pea crop in the Ontario counties of Essex and Kent.

Although a Pitcairn Autogyro was used for an experimental forest spray project in Algonquin Park, Ontario during 1944 (Howse and Sippell 1975), the first forestry use of a true helicopter for forest spraying in Canada occurred in British Columbia during the summer of 1948. In this program, a Bell Model 47B-3 employing boom- and-nozzle spray equipment applied a DDT- and-oil solution against western false hemlock looper infestations totalling 11,200 acres in the Windemere Valley and 400 acres near Radium Hot Springs. The treatment, combined with an onset of a nuclear polyhedrosis virus, virtually annihilated the looper population in the valley, and no further outbreaks occurred for over 20 years.

In 1959, a Bell 47G was used in British Columbia to apply BHC to floating log booms for protection of the wood against the striped ambrosia beetle (Lejeune and Richmond 1975). The degrading of lumber- and veneer-quality material by this insect had caused a sufficiently serious, continuing loss to forest industry that, in the early 1950's, individual hand spraying of the logs had to be undertaken with BHC. In 1958, spraying of the booms by fixed-wing aircraft was tried and abandoned, since the aeroplane's speed and relative lack of agility precluded achievement of the required precision and coverage. The helicopter trials proved so successful in 1959 that a spraying program was undertaken and continued until 1970. In 1959, the cost of helicopter spraying, in terms of lumber production cost, averaged between 22 and 23 cents per thousand fbm, while spraying by hand cost approximately $2.00 per thousand.

Since that time, helicopters have been used in numerous forest spraying programs in Canada (Table 2) involving a variety of insects and chemicals, and areas of from five to nearly 10,000 acres. Some of these programs have been classed as operational, while many have been experimental. Unfortunately, the experimental projects were not necessarily designed to evaluate the rotary-wing aircraft as a spray vehicle but, rather, many researchers appear to have used helicopters simply because of the operational convenience afforded by their unique flight capabilities.

Table 2: A general summary of rotary-wing aircraft in Canadian forest pest management, 1944 - 1973[1]

Year	Prov.	Aircraft	Equip.[2]	Acreage	Insect	Chemical[3]	Cost/Ac.
1944	Ont.	Pitcairn Autogyro	G.O.P.	N/A	Spruce budworm, red-headed pine sawfly	DDT, BHC	$
1948	B.C.	Bell 47B-3	b & n	11,200	W. false Hem. looper	DDT	
1959	B.C.	Bell 47G	b & n	Log booms	Str. ambrosia beetle	BHC	
1960	B.C.	Bell 47G Series	b & n	Log booms	Str. ambrosia beetle	BHC (Continues)	.23/Mfbm.
1961	B.C.	Bell 47G-2	b & n	9,800	Saddle-back looper	DDT	
		Bell 47G-2	b & n	1,500	Pine butterfly	DDT	
	Ont.	Helicopter		4,000[4]	White pine weevil	DDT	2.81 - 4.24
1962	B.C.	Bell 47G	b & n	Log booms	Str. ambrosia beetle	Thiodan, BHC	
	Ont.	Helicopter		4,000[4]	White pine weevil	DDT	
	Que.	Hughes 269A	b & n	200	Larch sawfly	DDT	2.42
1963	B.C.	Helicopter	b & n	N/A	W. hem. looper	Phos.	
	Ont.	Helicopter		4,000[4]	White pine weevil	DDT	
1964	B.C.	Bell 47G-2		1,600	Gr. Str. forest looper	Phos.	
		Helicopter		500	W. hem. looper	Phos.	
	Ont.	Helicopter		4,000[4]	White pine weevil	DDT	
1965	B.C.	Bell 47G-2		100	Hem. needle miner	Phos., Dimeth.	
	Ont.	Helicopter		4,000[4]	White pine weevil	DDT	
1966	Ont.	Bell 47G-5	b & n	3,960	Eur. pine sawfly	Phos.	
		Helicopter		4,000[4]	White pine weevil	DDT	
1968	Que.	Bell 47G-4		3,430	Spruce budworm	Phos.	
1970	Que.	Bell 47G-4		4,500	Spruce budworm	Fenit.	
1971	B.C.	Hiller UH12E	b & n	46	Doug. fir gall midge	Dimeth.	
		Helicopter		-	White pine weevil	Fenit., Meth. Tr.	
	Ont.	Hughes 269A	b & n	400	Spruce budworm	Fenit.	
		Helicopter	b & n	-	Spruce budworm	Virus (NPV)	
		Helicopter	b & n	12	Spruce budworm	Virus (EPV)	
1973	Que.	Helicopter (Bell)	b & n	30	E. Hem. looper	Juv. hormone	

Explanatory Notes

1. This table was compiled with general and specific reference to those authors listed as references, who contributed chapters concerning the insects specified in the table, in 'Aerial Control of Forest Insects in Canada', M.L. Prebble Editor, DOE, CFS. Catalogue No. Fo 23/19/1975.

2. Equipment Abbreviations: GOP - Gravity-feed, open pipe
   b & n - boom and nozzle

3. Chemical Abbreviations: Dimeth. - Dimethoate; Fenit. - Fenitrothion; Meth. Tr. - Methyl Trithion; Phos. - Phosphamidon.

4. A total of 4,000 acres were treated in connection with the same program during the period 1961-66. This total acreage was listed in each of the years for reference, as no annual area breakdown was available.

Most large-scale, forest spraying programs continue to maintain helicopters on standby in a search-and-rescue, aerial ambulance, or support role. However, very limited effort has been made to date in Canada to seriously investigate and evaluate the helicopter's unique flight capabilities and in-flight aerodynamics as they may relate to its overall efficiency in aerial applications for forest pest management. Numerous commercial operators have used helicopters for aerial spraying, but this experience has been gained predominantly in agricultural aviation. Lacking the guidance of a large-scale research effort, these operators have sometimes developed ingenious techniques and gadgets on their own, but kept their secrets to themselves.

Most helicopter operators, with an admitted degree of bias, feel that the helicopter is the ideal vehicle for aerial applications in far more situations than its present level of utilization would seem to indicate. However, most are extremely concerned with the lack both of information and of spray equipment specifically designed to exploit the helicopter's capabilities.

Finally, a problem which is more completely dealt with later, is the effect of the helicopter's high purchase price and reputation for high operating costs on its present degree of involvement in spraying activities. As already discussed, the armed forces have had a deciding influence on the directions taken by aerial applications technology through the release of military surplus aircraft to the civilian market, especially after World War II. These were all fixed-wing machines, understandably, since the helicopter did not exist as a viable concept until sometime after the war. Nevertheless, the availability of relatively inexpensive, high-performance aircraft, and their subsequent employment for forest pest management purposes, caused a channelling of technology, and a large-scale capital commitment on the part of the aerial applications industry to the fixed-wing aircraft, a channelling which largely persists to the present day.

5. Aerial Dispersal Systems

5.1 Scope of Discussion

Although aerial applications actually began in relation to forestry during the 1920's, the early treatments involved the use of chemicals in the form of dust. High costs, combined with only limited success against the spruce budworm, caused the discontinuation of dusting as a practical means of forest pest control (Section 3.1).

Modern forest pest management can thus be said to have begun in the mid-1940's. Then and since, the chemical substances used in forestry have been applied mainly as liquids, using various aerial spraying systems. Some understanding of the development and principles of these systems and related devices is basic to an appreciation of the criteria of aerial spray systems designed specifically for use by rotary wing aircraft.

5.2 The Basic Aerial Spray System

Any spray system used to disperse liquid chemicals from an aircraft must incorporate a number of basic components. These include a tank to contain the chemical, plumbing and related accessories which deliver it to some sort of emission device, and the emission device itself which is normally located on a boom outboard of the aircraft, and which discharges the chemical into the atmosphere. Various systems differ only in the various accessory components which influence or control the flow of chemical from the tank to its point of emission into the atmosphere, and the devices through which this emission occurs.

Primarily, airborne spray systems are merely adaptations of equipment commonly mounted on ground vehicles (Randall 1975), and are designed to atomize the chemical into small droplets as it enters the atmosphere. This may be accomplished by hydraulic pressure, mechanical energy, or air pressure. Hence, the basic spray system requires a spray pump and a source of power to drive it, a boom complete with the appropriate orifices or nozzles, a pilot-operated valve to control flow to the boom, a pressure gauge and a pressure relief valve with by-pass capability. The system should also include a pilot-operated dump valve to rapidly empty the tank in the event of any inflight emergency.

The power source which drives the spray pump may also be used to energize various types of spray emission devices, discussed later. The power sources in most common use are fans which are slung below the aircraft's wings or fuselage and turned by the slipstream or inflight relative wind, and various small electric, hydraulic, or gasoline motors.

5.3 Types of Emission and Atomization Devices

Adequate droplet breakup is a prime requisite of an effective emission device to maximize the effective width of the swath treated on each successive pass of the aircraft. During the past 30 years, a number of principles have been employed to break up the chemical into small droplets as it is emitted from the system (Randall 1975).

a) Gravity-Flow, Open Pipe

The gravity-flow, open pipe system was probably the earliest utilized. From the tank, the pesticide flowed under gravity down a pipe and out the end into the atmosphere. It was best suited for use on aircraft flying at high speeds, since the stream of liquid issuing from the open end of the pipe was shattered into droplets by the shearing action of the inflight relative wind or slipstream. In its day, the method proved largely unsatisfactory, providing poor control of droplet size and swath width, and it does not appear to have been utilized after 1946.

b) Boom and Hydraulic Nozzle

Developed for aircraft use in the 1930's (Section 3.1), and first used operationally about 1946, the boom and hydraulic nozzle system rapidly became the industry standard. With its simplicity and relatively low cost, it is still the most widely-used of all aerial dispersal equipment today.

Basically, it consists of a simple pipe or tubular boom mounted span-wise along the wings of an aeroplane, or braced laterally outward from the airframe of a helicopter. Nozzles are spaced along this boom. Pesticide is pumped, under pressure, from the tank into the boom and atomized by hydraulic pressure as it is forced out through the nozzles into the atmosphere. If the aircraft has sufficient speed, further breakup may be achieved when droplets are shattered by the inflight relative wind. A wide variety of nozzle types is available for various emission patterns and flow rates.

A modification of this system is the 'open nozzle' which has been used recently on the large, multi-engine aircraft employed for spruce budworm spraying in Quebec and, to some extent, on the Gumman TBM Avenger. Simply this involves removal of the tip from a standard nozzle and emitting the pesticide under low pressure from the resultant open tube. Atomization is accomplished by shattering of the stream of chemical by the shearing action of the relative wind (Randall 1975). This principle is obviously similar to that of the gravity-flow, open pipe system already discussed, but atomization is superior, due mainly to the much higher speeds of the aircraft involved.

c) Rotary Atomizers

So-called 'rotary atomizers' have developed from work which began during the 1960's to produce an emission device which would improve both the degree of droplet breakup and the characteristics of the droplet diameter spectrum thus obtained. Various devices were evolved in an attempt to achieve this by atomizing the pesticide mechanically rather than by means of hydraulic pressure. They are often installed on conventional spray booms on which all nozzle orifices have been plugged except those which provide a flow of chemical to the device involved.

One such device consists of a number of closely-spaced discs mounted on a hollow, perforated axle which passes through their geometric centres and is aligned parallel to the aircraft's longitudinal axis. As the discs spin, the chemical is introduced between them from the axle, carried in a thin film to their outer edges by centrifugal force, and sheared into droplets by the relative wind or slip-stream as it is thrown outward into the atmosphere. A modification of this principle was the replacement of the discs by a small, circular 'wire brush'.

Another device is the spinning cage which is a flat-ended, hollow cylinder whose curved sides are constructed of screen or some similar material. It is mounted on a hollow, perforated axle which passes through the geometric centres of its flat ends, and on which it spins while small streams of chemical are sprayed outward from the axle. As these streams encounter the spinning, screen cylinder wall, they are physically sheared into small droplets.

Initially, all these devices were rotated individually by means of small, integral fans, which were spun by the slipstream, or relative wind of the aircraft in flight. This principle is still used today for certain similar equipment. The angle of attack of the fan blades may be preset for a desired rotational rate at a specific airspeed, but it is possible for airspeed variations to compromise the effective operation of the device.

The spinning wire cage was developed in Britain during the 1950's (Randall 1975). This and subsequent American experimentation produced such equipment as the U.S.D.A. Minispin and the British Micronair, both wind-driven by fans.

The 1960's produced a breakthrough in the form of rotary atomizers powered by electric motors. The operation of such devices was completely independent of airspeed, and a constant, design r.p.m. could be maintained whether the aircraft was in flight or resting on the ground. In addition, they appeared capable of delivering a narrower droplet size spectrum than previous atomizers or nozzles.

The first such device was the Turbair (actually, the Turbaero Rotary Atomizer, produced by Turbair Ltd.), a British development utilizing the previously-described spinning disc principle. Subsequent versions of the Turbair were available with plastic discs whose peripheries were fine-toothed, curved flanges designed to improve spray breakup. A rheostat allowed the speed of rotation to be varied between 1,300 and 10,000 r.p.m. The new Micron spray head, also developed in Britain, is a recent modification of the same concept.

In 1968, P. Corbett of Beemer Engineering Company (Howitt 1973) conceived the idea of using porous filters to control droplet size. He designed a device which resembled a very small Micronair, except that it was powered by an electric motor and, instead of a cylinder wall of metal screen, it employed a porous (scintered) metal sleeve. In theory, with the sleeve spinning at high r.p.m., chemical introduced from inside will flow out through the porous wall under centrifugal force, extruding as fine threads of the same diameter as the pores, and these threads shear into droplets as they encounter the air. Droplet size is thus a function of the pore diameter and the rate of rotation of the sleeve. Varying the pore diameter in different sleeves makes it theoretically possible to preselect a droplet diameter spectrum conforming to specific requirements.

Thus, potentially better tools have started to become available to the aerial applicator. It remains now for researchers to test, adapt and evolve this equipment for use in forest pest management programs in Canada and to develop operational guidelines for its effective employment.

5.4 Criteria for Helicopter-compatible Aerial Spray Equipment

The helicopter's unique ability to vary its airspeed from zero to over 150 miles per hour permits its pilot to select the optimum spraying speed for the job at hand. For this reason, a helicopter-specific spray system should employ pump and atomization equipment whose operation is completely independent of airspeed. Electrically- or hydraulically-powered pumps and mechanical atomization devices appear to hold the greatest promise in this regard.

Other system criteria include light weight, versatility, and compatibility with on-board sources of hydraulic or electrical power. Higher-volume, agricultural equipment is usually capable of far greater pesticide flow rates than are normally required for forestry, and is correspondingly bulky and heavy. Space and payload is thus squandered, and excessive power is needlessly drained from the ship system when employing spray equipment of the type currently marketed for use by light turbine helicopters.

6. Status of Forest Pest Management Today

6.1 Scope of Discussion

The preceding sections of this chapter have reviewed the development of Canadian forest pest management in terms of the aircraft, equipment, systems and techniques employed since the 1920's. It now remains to assess the contemporary state of the art and the results of our efforts during the past three decades.

A comprehensive evaluation lies beyond the scope of this study. Rather, the following attempts to take an objective look at our successes, the apparent effectiveness of modern pest control practices and the implications for the future, and to summarize and explain our current technological orientation in Canadian forest pest control.

6.2 Success of Past and Continuing Programs

In terms of the total area affected, persistence, economic losses suffered, costs incurred, and sheer magnitude of control operations, the spruce budworm is by far the most serious forest pest in Canada (Section 3.2), and to evaluate our results here is to evaluate the bulk of our total, operational, forest pest management effort to date.

The degree of success achieved by any undertaking is normally determined by comparing the results to the initial objectives. The spruce budworm objectives fall into two basic categories. The first involves the suppression of infestations (Prebble 1975) to prevent their spread to valuable stands in the vicinity. Such a program was undertaken from 1960 to 1962 to suppress a remnant, in the Kedgwick-Rimouski area of Quebec, of the Lower St. Lawrence-Gaspe outbreak of the 1950's, and the program was deemed to have attained its goal.

The second type of objective is the one which has become the general policy in New Brunswick and Quebec. This has been to take protective action anywhere in the province, when necessary to keep the stands alive. The respective programs of these two provinces have been generally successful"...in that the forests have been maintained essentially intact throughout extended periods of repeated heavy annual infestation" (Prebble 1975).

It would thus appear that our major forest pest management effort has succeeded. We have kept the stands alive, but have we really controlled the insect? When Quebec's spraying program began in 1970 (Blais 1975), the goal was to treat all high hazard areas during the second year of attack. However, the infestation spread so rapidly in spite of treatment that this goal soon became unattainable. Even during the period 1973 to 1975 inclusive it grew from 28,200,000 acres to 87,400,000 (Paquet 1975), an increase of nearly 210 percent and, in 1975, only 7,133,700 acres, or 8.2 percent, could be treated. It is worth noting here that the total inventoried, non-reserved, forest land in Quebec is approximately 171,765,000 acres (Canadian Forestry Service 1974). The situation has been much the same in New Brunswick where, from 1952 to 1973 inclusive, the affected area increased ten-fold, from 1,200,000 acres to 12,500,000 acres (Miller and Kettela 1975).

At present, there appears to be no prospect of eliminating or even reducing the magnitude of the spruce budworm problem in eastern Canada. Plans in New Brunswick to utilize timber harvesting patterns which are detrimental to spruce budworm survival hold some promise if used in conjunction with other control methods, and this type of program"... should permit co-existence with the budworm at an acceptable economic and ecological cost" (Miller and Kettela 1975).

One complication is that, as stated by Randall (1975), "In practically all forest spraying operations in Canada, the target area represents only the most seriously affected part of a much larger infested area." Since forest spraying operations virtually never achieve 100 percent insect mortality, a residual budworm population will survive in the treated areas to multiply during ensuing seasons. In addition, the treated blocks may lie adjacent to infested areas of lower population which are not sprayed at all and from which additional insects may invade.

Curtailment of spraying operations would undoubtedly cause the eventual collapse of spruce budworm populations as the inevitable stand mortality eliminated the insect's food supply. However, there is little doubt that such action would also seal the fate of major, primary, forest industry in eastern Canada.

6.3 Aircraft and Aerial Spray Systems

The aircraft has provided man with a tool for the management of his renewable resources on a scale which would have been inconceivable even a few decades ago, including forest pest control programs involving areas whose size and inaccessability would make ground-based control measures unthinkable.

The surplus military machines which became available after World War II were all fixed-wing, and were thus compatible with previous work in forest pesticide application. The helicopter was not yet sufficiently developed to attract the serious attention of researchers in forest pest management. Consequently, available technology was devoted to the refinement of aerial applications equipment and methods based on the aeroplane. Much later, when the helicopter had evolved into an aircraft worthy of serious consideration for forest spraying, technology had become channelled and attitudes entrenched. Over the years, consistent with this orientation, huge investments have been made in terms of both human endeavour and financial resources for research, fleets of aircraft, and other capital equipment, all based on the fixed-wing.

Now, mainly because of the reputation earned by the helicopter in agricultural spraying, interest is beginning to grow in its application to forest pest management. The agricultural and forestry aviation environments, however, are vastly different, and the spraying equipment and techniques of one are seldom compatible with those of the other.

Section 5.4 of this chapter outlined the basic criteria of the forestry-oriented, helicopter-specific, spray system. Such a system has yet to be developed, although it should certainly lie well within the realm of existing technology. Smaller, lighter, lower capacity pumps and motors, plus mechanical atomizers powered by hydraulic or electric motors of a type already in use elsewhere, should provide at least part of the answer. Needless to say, if the cheaper, simpler, boom- and-nozzle system will do a particular job adequately, it makes little sense to invest in more complicated, expensive equipment. In a growing number of forestry situations, however, this does not appear to be the case.

The helicopter will never replace the aeroplane in all situations. Each has its role to play in forestry aviation. Unfortunately, their respective roles and capabilities are poorly defined in the minds of many people in both the research and aviation communities.

As has been stressed, we know too little about the helicopter and the harnessing of its apparent capabilities. We have not adequately assessed the new dispersal systems and the possible benefits of combining their characteristics with those of rotary wing aircraft. It is strongly indicated that, once this concept has been refined by a comparable concentration of research and development effort to that already received by fixed-wing aircraft equipped with boom and nozzle systems, we will have evolved a weapon of, at the very least, equal strategic importance in the war against Canada's forest insect pests.

CHAPTER II: BASIC AERODYNAMIC CHARACTERISTICS OF FIXED- AND ROTARY-WING AIRCRAFT.

1. Scope of Discussion

As emphasized in Chapter 1, fixed- and rotary-wing aircraft represent extremely divergent concepts in aviation technology. Engines and instrumentation are common to both, while many of the controls are alike in both form and function. Here, however, the similarity ends. The two are quite different structurally, mechanically, and in the means by which specific control inputs are translated into the desired responses.

When comparing the aeroplane and the helicopter in an aerial applications role, however, such differences are important only in relation to their respective effects on aerodynamics and flight capabilities. This is because these, in turn, influence both the aircraft's performance on the job and the behavior of the spray cloud emitted.

The following chapter examines the aerodynamic characteristics unique to each of the two aircraft types and the effects of each on the surrounding air during flight in terms of imparted movement which may be significant to spray cloud behavior. Finally, it briefly discusses the appended aircraft performance comparisons as these data relate to aerial forest spraying.

2. Fixed-Wing Aircraft: Aerodynamics and Performance Characteristics

While in flight, an aeroplane is supported in the air by its wing and derives propulsion from a propeller or jet engine. The wing is so shaped that, as it passes through the air, an area of low pressure is maintained above its upper surface, and an area of higher pressure beneath its lower surface. The net effect is the generation of a force called 'lift' which tends to draw the wing upward into the area of lower pressure. The wing's angle of attack, the angle between the wing's direction of travel and its chord axis, determines maximum lift for any given airspeed.

A secondary result of lift generation by a wing is the creation of a vortex effect in the air behind and near each wing tip. These vortices take the form of two rotating, expanding, cone-shaped masses of air which stream out behind the aircraft along its flight-path. The rotational direction of the vortex from the left wing is clockwise while that of the right wing is counter-clockwise. Since the propeller slipstream takes the form of a similar vortex, an aeroplane in flight can trail a vortex from each wing tip, and one from each propeller.

In simple terms, lift can only be developed by a wing which is moving at a velocity sufficient to create a smooth, laminar flow of air over its upper and lower surfaces. For every wing cross-section, wing loading or angle of attack, there is a minimum speed at or above which such laminar flow occurs. If the speed decreases below this minimum, the air flow over the top of the wing begins to 'burble', breaking away from the guidance of the wing's curved upper surface (Langewiesche 1944), and the smooth, laminar flow pattern disintegrates into simple turbulence. At this point, the wing ceases to generate lift, and the aircraft begins to fall in the same manner as a stone or any other heavier-than-air object. This condition is known as 'aerodynamic stall', and the speed at which it occurs in the 'stall speed'.

The stall speed may vary from one aircraft type to another since it depends to some extent on wing shape and wing area as these relate to the maximum allowable gross weight. For any specific aircraft type, the stall speed varies directly with gross weight. In other words, the more heavily you load a particular aeroplane, the more lift it requires in order to remain airborne, and the higher the stall speed becomes. For obvious reasons, unless otherwise specified, the stall speed published by an aeroplane manufacturer will normally have been established at the maximum certified gross weight of the machine involved. The stall speeds of specialty-design agricultural aeroplanes, for example, vary from 46 to 67 miles per hour, depending on type and model (Appendix B, Table 2).

A pilot can easily recover from a stall condition, provided it occurs at sufficient altitude, simply by diving the aircraft to regain the required airspeed. During spraying operations at low altitude, however, inadvertently entering a stall can mean disaster, and any pilot flying a loaded aeroplane down a spray swath will be most anxious to maintain an airspeed which is safely in excess of the stall speed for his particular aircraft type and gross weight. If he must climb steeply to clear obstacles at the end of the block, this speed margin must be even wider since an aircraft tends to lose speed in a climb as does an automobile going uphill. For this reason, a wide safety margin is also required by aircraft attempting to 'contour fly' in mountainous or rugged terrain.

It is thus readily apparent that the aeroplane is totally dependent for flight on the maintenance of adequate airspeed. By the same token, achievement of adequate speed is necessary before an aircraft can even leave the ground on 'take-off'. For this reason, every aeroplane requires some type of runway, an open, relatively smooth strip along which the machine can accelerate until it exceeds the minimum speed necessary for adequate lift generation by the wing, enabling it to become airborne. The runway requirements of various aircraft types range from the 1,000-foot grass or gravel airstrip of the agricultural aeroplane to the more than 6,000 feet of paved surface required by multi-engine, transport-class aircraft such as the Douglas DC-6B.

3. Rotary-Wing Aircraft

3.1 Aerodynamics and Performance Characteristics

As discussed in Chapter I, the helicopter derives both lift and propulsion from its main rotor system. The main rotor, or 'rotating wing', includes two or more blades which are airfoil in design, and whose angle of attack can be varied by the pilot. As an aircraft, the helicopter must be able to become airborne by overcoming the force of gravity and to travel horizontally by forcing its way through the air. In accordance with the laws of physics (Newton's Law), the force required to accomplish this must be opposed by a force equal in magnitude and opposite in direction (Anonymous 1975a). A large volume of air must be accelerated by the rotor blades to achieve this force.

When the helicopter is hovering, it must generate a lift force equal and opposite to that of gravity, and the rotor blades generate this lift by moving huge volumes of air vertically downward (Figure 1). For practical purposes, this volume of air is a function of the helicopter's weight. To put it another way, for a 2,650-pound helicopter to remain in a hover for one second, it must move 2,650 pounds, or more than 34,000 cubic feet, of air vertically downward during that one-second period. To equate this value in more standard terms, the 'downwash' from a hovering, 2,650-pound helicopter can total over 2,000,000 cubic feet of air per minute, depending on density altitude (Figure 3).

These values were based on weight data for a Bell Model 47 helicopter and, for the sake of comparison, it is worthwhile to consider corresponding data for a larger machine. The Bell Model 205A, a common, medium-lift, turbine helicopter, hovering at a gross weight of 10,500 pounds, could effect a downward air displacement in excess of 75,000,000 cubic feet per minute.

When the helicopter enters the forward flight mode, the same gravitational force exists and must be counteracted, as explained above, by accelerating a volume of air vertically downward. In addition, however, a secondary force must be generated to overcome the drag or resistance of the air through which the helicopter is attempting to pass (Figure 2) by moving a second volume of air parallel to the ground and in the opposite direction to that in which the helicopter is travelling. This force is called 'thrust'. Its magnitude and, hence, the volume of air moved, increases as the square of the forward velocity.

Thus, in forward flight, the combined forces of lift and thrust (Figure 2) cause a volume of air whose magnitude varies with speed (Figure 3) to be moved downward at an angle to the horizontal (Figure 4) and a velocity (Figure 5) which also depend on the speed of forward flight.

It will be obvious to many that the foregoing is an oversimplication involving generalizations and average values in relation to speeds, angles and volumes. Its purpose is merely to explain the various forces acting on the helicopter, how these are counteracted, the resultant effect on the air mass involved and, hence, to illustrate the basic aerodynamic differences between fixed-wing and rotary-wing aircraft.

Figure 1. Hovering flight[1]

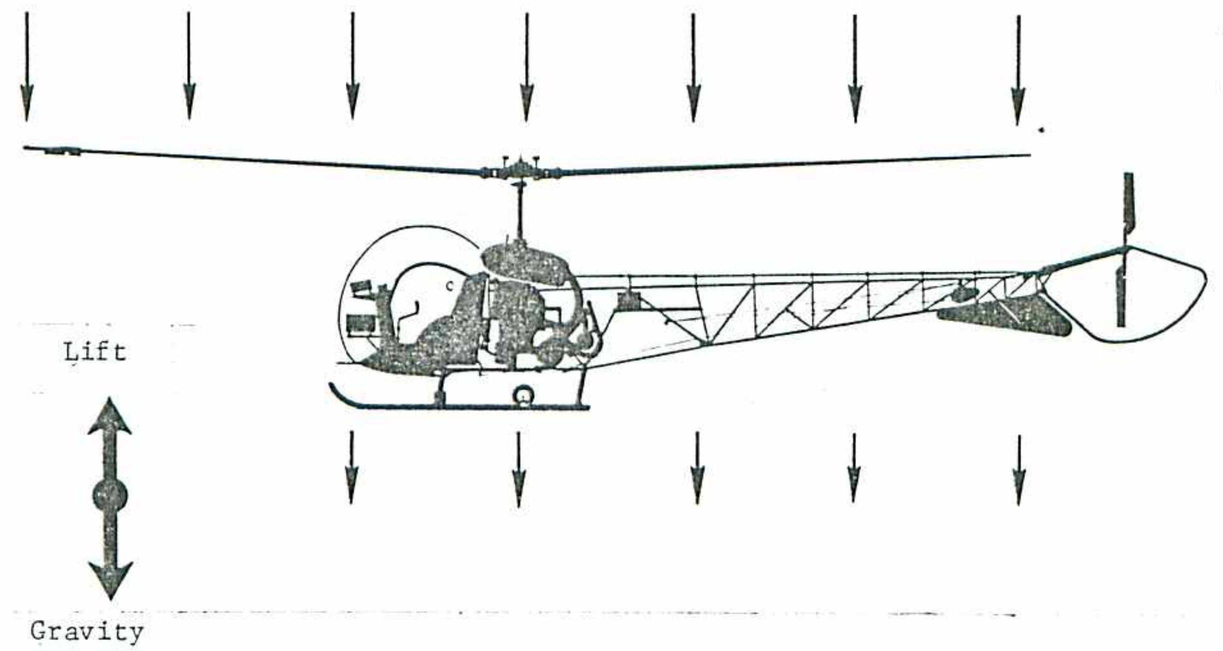
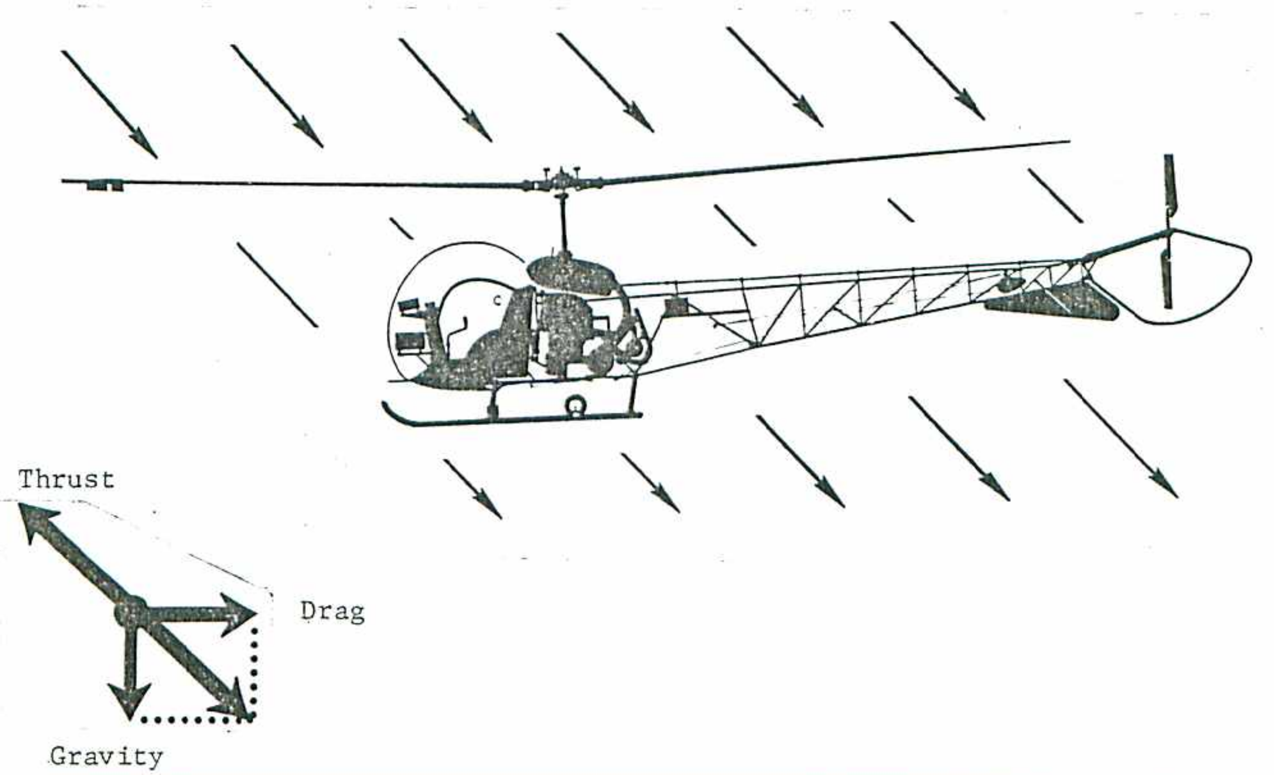


Figure 2. Forward flight[1]



[1] Helicopter techniques for aerial application. Bell Helicopter Company, Fort Worth, Texas, 1975.

Figure 3. Volume of air moved by rotor[1]

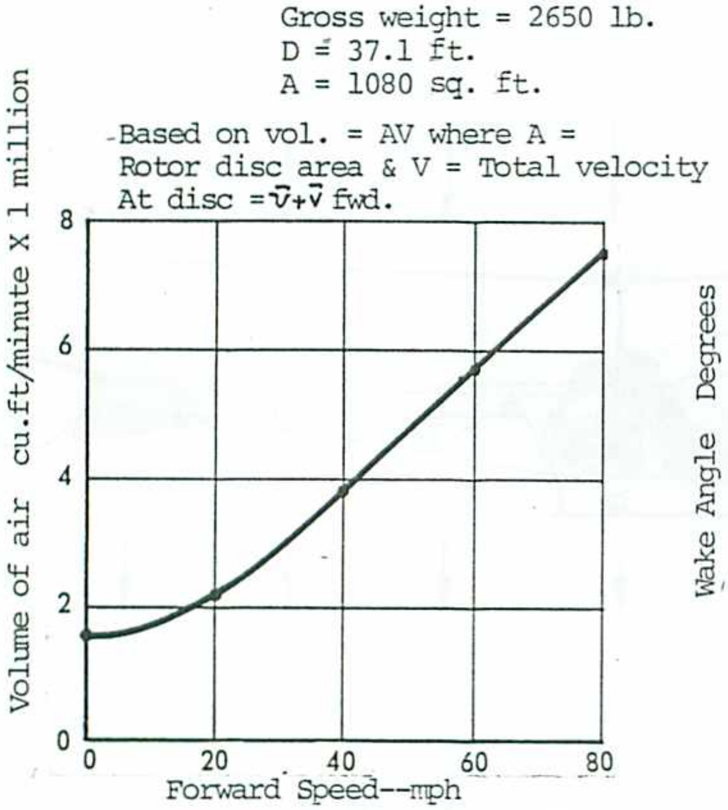


Figure 4. Wake angle[1]

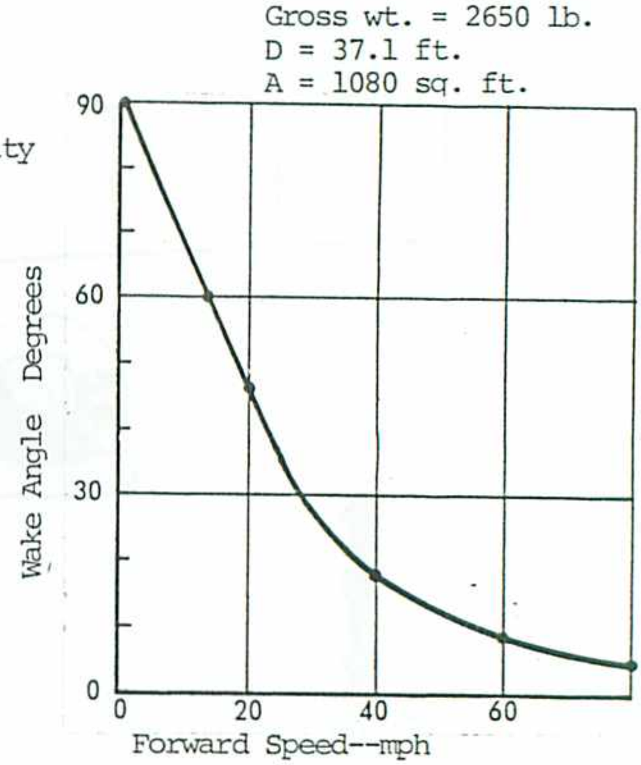
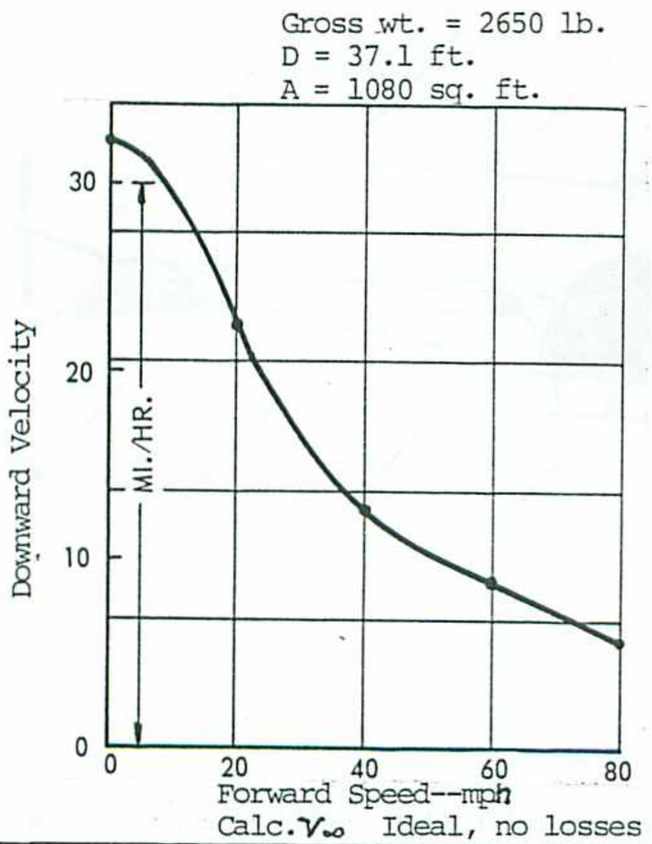


Figure 5. Downward velocity of air[1]



Data Basis

These data are based upon a Bell helicopter with a 37.1 feet diameter main rotor while operating at a gross weight of 2,650 pounds.

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[1] Helicopter techniques for aerial application. Bell Helicopter Company, Fort Worth, Texas, 1975.

3.2 The Helicopter Rotor Wake

The common term 'rotor downwash' is a misleading oversimplification of the processes which actually occur when the helicopter is in flight. Hence, the more accurate designation 'rotor wake' will be employed hereafter.

The rotor wake includes the total amount of air displaced by the helicopter's rotor, while downwash refers to that portion which is moved vertically downward. Only during hovering flight are the two terms synonymous. The characteristics of the rotor wake vary with airspeed and are sufficiently complex that simply averaging the downward velocities and vector angles would be misleading without simultaneous examination of the wake cross-section.

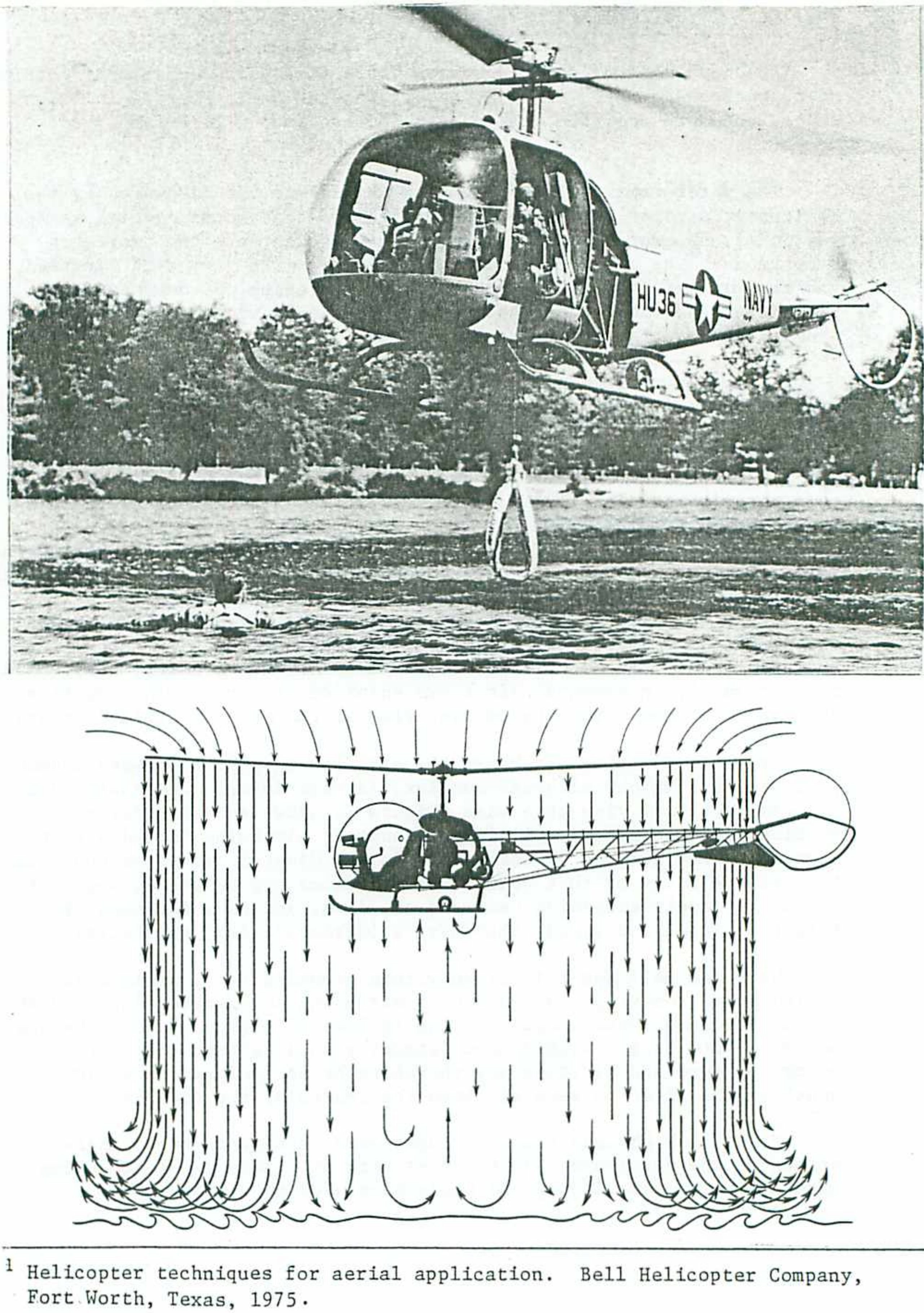
At speeds of zero to about 20 miles per hour, air flow within the wake is primarily downward. Since the main rotor turns at constant r.p.m., the actual speed of the rotor blades through the air increases with the distance from the rotor hub. Consequently, most of the lift and resultant air movement are generated by the outer portion of the main rotor's rotational disc, and the air flow assumes the shape of an annular ring (Figure 6) with a large area of dead air in the centre. As the helicopter begins to move forward, this ring becomes foreshortened into an ellipse whose minor axis continues to diminish as the helicopter accelerates. At approximately 20 miles per hour, although this value may vary with helicopter type, the aircraft has moved into the forward flight mode and the minor axis of the ellipse has shrunk to zero. As speed increases beyond this point, the wake becomes a fairly homogenous mass of small, incremental air flows enjoined or opposed in direction and force, although the predominant flow of the mass is still downward.

At 30 to 35 miles per hour, the air flow in the rotor wake assumes a new pattern which, although complex, is well-defined and consistent. A cross-sectional view of a wake (Figure 7) shows two well-defined vortices with an additional, large amount of air being forced directly downward. The lengths of the arrows in the diagram represent the relative air velocity at that point. The vortices may be visualized as two cones or funnels extending rearward and down, and as a function of flight altitude and speed, they may be 'directed' into the foliage.

When the helicopter is flown within ground effect, as in most agricultural spraying, the volume of air being accelerated downward and aft in the rotor wake encounters the surface of the ground and, having nowhere else to go, must expand laterally to dissipate its kinetic energy. Speed and altitude may therefore be manipulated to achieve swath widths of up to several times the length of the boom in use.

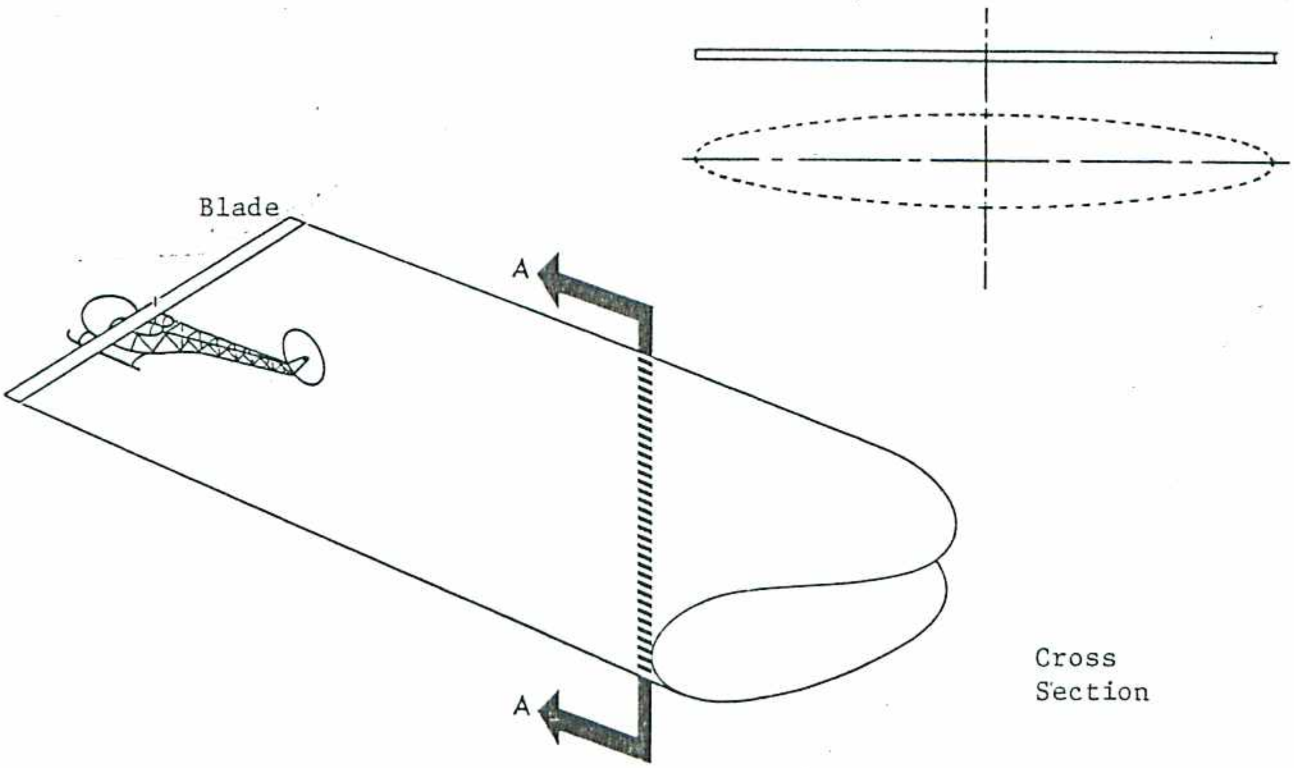
It is thus obvious that the rotor wake represents the primary effect of the aerodynamic differences between fixed- and rotary-wing aircraft. The same 2650-pound helicopter used to explain the

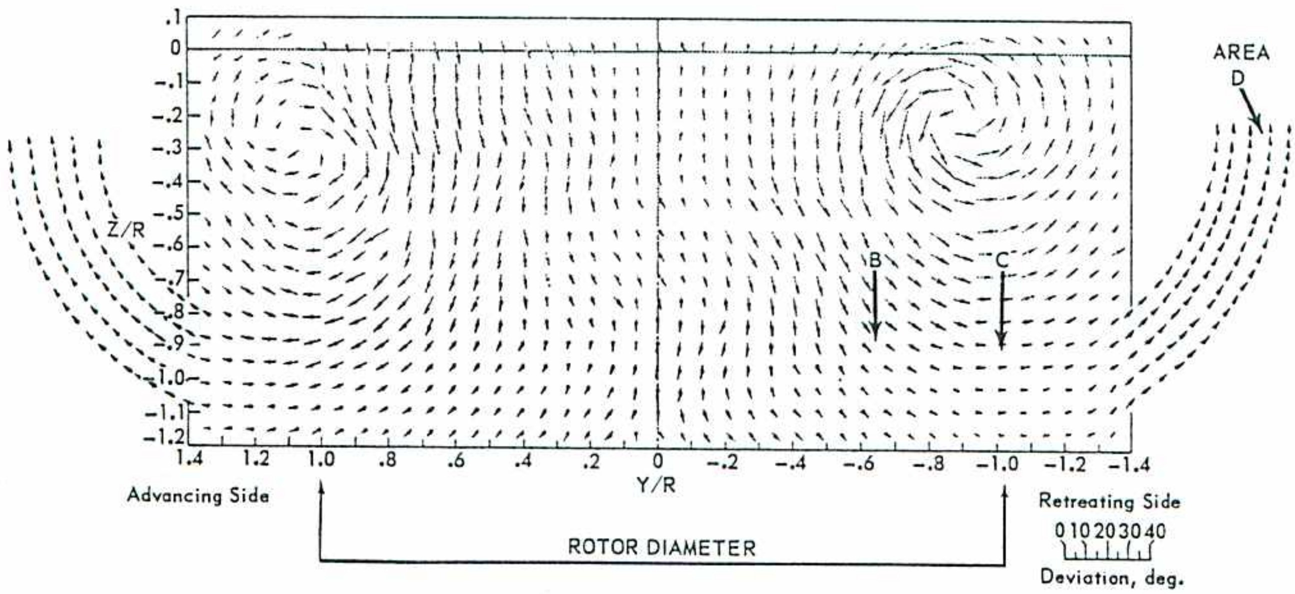
Figure 6. Air movement pattern in hovering flight.[1]



[1] Helicopter techniques for aerial application. Bell Helicopter Company, Fort Worth, Texas, 1975.

Figure 7. Air movement pattern in rotor wake during forward flight.[1]





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[1] Helicopter techniques for aerial application. Bell Helicopter Company, Fort Worth, Texas, 1975.

aerodynamics of hovering flight (Section 3.1) can also illustrate the rotor wake's behaviour during forward flight. At 60 miles per hour, this machine, a two-bladed Bell Model 47, would be accelerating over 5.8 million cubic feet of air aft and downward at an angle of 6.9 degrees from horizontal, and at an average mass-flow downward velocity of 8.5 miles per hour.

More work is urgently required to thoroughly analyze the rotor wake's characteristics for various helicopter and rotor types. For example, all Bell and Hiller helicopters are equipped with two-bladed main rotors, while those of Hughes, Aerospatiale (Vought), Sikorsky, etc. may have from three to five blades. Rotor blades may also vary in size, shape and method of mounting on the airframe. Does the number or design of the blades affect the wake characteristics and cross-sectional pattern? If such is the case, do these differences significantly influence the effectiveness of the wake as an aerial applications tool, and which type of helicopter and rotor design produces the optimum wake pattern?

Two helicopters of approximately the same size and gross weight will, for practical purposes, cause about the same volume of air to be displaced downward when they are in flight. If one employs a two-bladed rotor while the other uses a smaller-diameter, four-bladed rotor, the latter will produce a more concentrated, higher-velocity 'downwash' in the hover, but what occurs in forward flight, and at what speeds?

Does the wake pattern change significantly, or at all, when the helicopter's gross weight decreases as fuel is consumed and the spray load is dispersed? Certainly the volume of air displaced will decrease as the aircraft becomes lighter, but what other changes occur? There are innumerable questions to be answered before the effect of rotor wake can be fully understood. Only then can it be fully exploited to maximize aerial treatment effectiveness and total economy at the operational level.

4. Aircraft Performance and Technical Data

The past three decades have witnessed the realization, by forest managers and agriculturalists alike, of the potential of aircraft as airborne dispersal vehicles for pesticides, fertilizers, and even seed, in a host of field situations. As the concept gained acceptance, many different types of aircraft were tried, together with chemical dispersal systems which, as already discussed, were usually adaptations of ground-based equipment in common use.

Initially, the aircraft involved were selected on the basis of availability more often than suitability, and the degrees of success varied considerably. As experience accumulated, however, some aircraft types emerged which were equal to the task in terms of range, payload, economy and availability of both machines and trained crews. Such aircraft were usually ex-military trainers, light bombers and transports, and a number are still in service. Ultimately, aircraft manufacturers began to design and build specialized machines for the growing aerial applications market, and a wide range of such equipment is now available to this sector of the general aviation industry. Such specialized equipment has now almost completely replaced the light aircraft, originally designed for recreational flying, which were once extensively used for the spraying and dusting of agricultural crops and small forest plantations.

This report reflects current emphasis on the need to evaluate and develop superior aerial dispersal equipment, systems and techniques for use in pest management programs involving high-value trees and forest stands. Consequently, the appended summaries (Appendix B) deal only with those aircraft types which both have genuine potential in this regard and are currently available for field study. While most of the types listed are presently being manufactured, a few may represent lines which have been discontinued. In these cases, however, the type is still operated in adequate numbers and with sufficiently viable parts and maintenance support to qualify under the foregoing criteria. In addition, older types usually represent basic aerodynamic or operating principles which persist in current production models, thus permitting concept evaluation at correspondingly lower cost for the research program. The nature of the data involved in this type of summary is adaptable to presentation in tabular form, which also permits ease of reference and comparison. Foot notes are used to expand on any points requiring elaboration. Appendix B describes fixed-wing aircraft and helicopters under separate headings, classifies them according to military or civilian origin, gross weight category, number of engines and manufacturer, and provides pertinent weight and performance data, manufacturers' or agents' 1976 prices, and other factors influencing their general suitability for an aerial applications role. The number of each type in Canada is also shown as of June 30, 1976.

CHAPTER III: AERIAL FOREST SPRAYING OPERATIONS

1. Spray Aircraft Criteria

While all types of aerial spraying operations have much in common, each can also place its own, unique demands on the aircraft, flight crews and ground personnel.

The basic requirements of spray aircraft are listed below, and are very similar to those of general purpose machines in common use throughout the civil aviation industry.

(i) Ready availability of the required aircraft type, making possible its acquisition in adequate numbers for the job at hand, and facilitating replacement of any machines which become unserviceable;

(ii) Ease of maintenance in terms of convenience, length of overhaul cycles, availability of parts, consumables and service, and general ability to 'live' under the conditions imposed by the project's base of operations;

(iii) Ready availability of trained aircrews and maintenance personnel;

(iv) Adequate payload capability;

(v) Performance and flight capabilities which are compatible with the requirements of the job, including power, maneuverability and range;

(vi) Adequate speed characteristics including ability to safely vary speed for maximum effect over the treatment area, and sufficiently high cruise speeds to minimize ferry time;

(vii) Compatibility with the dispersal equipment required for optimum treatment effect by the project involved.

Obviously, it is not always possible to find an aircraft which possesses all of the above characteristics to the ideal degree or in the perfect combination for the project at hand. It is usually necessary to select equipment which represents the best compromise under the circumstances. This seems particularly true in forest spraying due to the great variations encountered in terrain, size of the treatment area from a few acres to several million, the confined-area nature of many smaller spray blocks, and the frequent scarcity of suitable airstrips or landing fields in the vicinity of the work site.

Aircraft performance comparisons and type availability are discussed later. However, some of the considerations involved in selecting an aircraft for a particular job were summarized by G.P. Markin (1974) during the proceedings of the Workshop on Aerial Application of Insecticides Against Forest Defoliators:

a) The individual making the selection must have adequate familiarity with the various aircraft available to select the best one for the job. Otherwise, he may simply invite tenders for a 'spray plane', and award the contract to the lowest bidder, regardless of the equipment involved.

b) Tie the aircraft's payload to the size of the blocks to be treated. Small or scattered plots usually call for small fixed-wing aircraft or helicopters; larger blocks may require many small machines or a few very large ones.

c) Consider terrain. Large, relatively flat areas can be treated more economically with high-capacity, multi-engine machines while rugged terrain or mountains may require the maneuverability of small aircraft regardless of block size.

d) What method of guidance is to be used? If ground markers or aerial pointers are employed, the small machine may be acceptable. Internal, electronic guidance systems usually require a large aircraft to justify their high cost and carrying sufficient crew to do the flying and the navigating.

e) The availability of qualified pilots and crews is important if we plan to use a new type of aircraft or system. Although such equipment may be perfect for the job, it will be useless unless the crew can exploit its capabilities to the fullest, under the conditions imposed by the job involved.

f) The aircraft must be equipped with the type of spray equipment required by the project, or be compatible with such equipment and systems. This point also ties into the next consideration.

g) Can the aircraft type legally do the job? When treating high-value stands in or around congested areas, the law may require the added safety factor provided by multi-engine equipment. Also, the insecticide to be used may influence the selection of an aircraft.

With all of the foregoing criteria and considerations in mind, the spruce budworm program in Quebec provides a good example of the reasoning behind the selection, in this case, of large, multi-engine equipment. The justifications (Randall 1974) were as follows:

1) Long range aircraft would preclude the necessity and expense of building and equipping the remote-area landing strips which would be required by smaller machines;

2) The higher spray capacity and speed of the larger aircraft would reduce both the time involvement and cost per acre of treating the vast infestation in question;

3) These aircraft would permit the use of electronic guidance systems to locate the target areas and provide parallel swath tracks over the spray blocks;

4) These aircraft had I.F.R. (Instrument Flight Rules) capability, ensuring their ability to proceed to and from the treatment area under marginal weather conditions;

5) The foregoing capabilities of the aircraft presented the possibility that operational spraying could be carried out at night;

6) These aircraft, as equipped, had been shown to emit a spray droplet diameter spectrum equal to or better than that of other aircraft such as the Grumman TBM, still in use for forest spraying programs.

A similar reasoning process could show that another project specifically requires the capabilities of a machine such as the Grumman AgCat, while a third would best profit by employing a particular model of helicopter. The point is that a sound choice can be made only on the basis of a thorough understanding of the performance capabilities, advantages, disadvantages and possible unique features of the various aircraft categories and types available.

Unfortunately, when it comes to consideration of the helicopter, too many individuals find that available data are insufficient for its realistic assessment in terms of the project's requirements. Comprehensive comparison is not possible between helicopters and aeroplanes, much less between the various types of helicopter. Nevertheless, as will be discussed later, such basic features of the helicopter as its vertical capability, accuracy of spray application, and the often effective but poorly-understood rotor wake effect are causing it to be used in a growing number of situations.

2. Aerial Spraying Equipment

2.1 Background

There are numerous manufacturers of aerial applications hardware in the United States and elsewhere (Appendix H). The various, specialty-design, 'agricultural aeroplanes' are delivered complete with certain components such as tanks or hoppers, pumps, and dump valves already installed, and the manufacturers normally offer certain specialized dispersal equipment as optional accessories to be installed prior to delivery or shipped as loose equipment. Ex-military, 'airline surplus' or general purpose aircraft must be completely equipped for aerial applications prior to service, and the first two categories usually require extensive modification as well. Helicopters are at an advantage in that most are readily compatible with a wide range of aerial applications equipment currently on the market, requiring little or no modification.

It is beyond the scope of this report to itemize and evaluate each equipment item currently marketed by each of the companies which specialize in aerial spraying apparatus. Rather, the following subsections discuss general equipment types in terms of their proven or indicated effectiveness, their advantages and their disadvantages as they may relate to aerial applications with rotary-wing aircraft.

2.2 Importance of Droplet Diameter Spectrum

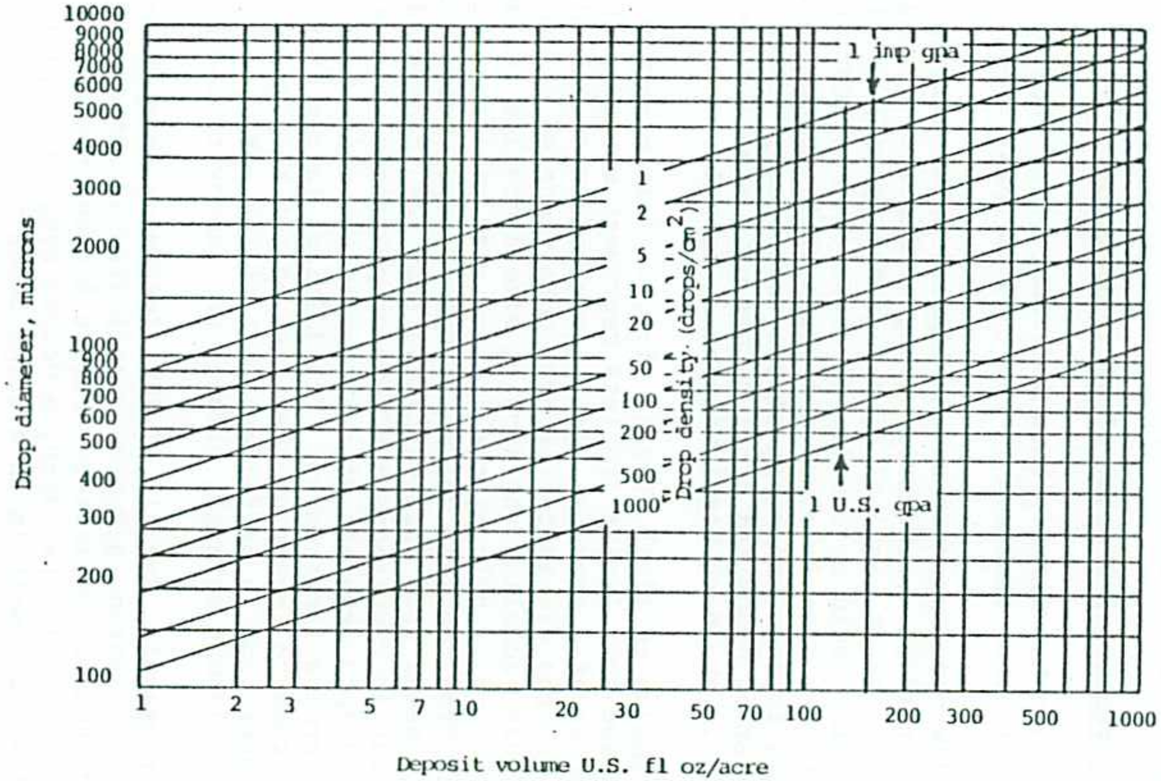
Mention has already been made concerning the importance of the droplet diameter spectrum in the emitted spray cloud.

While opinions vary on the ideal droplet size for treating individual insect species, there is strong evidence to suggest that there is an ideal diameter or range of diameters for specific applications. The optimum size could be considered to be the smallest droplet that is lethal to the pest involved and which will impinge on the insect itself or on the foliage and stems of the tree canopy. Needless to say, both the number of deposited droplets per unit area and the uniformity of the deposit are both highly important as well.

Assuming an ideal droplet size, or fairly narrow size range, it is easy to see that larger droplets represent wasted pesticide. This is true for several reasons. In a given volume of liquid, the potential number of droplets is the inverse cube function of droplet diameter. In other words, doubling the droplet size decreases the number of droplets eightfold, while halving the droplet size yields eight times as many droplets from the same volume of spray. One excessively large droplet not only means that more pesticide than required was deposited at that point, but it represents a volume of pesticide which might have been broken up into droplets of a more suitable size which would, in turn, have covered a larger area. In addition, larger droplets falling under gravity tend to impact on the first object they encounter in the peripheral canopy, and to be filtered out of the spray cloud altogether. Some may even plummet straight through the canopy to the ground.

For example, Randall (1971b) indicates that the minimum effective coverage for spruce budworm control lies in the order of 10 to 15 droplets per square centimeter. Figure 8 shows that, for a deposit volume of one U.S. gallon per acre, a volume average droplet diameter of 560 microns would result in an average deposit of one droplet per square centimeter. A mass median diameter (MMD) of 220 microns would yield an average deposit density of 15 droplets per square centimeter but, as has already been discussed, many of the larger droplets are filtered out of the spray cloud by the peripheral canopy. According to Howitt and Klos (1976), droplets larger than 50 microns do not penetrate inside the canopy. However, small airborne droplets are the most effective since, with adequate velocity, they tend to swirl within the canopy and deposit randomly on leaves and branches (Howitt 1973).

Figure 8: The relation of drop diameter and density (number of drops/cm^2) to spray volume deposit in U.S. fluid ounces/acre[1]



[1] Haliburton, et al. 1975.

Another consideration with regard to large droplets is that phytotoxicity appears to be related to droplet size (Howitt and Klos 1976). Particularly with ULV (Ultra Low Volume) sprays, the large droplets can create a lens effect, concentrating the sun's rays. Since the large droplets tend to deposit in the peripheral canopy, they are concentrated in the upper foliage where solar exposure is greatest.

On the other hand, if droplets are too small, a single one will not constitute a lethal dose of pesticide, and higher deposit density per unit area will be necessary. In addition, the smaller the droplet, the more difficult it becomes to achieve deposit unless the droplet has sufficient velocity to effect impingement. Table 3 suggests, for example, that even a droplet which is 75 microns in diameter requires a velocity of 0.7 miles per hour, or 1.03 feet per second, to impact on an object with a width of one-eighth inch. Excessively fine droplets will not only fail to deposit, but tend to drift away from the treatment area before they have even descended to the forest canopy height.

Table 3: Minimum air velocity for efficient deposition with elevation for droplets and objects of various size[1]

Width of Objects in Inches	Particle Size, in Microns Diameter								
	25	50	75	100	125	150	175	200	300
	....................Miles Per Hour								
1/8	4	1.2	0.7	0.8	1.0	1.4	1.6	1.8	5.5
1/4	8	2.2	1.2	1.1	1.3	1.6	2.0	2.5	5,7
1/2	16	4.2	2.1	1.6	1.6	1.8	2.2	2.7	5.8
1	32	8.2	3.9	2.6	2.2	2.3	2.5	2.9	5.9
2	64	16.2	7.5	4.6	3.5	3.1	3.2	3.4	6.0
3	96	24.2	11.0	6.6	4.8	4.0	3.8	3.9	6.1
4	128	32.2	14.6	8.6	6.0	4.9	4.6	4.4	6.2
8	256	64.2	28.0	16.0	11.0	8.0	7.4	5.4	6.3

[1] S.F. Potts, 1958 (Reproduced in Helicopter Techniques for Aerial Application. Bell Helicopter Company, 1975).

It becomes obvious here that any reduction in droplet size due to evaporation is another important consideration, as explained in Section 3 of this chapter.

Required, then, is an atomizing device which is capable of emitting a narrow spectrum of droplet diameters with an MMD in the order of 30 to 60 microns. This could increase canopy penetration, deposit density and, thus, spray efficacy which would in turn permit lower dosages.

The question of spray efficacy has assumed vastly greater significance in recent years since the operational withdrawal of the chlorinated hydrocarbon DDT, and the introduction of U L V spraying. Since the contemporary alternatives to DDT are costly and are relatively very low in residual activity, it is even more important that applications technology exhaust every possible means of maximizing their effectiveness.

2.3 Boom-and-Nozzle Apparatus

The use of boom-and-nozzle spraying equipment is by far the most widespread. It is the oldest, acceptable means of applying liquid chemical, it is simple, and it is relatively inexpensive to acquire and maintain. A wide variety of nozzles and tips are available for various flow rates and degrees of atomization and for emission of the spray in such forms as cones or flat fans, and such components are easy to install or change. Calibration is not complicated in principle. In addition, booms can usually be rotated around their longitudinal axes with little difficulty to permit emission of the spray at any desired angle with respect to the direction of flight, to maximize atomization and to take advantage of various aerodynamic effects on the characteristics of the spray cloud.

The greatest disadvantage attributed to the use of boom-and-nozzle equipment lies in the wide variety of droplet sizes produced. A typical droplet spectrum has been shown to range from fine to large droplets with an MMD of 225 microns and a Dmax in the order of 460 microns (Randall 1971). Even with a MMD and Dmax of 200 and 400 microns respectively, only about five percent of the droplets are less than 50 microns in diameter (Howitt and Klos 1976).

A more recent spraying standard for the control of spruce budworm specifies a deposit pattern of 20 drops per square centimeter at an emission rate of at least 20 fluid ounces (U.S.) per acre of oil diluent spray, with Dmax of 200 microns, MMD of 90 microns and NMD of 40 microns. This compares rather unfavourably with Randall's experience described above.

As mentioned in Chapter I, spray droplets emitted from standard nozzles may be further broken up by shattering as they encounter the inflight relative wind. This, however, occurs mainly at higher airspeeds, and not at the relatively lower operating velocities of smaller aircraft and helicopters.

Perhaps the most efficient nozzle in current use, properly employed, is the open nozzle (Randall 1975) which depends upon the interaction of two fluids, air and pesticide, to break up the spray into droplets. As discussed in Chapter I, Section 5.3b, this is a Spraying Systems nozzle without the TEE Jet tip, and is the type used against the spruce budworm in Quebec, installed on large, multi-engine aircraft. Properly adjusted to optimize the effect of the air flow over the open end of the nozzle to shatter the pesticide into droplets, MMD's of 70 to 90 microns have been produced. In 1972, during tests conducted in California (Randall and Zylstra 1974), a modified DC-7B spraying a diesel oil formulation at a speed of 200 knots (230 miles per hour), delivered an average droplet spectrum with a Dmax of 220 microns, MMD of 80 to 90 microns and NMD of 60 to 70 microns. In Quebec during the 1975 spraying program (Paquet 1975), all aircraft (Appendix E) delivered a Dmax of 230 to 240 microns and an NMD of 50 to 60 microns.

The open nozzle, as presently employed, at speeds in the order of 200 knots, thus appears to deliver a more acceptable droplet spectrum than the standard boom-and nozzle equipment used concurrently on such aircraft as the Grumman TBM. However, it does not appear likely that further refinement of the boom-and-mozzle principle is apt to yield a significantly superior droplet spectrum and deposit.

In relation to spraying by helicopter, if one assumes that the properly-utilized helicopter rotor wake is capable of effecting increased canopy penetration and droplet deposit within the canopy, it follows logically that the greatest treatment effectiveness will be achieved by maximizing the number of droplets which are emitted within the optimum diameter range. According to Howitt and Klos (1976), too few of the droplets produced by conventional boom-and-nozzle apparatus lie within this range. In addition, the open nozzle depends heavily for its atomization effect on speeds of which the present-day helicopter is not only incapable, but at which the indicated, positive effects of the helicopter's rotor wake and maneuverability would be lost. For these reasons, it must be concluded that the boom-and-nozzle system is not, under most circumstances, the ideal equipment for use in forest insect spraying operations by helicopter.

2.4 Fan-driven, Rotary Atomizers

Fan-driven rotary atomizers, such as the USDA Minispin and British-built Micronair AU3000, are rotating, wire-screen cages. Each unit is spun individually by its own fan which is turned by the slipstream or relative wind of the aircraft in flight (Chapter I, Section 5.3c).

One of the earliest such devices was the USDA Minispin which, during tests in 1965 (Randall 1971b), produced a superior droplet spectrum to that of conventional boom-and-nozzle equipment, including a Dmax range of 280 to 310 microns. The theory behind this device was good (Randall 1971b), but it was poorly engineered and tended to disintegrate during operation. In addition, it was very prone to internal damage from concentrate insecticides which could creep along the central shaft into the bearings. The main benefit of the Minispin was that its capabilities helped to confirm the effectiveness of the ULV principle for forest insect treatment and opened the door for further development of the concept.

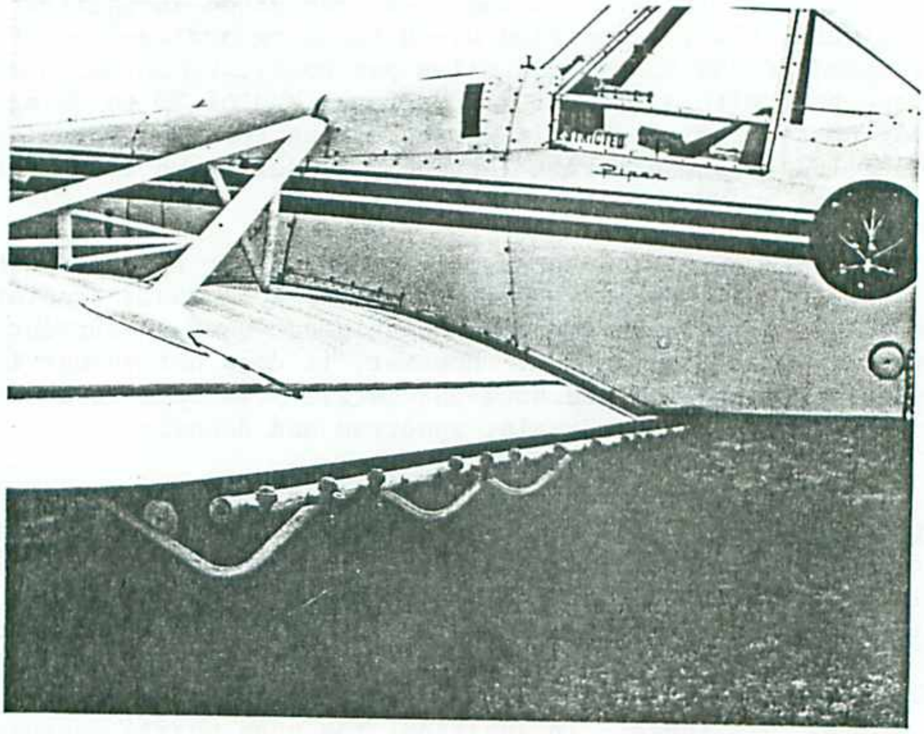


Figure 9. Boom-and-Nozzle apparatus installed on Piper PA-25 (C.C.R.I. Photo).

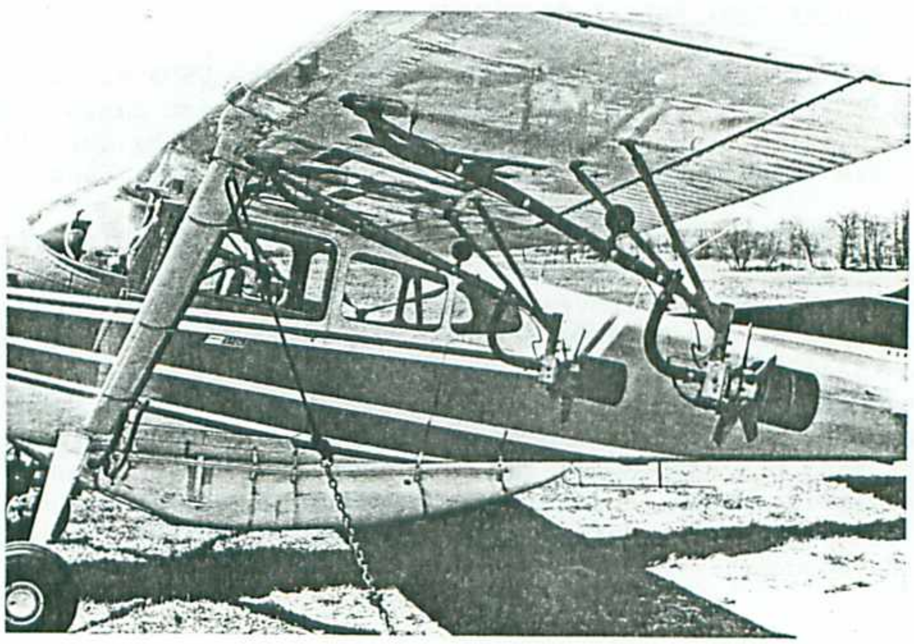


Figure 10. Micronair AU 3000 units installed on Cessna 185 'Ag Carryall' (C.C.R.I. Photo).

The Micronair AU3000 was tested in Canada during the period 1968 to 1969 (Randall 1971a). It proved capable of producing a superior droplet spectrum to that of the Minispin, evidenced by a Dmax range of 200 to 210 microns. The device is well-engineered (Randall 1971b) and can withstand sustained usage. The fan blades can be set for various rotational speeds, but Randall's tests showed that, for optimum droplet production, the blades must be set for maximum rotation and the flow rate reduced to less than one-half gallon per unit per minute. Otherwise, the droplet spectrum is not superior to that produced by flat fan nozzles. The Micronair has been employed quite extensively for smaller forest spraying operations and in experimental work in Canada (Appendix E). Its first use on a large scale in Canada took place in 1975 when, according to an unpublished report, six Rockwell Thrush Commanders equipped with Micronair AU3000 units treated 752,000 acres of spruce budworm infestation in New Brunswick, at an application rate of 5.28 fluid ounces total volume per acre. With an MMD of 70 microns, the deposit density averaged 37 droplets per square centimeter.

Wind-driven, rotary atomizers, however, have not been found to be very satisfactory for use on helicopters. The generally lower operating speeds and speed flexibility of the helicopter often do not result in a relative wind of adequate velocity to turn the fans at the required rotational rate.

2.5 Rotary Atomizers Powered by Electric or Hydraulic Motors

The earliest electrically-driven rotary atomizer to be tested in Canada was the British-built Turbair, a device which utilizes the spinning disc principle (Chapter I, Section 5.3c). In experimental work during 1966 and 1967 (Randall 1971a), the Turbair delivered a narrow, relatively uniform droplet spectrum with a Dmax range of 120 to 128 microns. The first models of the Turbair were underpowered, and their bearings and electric motors were subject to the same type of damage from concentrate insecticides as were the Minispins. This problem was corrected in subsequent models, the power was increased, and the rate of rotation was made controllable by means of a rheostat, from 1,300 to 10,000 r.p.m. During ULV mosquito control operations with a helicopter in the United States (Burgoyne and Akesson 1968), at an air-speed of 60 miles per hour, a pressure of 40 psi and an application rate of 6.8 fluid ounces per acre, the Turbair delivered a spray with an MMD in the order of 70 microns. This device is quite promising and renewed developmental activity is about to be initiated by a Canadian company which recently acquired rights to the Turbair in this country.

A second, highly promising, rotary atomizer is the Beecomist Spray Head. As previously discussed (Chapter I, Section 5.3c), the Beecomist is electrically-driven and achieves spray atomization by means of a porous, sintered-metal sleeve which is rotated at high speed. Spray is extruded as threads of the same diameter as the sleeve's pores and these are sheared into droplets as they emerge into the air. Droplet size is

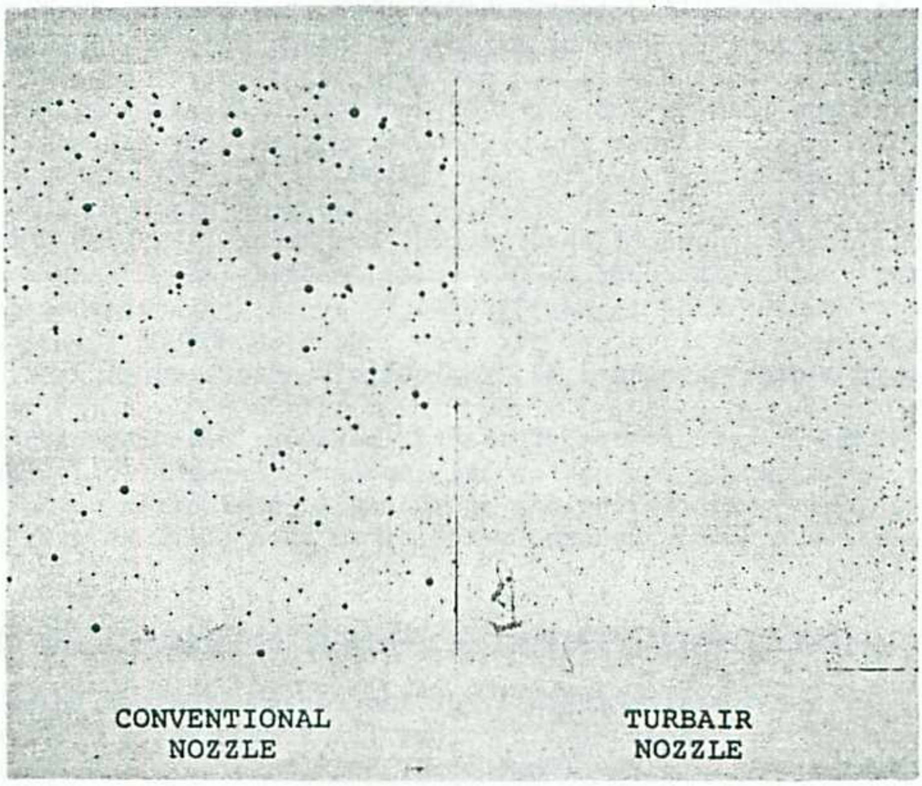


Figure 11. A comparison of droplets delivered by conventional Boom-and-Nozzle Apparatus and those delivered by electrically-powered, rotary, atomizing device (Randall 1969).

thus controlled by the size of the pores and the speed of rotation of the sleeve. Five basic sleeves are available in stainless steel or plastic, with controlled porosities respectively of 5, 10, 20, 40 and 60 microns, designed for use with fluid sprays. An 80- to 100-micron, perforated, metal sleeve is produced for use with wettable powders or viscous formulations.

Tests on the Beecomist by Metronics Associates, Inc. showed, for example (Appendix G), that when a 20-micron sleeve was spun at 11,800 r.p.m., 80.8 percent of the droplets, representing 91.1 percent of the spray volume emitted, lay within a diameter range of 10 to 40 microns, with median and mean diameters of 30 and 23.2 microns respectively. The operational potential of this principle is examplified by the following quotation (Howitt 1973): "In (other) aerial work a Bell helicopter fitted with two Beecomist spray heads controlled pests on 900 acres of apples at greatly reduced dosages. Zolone and Guthion gave outstanding control of fruit pests on 100 acres of apples applied aerially by a Piper Pawnee equipped with Beecomist nozzles. Only four applications were made during the season instead of the normal eight or nine sprays. In addition, in three of the four sprays only one-half the recommended dosage was used."

Tests were made (Howitt and Klos 1976) employing the FP (fluorescent particle) method, and rotation rates of 11,800 r.p.m. in conjunction with 20-, 40- and 60-micron sintered metal sleeves. The test results are summarized in Table 4.

Table 4: The range of droplets as determined by the FP method using Beecomist Sleeves with the Indicated Controlled Porosity (From Howitt and Klos 1976).

Drop Size	20 Sleeve		40 Sleeve		60 Sleeve	
(Microns)	% No.	% Mass	% No.	% Mass	% No.	% Mass
< 10	18	1	28	2	16	5
10 - 20	42	14	40	12	28	4
20 - 30	26	34	12	14	24	13
30 - 40	13	44	16	57	15	26
40 - 50	1	8	4	15	15	46
50 - 60	1	0	0	0	2	10
> 60	-	-	-	-	0	0

Figure 12. Two views of Beecomist Spray Head, Model 350, installed on Bell Model 47G-5A. (C.C.R.I. photo).

Beeco Products Company, manufacturer of the Beecomist Spray Head, has since reported that plastic sleeves of the same porosity achieve a significantly narrower droplet diameter spectrum and better control of droplet size in relation to the pore diameter of the sleeve used. The company also reports that droplet spectra and control are still further improved by using rotational rates of 9,400 to 10,000 r.p.m. versus the 11,800 r.p.m. employed in the above tests. A recently-developed warning light may be mounted on the aircraft instrument panel to advise the pilot should the r.p.m. decay below 9,400. The light is preferable to the digital read out of r.p.m. described by Rupp and Sutherland (1976), since the latter increases the pilot's work load by requiring him to monitor, read and interpret an additional gauge in the cockpit.

Beecomist units have enjoyed recent, limited, experimental use in Canada, and are employed operationally by a number of agricultural aircraft operators. The United States Forest Service (Wright 1976), during a 1975 program to evaluate various dispersal systems, field tested conventional boom-and-nozzle apparatus, Beecomist spray heads, spinning disc devices and the under-slung bucket with boom. Of these, the Beecomist system is reported to produce the most even deposit distribution, although results are still preliminary.

Miniature hydraulic motors now provide an alternative to the electric motors currently used to power rotary atomizers such as the Beecomist. Although these have not yet been used in conjunction with aircraft, their possibilities are intriguing. One such device has been adapted to the Beecomist Model 350 for spraying by ground vehicles. It is much smaller and lighter than the current electric motor, and delivers up to three horsepower compared with the latter's one-quarter horsepower. The advantages of a hydraulically-powered spray system should include strength, improved boom aerodynamics, reliability, and better control of spray-head rotational speed at high emission rates or when applying heavy, viscous formulations. In addition, such a system would place only a minute demand on the aircraft's electrical system since electric power would be required only for the activation of switches and solenoid valves to control the flow of pesticide and hydraulic fluid. This system would be powered by a small hydraulic pump installed on the engine gear-box of a light turbine helicopter. Such a pump has already been developed and certified for aircraft use in the United States.

In view of the foregoing, it is readily apparent that electrically- or hydraulically-driven, rotary atomizers currently represent the most suitable concept for insecticide application by helicopter. Their operation is completely independent of airspeed, they deliver a narrow droplet spectrum, and within reasonable limits, it is possible to control MMD.

Bernet (1975) recently stated, "Rotary atomizers permit a better selection of the required narrow droplet spectrum than conventional boom and nozzles. Unfortunately, the ideal, trouble-free, fully adjustable atomizer is not yet on the market." While this statement may have been true at the time, subsequent research has continued to refine the devices and systems involved. A case in point is the American Cyanamid Company's new (1976) label for Cythion and Malathion ULV concentrate insecticide. In the label's section covering ULV aerial application by helicopter, the dispersal equipment specified is the Beecomist Spray Head Assembly, Model 350.

3. Meteorological Considerations

Until the moment of chemical emission from an airborne dispersal system, all aspects of the spray operation can be closely controlled (Armstrong 1975a). Chemicals can be exactingly formulated, systems and emission devices calibrated with precision, and the aircraft positioned over the treatment area with great accuracy.

As the spray is dispersed through an atomizing nozzle or rotary atomizer (Randall and Zylstra 1972), its velocity is rapidly dissipated, and the cloud of droplets is subject to the effects of the slipstream, wake turbulence, and such meteorological influences (Armstrong 1975a) as wind speed and direction, temperature and relative humidity. The latter two factors (Armstrong 1975b) may cause droplet size to change, thereby affecting deposition rate and drift.

The 'Porton method' of aerial spraying, in which a crosswind component is utilized in combination with a specified emission altitude (Armstrong 1975b) to increase effective swath width, fails to consider the effects of temperature and humidity on droplet size. Droplets emitted at higher altitudes and with low crosswinds are exposed to these effects for longer periods than those released at lower altitudes. In four minutes, evaporation can reduce the volume of a 100-micron droplet of volatile oil by 50 percent, or a 100-micron droplet of non-volatile oil by 15 percent. Four minutes is approximately the time required for a 200-micron droplet to fall 200 feet (Table 5). At 63 percent relative humidity and 68 degrees Fahrenheit, a 100-micron droplet of water will evaporate completely in 20 seconds. The same droplet evaporates in six seconds at 73 degrees Fahrenheit at 18 percent relative humidity.

Table 5: Terminal velocities of water drops falling in air and time to fall 100 feet[1]

Drop Diam. (microns)	Rate of Fall (ft./min.)	Minutes to Fall 100 ft.
50	14.8	6.7
100	55.0	1.8
150	100.0	1.0
200	142.0	.7
300	235.0	.4
400	330.0	.3

[1] Constant volume assumed; volatile drops will have a lower average rate of fall (Brooks 1947).

It is thus possible, given the required conditions of temperature, relative humidity, particle size and spray formulation, for droplets to evaporate before they reach the forest canopy. Also, air turbulence and convective heating currents can cause droplets to remain airborne for extended periods while stable conditions can cause them to settle more rapidly. In the former case, the effects of evaporation will be magnified and, in both cases, deposit patterns and droplet concentrations can be adversely affected.

Unfortunately, meteorological measurements to evaluate the suitability of spray conditions are often minimal, or consist of subjective judgments by someone on the ground or flying above the spray block in a small aircraft (Armstrong 1975a). Once begun, spraying may continue (Armstrong 1975b) until it is obvious that spray deposition has ceased to occur. By the time this becomes obvious, of course, the condition may already have existed for some time and a large area will have received poor coverage. As the spray droplets proceed downward toward the canopy, the heaviest particles settling first, the cloud encounters still other meteorological, as well as micrometeorological conditions.

Until they reach a certain altitude above the canopy, the droplets are still passing through air which is undisturbed by the turbulence of the air flow over the tree tops (Cramer and Boyle 1974). At an altitude above the canopy approximately equal to the height of the canopy above ground, the droplets enter a zone within which the wind speed begins to decrease. At the top of the canopy, it is approximately half that in the undisturbed air flow. Within the upper one-third of a dense or moderately dense coniferous canopy, there is a further, sharp decrease in wind speed and, in the lower two-thirds of the canopy, this value is only five to ten percent that of the undisturbed air flow.

Under fair weather conditions (Cramer and Boyle 1974), the top of the canopy is warmed by the sun during the day and cools at night due to radiational heat losses, while the temperature tends to remain relatively unchanged in the lower part of the canopy. Consequently, thermally stable layers (temperature is constant or increases with height) form above and just below the top of the canopy at night, and just below the top of the canopy during the day. During the day, the layer above the top of the canopy is thermally unstable (temperature decreases with height).

Since periods of thermal stability, or 'inversion', provide the optimum spraying conditions, operations are normally carried on during the early morning and the evening, and the daily spraying period can be greatly extended by overcast conditions. This is also the reason for the serious consideration of night spraying.

The presence of thermally stable layers below the height of spray emission, on the other hand, is unfavourable to the diffusion of small droplets which cannot penetrate these layers unless they are heavy enough to settle under gravity. Gravitational settling is usually insignificant for droplets with diameter of less than 20 microns.

"If the spraying is performed with a helicopter that hovers at low altitude above the top of a dense canopy, the downwash from the rotors may drive the spray material into the below-canopy region" (Cramer and Boyle 1974). This should also be true during forward flight at air-speeds lower than some maximum yet to be determined.

Within the canopy itself, turbulence intensities tend to be quite large due to the low wind speeds and the flow of air around leaves, needles, twigs and branches. The resultant 'turbulent mixing' or 'diffusion' is thus very effective in spreading a cloud of small droplets throughout the canopy.

Deposition of small, airborne droplets on the various elements of the forest canopy occurs by gravitational settling, inertial impaction, turbulent deposition or impaction, and such other influences as electrostatic attraction, adhesion and absorption. Droplets smaller than 20 microns are undesirable since, as already indicated, gravitational settling and inertial impaction are ineffective in depositing them on target, and other processes are still not sufficiently well-established to be relied on. With such small droplets, both penetration of the canopy and retention within the canopy are difficult, and problems are maximized in relation to spray drift.

Meteorological influences constitute one of the most critical aspects of aerial spraying operations, and one which cannot be controlled. Presently, we must simply adapt programs and schedules to minimize their detrimental effects. To a limited extent, we have begun to find ways of using them to our advantage and, while research and experience may eventually enable us to do this more effectively, meteorological factors will undoubtedly continue to present many of their traditional problems.

Droplet evaporation may be retarded through the use of additives. This, combined with the employment of atomizing devices capable of maximizing the number of droplets in the required diameter spectrum from a given volume of liquid, can improve efficacy. Proper utilization of the helicopter rotor wake may aid in the distribution and deposition of these droplets, further increasing spray efficacy, and possibly helping to overcome meteorological conditions under which spraying cannot be carried out by other aerial means.

4. Aerial Applications by Fixed-Wing Aircraft

4.1 Scope of Discussion

In view of the various aspects of forest spraying which have now been discussed, it will be useful at this point to review the capabilities of the various spray aircraft under operational conditions in the field. Previous discussion of the aeroplane's past and present utilization levels and aerodynamics, together with the detailed performance and technical data given in Appendix B make it unnecessary here to delve into the relative merits of particular aircraft makes and models. Rather, general fixed-wing characteristics and features will be examined as they affect the aeroplane's capabilities, advantages and disadvantages in a forest spraying role, with reference to the broad categories of light, medium and heavy spray aircraft discussed later in this section.

4.2 The Speed-Dependent Fixed-Wing

The aeroplane's total inflight reliance on adequate airspeed having been discussed (Chapter II, Section 2), it now remains to examine the implications of this trait for aerial forest spraying operations. Since many of these can have both a positive and a negative side, depending on specific circumstances, they are simply discussed here under the appropriate headings with no attempt at formal classification as advantages or disadvantages.

a) Runway Requirement:

One of the most obvious outgrowths of the aeroplane's speed-dependence is the need for a prepared runway along which the aircraft may accelerate until it can achieve take-off speed and rise into the air. The runway is also needed to provide room for deceleration after landing, since the stall speed will usually be avoided at least until the undercarriage contacts the surface of the ground.

Runway requirements vary with aircraft type, ranging from the 1,000-foot sod strip of the light utility or agricultural machine to the 6,000 feet of pavement normally utilized by heavy, multi-engine aircraft such as the DC-6B. Although runway construction usually represents a considerable expense, actual cost obviously depends on the size, type of surface, and attendant facilities of the strip involved.

The fixed-wing's need for a runway is absolute and, as such, has come to be taken for granted rather than viewed as the major disadvantage which it is. If forest spraying plans call for the use of aeroplanes, runway facilities must either already exist, or they must be constructed and, in both cases, they require regular maintenance. If runways are available some distance away from the work area, and the size of the program warrants, one alternative is to employ aircraft with sufficient range to operate out of these distant airports.

The disadvantage represented here does not end with the cost of building and maintaining runways. After fueling and loading with pesticide, the aeroplane must take off and fly to the treatment area. When the load of pesticide is exhausted, it must return to the airstrip for more. Such ferry flights represent additional cost to the operation in terms of non-productive flight time during the relatively short daily periods of suitable spraying conditions.

b) Maneuverability:

The faster an aircraft flies and the greater its gross weight, the higher its momentum, the more space it requires to carry out a specific maneuver, and the longer the maneuver usually takes to complete.

As already explained, the stall speed is to be avoided at all times in flight. Since an aircraft entering a climb tends to lose speed just as does an automobile ascending a hill, a pilot who must pull up sharply to clear obstacles at the end of the swath, or who is attempting to contour fly in rough terrain, will maintain a very safe speed margin above the stall speed. While both the aeroplane and the automobile can increase power to maintain speed in a climb, it is possible in both cases to 'run out of available power'. In this situation, the automobile would either lose traction or the engine would stall. In the aeroplane's case, the wing would stall with very predictable and probably catastrophic consequences.

At the relatively high airspeeds thus employed during forest spraying operations, the aeroplane loses maneuverability and its ability to contour fly decreases. This means that it will skim low over the high ground, dipping into the valleys but passing much closer to the hill tops than to the valley floors. The spray cloud will thus be released from a constantly changing height above the canopy.

A second consequence of the aeroplane's speed and inertia is felt at end-run when the machine must execute a 180-degree turn to begin the next swath. The aircraft must pull up, swing wide as the turn is initiated, descending again as it completes this maneuver, and track realignment. This procedure can be very time consuming, with even a light utility or agricultural aeroplane taking from 25 seconds (Section 5.6) to 40 seconds (Philpotts 1971).

Since momentum is the product of mass and velocity, large, heavy machines are less maneuverable than smaller, lighter ones, even at the same airspeed. In fact, however, 'medium class' spray aircraft such as the Grumman Avenger normally fly at about 50 percent higher airspeed than the already more agile machines in the 'light' category (Appendix B, Tables 2-5), while the normal spraying speed of the large Douglas DC-6B is 53 percent higher than that of the Avenger. The resultant effect on turn time and contour flying ability should be obvious in both cases. In practice, lost time in procedural turns is less significant in relation to medium and heavy spray aircraft than one might expect, since these types are used only on large-scale forest spraying programs with long swath runs which compliment the aircraft's performance and minimize the amount of time lost in turns. There are, unfortunately, no similar compensations for the high-speed heavy aircraft's lack of ability to follow the contours of the land.

c) Pesticide Coverage:

The total area which a spray aircraft is able to treat per load of pesticide is a function of its airspeed, payload capacity and swath width. Swath width, in turn, depends on the emission altitude, wind and drift, volume emitted and, of course, the required deposit characteristics which define the effective swath for specific treatments.

With the foregoing in mind, it is easy to understand the use of multi-engine, transport class equipment (Table 6) for Quebec's multi-million-acre programs since 1973 (Section 4.5).

4.3 Light Spray Aircraft

The light spray aircraft category includes most of the general purpose aircraft which may be used for aerial applications, all specialty-class 'agricultural' aircraft except the Rockwell Thrush Commander and, of course, the venerable Boeing Stearman A75.

Today, the most widely-employed, general purpose aircraft used for aerial applications are the Piper Models J3 Cub and PA-18 Supercub, and the Cessna Models 185, 180 and 172. A special version of the Cessna 185, called the AgCarryall, is a 'borderline case' between general purpose and agricultural aeroplanes. General purpose aircraft are, on the average, less suitable for spraying than are the specialty machines in terms of aerodynamic characteristics, performance, spray capacity and ease of installation of dispersal equipment. The latter may require some degree of modification. Their greatest advantage from the operator's point of view is that the spray equipment can be removed and the aircraft used for other purposes at the close of the spraying season. Since the introduction of specialty-class agricultural aircraft in 1959-1960, however, major spray operators have gradually converted their fleets to this type, thus largely replacing general purpose equipment for spraying operations.

The specialty design of such aeroplanes as the Piper PA-25 Pawnee, Cessna 188 AgWagon and AgTruck, and the Grumman AgCat series makes them the ultimate in light spray machines. Special features include better speed control, minimized take-off roll, various built-in spray tanks and equipment, use of corrosion-resistant materials in key structural areas, ease of installation of dispersal equipment, and such safety features as excellent pilot visibility and protection. The spray capacity varies from 150 to 250 gallons, with normal gross weights of 2,900 to 4,500 pounds and take-off distances ranging between 1,000 and 1,500 feet.

The lighter aircraft, particularly the specialty designs, are more maneuverable than larger equipment. Thus, they have a greater capacity for low-level, contour flying, and the agility to better treat smaller plots and agricultural crops. Their main employment in forest spraying lies in the treatment of smaller acreages such as high-value stands, and in experimental work.

4.4 Medium Spray Aircraft

A greater variety of spray aircraft is employed in the United States than in Canada. In this country, the main medium class aeroplane is the Grumman TBM 'Avenger' which became the mainstay of large-scale forest spraying between the late 1950's and early 1970's. It has retained this status in connection with New Brunswick's spruce budworm program and is still the largest aircraft used for forest insect control anywhere in Canada except in the Province of Quebec. With a take-off distance of 3,000 feet at maximum gross weight, its runway requirement is approximately half that of the transport class aeroplane, and a system of suitable airstrips has existed in New Brunswick for many years. Using formulae discussed in Section 5.6 of this Chapter, the TBM's coverage may be shown to be in the order of 288 acres per minute, compared to the 1380 acres per minute of the DC-6B. For this calculation, the TBM is assumed to fly at 180 miles per hour with a swath width of 800 feet.

The maximum allowable gross weights of the TBM and DC-6B, respectively, are in the order of 17,000 and 97,000 pounds (Alberta 1975). Therefore, while the TBM is not as large as a transport class machine, it is by no means a small aeroplane. Its size, weight and speed lower its maneuverability compared to that of a lighter aircraft, resulting in time-consuming swath turns, a higher average flying height above canopy, and reduced ability to do precise contour flying (Section 4.2). Its most effective employment is therefore in large blocks involving long swath runs and few turns. An additional, growing problem with regard to this aircraft is its age, considering the fact that it has not been manufactured for nearly three decades. Consequently, both the numbers of aircraft and the supply of replacement parts are diminishing.

The Rockwell Thrush Commander, although technically a specialty-class 'agricultural' machine may, in practice, be considered a borderline case between the light and medium spray aircraft categories. The Thrush's top speed of 137 miles per hour, maximum gross weight of 7,800 pounds (Model C800 version), and pesticide capacity of 400 U.S. gallons, ranks it far above other aeroplanes in the specialty 'agricultural' class. In 1975, these machines treated 752,000 acres of spruce budworm infestation in New Brunswick, the largest forest acreage covered to that time by this aircraft type.

4.5 Heavy Spray Aircraft

For purposes of this discussion, the 'heavy' spray aircraft category includes those large, multi-engine machines used operationally in Canada since 1973, as listed in Table 6. These aircraft have a number of very significant advantages in a forest pest control role. Given sufficient area to be treated, their costs per acre can be relatively very low. While the same principle applies equally to other aircraft, the effect is augmented in the case of the transport class machines by their large spray capacities and ability to remain airborne for long periods. For example (Paquet 1975), the Douglas DC-6B, with a spray load of nearly 2,600 Imperial gallons and emitting 140 gallons per minute over a 3,000 - foot swath, can treat 25,830 acres per load. Table 6 summarizes the performance of the main aircraft of this type used in eastern Canada.

Table 6: Summary of operational performance of transport-class aircraft employed in Quebec (from Pelletier 1975).

Aircraft	Speed (mph)	Swath Interval (feet)	Load (U.S. Gal.)	Output (g.p.m.)	Boom T. (min.)	Acres per load
DC-4	172	3,000	2,500	125.09	19.98	20,828
DC-6B	230	3,000	3,100	167.27	18.53	25,830
L-749	205	3,000	3,200	149.09	21.46	26,662
L-1049	215	3,000	4,400	156.36	28.14	36,667
CL-215	150	1,500	1,320	54.54	24.20	11,000

The coverage and speed capabilities of these aircraft permit the treatment of very large areas in a minimum of time and, in view of the millions of acres sprayed annually in Quebec, treatment costs per acre have in fact been relatively low. Their range allows them to operate from airports located far from the treatment areas, making it unnecessary to construct and equip the airports which smaller machines would require closer to the work site. Their I.F.R. (Instrument Flight Rules) capability improves their ability to proceed to and from the treatment area under marginal weather conditions, their I.N.S. (Inertial Guidance System) locates the target areas and provides parallel swath tracks over the blocks, and their multi-engine configuration can enable a mission to be successfully completed even in the event of an engine failure.

Although all these features make aircraft in this category the most practical means of dealing with very large, remote-area pest infestations, not all represent unqualified advantages. For example, the high airspeed which contributes to these machines' productivity, combined with their gross weight, makes them the least maneuverable of all spray aircraft and the least capable of effective contour flight. This speed also reduces the time required to make long ferry trips between airport and spray block, ferry trips which would be shorter in any case if the aircraft's runway and ground-support requirements were less demanding (Section 4.2); 6,000-foot paved runways are, of course, found only at larger airports.

I.N.S. is not only a convenient means of navigating in the swath, but is the only feasible alternative to such other systems as the 'pointer' aircraft used in New Brunswick, whose speed and range cannot match those of the DC-6B or L-1049. I.F.R. capability and multi-engine configuration, likewise, are not only advantageous in getting the job done, but are essential safety features for aircraft operating over the forest, far from base.

Nevertheless, in terms of emitted droplet spectrum and deposit under optimum conditions of terrain and meteorology, the large aircraft equipped with boom and open nozzles unquestionably represent an improved means of achieving the required coverage for treatment of the vast spruce budworm infestations now prevalent in the forests of eastern Canada.

5. Aerial Applications by Helicopter

5.1 An Opinion

"Helicopters lend themselves well to insecticide application, especially in relatively small areas, areas bounded by tall windbreak trees, etc. Their commercial use has been limited by their relatively high initial cost as compared with fixed-wing planes. In addition, the maintenance costs of helicopters are rather high. This has limited their purchase and use, even in areas where, if other things were equal, they would be vastly superior to other means of pesticide application.

Helicopters provide for better control of dosage, uniformity of insecticide coverage, and for prevention of insecticide drift to non-target areas. The current demand for pest control with minimal environmental disturbance may lead to greater interest in helicopters for this purpose. To quote from the report of the Commission on Pesticides and

Their Relationship to Environmental Health (Mrak Commission) to the Secretary of the Department of Health, Education and Welfare: 'Increased engineering development effort is needed for the design of equipment for, and the adaptation of helicopters to, the aerial spraying of pesticides' (Mrak 1969)" (Ebeling 1975).

5.2 Background

The modern helicopter, in its various forms, has become an indispensable component of the air transport industry in this country. The same may be said of the helicopter's role in agricultural aviation, especially in the United States. In spite of this, its principles and capabilities are understood very poorly or not at all by the majority of even its regular end-users.

Nowhere is this lack of understanding more widespread than in the field of aerial forest spraying. Here, an aura of virtue often seems to surround the rotary-wing which, compared to the aeroplane, is supposed to effect superior accuracy, canopy penetration, deposit and pesticide efficacy, while providing greater environmental protection both because of these things and because of its ability to control drift. In actual practice this total effect is achieved with frustrating irregularity.

There appear to be three basic reasons for the helicopter's enviable reputation. In the first place, there is no question as to the existence of the rotor wake or the reality of the helicopter's maneuverability and speed flexibility, all features which make it a potentially ideal spray aircraft. Secondly, it has been proven to be highly effective in agricultural spraying where it is flown within ground effect, a few feet above the surface. Here, the turbulent rotor wake quickly encounters the surface of the ground and must dissipate its kinetic energy by expanding laterally, thus producing swaths more than three times the width of the boom and effecting pesticide deposit on all surfaces of the leaves and stems (Chapter II, Section 3.2).

Finally, the superior treatment efficacy and results of which the helicopter should be capable have, in fact, been achieved from time to time in forest spraying. Unfortunately, as previously indicated, too little is known concerning the properties of the rotor wake, or the required operational parameters for forest spraying by helicopter, to explain the reasons why results are occasionally excellent but frequently disappointing.

Although lack of information is the basic source of the helicopter's current level of misunderstanding, the situation has been aggravated by a certain amount of misinformation and rumour leading to many conflicting views and opinions concerning its advantages and disadvantages, its relative merits as a spray aircraft, its safety, and its costs. This appears to have arisen, in part, from attempts to explain phenomena not fully understood and, in part, from natural rivalries among certain elements of the aviation industry's fixed- and rotary-wing segments. It may be worth noting in this connection that, while many helicopter pilots are former fixed-wing aircraft pilots, qualified on both types, the reverse is not often true.

While considerable research is obviously required to resolve these questions, it is first necessary to analyze all existing data to separate fact or genuine, indicated potential, wherever possible, from biased opinion and speculation.

5.3 Indicated Advantages of Helicopters for Aerial Applications

The following lists and describes those characteristics and capabilities which, acting in concert, give the helicopter its potential as a superior type of spray aircraft.

a) Speed Flexibility and Maneuverability:

The helicopter's ability to vary its inflight speed from zero to over 150 miles per hour, combined with almost unlimited maneuverability, can easily permit the precise tailoring of flight and application techniques to the job at hand.

b) Contour Flying Capability:

With its vertical capability and speed control, the helicopter can maintain a constant ground speed and above-canopy altitude to ensure evenness of coverage, even in rugged terrain.

c) Precision:

The helicopter's speed flexibility and maneuverability, combined with the effects of the rotor wake, should facilitate very precise application of chemical to exactly those areas planned to be sprayed, and make it possible to prevent overlap into adjacent areas which may not require treatment or which may be environmentally sensitive.

d) Use of Unprepared Landing Areas:

Helicopters have no need for runways, a feature which can greatly reduce the amount of non-productive ferry time. In addition, the landing area can be selected on the basis of greatest convenience for loading. Ground-mobile nurse rigs can permit the helicopter to operate out of areas immediately adjacent to the treatment site, and can relocate at will to increase operational efficiency as the work progresses.

e) Transportability:

Most helicopters can, if required, be moved to the work site by trailer, barge, or other surface transportation, regardless of weather or darkness, ensuring their on-site availability and reducing effective ferry costs.

f) Reduced Ground and Positioning Time:

With its ability to land and take off vertically, the helicopter saves the time spent by the aeroplane in ground-roll and taxi. In addition, it can proceed direct from take-off point to the beginning of the next swath, or return and land for the next load without long approaches to a runway.

g) Faster Swath Turns:

The helicopter's speed flexibility and maneuverability, and the fact that it cannot stall in the same sense as the aeroplane, permits tighter, faster turns at the end of each swath run. Reports indicate (Anonymous 1975a; Anonymous 1975b) that the helicopter turns in only about 10 seconds, which is 20 to 25 percent of the time required by the average agricultural aeroplane. According to one study (Philpotts 1971) involving a swath length of one-half mile, an aeroplane spent an average time of 18.8 seconds actually spraying a swath, and required an average of 40.5 seconds to turn.

h) Dispersal Equipment Flexibility:

Since much of the available helicopter spraying equipment can be added on externally, hoppers, tanks and system configurations can be tailored to the job, or removed easily. In other words, the helicopter is not limited, as are most aeroplanes, by tanks and equipment whose bulk may prohibit internal installation.

i) Canopy Penetration and Deposit:

The downward vector of the rotor wake should achieve better canopy penetration and spray deposit by forcing the cloud down into the canopy, and creating turbulence within the canopy itself which, at lower speeds, may also be agitated by the wake.

j) Chemical Efficacy:

As indicated above, the helicopter's potential for placing more chemical on target could increase spray efficacy, making it possible to use lower dosages, less total emitted volume and, in some cases (Howitt 1973), fewer treatments.

k) Reduced Effect of Meteorological Influences:

The helicopter's unique ability to fly contour at low, uniform altitude, combined with the downward vector of the rotor wake, may effect rapid canopy penetration by the spray cloud, thereby controlling drift and permitting the helicopter to continue spraying during winds of sufficient velocity to curtail spraying operations by aeroplane. In addition, this effect of the rotor wake may not only help to counteract the negative effects of thermal convection currents, but may drive the spray material into the below-canopy region in spite of the thermally unstable air layers which develop during the day in fair weather just below the top of the canopy (Cramer and Boyle 1974). This, in addition to the factors indicated in 'l' below, could further extend available daily working time, perhaps making it possible to spray all day.

l) Extension of Working Time:

The helicopter's ability to fly slowly at low altitude may further extend the length of the working day or permit operations to continue safely under conditions of low visibility which would ground an aeroplane. Examples of this capability are discussed in Section 8.8. In addition, helicopter night spraying has been successfully conducted (Mark 1976)[1] to exploit the more suitable meteorological conditions which may prevail at that time.

m) Public Relations and Control:

On most projects, the entire operation, including loading and servicing, can be carried on from an unprepared landing area close to the job site. This permits closer liaison between the flight crew, operations manager, end user and members of the public, and can prevent misunderstandings as well as result in a superior degree of job tailoring in terms of the desired treatment effect.

n) Safety Considerations:

Six of the major, accident-prone, operational phases of aerial application by aeroplane (Anonymous 1975b) are diminished by the use of the helicopter. As evidenced by Table 7, these include accidents during taxi, take-off, climb-out from take-off, stalls, procedural turn-around, and flare-out for the swath run. The helicopter can take off and descend vertically, and can remain in a stationary hover, permitting the pilot to check his lift capability immediately upon take-off, in close proximity to the ground, with no forward speed. In the event of engine failure, the helicopter can make a safe, autorotational landing in open or confined areas, touching down with zero forward speed.

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[1] Personal communication: Charles Mark, Middlesex County Mosquito Commission, English Town, New Jersey; Dr.C.M. Voss, President, Ag-Rotors Inc., Gettysburg, Pa.

5.4 Discussion of Suggested Helicopter Disadvantages

A number of the helicopter's characteristics are frequently cast as disadvantages in both general-purpose and aerial spraying applications. Not all of these are completely invalid. However, since misinformation tends to manifest itself most often in the form of criticism, many supposed 'disadvantages' of the helicopter have little or no basis in fact. While some such points have already been dealt with above, the remaining, most common ones are discussed below.

a) Speed:

Reciprocating engine helicopters such as the Bell 47, Hughes 269 and Hiller UH12, with normal cruise speeds in the order of 70 to 85 miles per hour, are certainly not fast aircraft. For many years, they were the only light helicopter models in existence, and over 200 are still operated routinely in Canada alone (Appendix B, Table 1). These are the machines which gave rise to the helicopter's reputation for slowness, a reputation which still persists. However, in 1976, they made up roughly 25 percent of the total light helicopters in Canada, and, of these, only the Hiller UH12 is still being manufactured. The balance were turbine-powered machines such as the Bell 206, Hughes 500 and Aerospatiale SA341G with normal cruising speeds ranging between 125 and 150 miles per hour, and maximums of 150, 175 and 195 miles per hour respectively. This performance can be matched by few single-engine, utility aeroplanes in the same gross weight category. If speed flexibility is a consideration, the helicopter stands alone, and this is one of the features with high potential for aerial spraying. Any statement to the effect that helicopters are slow may therefore be an invalid and misleading generalization. Which helicopter model is being referred to, and to which aeroplane is it being compared? A Bell 47 is much slower than a DC-6B, but so is a Cessna 185 or a Thrush Commander, both of which are also slower than a Hughes 500D or an Aerospatiale Gazelle.

Speed, however, may not be a particularly significant factor in any case if the rotor wake can be harnessed to improve pesticide efficacy and deposit. Figure 4 provides an indication of the relationship between airspeed and the angle at which the wake's longitudinal axis may incline downward from the horizontal. Obviously, as airspeed increases, this angle decreases until, at the higher speeds of which modern turbine helicopters are easily capable, the wake angle will be extremely shallow. In fact, at such speeds, helicopters and aeroplanes produce wakes which are essentially similar, including airfoil turbulence and 'wing-tip vortices'. During high speed flight the helicopter, like the aeroplane, loses some of the maneuverability which would otherwise permit it to fly in relatively close proximity to the peripheral canopy.

In other words, a helicopter can be flown in the same manner as an aeroplane and, under such circumstances, may not produce significantly different deposit and results. This remains to be established, as does the real cost differential if other aspects of the operation were

Table 7: Assigned causes of agricultural aviation accidents, U.S. registration, 1976 preliminary statistics (World of Agricultural Aviation 1977).

Assigned Cause of Accident	Fixed-Wing		Helicopter	
	No.	%	No.	%
Crash during take-off	32	8.5	1	2.8
Crash during landing	38	10.1	1	2.8
Accident while taxiing	4	1.1	0	0
Collision with trees, wires, and other elevated obstructions	65	17.3	9	25.0
Collision with crop, ground, stand-pipes, embankments, etc.	27	7.2	5	13.9
Crash due to engine failure	118	31.5	10	27.8
Crash due to aerodynamic stall	28	7.5	0	0
Failure of landing gear	9	2.4	0	0
Failure of tail rotor	0	0	2	5.5
Miscellaneous and undetermined	54	14.4	8	22.2
Totals	375	100.0	36	100.0

ideally tailored to the helicopter. Assuming similar results at higher cost, however, then it obviously makes little sense to pay a premium for the helicopter's unique flight and aerodynamic qualities and then fail to make use of them, even to the extent that they are currently understood.

b) Payload, Useful Load and Endurance:

Since an aircraft's payload, useful load, and endurance or range are interdependent, it is almost essential that they be considered simultaneously. For every aircraft type, there is a maximum, certified, gross weight which cannot be legally exceeded. 'Useful load' refers to the total weight of fuel, oil, crew, passengers and cargo which can be carried within this limit, or the difference between the aircraft's empty weight and the maximum allowable. 'Payload' is the weight of passengers or cargo which can be accommodated on a particular trip in view of the pilot's weight and that of sufficient fuel to complete the trip with adequate reserve.

'Endurance' refers to the length of time an aircraft can remain aloft at a particular power setting which, obviously, is directly related to both the amount of fuel on board and fuel consumption. 'Range' is simply the spatial counterpart of endurance, measured in miles or kilometers under still air conditions. Since most weight and performance data are based on ICAO Standard Day conditions at sea level, consideration must be given in practice to the effects of air temperature and altitude on aircraft performance.

It is not easy, from manufacturers' published data, to compare helicopters and aeroplanes in terms of payload, useful load and endurance. In addition, the nature of the various data often make it difficult to draw parallels between reciprocating and turbine powered aircraft. The problem here is that only turbine helicopters are now produced by the major manufacturers while, as of this writing, all production spray aeroplanes are still powered by reciprocating engines.

Bearing in mind the foregoing, however, the available information suggests that, in general, for helicopters and fixed-wing aircraft in the same gross weight category, helicopters utilize engines of greater horsepower, requiring more horsepower per pound of weight transported. The helicopter's fuel capacity is generally greater and consumption higher. Useful load is frequently comparable but, in view of the foregoing, payload and endurance or range do appear to be somewhat lower in the case of the helicopter. However, it is just as important to avoid generalizations here as when comparing the speed capabilities of fixed- and rotary-wing aircraft. The useful load of a Bell 47 helicopter is many times lower than that of a Grumman Avenger, but so is that of a Thrush Commander, while the Bell Model 214B's useful load is greater than the Avenger's.

Finally, the helicopter's ability to operate out of small, unprepared landing areas close to the work site can eliminate the need for long ferry flights such as aeroplanes must frequently make from the nearest airport. In this type of situation, the helicopter will require less fuel per trip and can carry a correspondingly greater gallonage of pesticide. Full utilization of the helicopter's vertical capability can thus make possible various fuel-to-pesticide trade-offs which may more than compensate for any basic payload disadvantage of rotary-wing aircraft.

c) Cost:

High cost is probably the most frequently voiced argument against the use of rotary-wing aircraft for forest spraying. Again, however, generalizations can be grossly misleading. Many factors are involved.

Purchased new, helicopters can be several times more expensive than fixed-wing aircraft in the same gross weight category. For example, the 1976 basic prices of the Grumman AgCat G164A-600, Thrush Commander and Piper 'Pawnee Brave' were about $64,000, $72,500 and $43,000 respectively, while that of the Bell 206B 'Jet Ranger' was $170,000 and the Hughes 500C cost $155,000. However, at these prices, the three agricultural aeroplanes would be equipped and ready for work, while the helicopters would still require expenditures of $5,000 to $8,000 each for spraying equipment. In used condition, of course, almost any aircraft will be less expensive; how much less depends on the number of hours remaining until scheduled overhaul or replacement of major components, plus general condition. Again considering machines in the same gross weight category, used helicopters in good condition can be purchased for amounts which range from much less than those of new aeroplanes, including agricultural machines, to prices which may be up to 70 percent more, depending on type, year of manufacture, overhaul requirements, powerplant, and so on.

Helicopter operating costs, again depending on several factors, may vary in practice from approximately the same to more than twice the cost of an aeroplane of the same gross weight. Actual operating costs, however, are seldom easy to compare between aircraft types. In fact, it is often difficult to make such a comparison between two aircraft of exactly the same type owned by different organizations, due to differences in book-keeping procedures, methods of recording operating hours, overhead, insurance rates, area of operation, and a host of other considerations.

In spite of this, the important thing to the end user is the cost of treatment per acre. In Maine, during 1975, two helicopters were used to treat a small percentage of the total area sprayed for spruce budworm, and cost $13.20 per gallon emitted compared to $3.97 for the fixed-wing (Section 6.2). Although neither of these figures is currently available on a per-acre basis, the total cost of the program was about $2.75 per acre. In 1976, a west coast company bid on the same type of work in Maine, with Bell Model 205A-1 helicopters at about $4.50 per gallon emitted, versus $3.90 for the fixed-wing (Section 6.3). The spray helicopters used in the 1974 Douglas fir tussock moth program in Washington, Oregon and Idaho cost $1.78 per acre (Section 6.4), as did the same type of machine, the Bell Model 205, in tests conducted during 1973 (Section 6.6). In Pennsylvania during 1975, 30,000 acres were treated for gypsy moth (Nichols et al. 1976) at a total cost for the helicopters of $4.89 per acre, not including the chemical which, in this case, was Dylox applied at a rate of one pound per acre. In much of Canada, six to eight dollars per acre, including aircraft and chemical, is considered to be a realistic cost for treating moderate acreages with an agricultural aeroplane while, in British Columbia, some organizations are content to pay $10.00 per acre for the same service.

These data indicate that helicopter spraying, in relation to treatment by aeroplane, can cost more, it can be approximately the same, or it can sometimes cost less. It is obviously unreasonable to judge helicopter costs on the basis of the cost per acre for a Douglas DC-6B to treat 10 million acres. It would be equally unreasonable to compare the DC-6B to the Thrush Commander. Perhaps it is even illogical to attempt comparison of treatment costs for helicopters and aeroplanes of the same gross weight, since fixed-wing forest spray systems, application techniques, and ground support equipment and methods have been the subject of concentrated research and development activity for three decades, while the helicopter has received correspondingly less attention. If the helicopter is given an opportunity to benefit from similar efforts on its behalf, a new aerial forest spray vehicle may emerge which is strongly competitive in terms of costs and, in many situations, superior in terms of results.

d) Safety:

Helicopter safety has already been discussed to some extent in Section 5.3 of this Chapter.

According to Table 8, data covering the period 1970 to 1974 inclusive indicates, on the average, that a helicopter is somewhat more likely to have an accident than is a fixed-wing aircraft but, when an accident does occur, the occupants of the helicopter stand a better chance of survival. Table 9 suggests that this is especially true in agricultural flying.

Much of the blame for the helicopter's somewhat higher accident rate has been assigned to its relatively more hazardous work environment. Because of its unique flight capabilities, the helicopter operates much of the time in close proximity to the ground, often with bulky external loads hanging from the cargo hook. It operates in and out of confined areas, frequently near trees, wires, towers and other obstacles, and makes many landings and take-offs each day.

A lower incidence of death or injury occurs in helicopters for two basic reasons. Should a forced landing suddenly become necessary, any opening in the forest can serve as an emergency landing area. Such an opening need not be many feet larger in diameter than the overall length of the helicopter. Also, in an auto-rotational landing, ground contact is made at zero or very low forward speed.

It is useful to compare this ability of the helicopter to an emergency landing in a fixed-wing aircraft. The aeroplane must maintain adequate airspeed to avoid stalling, and attempt to locate a field or opening of adequate length. Speed must be maintained until the last moment to avoid loss of control, and the aircraft will probably make ground contact with a forward speed of between 40 and 90 miles per hour, depending on type. What happens now depends on the type of ground over which the aeroplane must decelerate before coming to a stop, and on whether or not the field or opening selected is long enough for the purpose.

Table 8: Helicopter and aeroplane accident statistics, Canadian registered, general aviation, 1970-1974 (Transport Canada 1976a)

	1970	71	72	73	74
Accidents to all aircraft of Canadian Registry	630	536	614	713	683
Helicopter Accidents	68	72	94	94	73
Percentage of Total which occurred to Helicopters	12.8	13.4	15.3	13.6	10.7
Helicopter Population	551	625	712	800	849
Fixed-Wing Accidents	458	493	520	616	610
Fixed-Wing Population	10,679	11,441	12,726	14,475	16,149
Percentage of Helicopter population involved in accidents	12.3	11.5	13.1	12.1	8.59
Percentage of Fixed-Wing aircraft involved in accidents	4.2	4.3	4.2	4.6	3.77
Fatal Helicopter accident	5	7	6	11	9
Fatal Fixed-Wing accidents	52	73	78	71	61
Percentage of Helicopter accidents fatal	7.4	9.7	6.5	11.3	12.3
Percentage of Fixed-Wing accidents fatal	11.4	14.5	15.0	11.5	10.0

Should an aeroplane experience engine failure beyond gliding distance from a suitable opening, forcing the emergency landing to be made in forested or rugged terrain, the implications are obvious. If a helicopter was placed in the same situation, an autorotational approach would be carried out and the machine would arrive at the peripheral canopy with zero forward speed and normal rotational speed of the main rotor. This, plus main rotor inertia, would allow the pilot to control his initial descent into the forest. By the time blade strikes on the trees caused loss of r.p.m. and, hence, of lift, the aircraft will usually have reached a survivable height above ground.

A rumour which is surprisingly persistent in view of its absurdity is that if a helicopter's engine fails, the main rotor stops turning and the machine falls out of the sky. What actually happens is that, as the engine revolutions decrease, the helicopter's centrifugal clutch disengages, the pilot decreases main rotor pitch to minimum, slows the machine to a speed of 60 to 80 miles per hour, depending on helicopter type, and enters a normal gliding descent. Under these conditions, normal main rotor r.p.m. is maintained automatically and the glide ratio lies in the order of 4:1, horizontal to vertical, depending again on helicopter type. The pilot now maneuvers to approach his emergency landing area into the wind and proceeds with a landing whose only major difference from a normal one is that he cannot change his mind at the last moment and 'go around again'.

Table 9: Helicopter and aeroplane accident statistics (preliminary), U.S. registered, agricultural aviation, 1974-1976 (World of Agricultural Aviation 1975, 1976, 1977)

	1974[1]	1975	1976
Total Ag. Aviation accidents to aircraft of U.S. Registration	427	428	411
Fixed-Wing accidents	393	381	375
Helicopter accidents	34	47	36
Percentage of total which occurred to Fixed-Wing	92.0	89.0	91.2
Percentage of total which occurred to Helicopters	8.0	11.0	8.8
Fatal Fixed-Wing accidents	26	28	34
Fatal Helicopter accidents	3	3	0
Percentage of Fixed-Wing accidents fatal	6.6	7.3	9.1
Percentage of Helicopter accidents fatal	8.8	6.4	0
Fixed-Wing accidents involving serious injury	53	30	20
Helicopter accidents involving serious injury	2	4	1
Percentage of Fixed-Wing accidents involving serious injury	13.5	7.9	5.3
Percentage of Helicopter accidents involving serious injury	5.9	8.5	2.8

[1] January 1 - November 17, 1974 only.

e) Navigation and Guidance:

It has been said that the helicopter cannot consistently maintain the parallel, evenly-spaced swath tracks required for good coverage. While this aspect of forest spraying does present some difficulty, it is not a problem unique to helicopters.

Parallel tracks can easily be maintained using standard, basic flight instruments. The problem relates to the achievement of even swath spacing, a difficult task for the pilot of any aircraft, particularly one attempting to fly contour at minimal altitude in rolling terrain. He is too low for effective use of maps, and continually loses sight of reference points as he dips into valleys.

Required for all light spray aircraft, both helicopter and fixed-wing, is a reliable, economical guidance system which will keep the pilot on track under the circumstances described above.

5.5 Implications of Rotary-Wing Versatility and Operator Attitudes.

The helicopter's versatility has already been discussed in relation to the wide scope of its mission capabilities. The modern, turbine-powered machines, with their speeds, payloads and vertical take-off ability, are felt by many to embody the best features of the helicopter and the aeroplane in one unique aircraft.

The helicopter's versatility is one of its greatest assets from the standpoint of the operations manager who must ensure that all aircraft are gainfully employed for as much of the year as possible. To him, long-term contracts are the most desirable, often involving periods of three to five months, minimizing the administrative work load and offering stability and guaranteed minimums per month of revenue flight time.

The helicopter's versatility also means that aerial spraying is only one of many missions of which it is capable. It is also one of the least attractive to the helicopter operator because, for a number of reasons, it is currently one of the least lucrative. The various forest spraying programs take place during the spring and summer months; they are not co-ordinated by the same agency, and the operator has little chance of keeping his fleet busy all season, moving from project to project. In addition, the spraying season occurs during part of the period of peak activity in other fields such as petroleum or mineral exploration, construction and even forest fire suppression, all of which can provide the stability of long-term contracts with guaranteed minimums of revenue flying hours and a greater possibility of exceeding daily minimums. In addition, since helicopters are reputed to be more expensive to use than aeroplanes, they are often employed for projects or parts of projects which aeroplanes cannot manage, and which may therefore be quite small both in area and in generated revenue. Such projects are unattractive to the operator not only because of their limited, short-term nature but also because he must often work with a narrow profit margin in order to obtain the contract at all. Even so, he must charge more per hour or per acre than would be the case if larger projects were involved, thereby confirming the contention of his critics that helicopters are too expensive to use for most operational spraying.

Further, aerial applications represent the unknown to most operators. Their information is sufficient only to provide a sketchy view of potential problems, but too little to suggest the solutions. Impressions of co-ordination and administrative problems, stringent licencing requirements, the need for expensive, specialized equipment and training for aircrews and supervisors, political decisions resulting from public concern over the environment, and other concerns all combine to give involvement in aerial spraying every appearance of being far more trouble than it is worth in terms of generated revenue or desirability as a market for their services. It is also obvious to most that, in relation to forest spraying at least, existing applications technology is inadequate to optimize economy of treatment by helicopter or provide any assurance that the helicopter treatment will yield any better results than the apparently less expensive fixed-wing aircraft.

Operators thus continue to work in more familiar territory, with many actively awaiting the day that the research establishment can furnish them with proven, helicopter-specific, aerial spray systems for forest applications, and dependable operating parameters.

5.6 On the Job with the Helicopter

As already discussed, the helicopter's vertical capability, speed flexibility, and unique rotor wake effect are the features of greatest potential benefit to aerial applications. It must be borne in mind that to optimize the results of helicopter treatments, the helicopter must be flown 'like a helicopter' rather than like a fixed-wing.

In forest spraying, the helicopter normally flies considerably higher than the ground-effect zone whose influence on swath width in agricultural spraying has already been described. Therefore, in any particular situation, swath width will be controlled by altitude, particle size and wind. During field calibration, the swath width will usually be established for the spraying altitude, speed, and emission rate required to yield the required number of droplets per square centimeter in the desired size spectrum.

From this point there are numerous formulae used to calculate coverage, productivity and required flow rates:

a) Coverage = $\frac{\text{Swath Length (Miles) X Swath Width (Ft.)}}{8.25}$ = Acres

b) Coverage/Min. = .002 X Swath Width (Ft.) X Speed (Mph) = Acres/Min.

c) Flow Rate = Appl. Rate (Gal./Ac.) X Speed (Mph) X Swath Width (Ft.) = Gal./Min.

In calculating the number of acres per flight hour or 'work rate', of any aircraft, four factors must be considered (Anonymous 1975b):

1) swath time, 2) time in turns, 3) ferry time and 4) loading time.

The Baltin-Amsden Formula, given below, is one of the means of expressing these time factors mathematically to calculate the time required to complete one spray cycle:

$$T = TR + TS + TT + TF + TM = \text{min./cycle.}$$

$$T = TR + \frac{495\ Qf}{Qbr} + \frac{726\ Tw\ QF}{Qbl} + \frac{120a}{V} + \frac{60\ C\ Qf}{VFQ} = \text{min./cycle.}$$

where: T = Minutes per complete spray cycle.
TR = Minutes spent on ground.
TS = Minutes spent in spraying in the swath.
TT = Minutes spent in total turns.
TF = Minutes spent in ferrying.
TM = Minutes for multiple-plot ferrying.
Q = Gallons dispersed per acre.
Qf = Gallons carried per load.
b = Swath width in feet.
r = Spraying speed in miles per hour.
Tw = Turning time in seconds, each turn.
L = Length of plot in feet.
a = Distance fetch and carry in miles.
V = Ferrying speed in miles per hour.
C = Distance between multiple plots in miles.
F = Area of plot in acres.

Taking the various elements of the formula separately, each may be explained as follows:

Loading Time (TR): All time spent on the ground, including landing roll, taxi, loading and take-off.

Swath Time (TS): TS = $\frac{495\ Qf}{Qbr}$, in which 495 converts acres, miles and hours to obtain minutes.

Turn Time (TT): Total time spent in reversing direction for alignment with next swath.

$TT = \frac{726\ Tw\ Qf}{QbL}$, in which 726 converts seconds and acres to obtain minutes.

Ferry Time (TF): The time required to leave the plot, fly to reloading point and return.

$TF = \frac{120\ a}{V}$, in which 120 converts hours to minutes and doubles the distance.

Multiple-plot Time (TM): This factor is included to cover situations in which a number of small acreages are treated. Use the average acreage of these plots and the average ferry distance involved.

$TM = \frac{60\ C\ Qf}{VFQ}$, in which 60 converts hours to minutes.

Solving this formula will provide the total time required for the aircraft to fly one complete spray cycle. The acreage covered will be the volume of one spray load divided by the application rate per acre. Productivity may now be calculated as follows:

$$\text{Productivity} = \frac{\text{Acreage Covered per Cycle}}{\text{Time to Complete One Cycle}} = \text{Acres/Minute}$$

Missing from these calculations are the ferry time from the aircraft's base to the work site, and the time required to 'touch up' edges and corners. The latter is not frequently encountered in forest spraying and, when it is, the helicopter's maneuverability and ability to make low-speed, flat turns can give it an advantage over the aeroplane.

The Baltin-Amsden Formula provides a means of comparing the productivity of the helicopter to that of the aeroplane although, of course, treatment effectiveness and spray deposit efficacy must be considered separately. It is unfortunate that the only such productivity comparisons readily available involve agricultural-type operations rather than forestry, and most of these were prepared by helicopter manufacturers whose motives may tend to be more commercial than scientific. Nevertheless, the basic data appear fairly accurate, and one of the comparisons involving a modern agricultural aeroplane and a light turbine helicopter is summarized in Appendix H. The other which compares a common, piston-engine helicopter and an agricultural, fixed-wing aircraft, is described below.

The example specifies that a number of blocks, totalling 150,000 acres, are to be treated with insecticide at an application rate of two gallons per acre and an average swath run of one-quarter mile. The helicopter carries 100 gallons of chemical, spraying a swath 120 feet wide (Chapter II, Section 3.2) while flying at 60 miles per hour and procedure-turning in 10 seconds. Using onsite loading, the average ferry trip between the nurse rig and the work area is one-quarter mile, and the trip is flown at 60 miles per hour.

The aeroplane carries 140 gallons of insecticide, sprays a 60-foot swath at 80 miles per hour, takes 25 seconds to make a procedure turn, and can be loaded in three minutes including landing and take-off rolls plus taxiing. The average ferrying distance from the nearest airstrip is three miles, and the trip is flown at 80 miles per hour.

According to the Baltin-Amsden Formula, the aeroplane will treat 150 acres per flight hour, while the helicopter's productivity will be 476 acres per hour. Deducting 20 percent in each case to cover such variables as 'touching up' plot ends and ferrying between plots, the productivity for the aeroplane and the helicopter will still be 120 and 380 acres respectively. This means that the aeroplane would require 1,250 flight hours to complete the job, while the helicopter could do it in 395 flight hours.

At the higher spraying height required for a forestry operation, depending on the type of atomizing device employed (the above comparison involves boom-and-nozzle), the swath width could vary from that specified. Also, the one quarter-mile swath length obviously favours the helicopter with its much shorter turn-time. Nevertheless, both this example and the one summarized in Appendix H appear to be fairly realistic in terms of treating high-value forest stands and plantations. If anything, the aeroplane's average ferry trip from the work site to the nearest airstrip would, in Canada, be substantially greater than three miles.

In forest spraying, utilization of the rotor wake is as important as in the treatment of agricultural crops, although in a somewhat different manner, since a more vertical distribution of spray is required in order to penetrate the canopy. Once within the canopy, it is desirable that the droplets deposit as uniformly as possible on all surfaces of the foliage. This implies a downward, lateral and upward flow of air, or turbulence, at sufficient velocity to effect impingement (Table 3). Dense foliage is itself a detriment to the maintenance of the required velocities. By extrapolation, Table 3 suggests that a 50-micron droplet requires a minimum velocity in the order of 0.7 miles per hour or 1.03 feet per second, to impinge on an object with a width of one-sixteenth inch. The air movement created by the rotor wake, properly utilized, could effect the required in-canopy turbulence and droplet/target relative velocity both by imparting a downward velocity to the air and by agitating the foliage itself.

Just as the helicopter should not be flown like an aeroplane in the swath, neither should it be supported like an aeroplane on the ground. Unless the nearest airport is located very close to the treatment area, it should not be required to return to an airport to load and refuel. Some advantages accruing to its vertical capability will be lost if it must make the same ferry flight between loads as would an aeroplane treating the same area. The 'nurse rig' which has come into widespread use in the United States is a mobile helicopter base consisting of a truck and/or trailer which contains tanks for the pesticide together with mixing and loading equipment, fuel, and other supportive material (Figures 13 and 14). In more remote areas, rail cars, barges or even the prior location of this equipment by helicopter in open areas close to water could greatly reduce ferry distances and provide an alternative to the cost of building and maintaining airstrips. The latter could assume special importance should the treatment prove sufficiently effective that no further spraying of the area was required for several years.

5.7 Helicopter or Fixed-Wing?

The purpose of this chapter thus far has been to take an objective look at the helicopter and the aeroplane in terms of their relative strengths and weaknesses, their advantages and disadvantages in an aerial applications role, and to give as up-to-date as possible an answer to the question, "which is really better for forest spraying: fixed- or rotary-wing?"

The answer should now be obvious: neither is 'better' than the other in all situations; each has a role to play. Since the helicopter has received less attention in terms of applications technology development and related, serious evaluation, its role is much less clearly defined. We are aware of many factors which give the helicopter great potential as a superior spray aircraft, a potential which seems to be borne out from time to time by excellent results, but the lack of knowledge and of helicopter-specific dispersal systems for forestry application imbue operational helicopter spraying with more risk than many forest pest managers are willing to hazard. In spite of this, even today, there are specific jobs in which the helicopter's unique features render it superior to the aeroplane, just as the reverse is frequently true. Since both fixed- and rotary-wing aircraft are available in many types and sizes, there is also an area of overlap within which helicopters and aeroplanes may compete for the same work.

It thus remains for the forest pest manager to be as familiar as possible with the capabilities of all aircraft types, and to select the best machine for the job at hand. He must equip himself not only to decide between fixed- and rotary-wing but to choose the specific aircraft model and dispersal system which will do the best job in his particular situation. In the meantime, he can only hope that the research establishment will soon launch a concerted effort to study the helicopter's capabilities as an aerial spray vehicle, develop related dispersal equipment and techniques specific to forestry, and set operational parameters within which optimum treatment results can reasonably be assured.

Figure 13: A small 'nurse rig' seen with Hughes Model 300 helicopter (Courtesy Aerial Applicator, April, 1972).

Figure 14: Larger 'nurse rig', seen with Bell Model 47 helicopter (Courtesy The World of Agriculture Aviation, NAAA, Vol. 3, No. 9).

6. Recent Experience in Helicopter Spraying

6.1 Background

It has already been shown that helicopters are rarely used for operational forest spraying in Canada. Even in agriculture, the aeroplane has enjoyed the lion's share of the aerial applications market.

In the United States, the picture is somewhat different. Proportionately, helicopters have had greater involvement in forest spraying and have become solidly entrenched in both agricultural aviation and in spraying operations against mosquitoes and biting flies. In addition, somewhat more work has been done to evaluate their capabilities as they relate to aerial applications, and to investigate ULV dispersal equipment. Nevertheless, little more appears to have been done in the United States than in Canada to analyze the rotor wake in terms of its capabilities as a dispersal tool, and agricultural spraying has received much of the attention even here. As already discussed, the rotor wake effect in agriculture, and its use, is quite different from that in forestry.

The picture appears much the same overseas in terms of research relating to use of the helicopter as a spray vehicle. However, more has been done, particularly in Great Britain, to develop ULV and other mechanical dispersal devices such as the Micronair, the Turbair, and the new Micron spray head. Helicopters are used for agricultural spraying in Europe, and recent correspondence with Dr. J.W. Ray, New Zealand Forest Service, indicates their extensive employment in that country for forestry, particularly in nursery and plantation situations. In Africa, considerable aerial spraying has been carried out by helicopter for the control of the tse-tse fly (Coutts and Spielberger 1977; Lee 1977; Johnstone et al. 1974), and helicopters are used very extensively to control a species of black fly which is the vector organism for a serious human disease known as river blindness in west Africa. The latter project is being carried out under a contract to the World Health Organization by a Canadian company, Viking Helicopters Limited of Ottawa.

Thus, while helicopter utilization for aerial spraying is on the increase in Canada, the United States, and abroad, interest in its potential is accelerating rapidly, accompanied by a resultant demand for information. Many requests for data are received in Canada, a recognized world leader in aerial applications technology. Unfortunately, much of the critical information is unavailable and will remain so until the required research and development has been carried out.

The following sub-sections summarize a number of operational and experimental programs conducted in the United States during the past four years. They have been selected for presentation here because of their specific reference to, or use of helicopters in the aerial treatment of forest insect infestations, or equipment evaluation trials, in a similar environment to our own in Canada.

6.2 Spruce Budworm in Maine, 1975

During the period May 25-June 12, 1975, 671,389 gallons of insecticide were applied to 2,260,399 acres of which slightly more than one percent involved experimental work (Struble et al. 1976). The total cost was approximately $2.75 per acre. The project employed 25 spray aeroplanes, 17 Cessnas used as 'pointers', and two helicopters for spraying 200-foot strips along inhabited lakeshores and wooded roadsides. Neither costs nor results are shown separately for the two aircraft types, although the contract price for the aeroplanes and helicopters respectively was $3.97 and $13.20 per gallon sprayed. This would make the helicopters 3.32 times more expensive than the aeroplanes.

6.3 Spruce Budworm Program in Maine, 1976

During the 1976 spruce budworm program in Maine, (Chadwick and Irland 1976)[1] eight Bell Model 47G-5 helicopters, equipped with boom-and-nozzle apparatus and flying in teams of four machines, sprayed a total area in the order of 21,000 to 22,000 acres. Each aircraft carried approximately 80 gallons of chemical (Dylox applied at one pound/quart/acre) and the teams flew approximately 25 feet above canopy at 55 to 60 miles per hour. Depending on conditions, each helicopter delivered a swath width in the order of 125 feet. Preliminary estimates indicate that the treatment cost for the helicopters alone was about $0.80 to $0.90/acre.

Irland further commented that the bid price for all aircraft on this project was about $3.90 per gallon of spray emitted. He said that one helicopter operator, whose bid involved the use of Bell Model 205A-1's, submitted a quotation for helicopters which was only about $0.60 more per gallon than this overall figure. Equated in terms of cost per acre, these larger helicopters would therefore have cost very little more than did the fixed-wing aircraft.

Irland said that helicopter treatment costs are sensitive to ferry time and, of course, to the size of the area involved. If the stands are fairly accessible by surface transportation to permit on-site loading, and if each helicopter is given sufficient area (up to 5,000 acres), then the resultant cost per acre will be very close to that of any fixed-wing aircraft.

6.4 1974 Douglas-Fir Tussock Moth Control Project

In June and July of 1974 (Mounts 1976), the largest, all-helicopter, aerial spraying project ever conceived in the United States applied DDT to 427,000 acres of Douglas-fir and grand fir timberlands in Oregon, Washington and Idaho, employing 37 helicopters for spraying and monitoring operations. Of this number, 16 of the helicopters were involved in insecticide application, and the balance were used for observation and monitoring. The main spray helicopter, the Bell Model 205, flew at

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[1] Personal communication: J.H. Chadwick and L.C. Irland, Maine Dept. of Conservation, Bureau of Forestry, Div. of Entomology, Old Town Maine.

speeds of 90 miles per hour and altitudes of 40 to 60 feet above the canopy, achieving a remarkable safety record for any forest spraying operation. A total of more than 2,900 helicopter flight hours were logged.

The cost was almost four times as high as those of previous applications of DDT, although this was ascribed in large measure to the very intensive monitoring carried out. Total project costs in order of $2,980,000 equated to $7.08 per acre (Graham et al. 1975) of which the total cost for the spray helicopters only amounted to $1.78 per acre.

The results of the project were judged to be excellent, with defoliation ceasing almost immediately. More than 410 million board feet of timber were saved from defoliation, with a net value in excess of $11,600,000. In addition, the treatment prevented a loss of $23,800,000 (Graham et al. 1975) in damage to immature trees, growth loss, reforestation expense, recreation loss and increased fire protection costs. The 21-day postspray corrected insect mortality for the total treated area was 98.8 percent.

Since the helicopters flew their missions at 90 miles per hour, the wake angle from horizontal would be small. Nevertheless, the mean above-canopy emission altitude of 50 feet would place them sufficiently close to the peripheral canopy that some rotor wake effect should have occurred. This height would also place the helicopters well within the zone of minimal air flow described by Cramer and Boyle (1974). It is difficult to establish the proportion in which the project's success may be attributed to the employment of helicopters as opposed to that resulting from the use of DDT. However, there is ample reason to believe that the helicopters themselves were a significant factor because of their low-level, contour flying ability, rotor wake effect, and capacity for on-site loading and fast turn-around.

6.5 Evaluation of the Bell Model 205A-1

Tests of the Bell Model 205A-1 were made under open ground conditions (Orchard et al. 1974) at various speeds and altitudes, and were designed to test the helicopter's suitability for forest application of insecticides.

The helicopter has a 48-foot diameter, two-bladed main rotor. It is powered by a 1,400-horsepower gas turbine engine and has an internal payload capability of 4,000 pounds. The test equipment included a 400-gallon (U.S.) internal tank and two, 24-foot booms equipped with Spraying Systems diaphragm Tee Jet nozzles and flat fan spray tips. The nozzles pointed forward and were inclined downward at an angle of 45 degrees from the line of flight.

The two treatments providing the best coverage were both flown at an altitude of 50 feet using No. 8010 spray tips. One was made at 50 and the other at 90 miles per hour. Respectively, these treatments yielded mean acceptable swath widths of 295 and 175 feet, .309 and .420

gallons per acre, 86 and 111 droplets per square centimeter, recovery of 48 and 44 percent, and VMD of 147 and 126 microns.

In general it was concluded that the swath width was wider than that of smaller helicopters, that both the downwash and vortices were stronger and more pronounced and that the helicopter was suitable for aerial application of insecticides for forest insect control. It was felt that the downwash and rotor wake may be advantageous in enhancing spray penetration and deposition, and it was recommended that the helicopter be further tested to establish the effect of rotor wake, vortices and downwash on dispersal of the spray under open ground and forest conditions.

6.6 Performance of the Bell Model 205A-1 Under Forest Spraying Conditions

In 1973, following open ground tests of this helicopter (Orchard et al. 1974), two Bell Model 205A-1's were used for the Douglas-fir tussock moth operational test in northeastern Oregon and southeastern Washington. "Before spraying, the helicopters were calibrated to deliver 1 gpa at a speed of 90 miles per hour and a swath width of 200 feet using Spraying Systems Tee Jet flat fan nozzle tips No.8020 at 60 pounds per square inch and later changing to 45 pounds per square inch. The average load at 3,000- to 5,000-foot elevation was 250 gallons, and the minimum loading time was 3 minutes with an average of 4 minutes. The average speed while ferrying was 120 miles per hour. The atomization of spray recovered at ground level at two different spray areas was 211 and 226 microns, VMD."

The average cost of the helicopters, including ferrying but not including standby time or insecticide costs, was $1,564.71 per flight hour or $1.785 per acre. Additional data are provided in Table 10.

Table 10: Field performance data of two Bell 205A-1 helicopters used in an operational insecticide spray test (from Orchard et al. 1974)

Item	Aircraft number		Average
	50-R	57	
Acres sprayed[1]	63,718	52,545	58,132
Flight hours[1]	73' 50"	58' 47"	66' 18"
Acres per hour[1]	863.4	893.6	876.8
Flight days	29	25	27
Acres per flight day	2197.2	2101.8	2153.0
Hours per flight day	2.54	2.35	2.46
Cost per flight hour[1]	$1,759.81	$1,319.85	$1,564.71
Cost per acre[2]	$2.038	$1.477	$1.785

[1] Includes ferrying time.

[2] Cost includes ferrying time but does not include standby time or insecticide costs.

6.7 Evaluation of the Boeing-Vertol 107

Tests of the Boeing-Vertol Model 107 were made under open ground conditions, although they were intended to test the aircraft's suitability for forest spraying (Orchard and Markin 1975).

This helicopter has two rotor systems mounted in a fore-and-aft arrangement, each rotor having three blades and a rotational plane-diameter of 50 feet. The helicopter is powered by two turbine engines and has a payload of 8,000 pounds. The test equipment included two 41-foot booms and a 250-gallon (U.S.) spray tank, although the operational tank size would probably be from 800 to 1,000 gallons. The nozzles were oriented downward at 90 degrees to the line of flight.

The tests included three basic spraying modes in terms of the location of the nozzles actually functioning during test runs:
1) nozzles spaced at 40-50 inches along entire length of boom,
2) nozzles spaced at 20 inches along inboard 24 feet of boom,
3) nozzles, with 10- or 20-inch spacing along outboard 21 feet of boom.
Of these, the inboard mode produced the best results in terms of deposit, percent recovery and atomization in the acceptable swath width. Over three runs, the mean swath width was 243 feet, within which the mean deposit was .495 gallons per acre and 65 droplets per square centimeter. Recovery was 44 percent and VMD of the droplets was 121 microns.

In general it was concluded that this helicopter and spray system were satisfactory for the aerial application of pesticides, providing a swath which was wider than those of smaller, single-rotor helicopters, but similar in terms of deposit, pattern and recovery. It was recommended that the helicopter be further tested to establish the effect of rotor wake, vortices and downwash on spray dispersal under open ground and forest conditions.

6.8 General Statements Concerning the Use of Helicopters for Aerial Applications

The following is a sample of quotations and statements from the publications and sources noted concerning the use of helicopters for aerial applications. Every effort is made to preserve the true intent of these statements and avoid the distortion which might otherwise result from quoting them out of context.

A number of the statements were obtained through personal contact with various operators, and others by means of a cross-Canada mail survey conducted during November, 1976. In this survey, questionnaires were mailed to a sample of operators of both fixed-wing aircraft and helicopter operators holding Class 7 AAD commercial licences, and a 50 percent return was obtained. In some cases, the operators wished to remain anonymous and their wishes are honored accordingly.

a) "An aerial spray program to control the Douglas-fir tussock moth with the insecticide DDT was planned for late spring and early summer of 1974. This involved several hundred thousand acres in parts of northeastern Oregon, southeastern Washington, and western Idaho. Because helicopters have the ability to fly slower and closer to the target, thus applying sprays in mountainous areas with more accuracy, they were chosen by the Forest Service over conventional fixed-wing crafts to apply the pesticide" (Orchard and Markin 1975).

b) "Helicopters are more expensive to operate but have proved far more useful and adaptable than fixed-wing aircraft for spraying forest land in the steep, mountainous terrain of the Pacific Northwest. Helicopters are more highly maneuverable and allow more accurate spraying along edges of cuttings, buffer strips, and ecologically sensitive areas. They can fly at low height and slow speed over the steepest terrain, where fixed-wing aircraft must fly at greater height and higher speed to ensure safety of the pilot.

"In addition, helicopters can operate from heliports on roads and landings in the immediate vicinity of the spray areas. This minimizes ferry time in reloading and eliminates possible contamination of streams and farmlands in flying cross country from airports or landing strips needed for fixed-wing aircraft" (Gratkowski 1974).

c) "We use helicopters exclusively for several reasons: (1) In gypsy moth spraying, our spray blocks are in high-use areas averaging 100-500 acres each. There may be as many as 300 blocks scattered over 2 dozen counties. Consequently, the easy mobility is needed. (2) To cut down the loss in ferry time and spray run turn-time. We have used TBM's in the past on some projects, and the Bell 205 (350 gallon) output equals or exceeds the TBM. (3) We feel we get better coverage with helicopters and there are fewer misses, especially with the 205 with a 200-foot spray swath. Visibility from helicopters is better and they can fly lower and pick up block markers more readily. (4) A helicopter-truck unit is self-contained--no need for complicated airport setups--and they can operate from most anywhere. (5) We have had better pilots and less aircraft down-time on helicopter operations" (Nichols 1976)[1].

d) An operator (Voss 1976[2]) stated that his company's 'ag' fleet consists of both helicopters and fixed-wing aircraft and that, due to an increasing demand for helicopter spraying, some of the aeroplanes often sit idle while the helicopters are all

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[1] Personal communication: James O. Nichols, Chief, Forest Pest Management, Department of Environmental Resources, Bureau of Forestry, Division of Forest Pest Management, Commonwealth of Pennsylvania.

[2] Personal communication: Dr.C.M. Voss, President, AgRotors Inc., Gettysburg, Pa.

away on contract. He predicted that, 'within the next few years', his company's aerial applications activities would be divided equally between the helicopters and the aeroplanes. He feels that the relatively low degree of helicopter utilization in many areas is due to this aircraft's reputation for being expensive, and it thus tends to be used only in situations which are not feasible for aeroplanes. Such projects are often quite small, and therefore cost proportionately more. The operator states that helicopters can be competitive with aeroplanes on a per-acre basis on large projects and that treatment effectiveness is superior. A further point was made concerning the fact that, to realize the treatment results of which the helicopter is capable, it "must be flown like a helicopter", and its capabilities exploited to the fullest.

e) Concerning costs, another operator (Anonymous by request) described a sample project. This involved a total of 5,000 acres of woodlots and plantations ranging in size from 10 to 300 acres and all lying within a 20-mile radius the centre of which was located 100 miles from the operator's headquarters. Two extreme operational situations were considered. In the first, the operator would be responsible only for application, with customer supplying the chemical, mixing and loading, and all related equipment. In the second situation, it was assumed that the operator would be responsible for all phases of the operation. The operator stated that his bid on the first situation, in 1976, would be approximately $1.25 per acre while, in the second, it would be in the order of $3.00 per acre. He admitted that the latter amount could vary depending on the chemical involved, the cost and required dosage, but that "...it should not be too much higher".

f) In terms of equipment, another operator who now uses boom-and-nozzle apparatus felt that electrically-driven, rotary atomizers were much superior, but require more research and development to be sufficiently trouble-free and to be proven in terms of operating parameters. Although this operator's company (Anonymous by request) is now using helicopters with two-bladed main rotors, he is becoming increasingly interested in another type utilizing a four-bladed rotor. He has been told by other operators, familiar with both types, that the wake effect of the four-bladed rotor is the superior and that the machine involved has greater agility and maneuverability. This operator also mentioned that the ingestion of spray droplets can be harmful to the compressor stage of the turbine helicopter's engine; consequently, such aircraft are best used on projects of sufficient swath length to permit spray settling prior to the helicopter's next pass.

g) "To us in forestry, helicopters have many features which make them quite attractive for our needs (Markin 1974). In theory, their high maneuverability lets them work on extremely steep slopes and in unusual situations such as deep canyons where they have to fly around snags. Sometimes, they are also more economical than fixed-wing aircraft since long ferrying times can be cut down if helicopters are set up near, or in, the area to be treated. Also, in theory, they should be able to give us better treatment with pinpoint accuracy since they fly lower and slower than fixed-wing aircraft and can cut the spray on and off to miss sensitive areas such as streams. However, these advantages only exist if they are used right and if the right helicopter is used for the right job."

h) "Its (the Bell Model 205) cost per acre was about the same as that of the small Bell 47G (Markin 1974) and in our 1973 tests averaged $1.78 per acre. Last year, these were flown at a speed of 90 miles per hour which is approximately the same flight speed as a fixed-wing aircraft. Flying at this speed, I think that we will find we have lost many of the advantages of pin-point application, because of which a helicopter is supposed to be superior to a fixed wing aircraft".

i) The responses to the questionnaires referred to above could generally be grouped into two categories: 1) responses from fixed-wing operators and 2) responses from helicopter operators. The concensus of those operating aeroplanes reflect the standard views of fixed-wing aviation described previously in this report, namely that helicopters are prohibitively expensive to both the operator and the end-user, they are too slow, they carry too little payload, and their treatment results are at best no better than those of the aeroplane. Helicopter operators, on the other hand, take the opposite tack. They feel cost-competitive, particularly in view of treatment results which they believe are superior. In addition, many of them quoted advantages of helicopter spraying similar to the list presented in Section 7.4 of this report.

Interestingly, of the responding helicopter operators who carried on aerial applications during 1975 and 1976, 50 percent were involved in forest spraying, 33 percent in agriculture and 66 percent in such activities as mosquito and biting fly spraying, and herbicidal treatment of hydro rights-of-way. In 1976, 83 percent reported that aerial applications constituted 15 percent or more of their total annual revenue hours while 33 percent spent more than 50 percent of their time annually in this activity. Increased involvement in aerial applications was predicted for 1977 by 33 percent, and 67 percent expect an increase in forest spraying.

Unfortunately, the sample was too small to establish reliable trends, and the survey results were further affected by the fact that the largest operators are making little or no use of their Class 7 AAD licences. Some active, small operators are known to be working under the licences of second parties, while many are discouraged by the lack of information, research and direction to help them effectively conduct and sell their services.

7. Canadian Aircraft and Operator Distribution

For obvious reasons, the feasibility of any program designed to research the use of aircraft for the aerial application of pesticide chemicals depends largely upon the availability of suitable aircraft, their location, numbers, and the licence classifications of their owners and operators. It is equally obvious that the operational feasibility and acceptance of the results and recommendations of any such research will be heavily dependent upon these same factors.

Appendix D provides this information, presenting it in a form which facilitates ready reference. For all of Canada, separate tables list all aircraft owners and operators who qualify for inclusion in the following categories:

a) Helicopter operators holding Class 7 AAD licences (Appendix F). Such companies may also operate fixed-wing aircraft;

b) Fixed-wing aircraft operators holding Class 7 AAD licence;

c) All helicopter operators not included in 'a' above. Such companies are licenced for commercial operations but do not hold Class 7 AAD licence. Together, these two tables list all Canadian commercial helicopter operators;

d) All Canadian federal and provincial government agencies owning and operating helicopters and/or fixed-wing aircraft;

e) All forestry and related industries which privately own and operate helicopters only or helicopters and fixed-wing aircraft;

f) A "catch-all" table including:

(i) Helicopter or aerial applications companies which are the registered owners of aircraft but which hold neither a Class 7 AAD licence nor, in most cases, any commercial licence whatever;

(ii) Private owners of "specialty, aerial applications" aircraft, who hold no commercial operator's licence, The information in the various tables is considered to be accurate as of August, 1976. In some cases, data obtained from the various references used was amended pursuant to personal contact with various operators.

The tables are primarily intended to provide the names, addresses, and aircraft complement of the aircraft owners and operators in the various categories outlined above. Such additional information as telephone and telex numbers and names of key personnel has been included where immediately available.

Appendix D, Table 4 was compiled from the Canadian Civil Aircraft Register for these organizations whose corporate names imply that they are the operators of charter helicopter or aerial spraying services. According to the C.T.C. Directory of Canadian Commercial Air Services, however, only three of these organizations are licenced to operate such a service, and none are holders of a Class 7 AAD licence. It does not lie within the scope of this report to clarify all such situations. However, cases of this nature may be explained in one of several ways. Such organizations may have incorporated, applied for licences, and purchased aircraft which are either leased to licenced operators while the said applications are being processed, or operated during the interim under an existing licence held by another operator, according to the terms of some formal agreement between the two parties. Alternatively, such companies may be in business solely for the purpose of conducting such leasing activities, and may never be required, or intend to become licensed operators.

On this subject, there are a number of Canadian aircraft leasing companies from whom machines are available to operators and other interests. An operator may thus vary the size of his fleet through agreements with such companies. Any individual or organization importing an aircraft from the United States with the specific intention of leasing it to an operator will normally have already signed the lease agreement, and the aircraft will be registered in the name of the operator involved in order that the lessor may avoid the federal and provincial taxes which would otherwise apply. Such aircraft thus appear in the Civil Aircraft Register as the property of the operator involved when this is actually not the case.

Some companies may have sold their charters, but are still the registered owners of the aircraft which they now lease to the new owners of the charter. It is also possible that some of the organizations in question are simply companies set up by industrial concerns or private individuals for legal or tax purposes, and that no commercial licencing is required for the type of activities involved.

Appendix D, Table 4 also lists a number of private individuals who are the registered owners of "specialty-design" agricultural aircraft, but who hold no commercial licence. These cases usually represent the private ownership of such aircraft by farmers and growers who use them exclusively to treat their own properties. From time to time, they may lease them to licenced commercial operators for contract flying under the operators' licences.

Finally, when attempting to catalogue all aircraft suitable or available for aerial applications work in Canada, there is an important factor which must be considered. Specialized aircraft designs such as the Piper Pawnee, Grumman Ag Cat and Cessna AgWagon, and the modified, ex-military machines such as the Grumman TBM Avenger, are used only for aerial applications. However, numerous other non-specialized aircraft types can, when properly equipped, be used effectively for the aerial dispersal of forestry and agricultural chemicals. This is true of virtually all helicopters and of many general-purpose, fixed-wing aircraft such as the Piper PA-18 (Supercub), Cessna Models 170, 180 and 185, Helio Courier, Pilatus Porter and the de Havilland Beaver or Otter. To further complicate the picture, Cessna manufactures a specialized version of the Model 185 called the "Ag Carryall". Since it is impossible to distinguish this type from the standard Model 185 in the Civil Aircraft Registry, the number in Canada, although very low, is difficult to establish. One of these is currently owned and operated by the Forest Pest Management Institute of the Canadian Forestry Service.

Apart from the above mentioned, specialized aircraft types, therefore, the number of helicopters and general-purpose fixed-wing aircraft actually available for aerial applications work is really equivalent to the number of sets of dispersal equipment on hand or immediately available (Southwell 1972). Such information is extremely difficult to obtain. Some commercial operators may once have conducted spraying operations but no longer do so and have given up their Class 7 AAD licences. They may, however, still own spraying equipment. Others may still hold the appropriate licences, but have disposed of the equipment. In addition, many farmers with large businesses own aircraft privately and may also own spraying equipment which they install and use to treat their own property as required. Such farmers require no special licences and, hence, do not appear as aerial applicators on any published lists.

The appended tables are based on the latest data available. They are as complete and accurate as possible, and are considered reliable for practical purposes. Further, since the basic structures within the general aviation industry are less prone to change than are the specific aircraft inventories of individual operators, this document should retain some usefulness as a guide and general reference for several years from its date of publication.

Appendix D shows that, of the 91 commercial helicopter operators in Canada, 23 hold Class 7 AAD licences of which 23 are for helicopter only and five specify both helicopter and fixed-wing aircraft. Class 7 AAD licences are also held by 84 commercial fixed-wing aircraft operators.

This study has shown that a total of 84 additional individuals and organizations, some of the latter being listed as 'Spraying Companies', own helicopters, specialty aircraft, or modified ex-military equipment. However, none of these hold Class 7 AAD licences or, in most cases, even commercial operating certificates, as discussed previously.

In forest industry, 16 companies own helicopters privately, while 24 Canadian government agencies own and operate fixed-wing aircraft and/or helicopters.

CHAPTER IV: HIGH-VALUE FOREST STANDS AND TREES IN CANADA

1. Extent and Importance of High-Value Stands

1.1 Definition and Classification

The term 'high-value stands' is commonly used to denote those stands whose intrinsic importance stems from specific social, environmental or economic considerations which render them more valuable on an individual or per-acre basis than the larger forest areas which serve as the basic source of raw material for forest industry.

Included within the broad classification of high value stands, for practical purposes, are urban plantings and shade trees, municipal parks and greenbelt areas, parts of provincial and national parks, resort areas, key portions of watersheds such as headwater areas, public and corporate forest nurseries, municipal forests, woodlots and shelterbelts, plantations, tree farms and seed production areas.

Such stands are usually subject to intensive management, the resultant high costs of which are proportional to the values represented. Consequently, the objectives of pest management programs may be radically different from those of fibre forestry which is mainly con- concerned with keeping the stands alive. For example, the Christmas tree grower's livelihood depends on the production of healthy, well-formed trees. In the event of an insect infestation, he will not merely be interested in minimizing tree mortality, but will often bear whatever cost is required to suppress or exterminate the insects on a per-tree basis.

1.2 Regional Priorities

The frequency of occurrence and relative importance of the foregoing types of high-value stands varies among three broad geographic areas in Canada.

On the west coast, key watershed areas are a major priority as are various classes of parks, and aerial spraying is normally required due to the acreage, terrain and limited access features which characterize many of the areas involved. Also of importance are the large forest nurseries and plantations of the private industry sector whose pest management programs receive support from the B.C. Forest Service and the Council of Forest Industries of British Columbia.

Priority, high-value stands in the prairie provinces consist mainly of urban trees and parks, parts of provincial and national parks, and shelterbelts. Most of the agricultural spraying is presently carried out with custom ground equipment (DeBoo 1971) and similar means are used to treat the preponderance of urban forestry situations.

The high-value stands of eastern Canada are somewhat more varied, and include urban trees and parks, portions of provincial and national parks.

plantations, woodlots and certain resort areas. Both ground and aerial pest control methods may be employed depending on the location, acreage, topography and accessibility of the area to be treated.

For discussion purposes, the various types of high-value stands are categorized into five groups: urban and municipal stands, provincial and national parks, plantations, woodlots and shelterbelts, and resort and outdoor recreation areas.

1.3 Urban and Municipal Stands

The urban and municipal category includes shade trees, municipal parks and greenbelt areas. Forest lands, such as those administered in the Ottawa-Hull region by the National Capital Commission, would also be included in this category. The primary importance of these areas is a social one and their value is very high because of the aesthetic and recreational benefits which they provide. A good indication of their status is the tremendous effort made during the last few years in eastern Canadian towns and cities to protect urban trees from the Dutch elm disease and to save those already infected. If these efforts failed, trees were often removed and replaced. Also, of course, most urban stands are inspected regularly and are pruned or treated for insects or disease as required.

The compilation of a comprehensive list, with acreages, of all municipal parks and greenbelt areas in Canada would be a formidable task even if no consideration was given to shade trees and related stands. According to the Canadian Dominion Bureau of Statistics (Canada Yearbook 1970-71), as at January 1, 1970, there were 4,633 municipalities of all types in Canada (Table 11). Most of these, particularly in the more heavily populated portions of the country, have parks and recreation areas in addition to shade trees and other 'cosmetic' urban stands. Since the number of parks and related areas, as a function of total acreage covered in any given municipality, normally varies directly with population size, larger cities may have scores of such areas of various sizes within their boundaries.

1.4 Provincial and National Parks

Provincial and national parks are valuable socially as focal points for many types of outdoor, recreational activities. They also have considerable economic importance, although this is less true in terms of the revenue generated by day-use and camping fees than in terms of the stimulation of local businesses through money spent by tourists who are drawn to the areas involved by the presence of the parks. According to estimates (Stanton 1976), Canadian income from domestic and international tourism associated directly or indirectly with forest-oriented activities lies in the vicinity of one billion dollars. Where parks are managed under a multiple-use program which permits timber harvesting operations to be carried, on, the local economy may be further stimulated in terms of employment and local business income, while Crown charges for the volume of

Table 11: Number of municipalities in Canada classified by type and size, by Province as at Jan. 1, 1970.[1]

Type or Size Group	Nfld.	P.E.I.	N.S.	N.B.	Que.	Ont.	Man.	Sask.	Alta.	B.C.	Y.T.	N.W.T.	Canada
Regional Municipalities	-	-	-	-	74	38	1	-	-	28	-	-	141
Metropolitan Corporations	-	-	-	-	-	1	1	-	-	-	-	-	2
Regional Municipalities	-	-	-	-	-	2	-	-	-	-	-	-	2
Counties and Regional Districts	-	-	-	-	74	35	-	-	-	28	-	-	137
Unitary Municipalities	74	32	66	120	1,635	800	195	794	326	138	2	4	4,276
Cities	2	1	3	6	64	38	9	11	9	31	2	1	177
Towns	72	7	39	21	195	151	36	131	101	13	-	3	769
Villages	-	24	-	93	292	150	41	360	168	54	-	-	1,182
Rural Municipalities	-	-	24	-	1,084	551	109	202	48	40	-	-	2,148
Quasi-Municipalities (Improvement Districts)	116	-	-	-	-	17	18	9	50	-	3	3	216
Totals	190	32	66	120	1,700	945	214	803	376	166	5	7	4,633

[1] Canada Yearbook, 1970 - 1971.

wood extracted provide an additional source of provincial revenue. Provincial and national parks may also serve as 'outdoor laboratories' for research in various aspects of resource management while helping to preserve an overall sense of national heritage and pride in country. Depending on specific use patterns, some areas may be considered higher in value than others within the boundaries of any given park. For example, selected, high use areas (Foisy et al. 1975) totalling over 1500 acres were sprayed during 1975 in La Mauricie and Forillon National Parks, using a fixed-wing aircraft which cost $4.00 per acre for the aircraft alone. Two similar areas totalling 350 acres were treated by helicopter in La Mauricie National Park during 1976 (Foisy et al. 1976) at a cost of $6.50 per acre for the helicopter. Following aerial application in both years, mist blowers were employed for 'touch-up' operations in the more accessible, conspicuous areas.

As of January 1, 1971 there were 21 national parks in Canada (Table 12) with a total area in the order of 29,723 square miles or 19,022,848 acres (Canadian Dominion Bureau of Statistics 1971). About 75 percent of this area is represented by nine parks located in Alberta and British Columbia where the generally mountainous terrain poses severe problems for aerial spraying operations.

Provincial parks are difficult to itemize due to their large numbers, their diversity of purpose and their great variation in size, from a few acres to many thousands of square miles. Table 13 gives the number of parks and total area occupied by parks in each province, as well as the proportion which this area represents in relation to the total area occupied by provincial parks in Canada. It must be pointed out that these data do not include small picnic sites and rest stops. Thus, in 1971, 544 provincial parks occupied a total area of 107,625 square miles or 68,880,000 acres, almost 70 percent of which lies in Quebec, with over 30 percent situated west of the Quebec-Ontario border. The Maritime Provinces altogether accounted for only 0.125 percent of Canada's total provincial park acreage.

In some parks, therefore, merchantable timber values must be protected in support of local industry. In all, aesthetic and environmental considerations are of prime importance and this aspect, in turn, can significantly influence local and national revenue from tourism.

1.5 Plantations

In the context of this report, plantations are considered to include government and private nurseries, certain types of reforestation areas and tree farms such as those of the Christmas tree-growing industry.

It is virtually impossible to establish an accurate breakdown of plantations in Canada by type and acreage. The greatest concentrations in terms of numbers and area covered are found in central, southern and eastern Ontario and in southwestern and central Quebec.

Table 12: Canada's national parks.

Province	Name of Park	Area (sq. mi.)
Newfoundland	Terra Nova	153
Prince Edward Is.	Prince Edward Island	7
Nova Scotia	Cape Breton Highlands	367
	Kejimkujk	147
New Brunswick	Fundy	80
Quebec	La Mauricie	215
	Forillon	85
Ontario	Georgian Bay Islands	5
	Point Pelee	6
	St. Lawrence Islands	1
Manitoba	Riding Mountain	1,148
Saskatchewan	Prince Albert	1,496
Alberta	Banff	2,564
	Elk Island	75
	Jasper	4,200
	Waterton Lakes	203
British Columbia	Glacier	521
	Kootenay	543
	Mount Revelstoke	100
	Yoho	507
Alberta/Northwest Territories	Wood Buffalo	17,300
	Total	29,723

Table 13: Land area of Canada's provincial parks*

Province	No. of Parks	Park Area Sq. Miles	Total Acres	% of Total
Newfoundland	36[1]	107	68,480	.100
Prince Edward Island	20	4	2,560	.004
Nova Scotia	UD[2]	14	8,960	.013
New Brunswick	19	9	5,760	.008
Quebec	27	75,000	48,000,000	69.686
Ontario	97[3]	15,030	9,619,200	13.965
Manitoba	10	3,190	2,041,600	2.964
Saskatchewan	14	1,803	1,153,920	1.675
Alberta	46	2,348	1,502,720	2.182
British Columbia	275	10,120	6,476,800	9.403
Totals	544	107,625	68,880,000	100.000

Explanatory Notes

1) 17 additional areas reserved for future development.

2) A number of sites under development but none completed.

3) 78 additional areas reserved for future development.

* Data from 1970-71 Canada Yearbook, Dominion Bureau of Statistics.

As already indicated, the intensive management practiced in these stands, particularly in relation to nurseries and Christmas tree farms, may give them an extremely high value per acre or even per tree. The Christmas tree grower's crop may well represent a per-acre retail value in excess of $7,000. Hence, spray application must achieve a high degree of precision and treatment effectiveness. These factors, combined with the size, shape and confined-area nature of many plots can make aerial treatment difficult for the conventional aerial applicator.

1.6 Woodlots and Shelterbelts

Both woodlots and shelterbelts contribute greatly to the aesthetic appeal of much of rural Canada. The importance of shelterbelts, as the name implies, also stems from the protection afforded to cropland from wind erosion and dehydration, and to buildings and vehicle routes from such weather effects as storms and snow accumulation. Well-managed woodlots can provide more direct economic benefits as sources of quality raw material for various classes of forest industry, as well as sources of owner-income generated by timber sales.

Like plantations, an accurate list of woodlot acreages in Canada is almost impossible to compile. The 1966 Census of Agriculture placed the total woodlot area in Ontario in excess of 2,800,000 acres. Also, like plantations, the accurate, effective application of any required pesticide is of extreme importance since woodlots are usually located in rural areas where environmental considerations are paramount.

1.7 Resort and Recreation Areas

Much of what has already been said concerning the importance of aesthetics to Canada's highly lucrative tourist and outdoor recreation-oriented industries applies to the resort-area category. In addition, many such areas may be located in close proximity to provincial and national parks and to urban areas, and similar values apply.

While commercial timber values are seldom a factor, summer and winter resort areas rely heavily on their aesthetic appeal and tranquility for success. Treatment of insect infestations is 'cosmetic' in nature and pesticide must be applied with great precision and minimal inconvenience to resort users, employing spraying methods which afford the greatest possible protection to adjacent lakes, streams and other environmentally sensitive areas.

A case in point is the so-called 'Laurentian Playground' area north of Montreal, Quebec. Here, unfortunately, the lack of a government protection policy for the area was largely responsible for its devastation by a spruce budworm infestation during the period 1970-1975. Nevertheless, the area's local importance was emphasized by the fact that local citizens and property owners undertook spraying operations independently. Regrettably, this action came too late to prevent heavy tree and stand mortality.

2. Aerial Applications for Pest Management in High-Value Stands

By way of summary, it can be said that high-value stands, as the name implies, are worth more on a per-acre or per-tree basis than the comparatively larger areas in which fibre forestry is practiced. This value derives from specific social and/or economic considerations which warrant the intensive management practices characteristically applied to such stands.

High-value stands can vary greatly in size, from a few acres to many square miles. They may be highly irregular in shape and, because of their very nature, environmental considerations are usually paramount both within the stands themselves and in relation to their surrounding areas. In parks and resort areas, the terrain whose scenic ruggedness influenced the initial choice of site can pose several problems in relation to aerial spraying. On the other hand, plantations and nurseries are often surrounded by various obstacles such as power lines, towers, tall trees or buildings which, again, seriously handicap or prevent conventional aerial spraying operations. Airstrips are often not located conveniently nearby in any case, but road access to these stands is usually available.

The ideal aircraft for aerial spraying operations in most high-value stands should therefore be able to work out of unprepared, confined landing areas remote from airports. Such an aircraft should have great maneuverability and speed flexibility, the ability to fly topographical contours at low, uniform altitude above the canopy, and the capacity for precise chemical application and control of drift. The helicopter fulfils all of these criteria. In addition, it possesses the great potential advantage of the rotor wake effect for directing the spray cloud into the canopy, effecting canopy penetration, and maximizing droplet deposit within the canopy.

Also, in some situations, helicopter spraying could minimize both cost and inconvenience to the pesticide applicator and to the public. For example, most pesticide treatment in urban forestry and urban park management is presently carried out with mist blowers and other ground equipment. In many cases, however, ULV spraying by helicopter could prove to be a far less expensive and complicated means of applying the required chemical, provided appropriate clearances are obtained to ensure that such operations are conducted legally. A local park or system of scenic, tree-lined, urban streets could be sprayed neatly by helicopter in one or two hours during the early morning, causing no inconvenience to the public and using a fraction of the chemical required by ground equipment. Doing the same job by mist blower could take one or two days and many man-hours to complete, during which a ponderous and noisy piece of heavy machinery would be moving slowly through the area, possibly creating traffic tie-ups, inadvertently contaminating vehicles and windows with spray, and maximizing the hazard of chemical spills.

An example of a comparable use of helicopters for ULV spraying in urban areas is the mosquito control program in the State of New Jersey (Mark 1976)[1]. Using Beecomist spray heads installed on a Hiller UH12E helicopter, the Middlesex County Mosquito Commission routinely treats urban areas from low altitude at night and during the early morning hours.

In a park setting, the helicopter's ability to operate from small, temporary bases on or near job site and to effect precisely controlled, low-level application of chemical, suit it ideally for employment in such socially and environmentally sensitive situations as those which may exist during insect infestations of our provincial and national parks.

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[1] Personal communication: Charles Mark, Middlesex County Mosquito Commission, English Town, New Jersey.

It is in relation to the rotor wake effect that much work remains to be done. Research must be carried out to fully investigate the characteristics of the rotor wake and to establish speed, altitude and other operating parameters to maximize its desirable effects. Concurrently, specialized, helicopter-specific, forest spraying equipment must be evolved to fully exploit this aircraft's unique, aerodynamic qualities.

ULV spraying by helicopters employing electrically- or hydraulically-driven rotary atomizers holds the most promise in this regard. In view of existing and foreseeable environmental constraints, together with increasing chemical costs and the proven effectiveness of the ULV concept, ULV spraying is here to stay. Apart from obvious benefits, ULV application can also alleviate one of the light helicopter's former operational disadvantages, that of a relatively low payload.

We have yet to establish the actual costs of a well-organized helicopter spraying program, utilizing the correct helicopter model, most appropriate spraying equipment, and most effective application techniques. Consequently, valid comparison of the relative effectiveness of helicopter and aeroplane spraying is not currently possible. At present, depending on the nature of the project involved, it appears that helicopter costs per acre may sometimes be less than those of the aeroplane but, generally will be somewhat higher. Overall costs will decrease as the size of the treatment area increases, of course, as is the case in aerial treatment with any aircraft.

In relation to many high-value stands, the overall management requirements and the costs per management item are already high in relation to similar costs in the field of fibre forestry. Consequently, individual management activities such as pest control are less cost-sensitive on a per-acre basis. Within reason, the managers of many types of high-value stands have both the willingness and the budget to pay the cost of achieving their management objectives, and are less prepared to gamble on compromising treatment results in the interests of economy.

In consideration of all these factors, a research program to evaluate and develop helicopter techniques and dispersal equipment for aerial application in forestry should initially confine its activities to the treatment of situations in the high-value stand category. Once the various concepts have been refined and evolved to an operational level here, their implications to fibre forestry will be more apparent and the program will be better equipped to expand its horizons in this direction.

CHAPTER V: SUMMARY AND RECOMMENDATIONS

1. Summary

Today, aerial forest spraying in Canada is conducted almost exclusively by fixed-wing aircraft. Helicopters are generally used only in areas which, for various physical, topographical or political reasons, cannot be treated by aeroplanes.

This situation may be ascribed to a number of factors. The fixed-wing aircraft was here first. It has existed as a functional, practical concept since the time of World War I, and its use and development in agricultural and forestry aviation was encouraged and facilitated by the availability of both cheap, military surplus aircraft and military-trained crews, especially after World War II.

The helicopter, on the other hand, did not put in an appearance until the mid-1940's, floundering awkwardly through its developmental period under the critical, often amused eye of an aviation industry already flying sophisticated, specialized aeroplanes. Many of the attitudes fostered by these early impressions became strongly rooted, and have persisted.

Nevertheless, one of the helicopter's earliest operational uses was in the aerial application of pesticides to agricultural crops. As experience accumulated, it became evident that the new machine's greatest asset here, apart from the obvious advantages of great maneuverability, speed flexibility and vertical capability, was the 'downwash' or 'rotor wake'. When the helicopter was flown within ground effect, low over the crop, this feature made it possible to achieve surprisingly wide swaths together with exceptional canopy penetration, and uniform deposit of droplets on all surfaces within the canopy. Research has since shown that this may often make it possible to obtain superior treatment results with fewer applications of less pesticide than when using aeroplanes in the same situations. Furthermore, in many instances, the rotor wake seems able to permit better control of spray drift.

The helicopter's success in agriculture ultimately led to its tentative, limited use in forestry where, however, the very different aerial spraying environment has generally produced much less spectacular results. Not only do normal emission altitudes lie high above the ground effect zone discussed above, necessitating both different and ill-understood techniques for exploitation of the rotor wake, but the helicopters are utilized in the same manner as the aeroplanes, spraying at 90 to 110 miles per hour and making the same block-to-airport ferry trips between loads. This practice effectively causes the helicopter to perform like an aeroplane in every way. Its on-site loading capability is ignored, valuable air time and project funds are squandered on long ferry flights, and its maneuverability, and the potential benefits of the rotor wake effect are lost because of the high airspeeds.

Yet another obstacle is created by the nature of the aerial spraying equipment helicopters are forced to use in forestry. In general, this equipment was originally designed for agricultural spraying by ground equipment, modified for agricultural spraying by aeroplane and remodified for agricultural spraying by helicopter. Its output capacity is many times greater than required for most forestry applications, causing it to be bulky, heavy, and wasteful of space, payload and on-board power. Pesticide pumps are generally powered electrically or hydraulically but when a mechanical atomization device is employed it is usually a Micronair, operated by a wind-driven fan which requires the helicopter to fly at a relatively high airspeed. The type of emission equipment in most common use, however, is some form of the boom-and-nozzle principle which appears generally adequate for agriculture and occasionally so for forestry. However, it provides inadequate control of the droplet spectrum for precision, ULV-type helicopter applications. Such work in forestry requires a light-weight, compact, low-volume system with low power requirements and electrically- or hydraulically-powered, mechanical atomizers.

In the light of available evidence, therefore, the helicopter must be regarded as a high-potential forest spray aircraft. Its three major stumbling blocks in this role are lack of information on rotary-wing aerodynamics as they relate to spray cloud behavior, lack of understanding of operational logistics, and lack of an aerial dispersal system which is both helicopter-specific and forestry-specific. Only through a determined effort to overcome these obstacles can the helicopter's true potential be realized and its role in forest pest management become clearly defined. The demand for this work is both urgent and immediate.

2. Recommendations

Since presentation of the original report in December, 1976, a number of its recommendations have already been implemented. The list of recommendations submitted at that time included the following.

i) That the proposed research program be undertaken by the Chemical Control Research Institute, now the Forest Pest Management Institute, of the Canadian Forestry Service, Environment Canada;

ii) That the program fully evaluate the effect of the helicopter rotor wake on forest canopy penetration and in-canopy droplet deposit at various airspeeds and spray emission altitudes to establish valid operational parameters for helicopter spraying operations;

iii) That electrically-powered, rotary, atomizing devices be assessed in relation to their suitability for forest spraying operations with rotary-wing aircraft;

iv) That a light-weight, economical helicopter-compatible, spray delivery system be developed for use in conjunction with electrically-powered, rotary, atomizing devices;

v) That various, representative, situational models be developed as bases for the planning of helicopter spraying operations which maximize exploitation of the helicopter's flight capabilities, for the analysis of helicopter treatment costs, and for the preparation of cost-benefit studies;

vi) That the program and related field studies be initially conducted in relation to pest control in high-value stands; and

vii) That, if justified by the findings of the program, the helicopter spraying techniques, equipment and procedures thus developed be refined and evolved to an operational level suitable for, and acceptable to, commercial operators for application in the field.

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APPENDICES

APPENDIX A

AIRCRAFT NAMES AND MANUFACTURERS' DESIGNATIONS

AIRCRAFT NAMES AND MANUFACTURERS' DESIGNATIONS

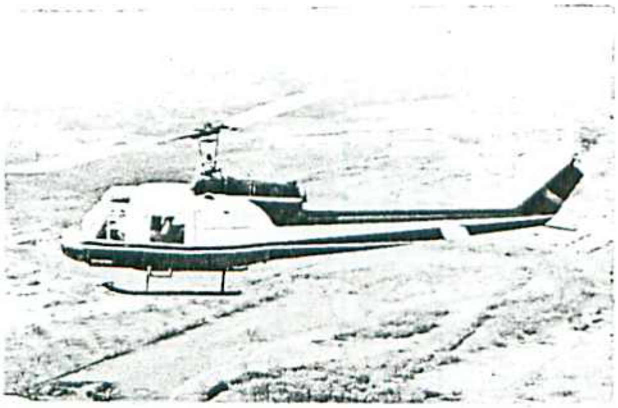
A. HELICOPTERS

Bell Model 206 B 'JetRanger II'

Bell Model 206L 'LongRanger'

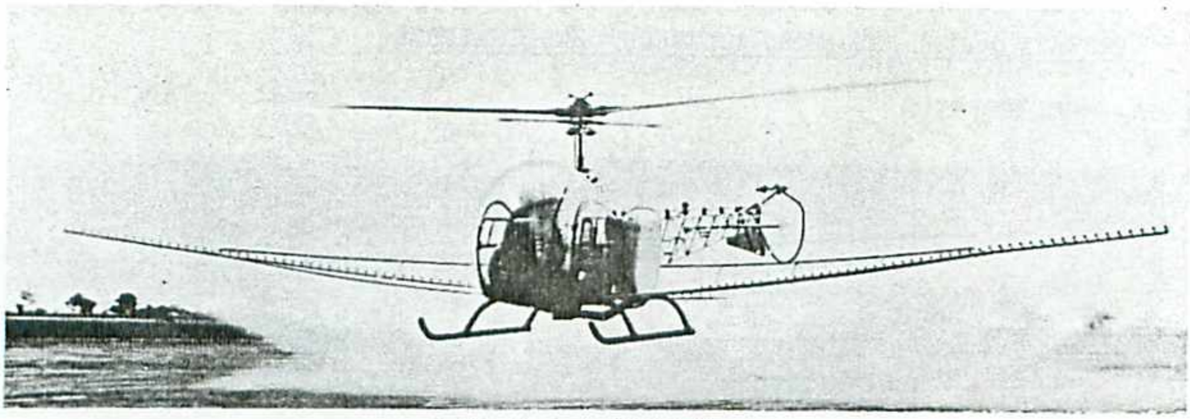
Bell Model 205A-1

Bell Model 212 'Twin'

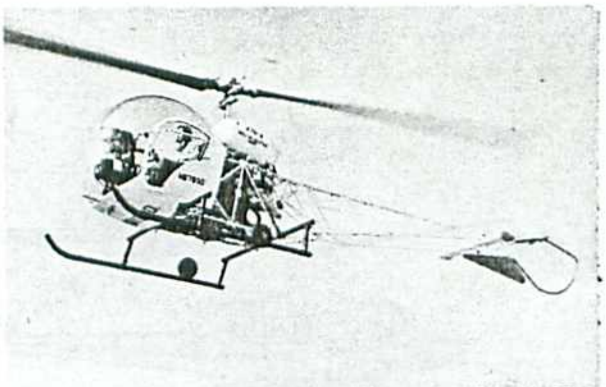


Bell Model 204 B

Bell Model 47G-4

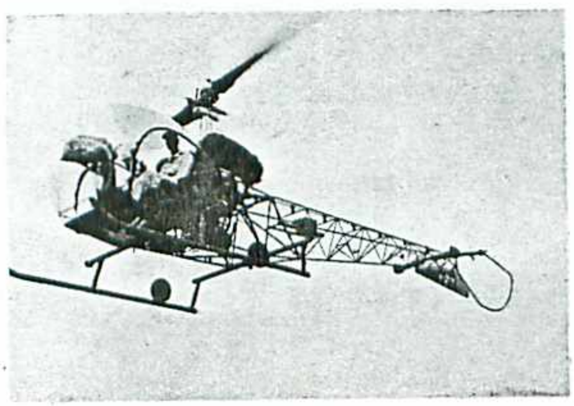


Bell Model 47AG-5



Bell Model 47G-3

Bell Model 47G-2A



Bell Model 47G-2

Bell Model 47G

Boeing-Vertol BV-107

Boeing (Boelkow) BO-105

Enstrom F-28

Hiller UH12E

Hughes 500C

Hughes 500D

Hughes 300

Sikorsky S-55T

Sikorsky S-58T

Sikorsky S-61

Vought (Aerospatiale)
Allouette II

Vought (Aerospatiale)
Alouette III

Vought (Aerospatiale)
Lama

Vought (Aerospatiale)
Dauphin

Vought (Aerospatiale)
SA 341G 'Gazelle'

APPENDIX B

AIRCRAFT PERFORMANCE AND TECHNICAL DATA

Explanation of Abbreviations, Terminology and Format

Table 1: Rotary-wing (Helicopter)/Single- or Twin-engine, Commercial Manufacture

Table 2: Fixed-wing/Single-engine, Commercial Manufacture: 'Specialty Design'

Table 3: Fixed-wing/Single-engine, Commercial Manufacture: Non-specialty Design

Table 4: Fixed-wing/Multi-engine, Commercial Manufacture, Non-specialty Design

Table 5: Fixed-wing/Single- or Multi-engine, Military Design

PURCHASE PRICE INFORMATION

1. Current Production Models

The purchase prices shown for current production models are manufacturers' so-called 'standard configuration' prices which include the basic aircraft, instrumentation, control systems, cabin interiors and avionics normally installed during manufacture. Such standard equipment is listed in the respective manufacturers' specifications. As with automobiles, a purchaser may choose from a variety of optional accessory equipment or 'kits' to be installed by the manufacturer at extra cost prior to delivery.

Values quoted are normally F.A.F. prices at the various manufacturers' facilities. They are expressed in U.S. dollars, unless otherwise noted, because nearly all the aircraft discussed are manufactured or distributed in the United States, and Canadian prices are dependent both upon the exchange rate in effect at the time of purchase, and upon various Canadian federal and provincial taxes whose applicability is determined by the use to which the aircraft is put.

2. Discontinued Models

Aircraft models which are no longer in production are now, of course, only available in used condition, and the valuation of used aircraft is a complicated and specialized field. Such aircraft must usually be purchased 'as is', and are often equipped with various optional accessories according to the requirements of previous owners. In addition, market values are affected by such factors as original purchase price, with the effects of depreciation and inflation taken into account, by operating time remaining before overhaul, by possible seasonal demand for the type involved, and by general condition and appearance. Finally, the above-mentioned federal and provincial taxes which may apply to aircraft, parts and accessories imported into Canada have contributed greatly to making aircraft more expensive here than in the United States. The extra cost represented by such taxes is reflected in the domestic purchase price of a used, Canadian-registered aircraft, whether or not the vendor was required to pay such taxes at the time of original importation.

The used aircraft prices presented in the following tables give the 1976 U.S. price in U.S. dollars according to the U.S. General Aviation Bluebook, and the Canadian price based on the author's aircraft marketing experience in Canada during 1976. Due to the wide variation in used aircraft condition and accessory equipment, the prices shown are type-illustrative of the average, fully-equipped aircraft in good condition, and with limited or nil operating time since complete overhaul. Further, these values represent aircraft produced during the final year that the type or model was manufactured.

TERMS AND ABBREVIATIONS

Unless otherwise specified, all performance data presented in the following tables reflect the capabilities of the various aircraft at sea level under ICAO Standard Day Conditions, and at maximum certificated gross weight for take-off. The following explains the various abbreviations and terminology, not self-explanatory, used in the tables.

1. SINGLE ENGINE

a) Weights

Gross: Maximum certificated take-off weight, including aircraft, fuel, oil, fluids, crew* and payload.

Empty: Empty weight of aircraft including unusable fuel, oil and all fluids, equipped as outlined under Price.

Usefl.: Useful load of aircraft including usable fuel, crew* and payload.

* For calculation purposes, a man is considered to weigh 170 pounds.

b) Airspeed

Max.: Maximum speed in level flight

Cruise: Normal cruise speed from base to work site.

Stall: Speed at which aircraft will normally enter aerodynamic stall.

Maximum and cruise speeds may vary depending on type of aerial dispersal equipment installed.

c) Performance

RC: Rate of climb at sea level.

MFL: Minimum distance required to clear a 50-foot obstacle on take-off from standing start.

Fuel: Unless noted, all fuel data is given in U.S. Gallons since most of the aircraft are manufactured in the United States, and gauges read in terms of U.S. Gallons.

Endur.: Normal working endurance from take-off at maximum gross weight, 45 minutes reserve fuel.

2. MULTI-ENGINE

All information same as in 1 above, except:

b) Airspeed

Vme: Minimum control speed with the critical engine inoperative.

c) Performance

RC-2: Rate of climb with both (in the case of twin-engine) engines developing full climb power.

RC-1: Rate of climb with one engine inoperative.

Tot. H.P.: Total combined horsepower capability of both engines (in the case of twin-engine).

Endur.: Normal working endurance from take-off at maximum gross weight, 45 minutes reserve fuel.

3. SPECIALTY - AERIAL APPLICATIONS

All information same as 1 above, except:

Endur.: Normal working endurance from take-off at maximum gross weight, no reserve fuel.

Hopper: Volume capacity of the hopper in U.S. Gallons.

4. ROTARY WING (HELICOPTER)

a) Weights

MGWI: Maximum certificated take-off weight with internal load, including aircraft, fuel, oil, fluids, crew* and payload.

MGWE: Maximum certificated take-off weight with external (sling) load, including aircraft, fuel, oil, fluids, crew*, and payload; for turbine powered helicopters, MGWE may be greater than MGWI.

Empty: Empty weight of aircraft including unusable fuel, oil and all fluids, equipped as outlined under Price.

ULM: Maximum useful internal load of aircraft including usable fuel, crew and payload.

Sling: Maximum allowable weight to be carried externally on a cargo sling.

* For calculation purposes a man is considered to weight 170 pounds.

b) Airspeed

Vne: Speed never to be exceeded

Cruise: Normal cruise speed with internal load.

Vne and cruise speeds may vary depending on type of aerial dispersal equipment installed.

c) Performance

IGE: Stationary hovering ceiling in ground effect.

OGE: Stationary hovering ceiling out of ground effect.

RCM: Maximum rate of climb at sea level, internal load.

RCV: Maximum vertical rate of climb at sea level, internal load.

Endur: Normal working endurance from take-off at maximum gross weight, no reserve fuel.

d) Engine Power Ratings

SHP: Shaft Horsepower

Tot. H.P.*: Maximum horsepower capability of engine or, in the case of twin-engine, total combined horsepower capacity of both engines.

MTO*: Maximum allowable take-off power.

MCP*: Maximum allowable continuous power.

* Some engines are derated to provide a power reserve and to reduce engine wear. Power input to the transmission is controlled automatically to prevent the exceeding of design limitations.

ENGINE DESIGNATIONS

L: Lycoming

C: Teledyne Continental

PW: Pratt and Whitney Aircraft of Canada (UACL)

AL: Detroit Diesel Allison

GE: General Electric

AIR: Garrett-Airesearch

W: Wright

TA: Turbomeca Astazou

TAR: Turbomeca Artouste

TT: Turbomeca Turmo

Table 1

Rotary-Wing (Helicopter)/Single- or Twin-Engine - Commercial Manufacture

Manufacturer	Designation	Engine		SHP Rating			Fuel (Usable, US Gal.)			Endur.	Hover Ceiling	
		No.	Type	Tot.HP	MTO	MCP	Type	Capy.	Flow	(hrs.)	IGE	OGE
Aerospatiale (Vought)	Alouette II SA318C	1	TA 2A	530	523	473	Turbo	146	28.0	5.3	5180	2950
	Alouette III SA316B	1	TAr 3B	858	562	542	Turbo	146	48.7	3.0	9510	4920
	Alouette III SA319B	1	TA 14B	858	592	542	Turbo	146	38.4	3.8	10400	5900
	Dauphin SA360C	1	TA 18A	1032	871	804	Turbo	169	70.0	2.4	8035	5740
	Gazelle SA341G	1	TA 3A	600	494	494	Turbo	120	33.0	3.6	7215	6890
	Lama SA315B	1	TAr 3B	858	562	542	Turbo	146	56.0	2.6	16730	15170
	Puma SA330G	2	TT 4C	3110	N/A	N/A	Turbo	410	178.0	2.3	7050	4260
Bell	Model 47G-2/2A	1	LVO-435	200-240	-	N/A	80/87	41	16.0	2.5	N/A	N/A
	Model 47G-4/4A	1	LVO-540	305	280	220	100/130	57	15.0	3.7	7700	3900
	Model 47G-5/AG-5	1	LVO-435	265	260	220	100/130	57	15.0	3.7	5900	1350
	Model 204B	1	LT53-L-11A	1100	1100	N/A	Turbo	200	60.0	3.3	3000	1800
	Jet Ranger 206A	1	AL250-C18	317	317	270	Turbo	76	25.0	3.0	9100	3500
	Jet Ranger II 206B	1	AL250-C20	400	317	270	Turbo	76	27.0	2.8	11300	5800
	Long Ranger 206L	1	AL250-C20B	420	420	370	Turbo	98	32.0	3.2	7500	1800
	Model 205A-1	1	LT-53-13B	1400	1250	1100	Turbo	215	80.0	2.7	10400	6000
	Model 212 Twin	2	PW PT6T	1800	1290	1135	Turbo	215	90.0	2.4	11000	9300
	Model 214B	1	LT-55-08D	2930	2050	1850	Turbo	215	154.0	1.4	16000	13000
Hiller	UH12E	1	LVO-540-C2A	340	305	N/A	100/130	46	14.0	3.2	10800	7200
Hughes	Model 300	1	LH10-360-A1A	180	N/A	N/A	80/87	25	10.0	2.5	7700	5500
	Model 300C	1	LH10-360-C1A	190	N/A	N/A	80/87	30	13.0	2.3	6900	4250
	Model 500	1	AL 250-C18	317	278	243	Turbo	64	18.0	3.6	8200	5300
	Model 500C	1	AL 250-C20	400	278	243	Turbo	64	19.0	3.4	12900	6700
	Model 500D	1	AL 250-C20B	420	375	350	Turbo	64	23.0	2.8	8500	7500
Sikorsky	Model S-55	1	PW R-1300	800	700	N/A	100/130	220	56.0	3.9	5800	2300
	Model S-58	1	W R-1820-84	1525	1525	N/A	100/130	264	106.0	2.5	4900	2000
(Avn. Spec.)	Model S-55T	1	AiR TSE-331 3U-303	840	700	N/A	Turbo	180	48.0	3.8	10500	6800
	Model S-58T	2	PW PT6T-6	1875	1620	1420	Turbo	284	108.0	2.6	10400	6500
	Model S-61	2	GE CT58-140	3000	2300	2100	Turbo	428	199.0	2.2	8700	3700

Table 1 (Cont'd.)

Manufacturer	Designation	RCM (fpm)	RCV (fpm)	Airspeed (mph) Vne	Cruise	Weight Data (Pounds) MGWI	MGWE	Empty	ULM	Sling	No. of Blades	Prod. Status	1976 Purch. Price ($US)	No. in Canada
Aerospatiale	Alouette II SA318C	1320	N/A	127	112	3650	3650	1990	1660	1320	3	Disc.	132,500	43
(Vought)	Alouette III SA316B	850	N/A	130	115	4850	4850	2467	2383	1800	3	Curr.	318,000	4
	Alouette III SA319B	886	N/A	135	120	4960	4960	2486	2474	1800	3	Curr.	310,000	0
	Dauphin SA360C	1400	N/A	196	160	6615	6615	3440	3175	3300	4	Curr.	620,000	0
	Gazelle SA341G	1338	N/A	192	147	3970	3970	2021	1949	1540	3	Curr.	297,000	13
	Lama SA315B	1080	N/A	130	118	4300	5070	2216	2084	2500	3	Curr.	276,000	0
	Puma SA330G	1400	N/A	170	165	14770	14770	7836	6934	5000	4	Curr.	1,640,000	1
Bell	Model 47G-2/2A	N/A	N/A	100	89	2450	2450	1564	886	N/A	2	Disc.	25,000	84
	Model 47G-4/4A	800	N/A	105	84	2950	2950	1866	1084	1000	2	Disc.	43,500	61
	Model 47G-5/AG-5	860	N/A	105	84	2850	2850	1672	1178	1000	2	Disc.	47,500	3
	Model 204B	N/A	–	140	115	8500	9500	4620	3880	4000	2	Disc.	210,000	12
	Jet Ranger 206A	1430	–	150	131	3000	3350	1570	1430	1200	2	Disc.	95,000	77
	Jet Ranger II 206B	1260	280	150	132	3200	3350	1570	1630	1500	2	Curr.	170,000	291
	Long Ranger 206L	1530	150	150	133	4000	4000	2053	1947	2000	2	Curr.	250,000	6
	Model 205A-1	1680	850	138	128	9500	10500	5212	4288	5000	2	Curr.	595,000	18
	Model 212 Twin	1420	–	150	116	11200	11200	6040	5160	5000	2	Curr.	815,000	17
	Model 214B	1450	–	161	140	13800	16000	7714	6086	8000	2	Curr.	1,250,000	0
Hiller	UH12E	1290	740	96	90	2800	2800	1759	1041	1000	2	Curr.	57,460	30
Hughes	Model 300	1200	N/A	87	80	1670	1670	950	720	N/A	3	Disc.	–	32
	Model 300C	990	350	105	100	2050	2050	1046	1004	1104	3	Curr.	55,000	
	Model 500	1700	520	150	144	2550	3000	1200	1350	1800	4	Disc.	105,000	5
	Model 500C	1700	520	150	144	2550	3000	1240	1310	1800	4	Curr.	155,000	93
	Model 500D	1900	900	175	161	3000	3550	1360	1640	2000	5	Curr.	175,000	0
Sikorsky	Model S-55	1020	100	112	91	7500	7500	5250	2250	N/A	3	Disc.	–	4
	Model S-58	1100	200	123	98	13000	13000	7630	5370	N/A	4	Disc.	–	3
(Avn. Spec.)	Model S-55T	1200	500	120	104	7200	7200	4200	3000	3000	3	Disc.	–	13
	Model S-58T	1260	480	138	127	13000	13000	7577	5423	5000	4	Curr.	685,500	9
	Model S-61	1300	470	150	138	19000	19000	12459	6541	8000	5	Curr.	2,650,000	6

Table 2

Fixed-Wing/Single-Engine - Commercial Manufacture 'Specialty Design' for Aerial Applications

Manufacturer	Designation	Engine		Fuel (US Gal.)			Endur.	MFL	RC
		Type	HP	Type	Capy.	Flow	(hrs.)	(ft.)	(fpm)
Cessna	188 'Ag Pickup'	CO-470-R	230	N/A	37.0	14.2	2.6	1320	755
	188 'Ag Wagon'	C10-520-D	300	100/130	37/54	21.0	1.7/2.7	970	940
	188 'Ag Truck'	C10-520-D	285	100/130	54.0	28.8	2.6	1090	690
	185 'Ag Carryall'	C10-520-D	300	100/130	61/80	20.0	2.9/4.1	1450	845
Imco	Call-Air A-9	L0540-B2B5	235	80/87	40.0	14.0	2.8	1200	650
Grumman	G164A-600	PW R-1340	600	80/87	64/80	28.0	2.8	505[1]	1600
	G164A-450	PW R-985	450	N/A	64/80	22.0	3.6	635[1]	990
	'Ag-Cat'	PW R-985	450	N/A	46.0	N/A	N/A	750[1]	1080
	'Ag-Cat'	J R-755	300	N/A	46.0	N/A	N/A	630[1]	700
	'Ag-Cat	J R-755	275	N/A	46.0	N/A	N/A	650[1]	660
Piper	'Pawnee' D-260	LO-540 B2C5	260	N/A	38.5	14.1	2.6	1250	755
	'Pawnee' D-235	LO-540 G1A5	235	80/87	38.5	14.0	2.7	1350	700
	'Pawnee Brave'	C6-285-B2	285	N/A	89.0	17.1	5.0	1473	355
Rockwell (Snow/Commander)	'Thrush' C800	PW R-1300-1B	800	N/A	100.0	36.0	2.7	1000[1]	1600
	'Thrush' C600	PW R-1340	600	80/87	100.0	32.0	3.1	775[1]	800
	'Quail'	L10-540-G1CS	290	N/A	40.0	17.0	2.4	650[1]	850
	'Sparrow'	LO-540-B2B5	235	80/87	40.0	14.0	2.8	800[1]	650

[1] Ground Roll <u>Only</u>.

Table 2 (Cont'd.)

Manufacturer	Designation	Airspeed (mph)			Weight (pounds)			Hopper (US Gal.)	Prod. Status	1976 Purch. Price ($US)	No. In Canada
		Max.	Cruise	Stall	Gross	Empty	Usefl.				
Cessna	188 'Ag Pickup'	138	128	58	3800[1]	1830	1970	200	Curr.	-	
	188 'Ag Wagon'	138	128	50	4000[1]	2140	1860	200	Curr.	-	75
	188 'Ag Truck'	138	128	50	4200[1]	2214	1986	280	Curr.	-	
	185 'Ag Carryall'	170	145	49	3350	1902	1448	151	Curr.	-	Unkn.
Imco	Call-Air A-9	110	105	60	3400	1600	1800	170	Disc.	-	3
Grumman	G164A-600	N/A	N/A	59	4500[2]/6075	3145	2930[2]	300	Curr.	63,995	
	G164A-450	147	100	58	4500[2]/6075	2870	3205[2]	300	Curr.	56,465	15
	'Ag Cat'	147	100	67	4500	2690	1810	247	Disc.	-	
	'Ag Cat'	131	95	55	3750	2410	1340	247	Disc.	-	
	'Ag Cat'	131	85	55	3750	2400	1350	247	Disc.	-	
Piper	'Pawnee' D-260	117	105	53	2900	1472	1428	150	Curr.	32,870	83
	'Pawnee' D-235	110	100	53	2900	1420	1480	150	Curr.	31,540	
	'Pawnee Brave'	N/A	N/A	58	4400	2185	2096	255	Curr.	43,090	0
Rockwell	'Thrush' C800	N/A	137	49	7800[3]	4100	3700	400	Curr.	72,500	
(Snow/Commander)	'Thrush' C600	140	124	47	6900[3]	3700	3200	400	Curr.	72,500	13
	'Quail'	120	100	46	3000[3]	1775	1225	210	Disc.		
	'Sparrow'	119	95	46	3000[3]	1740	1260	170	Disc.		

[1] Restricted Category.

[2] FAA Authorized overload of 6,075# based on design gross weight of 4,500# and design load factor of 4.2 G.

[3] Under FAR 8, operator may choose own gross wieght within approved limits.

Table 3

Fixed-Wing/Single-Engine - Commercial Manufacture. Design Not Specialized for Aerial Applications

Manufacturer	Designation	Engine Type	Engine HP	Fuel (US/Imp. Gal.) Type	Fuel Capy.	Fuel Flow	Endur. (hrs.)	MFL (ft.)	RC (fpm)
Cessna	180	CO-470-S	230	80/87	61/80	14.0	3.6/4.9	1205	1090
	185	C10-520-D	300	100/130	61/80	15.6	3.2/4.4	1365	1010
de Havilland	DHC-2 'Beaver'	PW R-985	450	80/87	129(IG)	18.0	6.4	1015	820
	DHC-2 'Turbo-Beaver'	PW PT6A-6	578	Turbo	160(IG)	32.0	4.4	1030	1220
	DHC-3 'Otter'	PW R-1340	600	80/87	170(IG)	26.0	5.7	1200	N/A
Helio	H-391B 'Courier'	N/A	295	80/87	60/85	13.0	3.8/5.7	635	1250
	'Stallion'	UACL PT6A-24	750	Turbo	250	30.0	8.3	900	2050
Pilatus	'Porter'	PW PT6A-27	550-575	Turbo	172	45.2	3.8	770	1260
Piper	J3 'Cub'	N/A	40-65	80/87	9	3.0	3.0	725 GR	450
	PA-18 'Supercub'	LO-320	150	80/87	36	9.0	3.2	700	960

Manufacturer	Designation	Airspeed (mph) Max.	Airspeed Cruise	Airspeed Stall	Weight (Pounds) Gross	Weight Empty	Weight Usefl.	Prod. Status	1976 Purch. Price ($US)	No. in Canada
Cessna	180	170	141	58	2800	1617	1183	Curr.	30,150	894
	185	178	145	59	3350	1674	1676	Curr.	35,550	615
de Havilland	DHC-2 'Beaver'	160	135	60	5100	3000	2100	Disc.	N/A	319
	DHC-2 'Turbo-Beaver'	163	150	60	5400	2800	2600	Disc.	N/A	43
	DHC-3 'Otter'	N/A	110	48	8000	4400	3600	Disc.	N/A	128
Helio	H-391B 'Courier'	175	162	30	3000	1990	1010	Curr.	N/A	19
	'Stallion'	220	160	38	6100	2835	3265	Curr.	N/A	0
Pilatus	'Porter'	174	136	58	4850	2415	2435	Curr.	N/A	3
Piper	J3 'Cub'	87	75	38	1220	680	540	Disc.	N/A	576
	PA-18 'Supercub'	130	115	43	1750	930	820	Curr.	17,950	450

Table 4

Fixed-Wing/Multi Engine - Commercial Manufacture. Design Not Specialized for Aerial Applications

Manufacturer	Designation	Engine Number	Engine Type	Engine Tot.HP	Fuel (US/Imp.Gal.) Type	Fuel Copy	Fuel Flow	Endur. (hrs.)	MFL (ft.)	RC-2 (fpm)	RC-1 (fpm)
Canadair	CL - 215	2	PW R-2800-83	4,200	100/130	880(IG)	128	6.1	2,620	1,550	246
de Havilland	DHC-6 'Twin Otter'	2	PW PT6A-27	1,240	Turbo	315(IG)	77	3.3	1,500	1,600	340
Douglas	DC-4	4	PW R-2000	5,800	100/130	N/A	N/A	N/A	N/A	N/A	N/A
	DC-6 A/B	4	PW R-2800	8,400	100/130	5,508	385	13.6	5,900	N/A	N/A
	DC-7 B	4	W Turb.Comp.	13,000	100/130	4,512	450	9.3	6,000	N/A	N/A
Lockheed	L-749 'Constellation'	4	WC 749C18BD1	10,000	100/130	5,820	N/A	N/A	3,000	N/A	N/A
	L-1049 'Super Const.'	4	CW Tb.Comp R-3350-DA3	13,000	100/130	6,550	N/A	N/A	6,000	N/A	N/A

Manufacturer	Designation	Airspeed (mph) Max.	Cruise	Spray	Stall	Weight (Pounds) Gross	Empty	Usefl.	Prod. Status	Tank Capy. (U.S. Gal.)	No. in Canada
Canadair	CL - 215	N/A	189	150	79	37,700	27,614	10,086	Curr.	1,320	16
de Havilland	DHC-6 'Twin Otter'	234	184	N/A	85	12,500	6,782	5,180	Curr.	N/A	123
Douglas	DC-4	280	219	172	88	73,000	40,806	32,194	Disc.	2,500	1
	DC-6 A/B	N/A	270	230	105	106,000	54,148	51,852	Disc.	3,100	11
	DC-78	305	275	230	N/A	124,272	96,000	28,272	Disc.	4,800	1
Lockheed	L-749 'Constellation'	347	298	205	N/A	105,000	57,000	48,000	Disc.	3,200	0
	L-1049 'Super Const.'	370	327	215	N/A	150,000	73,000	77,000	Disc.	4,400	4

Table 5

Fixed-Wing/Single- or Multi-Engine - Manufactured for Military. Design Not Specialized for Aerial Applications.

Manufacturer	Designation	Engine Number	Engine Type	Engine Tot.Hp	Fuel Type	Fuel Capy.	Fuel Flow	Endur. (hrs.)	MFL (ft.)
Consolidated	PBY 'Canso'	2	PW R-1830-92	2400	100/130	300	96.0	2.4	4000
Douglas	DC-3	2	PW R-1830	2400	100/130	768	96.0	7.2	3500
Grumman	TBM 'Avenger'	1	W R-2600	2000	100/130	324	72.0	3.8	3000
	S2F-1 'Tracker'	2	W R-1820-82	3050	100/130	500	100.8	4.2	3000
Boeing	A75 'Stearman'[1]	1	J R-755	225	N/A	43	N/A	3.8	N/A

Manufacturer	Designation	Airspeed (mph) Max	Airspeed Cruise	Airspeed Stall	Weight (Pounds) Gross	Weight Empty	Weight Useful.	Tank Capy. (US/Imp.Gal.)	No. in Canada
Consolidated	PBY 'Canso'	196	115	55	30,500	21,000	9,500	800	29
Douglas	DC-3	230	207	67	26,900	19,200	7,700	--	150
Grumman	TBM 'Avenger'	271	150	82	17,000	10,000	7,000	700	45
	S2F-1 'Tracker'	N/A	180	90	26,000	16,000	10,000	720	6
Boeing	A75 'Stearman'[1]	124	106	52	2,717	1,936	781	125	25

Note: 1) Engine, horse power and weight data are representative of the Stearman military trainer. Spraying modifications had 450- and 600-HP engines with correspondingly higher performance, but data on these models was not available.

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APPENDIX C

AIRCRAFT MANUFACTURERS

APPENDIX C: AIRCRAFT MANUFACTURERS

A. ROTARY WING AIRCRAFT (HELICOPTERS)

1. Aviation Spec.: H.Q.-Aviation Specialties, Inc.
   4930 East Falcon Drive/Falcon Field
   Mesa, Arizona 85201
   Ph. (602) 969-7217

2. Bell: H.Q.-Bell Helicopter Textron
   Division of Textron, Inc.
   P.O. Box 482
   Fort Worth, Texas 76101
   Ph. (817) 280-2574
   Tx. 75-8229

   Cda.-Bell Helicopter Textron
   2090 Walkley Road
   Ottawa, Ontario, K1G 3V3
   Ph. (613) 521-8320
   Tx. 053-4126

3. Boeing: H.Q.-Boeing Vertol Co.
   Boeing Centre
   Box 16858
   Philadelphia, Pennsylvania 19142
   Ph. (215) 522-2121

   Cda.-Boeing of Canada Ltd.
   Winnipeg Division
   99 Murray Park Road
   Winnipeg, Manitoba, R3J 3M6
   Ph.(204) 888-2300
   Tx. 07-57309

4. Boelkow: H.Q.-Messerschmitt-Boelkow-Blohm GMBH
   Helicopter Division
   P.O. Box 80 11 20
   8000 Munich 80, Germany
   Ph. (089) 6000-1
   Tx. 22279

   Cda.-Boeing of Canada Ltd.
   Winnipeg Division
   99 Murray Park Road
   Winnipeg, Manitoba. R3J 3M6
   Ph. (204) 888-2300
   Tx. 07-57309

5. Brantly: H.Q.-Brantly-Hynes Helicopter Inc.
Industrial Park
P.O. Box 1046
Frederick, Oklahoma 73542
Ph. (405) 335-2256

6. Enstrom: H.Q.-Enstrom Helicopter Corporation
2229 22nd Street
Box 277
Menominee, Michigan 49858
Ph. (906) 863-9971
Tx. 26-3451

Cda.-Pultz Aviation Ltd.
Saskatoon
Saskatoon, Saskatchewan

7. Hiller: Hiller Aviation
2075 W. Seranton Avenue
Porterville, Calif. 93257
Ph. (209) 781-2261
Tx. 682454

8. Hughes: H.Q.-Hughes Helicopters
Division of Summa Corporation
Culver City, Calif. 90230

Cda.-A.S. 'Tony' Brown
Eastern Regional Manager
Canadian Sales
Hughes Helicopters
Division of Summa Corporation
28 Pipers Crescent
Kirkland, Quebec. H9H 3J4
Ph. (514) 697-5957

9. Sikorsky: H.Q.-Sikorsky Aircraft Division
United Technologies Corporation
Stratford, Connecticut 06602
Ph. (203) 378-6361
Twx. 710-453-1330

Cda.-Pratt & Whitney Aircraft of Canada, Ltd.
Division of United Technologies Corp.
P.O. Box 10, 1000 Marie-Victorin Blvd.
Longueuil, Quebec, J4K 4X9
Ph. (514) 677-9411
Twx. 610-422-3872

10. Vought: H.Q.-Vought Helicopter Corporation
A Subsidiary of Aerospatiale (France)
1701 W. Marshall Drive
Grand Prairie, Texas 75050
Ph. (214) 264-2318
Tx. 730695

Cda.-Vought Helicopter Corporation
Hangar No.57
Calgary International Airport
Calgary, Alberta, T2P 2G3
Ph. (203) 277-5338

B. FIXED WING AIRCRAFT

1. Canadair: H.Q.-Canadair Limited,
Subsidiary, General Dynamics Corp.
P.O. Box 6087, Station A
Montreal, Quebec, H3C 3G9
Ph. (514) 744-1511
Twx. 610-421-3225

2. Cessna: H.Q.-Cessna Aircraft Company
P.O. Box 1521
Wichita, Kansas 67201
Ph. (316) 685-9111

Cda.-Dealer franchises in most major centres.

3. Convair:

4. deHavilland H.Q.-The deHavilland Aircraft of Canada, Ltd.
Downsview, Ontario. M3K 1Y5
Ph. (416) 633-7310
Tx. 06-22128

5. Douglas H.Q.-McDonnell Douglas Corporation
P.O. Box 516
St. Louis, Missouri 63166
Ph. (314) 232-0232
Tx. 44-857
Twx. 910-762-0635

Cda.-Douglas Aircraft Co. of Canada Ltd.
McDonnell Douglas Corp.
Toronto AMF, Toronto,
Ontario, L5P 1B7
Ph. (416) 677-4341
Twx. 610-492-4350

6. Grumman	H.W.-Grumman American Aviation Corp. Subsidiary of Grumman Corp. 318 Bishop Road Cleveland, Ohio 44143 Ph. (216) 449-2200 Tx. 980-245
7. Helio	H.Q.-Helio Aircraft Company Division of General Aircraft Corp. Hanscom Field Bedford, Massachusetts 01730 Ph. (617) 274-9130 Twx. 710-326-0696
Imco	H.Q.-Imco, Inc. P.O. Box 547 Afton, Wyoming
8. Pilatus	H.Q.-Pilatus Aircraft Ltd. 6370 Stans Switzerland Ph. (041) 61 14 46 Tx. 78329 CH
9. Piper	H.Q.-Piper Aircraft Corporation Lockhaven, Pennsylvania 17745 Ph. (717) 748-6711 Tx. 84142 Cda.-Dealer franchises in most major centres
10. Rockwell	H.Q.-Rockwell International Corporation General Aviation Division 5001 N. Rockwell Avenue Bethany, Oklahoma 73008 Ph. (405) 789-5000 Tx. 748-512 Twx. 910-830-6870

APPENDIX D

CANADIAN AIRCRAFT AND OPERATOR DISTRIBUTION

Table 1: Operators Holding Class 7 AAD Licence for Helicopter Only or Helicopter and Fixed-wing Aircraft.

Table 2: Operators Holding Class 7 AAD Licence for Fixed-wing Aircraft Only.

Table 3: Operators Licenced for Helicopter Only or Helicopter and Fixed-wing Aircraft, but Not Holding Class 7 AAD Licence.

Table 4: Registered Aircraft Owners Holding No Commercial Operators Licence or Holding Such Licence but Not Holding Class 7 AAD.

Table 5: Government Agencies Which Own and Operate Aircraft.

Table 6: Forestry and Related Industries which Privately Own and Operate Helicopters Only or Helicopters and Fixed-wing Aircraft.

Table 1: OPERATORS HOLDING CLASS 7 AAD* LICENSE FOR HELICOPTER ONLY (H) OR HELICOPTER AND FIXED WING AIRCRAFT (HF)

Company Name	Lic.	Key Personnel	Aircraft Type & No.	Comments
Aero Arctic Ltd., P.O. Box 1496, Yellowknife, N.W.T., XOE 1HO Ph. (403) 873-5230, Tx. 034-4-5569	H	R. O'Connor - Pres. F. O'Connor - V.P. N. Murphy - Ch. Engr.	(1) Sikorsky S-55T (1) Bell 206B	
Aero Trades (Western) Ltd., Winnipeg Int'l. Airport, Winnipeg 21, Man., R2R 0S6	HF	C. Jeffs - Pres. B. MacPherson - Ops. Mgr.	(1) Bell 47G-4A (5) Bell 206A (4) Bell 206B (1) BN 2A20 (1) DHC-6 Tw. Otter (1) Cessna 150 (2) Cessna 172 (1) Cessna 180 (1) Cessna 182 (4) Cessna 185 (1) Cessna 337 (1) Cessna 401 (2) Cessna 402 (4) DC-3C (5) PA-23	
Argo Copter Enterprices Ltd. 3926 - 4th St. S.W., Calgary, Alta. T2S 1V5 (403) 243-5172	H	E.W. Brooks - Pres. D.E. Brooks - Sec. Tr. J.D. Durkie - Ch. Pilot	(3) Hiller UH12E (1) Bell 47G-2 (1) Bell 47G3B-1	Operations base at Red Deer.

* Class 7: Specialty commercial air service: (i) "aerial application and distribution"; Canadian Transport Commission, "Directory of Canadian Commercial Air Services, 116th Revision, August 15, 1976".

Company Name	Lic.	Key Personnel	Aircraft Type & No.	Comments
Alpine Helicopters Ltd., McCall Field, Calgary, Alta.	H	J.D. Nicolson - Pres. T. Jansen - Sec. Tr. J. Flippo - Ch. Engr.	(9) Bell 47G3B1 (6) Bell 206B (2) Sikorsky S-55T (1) Bell 204B	
Athabaska Airways Ltd. P. O. Box 100, Prince Albert, Sask, S6V 5R4	HF	Floyd R. Glass - Pres. E. Kydd - Ops. Mgr. W. Adrian - Ch. Engr.	(6) Bell 47J-2A (3) Bell 206B (1) Sikorsky S-55T (5) Cessna 150 (3) Cessna 172 (1) Cessna 180 (5) Cessna 185 (2) Cessna 206 (1) Cessna 310 (2) DHC-2 Beaver (2) DHC-3 Otter (2) DHC-6 Tw. Otter (1) MU2B35	
Caledon Helicopters Ltd. Orangeville Airport, R.R. #1, Caledon, Ontario, LON 1CO	H	Len C. Dobbs - Pres.	(1) Sikorsky S-55T	
Codiac Helicopters Ltd. P.O.Box 670, R.R.#4, Moncton, N.B., E1C 8J8	H		(1) Bell 47G-2 (1) Bell 206B (1) Hiller UH12L4 (1) Hughes 269C	

Company Name	Lic.	Key Personnel	Aircraft Type & No.	Comments
Dominion Pegasus Helicopters Ltd. P.O. Box 340, King City, Ont. LOG 1KO (416) 832-2203, Tx. 06-23394	H	K.C. Blackwood - E.Reg. Ops.Mgr. T.C. Jones - E. Reg. Mktg. Mgr. C. Neal - Mktg. Mgr.	(25) Bell 206B (2) Bell 206A (1) Bell 205A-1 (1) Bell 212 (1) SA341G Gazelle (1) SA318C Al. II	Managed by Okanagan Helicopters Ltd.
Estlin Air Services Ltd., P. O. Box 100, Prince Albert, Sask, S6P 5R4	H		(1) S-55T	
Great Lakes Helicopters Ltd. 439 Queens Quay West, Toronto, Ont. M5V 2A5 (416) 363-0041	H	D.V.N. McCutcheon - Pres. R.M. Boyd - Dir. Ops. J. Benben - Dir. Maint.	(3) Bell 47G-2 (1) Bell 47G-4 (1) Bell 206B (3) Hughes 500C (3) SA341G Gazelle	
Helicraft Ltd. - Ltée. 6500 ch. de la Savanne, St. Hubert, P.Q.	H		(1) Bell 47G-2 (1) Bell 47G-2A (1) Bell 206A (1) Bell 206B (3) Hughes 269 (1) Hughes 500 (1) SA318C Al. II	
Horley Construction Ltd. Neilburg, Sask., SOM 2CO	HF		(1) Cessna 170A (1) Erco 415E	

Company Name	Lic.	Key Personnel	Aircraft Type & No.	Comments
Len-Air Services Ltd., Box 164, Craik, Sask.	H			
Liftair International Limited Hangar #4, McCall Field, Calgary, Alta., T2E 5G3 (403) 276-6625, Tx. 03-822-632	H	F.C. McConnell - Mng. Dir. N.J. Armstrong - Pres. H. Carmichael - Ch. Engr.	(2) Bell 47G-2A (3) Bell 47G-3B-1 (2) Bell 47G-3B-2 (1) Bell 47G-4A (1) Bell 206B (7) Hughes 500 (1) SA 318C Al. II	
McPhail Air Services Limited 500 - 11th Avenue, North Battleford, Sask., S9A 2S6 (306) 445-2347	HF	H.D. McPhail - Pres.	(1) Bell 47G-2 (2) Bell 206A (1) Bell 206B (1) Call-Air-A9A (2) Cessna 150 (2) Cessna 172 (1) Cessna 185 (2) Cessna 188 (1) Cessna 206	
Niagara Helicopters Limited 1 Victoria Ave., P.O.Box 143, Niagara Falls, Ont., L2E 6S8	H	Frank Edwards - Pres.	(8) Bell 47G-2 (1) Bell 47G-4 (1) Bell 476-4A (1) Cessna 150	

Company Name	Lic.	Key Personnel	Aircraft Type & No.	Comments
Okanagan Helicopters Ltd. 439 Agar Drive, Richmond AMF, B.C., V7B 1A5 (604) 278-5502, Tx. 04-355594	H	J.W. Pitts - Chairman F.A. Moore - V.P. Mktg. D.T. Dunn - V.P. Ops.	(30) Bell 206B (3) Bell 206A (4) Bell 205A-1 (7) Bell 212 (1) Bell 204B (1) Sikorsky S-62 (6) Sikorsky S-58T (5) Sikorsky S-61	Class 7AAD operations at Kemano, Kamloops, Nelson, Revelstoke, Prince George, Campbell River, Terrace. See also Dominion Pegasus Helicopters etc.
Olympic Helicopters Ltd., P. O. Box 622, Montreal 379, P.Q. H3C 2T8	H	Jean Becker - Pres.	(1) Bell 47G-Z (3) Bell 206B (3) Hughes 269 (2) Hughes 500	
Ontario Helicopter Services R.R. #3, Lakefield, Ont.	H	D.T. Doughty - Pres.	(1) Bell 47J-2 (1) Hughes 269	
Point West School of Aviation Limited, 6 Grp 6A, Winnipeg, Man. R3C 2E4	HF	R.W. Briggs - Pres.	(1) Bell 47G (1) Bell 47G-4 (1) Bellanca 7KCAB (1) North American AA1A (6) Piper PA-28	
Shirley Helicopters Ltd. Hangar #3, Edmonton Industrial Airport, Edmonton, Alta.	H	R.L.Rasmussen - Gen. Mgr. L.A. Davison - Ops. Mgr. P. Sauriol - Ch. Engr.	(1) Bell 47D-1 (1) Bell 47G-2 (1) Bell 47-3B-1 (3) Bell 206B (2) Bell 206A (2) Bell 206L (3) SA 341G Gazelle (2) Hughes 500C	

Company Name	Lic.	Key Personnel	Aircraft Type & No.	Comments
The Gosselin Lumber Company Ltd. P.O. Box 1180, Hearst, Ont. POL 1NO	H	Real Gosselin - Pres.	(1) Hiller UH12E	Operations at Carey Lake.
Toronto Helicopters Ltd., Buttonville Airport, Buttonville, Ont. LOH 1BO	H	L. Routledge - Pres. D. Dunlop - Sec. Tres. & Chf. Pilot	(1) Bell 47G-2 (3) Hughes 269 (6) Hughes 500	Recent purchase of Hicks & Lawrence Cl. 7AAD and Cl. 4 helicopter charter.
Transwest Helicopters (1965) Ltd. 2792 Norland Ave., North Burnaby, B.C. V5B 3A6 (604) 291-7578, Tx. 04-354865	H	J. McMahon - Pres. W. James - V.P. R. Burton - V.P.	(3) Bell 47G-2 (5) Bell 47G-3B1 (1) Bell 204B (3) Hiller UH12E (8) Hughes 500C	Operations at Vancouver.
Twinn Pest Control Aerial of Ottawa Limited, 120 Eccles St., Ottawa, Ont., K1R 6S8	H	Roy Twinn - Pres.		
Universal Helicopters Ltd. Carp Airport, Carp, Ont., KOA 1LO	H	Gary Fields - Pres.	(1) Bell 47G2-A1 (5) Bell 206A (2) Hiller UH12E (1) Sikorsky S-55 (1) Sikorsky S-58T	Subsidiary of Okanagan Helicopters Ltd.

Company Name	Lic.	Key Personnel	Aircraft Type & No.	Comments
Viking Helicopters Ltd. P.O. Box 5104, Stn. 'F', Ottawa, Ontario., K2C 3H4 (613) 257-4660, Tx. 053-3659	H	L. Camphaug - Pres. John Schultz - V. P. Earl Johns - Dir. Flt.Ops. S. Mills - Dir. Dom. & Intl. Mktg.	(3) Bell 47G-2 (2) Bell 47G-4 (8) Bell 47G-4A (1) Bell 47J-2 (2) Bell 205A-1 (25) Hughes 500	
Yvon Fournier Limitée, 225 Rue des Erables, Cap-de-la-Madeleine, P.Q. G8T 5G9	H	Y. Fournier - Pres.	(1) Bell 47G-5 (1) Sikorsky S-55T (1) Bullet	Operations at Trois Riviéres.

Table 2: OPERATORS HOLDING CLASS 7 AAD* LICENSE FOR FIXED WING AIRCRAFT ONLY

Company	Key Personnel	Aircraft Type & No.	Comments
Aerial Spray & Charter Ltd. Box 905, Neepawa, Man., R0J 1H0 (204) 476-2836	Gordon Murray - Pres.	(1) Cessna 172 (1) Cessna A188B (1) Piper PA-11 (1) Piper PA-18	
Agair Spraying Co. Ltd. P.O. Box 1022, Dawson Creek, B.C., V1G 3K4		(1) Boeing A75N1 (Steerman) (2) Cessna 150 (1) Cessna A188 (1) Piper J3C65 (1) Piper PA18	
Agricultural Air Services Ltd. 196 Adelaide St. W., Toronto, Ont. M5H 1W7		(1) Cessna A188B (1) Piper PA-25	Operations at Dundalk, Ontario.
Agro Air Spray Ltd., No.2 Hangar, Mun. Airport, P.O. Box 1006 Regina, Sask., S4P 3B2		(2) Piper PA-18	
Air Agro Services Ltd., P.O. Box 6, Hardisty, Alta., T0B 1V0	A. Thompson	(1) Cessna 185 (1) Cessna A188B (1) Piper PA-25	

* Class 7: Specialty commercial air service: (1) "aerial application and distribution"; Canadian Transport Commission, Directory of Canadian Commercial Air Services", 116th Revision, August 15, 1976.

Company	Key Personnel	Aircraft Type & No.	Comments
Airberta Farms Ltd., P.O. Box 181, Airdrie, Alta., TOM OBO		(1) Aeronea 7CCM (1) Aeronea 7DC (1) Cessna 180 (1) Grumman G164A (1) Lockheed 18	
Aircraft Company (Regina) Ltd. P.O.Box 13, Regina, Sask. S4P 2Z5		(1) Bellanca 8GCBC (1) Cessna 180 (5) Piper PA-18 (3) Piper PA-23 (8) Piper PA-28 (1) Piper PA-31 (1) Piper PA-32 (2) Piper PA-34 (1) Waco YKS-7	
Airspread Services Ltd. 1900 Guiness Tower 1055 West Hastings St., Vancouver 1, B.C., V6E 2E9		(1) Call-Air A9A	Operations at Chilliwack, B.C.
Angus Aviation Ltd., Hangar #1, 11930-109 St., Industrial Airport, Edmonton, Alta., T5G 2T8 (403) 474-1488	Harry F. Byrt - Mgn. Dir.	(3) Beech Baron (1) Beech King Air (1) Cessna 180 (1) Rockwell Sabre 60 (1) Beech B90 (1) Beech D55 (2) Beech 58 (1) Beech 95C55 (1) Cessna 180H	

Company	Key Personnel	Aircraft Type & No.	Comments
Annapolis Valley Flying Services Ltd., P.O.Box 93, Waterville, N.S., BOF 1V0	H. A. Bull - Pres.	(1) Cessna 150 (1) Cessna 172 (4) Piper PA-28	
Beaver Air Spray Inc. C.P. 642, Marieville, P.Q., J0L 1J0		(1) Piper PA-18A (4) Piper PA-25	
Bond, Richard Gwilym, P.O. Box 258, Grimshaw, Alta.		(1) Cessna 185F	Operations at Whitehorse, Y.T.
Bonnyville Air Service, P.O. Box 926, Bonnyville, Alta., T0A 0L0		(2) Cessna A188B	
Bouckaert, Edgar J. R.R. #1, Aylmer (West), Ont. N5H 2R1		(1) Piper PA-25	

Company	Key Personnel	Aircraft Type & No.	Comments
Bradley Air Services Ltd., Carp Airport, Carp, Ont. K0A 1L0 (613) 839-3340, Tx. 053-3158	J.G. Jamieson - Pres. & Gen. Mgr. R. M. Blicquy - V.P. Ops. T.W.I. Kirkconnell - Sec. Tr.	(3) Beech 18 (3) Cessna 150 (3) Cessna 172 (1) Cessna 180 (2) Cessna 182 (1) Cessna 185 (1) Cessna 402 (1) Cessna 421 (3) DHC-2 Beaver (10) DHC-6 Tw. Otter (4) DHC-3 Otter (4) DC-3C (1) Noorduyn UC64A (1) Piper J3 (1) Piper PA-18A (1) Piper PA-24 (7) Piper PA-28 (1) Piper PA-30 (1) Piper PA-32	
Brunswick Air Services Ltd., P.O. Box 1297, Woodstock, N.B. E3B 5C8		(1) Cessna 172 (1) Cessna 180G (1) Cessna 185E (2) Piper PA-25	
Cariboo Air Charter Ltd., P.O. Box 339, Kelowna Airport, B.C. V1Y 7N8		(1) Beech A60 (1) Beech 95C55 (2) Cessna 150 (3) Cessna 180 (1) Cessna 182 (1) Piper PA-23	

Company	Key Personnel	Aircraft Type & No.	Comments
Cedar Brook Farms Ltd., P.O. Box 103, Centreville, N.B., EOJ 1HO		(1) Grumman G164A (2) Piper PA-25	
Central Ag-Air Ltd., 263 Forest Avenue, St. Thomas, Ont. N5R 2K5			
Central Airspray, Watson, Sask., SOK 4VO	H. Sproule - Pres.	(1) Grumman G164A	
Chieftain Flying Services Ltd. Indian Head, Sask. SOG 2KO	B.G. Hewson	(1) Piper PA-25	
Collins Airspray, Box 170, Grp. 261, R.R. #2, Winnipeg, Man., R3C 2E6		(1) Cessna A188B	
Conair Aviation Ltd., P.O. Box 220, Abbotsford, B.C. V2S 4N9 (604) 853-1171	L. G. Kerr - Pres. & Gen. Mgr. K.B. Marsden - Supt. Flt. Ops.	(2) Aerostar 600 (3) Aerostar 601 (3) Cessna 188 (3) Cessna 210 (2) Cessna 337 (12) Douglas A26 (8) Douglas DC-6 (10) Grumman TBM3 (1) NA Harvard IV	

Company	Key Personnel	Aircraft Type & No.	Comments
Cook, Brian Earle, P.O. Box 273, Bedford, P.Q.		(1) Cessna 150L	
Cummings Agricultural Air Services Ltd., P.O. Box 21, Wetaskiwin, Alta.		(1) Piper PA-25	
Douglas Aero Service, P.O. Box 355 Eatonia, Sask., SOL OYO			
Evergreen Air Service Ltd. P.O. Box 51, Roxboro, P.Q., H9G 2H5 (514) 626-1022	G. Lovett - Pres.	(2) Grumman G164A (4) Boeing A7tN1 (2) Grumman TBM3	
Fort Air-Ways Ltd. Fort Qu'Appelle, Sask., SOG 1SO		(1) Cessna 180 (1) Piper PA-28	
Fossen Air, P.O.Box 111, Abbotsford, B.C. V2S 4N8 (604) 853-4771	Edwin S. Fossen - Mgr.	(2) Piper PA-25 (2) Taylorcraft F19	

Company	Key Personnel	Aircraft Type & No.	Comments
Gem Air Spray Ltd. Stettler, Alta.		(2) Piper PA-25	
General Airspray Ltd., 27 Mandeville Road, St. Thomas, Ont., N5R 4H9, (519) 631-8931; 227-4091	D. Worgan - Pres. & Gen. Mgr.	(2) Grumman G164A (2) Boeing A75N1 (Stmn) (2) Piper PA18A	Operations at Lucan, Ont.
Hicks & Lawrence Ltd., R.R. #7, Tillsonburg, Ont. N4G 4H1, (519) 842-5926	Mervin Hicks - Pres.	(3) Cessna 150 (2) Cessna 172 (4) Grumman TBM3 (1) NA Harvard 2 (2) Piper PA-25 (1) Piper PA-31	
Highwood Air Service Ltd., R.R. #1, DeWinton, Alta., TOL 0X0		(1) Boeing A75N1 (Stmn) (2) Cessna 185 (1) Cessna 337 (1) Piper PA-25	
Interprovincial Airways Ltd., Box 768, Lloydminster, Sask., 39V 0Y7	Ed. J. Jensen - Pres.	(4) Cessna 150 (1) Cessna 172 (1) Piper PA-23 (1) Piper PA-28	

Company	Key Personnel	Aircraft Type & No.	Comments
Kamloops Aircraft Ltd., 110 - 5852 Patterson Ave., Burnaby, B.C., V5H 2M8		(4) Cessna 172 (1) Cessna 185F (1) Cessna TU206 (1) Piper PA-25 (1) Piper PA-28 (1) Piper PA-32	
Kincardine Air Services Ltd., Kincardine Town & Twp. Airport Kincardine, Ont. NOG 2GO		(1) Cessna 172 (1) Cessna 180 (1) Grumman G164A (2) Piper PA-25	
Kinniburgh Spray Service Ltd., Purple Spring, Alta., TOK 1XO		(2) Aero Comm. B1A (3) Grumman G164A (1) NA Harvard 2 (1) Piper PA-12 (3) Piper PA-23 (1) Piper PA-25	
Klahannie Air Ltd. P.O. Box 3061, Mission, B.C. V2V 4J3		(1) Cessná A185F	
Koolair, P.O. Box 24, Fisher Branch, Man. XOE 1HO			

Company	Key Personnel	Aircraft Type & No.	Comments
Kootenay Airways Ltd. P.O. Box 478, Cranbrook, B.C., V1C 4H9		(2) Cessna 150 (1) Cessna 172 (1) Cessna 177 (2) Cessna 182 (1) Cessna T210 (1) Cessna T337 (1) Piper PA-18 (1) Piper PA-23 (1) Piper PA-25	
Lammens' Spraying Service, R.R. #5, Langton, Ont., N0E 1G0			
Lethbridge Air Service Ltd., P.O. Box 850, Lethbridge, Alta., T1J 3Z8		(2) Cessna 150 (4) Cessna 172 (2) Cessna 182 (1) Cessna 337 (1) Piper PA-23 (3) Piper PA-28 (1) Piper PA-31	
Maple Leaf Aviation Ltd., P.O. Box 160, Brandon, Man., R7A 5Y8		(7) Cessna 172 (1) Cessna A188B (2) Cessna U206F (1) Piper PA-24	
Maritime Air Service Ltd., R.R. #4, Box 29, Moncton, N.B. E1C 8J8		(1) Cessna 172 (1) Piper PA-18 (1) Piper PA-31 (5) Snow Comm.6002D (1) Bell 47G (1) Bell 47G-2	

Company	Key Personnel	Aircraft Type & No.	Comments
McCaig Flying Services, P.O. Box 305, Kenaston, Sask., SOG 2NO	D. McCaig. - Pres.	(1) Aero Comm. S2R (1) CAll-Air A9A	
McRae, Norman, Box 42, R.R. #1, Grp. 5 Winnipeg, Man., R3C 2E4		(1) Cessna A188B	
Mesinchuk Flying Service Ltd. Suite 201, 1822 Scarth St., Regina, Sask., S4P 2G4	J.Mesinchuk - Pres.	(1) Piper PA-11	Operations at Watrous, Sask.
Midair (Canada) Ltd., Box 340, Norwich, Ont. NOJ 1PO		(1) Boeing A75N1 (1) Cessna 188 (1) Douglas DC-7B (1) Piper PA-18	Operations at Aylmer, Ont.
Miramichi Air Service Ltd., P.O. Box 90, Douglastown, N.B., EOC 1HO (506) 773-7070	E.A. Retfalvy Haden - Pres.	(2) Aeronea 7DC (1) Bellanca Scout (1) Cessna 172 (1) Cessna 185 (5) Cessna A 188B (3) Grumman TBM3	

Company	Key Personnel	Aircraft Type & No.	Comments
Modern Air Spray Ltd., P.O. Box 156, St. Jean Mun. Airport, St. Jean, P.Q., J3B 6Z4		(1) Aero Comm 520 (3) Cessna A188B (1) Piper PA-25	
Nipawin Air Services Ltd., Box 1540, Nipawin, Sask, SOE 1EO (306) 862-4673	L. R. Andrews - Gen. Mgr. G. O. Thompson - Ops. Mgr.	(1) Beech 3NM (1) Cessna 150 (6) Cessna 185 (1) Champ. 7ECA (3) DHC-2 Beaver (2) DHC-3 Otter (1) Norseman V (2) Piper PA-23 (2) Piper PA-28 (1) Piper PA-31	
Norcanair, P.O.Box 850, Prince Albert, Sask. S6V 5S4 (306) 764-4271, Tx. 074-29236	J.B. Lloyd - Pres. & Gen. Mgr. A. Aaron - Sec. Treas. I. MacLeod - V.P. Traf.& Sales J. A.Pool - V.P. Engr. & Maint. K. Hornseth - Ops. Mgr.	(1) Bristol Mk31 (4) PBY-5A Canso (5) Cessna 180 (3) Cessna 185 (1) Cessna 206 (2) DC-3 (5) DHC-2 Beaver (3) DHC-3 Otter (3) F-27A Fairchild (3) Piper PA-23	Operations at Prince Albert & La Ronge under Cl. 7 AAD.

Company	Key Personnel	Aircraft Type & No.	Comments
Norfolk Aerial Spraying Ltd. R.R. #7, Simcoe, Ont. N3Y 4K6		(2) Grumman G164A (6) Grumman TBM 3E (4) Piper PA-25	Operations at Brantford, Ont.
Norm Air Services, Box 447, Estevan, Sask.	N. Pischke - Pres. B. Pischke - Sec. Treas.	(3) Cessna 150 (1) Cessna 172 (1) Piper PA-12 (1) Piper PA-18A (1) Piper PA-24 (1) Piper PA-25	
Northern Thunderbird Air Ltd., Box 1510, Prince Grorge, B.C., V2L 4V5 (604) 963-9611, Tx. 047-8880	E. R. Loftus - Pres. J. Stelfox - EVP & G. Mgr. L. Ritchey - Asst. G. M. E. Goodgay - Cont.	(2) Beech D-18S (2) Cessna 337 (2) Cessna 185 (3) DHC-2 Beaver (2) DHC-3 Otter (3) DHC-6 Twin Otter (1) DC-3C	
Parkland Aerial Crop Spraying, Services Ltd., P. O. Box 457, Dauphin, Man. T2P 2G7		(3) Cessna A188B	Operations at Grandview, Man.

Company	Key Personnel	Aircraft Type & No.	Comments
Peace Air Limited, P.O. Box 277, Peace River, Alta., TOH 2XO (403) 624-3060/1339	L.J. Gayton - Pres. K.A. Harvey - Ops. Mgr. & Ch.Pilot J.E. Holt - Sales Mgr.	(1) BN 2 A1 (3) Cessna 150 (1) Cessna 172 (2) Cessna 180 (8) Cessna 185 (1) Cessna 402 (2) Piper PA-23 (1) Piper PA-30	
Pembina Air Services Ltd., Box 630, Morden, Man., ROG 1JO	R. Weibe	(2) Cessna 150 (4) Cessna 172 (2) Cessna A188B (1) Piper PA-23	
Quikway Aviation Ltd., P.O. Box 488, Brooks, Alta.		(1) Aero Comm. S2R (2) Cessna 188	
Ray's Flying Service Ltd., P.O. Box 181, Saskatoon, Sask. S7K 3K4		(1) Beech 3NM (1) NA Harvard IV (2) Piper PA-23 (1) Piper PA-28 (2) Piper PA-31	
Red Deer Air Services Ltd., Box 298, Strathmore, Alta.		(2) Cessna 180	

Company	Key Personnel	Aircraft Type & No.	Comments
Rosebud Aerial Spray Service Ltd., Box 100, Standard, Alta., TOJ 3GO		(1) Piper PA-25	Operations at Rosebud.
Rowan's Flying Service Ltd. 1856 Alexander Street, Regina, Sask., VOA 1KO		(1) Cessna 172 (1) Cessna 188	Operations at Wakaw.
Sandham, Wm. Alexander, R.R. #2, Port Hope, Ont., L1A 3V6 (416) 797-2643	W.A. Sandham - Owner & Operator	(1) Piper PA-18 (1) Piper PA-25	
Sharpe, James Alexander, P.O. Box 90, Val Marie, Sask., SON 2TO		(1) Piper PA-25	
Skocdpole Bros. Aviation Ltd., Olds, Alberta. TOM 1PO.	I. Skocdpole - Pres.	(1) Cessna 150 (1) Cessna 172 (1) Cessna 177	
Smith Airways Ltd., P.O. Box 455, Swift Current, Sask., S9H 3W9, (306) 773-9349	G.A. Smith - Pres.	(3) Cessna 150 (4) Cessna 172 (1) Cessna 182 (1) Cessna A188B (1) Cessna 206 (1) Cessna 310Q	

Company	Key Personnel	Aircraft Type & No.	Comments
Smith, Glen, Eastend, Sask. SON OTO		(3) Cessna 150 (1) Cessna 172 (3) Cessna A188B	
South Central Air Services, Box 31, Assiniboia, Sask. SOH OBO			
Southern Spray Services Ltd. Box 27, Hazelmore, Sask. SON 1CO		(1) Cessna 172 (1) Cessna A188B	Operations at Gravelbourg.
Superior Airways Ltd., P.O. Box 52, Stn. 'F', Thunder Bay, Ont., P7C 4V5. (809) 577-1166	O.J. Wieben - Pres.	(1) Beech 3T (1) Beech 95B55 (4) Cessna 180 (1) Cessna 310F (4) DHC-2 Beaver (1) DHC-3 Otter (1) DC-3C	
T & D Aerial Spraying Ltd., Box 518, Bow Island, Alta., TOK OGO		(1) Cessna A188B (1) Piper PA-18A	
Thompson Bros. Richlea, Sask., SOL 2TO (306) 962-3963	N.M. Thompson - Owner M.E. Thompson - Secy.	(1) Cessna 182 (2) Luscombe T8F	Operations at Eston.

Company	Key Personnel	Aircraft Typer & No.	Comments
United Air Spraying Services Ltd. Box 34, Theodore, Sask., SOA 4CO		(1) Piper PA-18A	
Valley Air Services Ltd., P.O. Box 280, Melfort, Sask., SOE 1A0		(1) Beech 3NM (2) Cessna 172 (1) Cessna A185F (1) Mooney M20F (1) Piper PA-25	
Virden Aviation Ltd., Box 898, Virden, Man., ROM 2CO (204) 748-2349	Glen Holmes - Pres. & Mgr.	(1) Aeronea 7CCM (1) Bellanca 7ECA (1) Cessna 170B (1) Cessna 180 (1) Cessna 185 (1) Cessna A188B (2) Champ. 7ECA (1) Piper PA-J3C65 (1) Piper PA-12	
Walker Flying Services Ltd., Box 5178, Stn. 'E', Edmonton, Alta., T5P 4C1 (403) 489-6682	G.A. Walker - Pres. & Gen. Mgr.	(5) Cessna A188B (1) Cessna 310I	
Wallace Aviation Ltd., Oxbow, Sask., 30C 2B0		(1) Piper PA-25	

Company	Key Personnel	Aircraft Type & No.	Comments
West-Air Ltd., P.O. Box 248, Moose Jaw, Sask. S6H 4N9	Brian Walz - Ch. Pilot	(4) Cessna 172L (2) Cessna A188B	
Wetaskiwin Air Services Ltd. P.O. Box 819, Wetaskiwin, Alta.		(8) Cessna 150 (1) Cessna 172 (1) Piper PA-25	
Wilton Sky Spray Limited, 130 Centre Street, St. Thomas, Ont., N5R 2Z9		(1) Piper PA-18A (1) Piper PA-25	
Yorkton Flying Services Ltd., P.O. Box 782, Yorkton, Sask., S3N 2W8 (306) 783-4118	L.A. Ingham - Pres. D. W. Ingham - Sec. Tr.	(1) Bellanca 7KCAB (4) Cessna 150 (1) Cessna 172 (1) Cessna A188B (1) DHC-1B Chipmunk (1) Piper J3C65 (1) Piper PA-23 (1) Piper PA-25	
Zarn Air Ltd., Box 1486, High River, Alta.		(1) Boeing A75N1 (1) Piper PA-18	
Zimmer Travel & Air Services Ltd. 66 Elmwood Ave., St. Thomas, Ont. N5R 4Z7		(1) Boeing A75N1	Operations at Chatham.

Table 3: OPERATORS LICENSED FOR HELICOPTER ONLY (H) OR HELICOPTER AND FIXED WING AIRCRAFT (HF) BUT NOT HOLDING CLASS 7 AAD, AERIAL APPLICATIONS

Company Name	Lic.	Key Personnel	Aircraft Type & No.	Comments
Air Alma Inc. 693 Sacré-Coeur Est, Alma, P.Q.	HF	Roland Simard - Pres.	(1) Bell 47J (1) Bell 47G-2 (1) Cessna 172 (1) DHC-2 Beaver (1) FH-1100 (2) FBA-2C	
Associated Helicopters Ltd. No. 10 Hangar, Industrial Airport, Edmonton, Alta. T5G 2Z3 (403) 455-4157	H	S.R. Kaufman - Pres. T. Vaasjo - Ops. Mgr.	(12) Bell 206 B (2) Bell 204B (2) Bell 212 (2) Bell 47G-3B (2) Bell 47G-3B-1 (4) Bell 47J-2	
Aston Helicopters Ltd., P.O. Box 522, Oshawa Airport, Oshawa, Ont. (416) 725-2141, 449-9280	H	A.T. Verrico - Pres.	(4) Bell 47G-2 (1) Bell 206B	
Bow Helicopters Ltd. No. 10 Hangar, International Airport, Calgary 67, Alta., T2E 5T3 (403) 276-3366	HF	J.R. Prendergast - Gen. Mgr. B.H. Becker - Contr. Mgr. E.J. Amann - Opps Mgr. J. Albe - Ch. Pilot	(10) Bell 206B (3) Bell 204B (3) Bell 212 (1) Bell 47G-3B-1 (1) Cessna U206 (1) SA313C Al.II	

Company Name	Lic.	Key Personnel	Aircraft Type & No.	Comments
Buffalo Airways Ltd., P.O. Box 168, Fort Smith, N.W.T., XOE OPO (403) 872-2216, Tx. 934-4819	HF	Joe McBryan - Pres. Fred Kueber - V.P. E.R. Whitticase, Maint. Mgr.	(2) SA318C Al. II (1) SA341G Gazelle (1) Bell 47G-2 (1) Bell 206B (3) Cessna 185 (3) DHC-2 Beaver (1) DHC-3 Otter (1) Piper PA-23 (1) Piper PA-31	
Canadian Helicopters Ltd. 9501 Ryan Ave., Dorval, P.Q., H9P 1A2	H		(5) Bell 206B (6) Bell 206A (1) Bell 204B (1) SA318C Al. II (1) Sikorsky S-62A	Subsidiary of Okanogan Helicopters Ltd.
Canwest Aviation Ltd. No. 4 Hangar, Calgary Int'l. Airport, Calgary, Alta. T2P 2G3	HF		(2) Bell 47G-3B-2 (2) SA318C Al. II (1) SA316C Al. III (2) SA341G Gazelle	
Cascade Rotors Ltd. P.O. Box 443, Princeton, B.C.	H			
Civet Inc., R.R.1, Harrowsmith, Ont. KOH 1VO	H	R.M.Bourassa - Pres. R. Brough - Ops.Mgr.	(1) Bell 47G-2A	

Company Name	Lic.	Key Personnel	Aircraft Type & No.	Comments
Com-Logics Limited One Yonge Street, Toronto, Ont. M5E 1G1	H	E.S. Rogers - Pres.	(1) Hughes 269 (1) Hughes 500	
Crowsnest Helicopter Ltd. Box 705, Blairmore, Alta., TOK OEO	H		(1) Bell 47G-3B-1	
Delta Helicopters Ltd. P.O.Box 177, High Level, Alta. (403) 926-3848	H	Don Stubbs - Owner Mgr.	(2) Bell 47G-2	
Ed Darvill Copters Ltd., 74 Glenwood Cres., St. Albert, Alta., T8N 1X5	HF		(3) SA318C Al. II (1) Cessna TU206F	
Forest Industries Flying Tankers Ltd., R.R. #3, Port Alberni, B.C. V9Y 7L7 (604) 723-6225	HF	H.R. Chisholm - Pres. W.F. Waddington - Mgr.	(1) Bell 206B (1) Grumman G21A (2) Martin JRM3	
Fredericton Helicopter Ltd., P.O.Box 115, Oromocto, N.B., E2V 2G4	H		(3) Bell 206B (1) Bell 47G-2	Subsidiary of Les Helicopters Trans-Québec Ltée.

Company Name	Lic.	Key Personnel	Aircraft Type & No.	Comments
Frontier Helicopters Ltd., P.O.Box 10, Watson Lake, Y.T., YOA 1CO, (403) 536-7766, Tx. 036-88517	HF	S.H. Baird - Pres.	(6) Bell 206B (3) Bell 47G-3B-1 (1) Bell 47G-3B-2 (1) Bell 47J-2 (1) Cessna 180	
Gem Air Ltd., Box 10, Grp. 28, R.R. #1, Winnipeg, Man., R3C 2E4, (204) 334-6741	HF	G.E. McArthur - Pres. H.J. McArthur - Sec. Tres.	(1) Bell 47-J2 (1) Bell 206B (1) Piper J365	
Geophysical Engineering Ltd., Suite 4900, Toronto-Dominion Centre, Toronto, Ont. M5K 1E8	H	M. Steiner - Ch. Geologist	(1) Hiller FH1100 (1) SA 318C A1.II	
Glanford Helicopter Service, Mount Hope Post Office, Mount Hope, Ont., LOR 1WO	H	W. Marsh - Pres.	(4) Bell 47G-2	
G.N. MacKenzie Limited, 25 Adelaide St. East, Toronto 210, Ont., M3C 1V2	H	G.N. MacKenzie - Pres.	(1) Hughes 269B	

Company Name	Lic.	Key Personnel	Aircraft Type & No.	Comments
Golfe Hélicoptère Service/Les Hélicoptères de Mont Joli Ltee. C.P. 70 Rimouski, P.Q. G5L 7B7	H		(1) Bell 206B (1) Bell 206A (1) Bell 47G-4A	
Helair Limited, P.O. Box 770, Kenora, Ont.	H		(1) Hughes 500	
Heli-Quebec Limitee 805 St. Clare Road, Montreal, 305, P.Q. H3R 2M4	H	L. Labbe - Pres.	(3) Hughes 500	
Helitac Limited, 1103 River Road, Fort Frances, Ont.	H			
Heli Voyageur Ltee. C.P. 1330, Val d'Or, P.Q. J9P 4P8 (819) 825-4232	H	J.J. Cosette - Pres. J.P. LaHaie - Gen Mgr. J.P. Fuch - Ch. Pilot	(14) Bell 206B (1) Bell 206A (1) Bell 204B (1) Bell 47G (1) Bell 47G-2 (1) Bell 47G-4A (1) Cessna 185 (1) Hughes 269A (6) SA318C Al. II (1) SA313C Al. II (1) SA341G Gazelle	

Company Name	Lic.	Key Personnel	Aircraft Type & No.	Comments
Highland Helicopters Ltd., 424 Agar Drive, Int'l. Airport South, Vancouver, B.C. V7B 1A3 (604) 273-6161	H	E.C. Dunn- Mngng. Dir. R.G. Askin - Ch. Engr. J.D. Anderson - Ch. Pilot	(3) Bell 206A (7) Bell 206B (1) Hiller UH12E	
Hudson Bay Air Transport Ltd. Flin Flon. Man. (204) 687-5267	H	J.E. Goodman - Pres. M.J. Stelnicki - V.P. W.H. Beveridge - Ch. Pilot	(1) Beech E18S (1) Cessna 185 (3) DHC-3 Otter	Had (1) FH-1100; sold.
Huisson Aviation Ltd. P.O. Box 600, Timmins, Ont., P4N 7E7 (705) 267-2993	H	R.D. Huisson, Pres.	(1) Bell 206A (4) Bell 206B (1) Bell 206L	Ops. at Timmins & La Sarre, P.Q.
Kenting Aircraft Ltd. 380 Hunt Club Rd., Ottawa, Ont. K1G 3N3	HF		(1) Aero Comm. 680E (1) Beech C45H (3) BN 2A (1) Cessna 402A (1) Consol. PBY5A (1) Douglas C47B (3) Piper PA-23 (3) Piper PA-31	

Company Name	Lic.	Key Personnel	Aircraft Type & No.	Comments
Kenting Aircraft Ltd. 1323 McKnight Blvd., N.E., Calgary, Alta.	HF		(9) Bell 206B (1) Bell 206A (3) Bell 205A-1 (2) Bell 47G-2 (1) Cessna 320 (1) DHC-6 Tw. Otter (3) DC-3C (4) Hiller FH 1100 (1) Sikorsky S-58 (1) Sikorsky S-58T	
Klondike Helicopters, Hangar #3, Calgary Int'l. Airport, Calgary, Alta., T2P 2G3 (403) 277-8526, Tx. 038-21732	H	N.Crawford - Gen.Mgr. T. Protheroe - Sales Mgr. K. Mizera - Maint. Mgr.	(2) Bell 47G-2 (9) Bell 206 (2) Bell 205A-1 (2) Sikorsky S-58	
Lac St. Jean Aviation Ltee., 9501 Ryan Ave., Dorval, P.Q. H9P 1A2	H		(5) Bell 206B (1) Bell 206A (1) Bell 205A (16) SA318C Al.II	Ops.at Quebec. Subsidiary of Okanogan Helicopters
Lambair Ltd., P.O. Box 808, The Pas, Man., R9A 1K8 (204) 623-3461, Tx. 0766-212	HF	D. Lamb - Pres. G. Lamb - V.P., Ops. Mgr. J. Lamb - Sec. Treas., Mgr.	(2) Bell 47G-4A (3) SA318C Al. II (1) SA341 Gazelle (1) BN2A (2) Cessna 180 (1) Cessna 337 (1) Cessna 401 (5) DC-3 (2) DHC-3 Otter (5) DHC-6 Twin Otter (1) Fairchild F-27 (2) Piper PA-23	

Company Name	Lic.	Key Personnel	Aircraft Type & No.	Comments
La Verendrye Helicopters, P.O. Box 10, Limbour Airport, Limbour, P.Q., J8T 4Y8	H	Marcel Payant - Pres.	(4) Bell 206B (2) Bell 206A (1) Bell 47G-2A (3) Bell 47G-4A (2) Hughes 500	
Les Helicopteres Trans-Quebec Ltee, C.P. 460, Matagami, P.Q. JOY 2AO	H	A. LaChapelle - Pres. A. Marsan - V.P. Fin. D. Hogan - V.P. Ops.	(2) Bell 206A (20) Bell 206B (2) Bell 206L (2) Bell 205A-1 (2) Bell 47G4A (1) Cessna 185E	Ops. at Amos and Matagmi.
Mayo Helicopters Limited P.O.Box 5, Mayo, Y.T., YOB 1NO (403) 996-2375	H	R.R.Grant - Gen. Mgr. F. Johnson - Ch.Pilot E. Grant - Treas.	(3) Hiller UH12E (1) Hughes 500	
McGillivary Helicopters Ltd. Post Office, Cassidy, B.C.	H		(1) Bell 206B (1) Bell 47G-2 (1) Bell 47G-3B-1	Ops. at Nanaimo.
Midwest Airlines Ltd., Winnipeg Int'l Airport, Winnipeg 21, Man, R3J OH7	HF	A.L. Nelson - Gen.Mgr. E. Derkach - Ch. Pilot J.F. Hawes - Ch. Engr.	(8) Bell 206B (4) Bell 206A (3) Bell 47G-4A (1) DHC-6 Tw. Otter (1) Piper PA-30	

Company Name	Lic.	Key Personnel	Aircraft Type & No.	Comments
Multiple Access Limited, 405 Ogilvy Avenue, Montreal, P.Q., H3N 1M4	H		(1) Hughes 500	
Nahanni Helicopters Ltd. 4193 - 104th Street, Delta, B.C., V4E 1A5	H	W.D. Crowe - Pres. A.D. Thomas - V.P. A. Ascah - Ch. Pilot	(2) Bell 205A (1) Bell 47G-4A (1) Hughes 500 (4) Sikorsky S-55T (1) Sikorsky S-58	Ops. Base: Box 32, Fort Simpson, N.W.T., (403) 695-2265
Northern Mountain Helicopters Inc. Box 368, Prince George, B.C. V2L 4S2 (604) 963-9622, Tx. 047-8027	H	E.W. MacPherson - Gen. Mgr. D. Buchanon - Ch. Pilot R. Fessenden - Ch. Engr.	(6) Bell 206B (5) Bell 476-3B-2 (1) Piper PA-23	Ops. at Prince George and Fort St. James.
Northern Wings Helicopters Ltd. Montreal Int'l. Airport, Montreal 300, P.Q.	H		(7) Bell 206B (1) Bell 204B (2) Bell 47G-4A (1) Hughes 269 (4) Hughes 500	Ops. at Montreal and Sept. Isles.
Regasus Airlifts (Inspiration Helicopters) P.O. Box 340, King City, Ont., LOG 1KO	H		(1) Bell 206A (1) Bell 206B	See Dominion-Regasus Helicopters Ltd.

Company Name	Lic.	Key Personnel	Aircraft Type & No.	Comments
Pointe du Jour Aviation Engrg. 355 rue Notre-Dame, Repentigny, P.Q., J6A 2S7	HF			
Pultz Aviation Training Ltd., P.O. Box 201, McNabb Park, Saskatoon, Sask., S7K 3K4	HF	Vern Forbes - Mgr. G. McGuire - Asst. Mgr.	(1) Enstrom F28A (1) Beech D95A (2) Cessna 150 (1) Cessna 210 (15) Piper PA-28 (2) Piper PA-32 (4) Piper PA-34	
Quasar Aviation Ltd., 627 English Bluff Rd., Delta, B.C., V4M 2M9	H		(4) Bell 206B (1) Bell 47G-3B-2 (1) Hughes 500 (2) SA318C Al.II (3) Sikorsky S-55T	Operations at Abbotsford
Ranger Lake Helicopters Ltd. Suite 14, 78 Breton Road, Sault Ste. Marie, Ont.	H	R.F. MacRae - Pres. J.T. Pearce - Sec.Treas. R.A. Pearce - Ch.Pilot	(1) Bell 47G-4 (1) Bell 47G-4A	
Rocky Mountain Helicopters Ltd. P.O.Box 910, Invermere, B.C.	H		(3) Bell 206B (1) Bell 47G-3B (1) Bell 47G-3B-1 (1) Hughes 500	Subsidiary of Rotoflite.
Rotaire Helicopters Ltd.	H	M. Neville - Pres.	(2) Bell 47G-2	

Company Name	Lic.	Key Personnel	Aircraft Type & No.	Comments
Rotoflite Box 910, Invermere, B.C.	H			See Rocky Mountain Helicopters Ltd.
Sander Geophysics Ltd., 250 Herzberg Road, P.O. Box 13070, Kanata, Ont. K2K 1X3	HF		(1) Bell 47G-3B-2	
Sept-Isles Helicopter Services Ltd. P.O. Box 575, Sept-Isles, P.Q., G4R 4K7	H	J.H. Last - Mgr.	(8) Bell 206B (2) Bell 206A (1) Bell 204B (1) Bell 47G-4A (1) Bell 47J	Subsidiary of Les Helicopteres Trans - Quebec.
Terr-Air (Territorial Airways) Ltd. Ross River, Y.T., YOB 1SO Ph. 969-0040-41, Tx. 036-8-320	HF	J.W. Rolls - Pres. R. Newson - Ops. Mgr. W.L. Johnson - Ch.Pilot F/W D.P. Zutter - Ch. Pilot R/W	(2) Bell 206B (2) Bell 47G-3B-2 (1) Cessna 185 (1) DHC-2 Beaver (1) Fairchild F11 (1) Hiller UH12E (4) Hughes 500 (2) Pilatus PC6B (1) Twin Pioneer 1	
Totem Air Limited, P.O. Box 60, Fort Simpson, N.W.T. XOE ONO. (403) 695-2785	H	R.McBride- Owner; Mgr.	(2) Bell 206B (1) Bell 206A (1) Bell 47G-3 (1) SA341G Gazelle	

Company Name	Lic.	Key Personnel	Aircraft Type & No.	Comments
Trans-Canada Helicopters Ltd. 10105 Ave. Ryan, Dorval, P.Q. H9P 1A2	HF	W. Bates - Ops. Mgr.	(1) Bell 206A	Subsidiary of Les Helicopteres Trans-Quebec Ltee.
Trans North Turbo Air Limited P.O.Box 4338, Whitehorse Airport, Whitehorse, Y.T., Y1A 3T6 (403) 668-2177, 688-5111, Tx 0757779	HF	T.A.Kapty - Gen. Mgr. A. Meyer - Asst. G.M. R. B. Cameron - Ops Mgr.	(8) Bell 206B (5) Bell 47G-3B-2 (2) Beech 95 (1) Beech 55 (2) Cessna 185E (1) Cessna 402B (2) DHC-2 Beaver (2) DHC-2 Turbo Beaver (1) DHC-3 Otter (1) DHC-6 Tw. Otter (1) Hughes 500 (1) Piper PA-34 (1) Sikorsky S-55T	Operations at Whitehorse, Ross River, Atlin, Dawson, Mayo.
United Helicopters Limited, Room 206, Agri-Mart Bldg., Calgary, Alta.	HF	D.R. Ward - Owner, Mgr.	(1) Bell 47G-3B-1 (3) Bell 47G-3B-2 (1) Bell 47G-4A (1) Bell 47J-2 (5) Hughes 500 (1) Piper PA-23	
Vancouver Island Helicopters Ltd. P.O.Box 2095, Sidney, B.C., V8L 3S6	HF	A.L. Stringer - Pres.	(6) Bell 206B (1) Bell 47G-3B-1 (4) Bell 47G-3B-2 (1) Bell 47G-4	

Company Name	Lic.	Key Personnel	Aircraft Type & No.	Comments
Vernon Helicopters Ltd., R.R. #4, Vernon, B.C.	H		(1) Bell 206B (1) Bell 47G-3B-1	
Verreault Aviation Inc. Les Méchins, Cté Matane, P.Q.	H			
Versatile Air Services P.O. Box 130, Commercial Street, North Sydney, N.S.	H			
Yukon Airways Ltd., P.O. Box 4428, Whitehorse, Y.T. Y1A 3T5	HF		(2) Hiller UH12E (1) Hughes 500 (1) Cessna 172M (1) Cessna TU206 (1) Cessna 337 (1) Piper PA-34	

Table 4: REGISTERED AIRCRAFT OWNERS[1] HOLDING NO COMMERCIAL OPERATOR'S LICENCE OR HOLDING SUCH LICENCE (C) BUT NOT CLASS 7 AAD[2]

Registered Owner	Equip.	Lic.	Aircraft Type & Number
Airspray (1967) Ltd., Hangar #8, Mun. Arpt., Edmonton, Alta. T5G 2Z3	F	C	(4) Cessna 310 (4) Douglas A26B (5) Douglas B26
Aberson, W.H., P.O. Box 386, Dauphin, Man. R7N 2V2	F		(1) Piper PA-25
Atlantic Helicopters, Box 531, Stn. AMF, Montreal, P.Q., H4Y 1B3	H		(1) Bell 47G-2A (1) Vertol 42A
Balmer, C.P., P.O.Box 34, Elie, Man., ROH OHO	F		(1) Piper PA-25
Bar 40 Ranches Ltd., P.O. Box 1012, Fernier, B.C., VOB 1MO	F		(1) Call-Air S1B1
Bardar, J. & Miskey, D., Box 458, Stoney Plain, Alta., TOE 2GO	F		(2) Boeing A75N1

Note: 1. Aircraft owners registered as: a) Aerial applications companies or helicopter companies owning helicopters (H) and/or fixed-wing aircraft (F); b) private individuals owning fixed-wing aircraft of "specialty design - aerial applications".
2. Class 7: Specialty commercial air service: (i) "aerial application and distribution"; Canadian Transport Commission, "Directory of Canadian Commercial Air Services, 116 th Revision, August 15, 1976".

Registered Owner	Equip.	Lic.	Aircraft Type & Number
Bell, John, 1894 Bernard Rd., Windsor, Ont., N8W 4R4	F		(1) Call-Air A3
Benovsky, Paul, P.O. Box 177, Picture Butte, Alta., TOK 1V0	F		(1) Piper PA-25
Berger, Brian, P.O. Box 1318, High River, Alta., TOL 1B0	F		(1) Boeing E75
Boklaschuk, G., Warren, Man., ROC 3E0	F		(1) Piper PA-25
Briscoe, Roy G., 20649 - 90 Ave., R.R. #5, Langley, B.C. V3A 4P8	F		(1) Boeing D75N1
Bronson Aero Services Ltd., P. O. Box 744, Hope, B.C.	H		(1) Bell 47G-3B

Registered Owner	Equip.	Lic.	Aircraft Type & Number
Bublish, W.C., P.O. Box 463, Davidson, Sask., SOG 1A0	F		(1) Piper PA-25
Buffalo Helicopters Ltd., P.O.Box 232, Buffalo Narrows, Sask.	H		(1) Hiller UH12E
Cargair Ltee., St. Zenon, Cte. Berthier, P.Q., JOK 3N0	F	C	(1) Piper PA-25
Champion, D.J., P.O. Box 166, Donnelly, Alta., TOH 1G0	F		(1) Piper PA-25
Charolais Acceptance Ltd., Cut Knife, Sask., SOM 0N0	F		(1) Call-Air S1B1
Chieftain Aviation Ltd., 5003 - 59 Street, Delta, B.C., V4K 3J8	H		(1) Hiller UH12E
Coralta, Angus, Ltd., P.O.Box 353, Coronation, Alta., TOC 1C0	F		(1) Piper PA-25

Registered Owner	Equip.	Lic.	Aircraft Type & Number
Crop Protection Svcs. Ltd., R.R. #2, Hespeler, Cambridge, Ont.	F		(2) Piper PA-25
Donalda Air Ltd., Donalda, Alta., TOB 1HO	F		(1) Piper PA-25
Douglas, Richard, P.O. Box 355, Eatonia, Sask., SOL OYO	F		(1) Piper PA-25
Eatonia Airspray Ltd., P.O. Box 337 Eatonia, Sask., SOL OYO	F		(1) Cessna A188B (1) Cessna 180
Eastcoast Helicopters Ltd., 24 Canary Cres., Halifax, N.S.	H		(1) Bell 47G-2
Farmers Spraying Service, 302-1853 Hamilton St., Regina, Sask.	F		(1) Cessna 188B
Forgerson Spraying Ltd., 1133 - 1 Ave., N.W., Moose Jaw, Sask, S6H 3N4	F		(1) Cessna 188B

Registered Owner	Equip.	Lic.	Aircraft Type & Number
Frame, H.E. & M.E., P.O. Box 113, Consul, Sask., S0N 0P0	F		(1) Piper PA-25
Friedley, D.R., P.O. Box 191, Delia, Alta., T0J 0W0	F		(1) Cessna 188A
Gardiner, Irving L., P.O. Box 3659, Regina, Sask., S4P 3N8	F		(1) Piper PA-25
Gilvesy, John & George, R.R. #2, Tilsonburg, Ont., N4G 4G7	F		(1) Boeing A75N1 (1) DHC-1 Chipmunk (1) Piper PA-11
Graham, J.R., P.O. Box 1352, Kindersley, Sask., S0L 1S0	F		(1) Cessna 188
Gulay, Adam J., P.O. Box 31, Fisher Branch, Man., R0C 0Z0	F		(1) Piper PA-25
Harrington Air Service Ltd., Hangar #13A, Indl. Arpt., Edmonton, Alta.	F		(1) Boeing A75N1

Registered Owner	Equip.	Lic.	Aircraft Type & Number
Highwood Land & Cattle Co. Ltd., R.R. #3, High River, Alta.	F		(1) Boeing A75N1
Hoff, Max, Box 44, Gleichen, Alta., T0J 1N0	F		(1) Cessna 188
Husak, Peter, Grp. 201, Box 16, Winnipeg, Man., R3C 2E6	F		(1) Piper PA-25
Jackson, R.A., R.R. #7, Calgary, Alta.	F		(1) Cessna 188
Janz, B.R., P.O. Box 1872, Steinbach, Man., R0A 2A0	F		(1) Piper PA-25
Johnston, Stan, P.O. Box 489, Eston, Sask.,	F		(1) Piper PA-25
Kane, K, P.O. Box 861, Minnedosa, Man. R0J 1E0	F		(1) Piper PA-25 (1) Cessna 188B

Registered Owner	Equip.	Lic.	Aircraft Type & Number
Keenan, Alvin, Ltd., Woodstock, N.B.	F		(1) Grumman G164A
Kerkowich, F., General Delivery, Arden, Man., ROJ OBO	F		(1) Piper PA-25
Knox, David E., R.R. #1, Austin, Man., ROH OCO	F		(1) Piper PA-25
Kohls, R.M., P.O. Box 117, Golden Prairie, Sask., SON OYO	F		(1) Piper PA-25
Majeur Lefebvre Assoc. Inc., St. Dominique du Rosaire, P.Q., JOY 2KO	H		(1) Bell 206B (1) Bell 47G-4A
M & B Helicopter Service, 463 Agar Drive, Intl. Arpt., Vancouver, B.C.	H		(3) Hiller UH12E (1) Hiller UH12L4
McCord Helicopters Ltd., Hangar #2, Intl. Arpt., Calgary, Alta.	H		(1) Hughes 500

Registered Owner	Equip.	Lic.	Aircraft Type & Number
McLaughlin, Ken, Nampa, Alta., TOH 2RO	F		(1) Piper PA-25
Metro Helicopters Ltd., 901-100 Park Royal, West Vancouver, B.C.	H		(1) Bell 206B
M & M Farm Spraying Ltd., 210 Birks Blvd., Saskatoon, Sask.	F		(1) Cessna 182A
Moore, Larry, Bentley, Alta., TOC 0J0	F		(1) Piper PA-25
Ness, Irving, New Brigden, Alta., TOJ 2G0	F		(2) Piper PA-25
Nolan, Brian, P.O. Box 280, Rouleau, Sask., SOG 4H0	F		(2) Piper PA-25
North Delta Copters Ltd., 6435 - 64 St., Delta, B.C. V4K 3N3	H		(1) Hiller UH12E

Registered Owner	Equip.	Lic.	Aircraft Type & Number
Northern Helicopters, R.R. #1, Abbotsford Arpt., Abbotsford, B.C.	H		(1) Bell 47G-2 (2) Bell 47G-3B (1) Bell 47G-3B-1
Pacific Rim Helicopters Ltd., 149 - 15 St. E., North Vancouver, B.C.	H		(1) Hiller UH12E
Pacific Northwest Helicopters, Box 549, Qualicus Beach, B.C.	H		(1) Bell 47G-3B-1
Paterson, J.N., 1735 McGregor Ave., Thunder Bay, Ont.	F		(1) Boeing A75N1
Phillips Aero Service Ltd., 616 - 2 Ave., N.W., Calgary, Alta.	H		(1) Bell 47G-2
Pomeroy, C.S., P.O. Box 565, Souris, Man. ROK 2CO	F		(1) Piper PA-25
Pouliot Helicopters Ltd., Chomedey, P.Q.	H		(1) Hughes 269B

Registered Owner	Equip.	Lic.	Aircraft Type & Number
Russell Airspray Ltd., Milk River, Alta., TOK 1MO	F		(1) Piper PA-25
Sam's Discount Warehouse Ltd., R.R. #5, Langton, Ont., NOE 1GO	F		(2) Boeing A75N1 (1) Cessna 188
Sande, R. E., P.O.Box 68, Watson Lake, B.C.	F		(1) Boeing B75N1
Schultz, Elmer, P.O. Box 988, Vegreville, Alta., TOB 4LO	F		(1) Piper PA-25
Semochko, Metro J., Russell, Manitoba, ROJ 1WO	F		(1) Piper PA-25 (1) Cessna 188
Shook, Alan E., Wymark, Sask, SON 2YO	F		(1) Piper PA-25
Searphol, Mark, P.O.Box 35, Frontier Sask. SON OWO	F		(1) Piper PA-25

Registered Owner	Equip.	Lic.	Aircraft Type & Number
Skyway Air Services Ltd., 5385 - 216 St., Langley, B.C.	F	C	(1) Boeing A75N1
Smith, Stanley, Box 26, R.R. #3, Regina, Sask., S4P 2Z3	F		(1) Piper PA-25
Sorenson, H.C. P.O. Box 368, Yellowknife, N.W.T., XOE 1HO	F		(1) Boeing A75N1
Summit Helicopters Ltd., 403 North Road, Coquitlam, B.C.	H		(1) Hiller UH12E
Summers Agricultural Aviation Services, R.R. #5, Calgary, Alta.	F		(1) Piper PA-34
Teichrib, G & J R.R. #1, Gladstone, Man., ROJ OTO	F		(1) Piper PA-25
Thiessen, A.W., P.O.Box 27, Forestburg, Alta., TOB 1NO	F		(1) Piper PA-25

Registered Owner	Equip.	Lic.	Aircraft Type & Number
Thomas Air Spray Ltd., P.O. Box 94, Vanscoy, Sask., SOL 3J0	F		(1) Cessna A188B
Tonque Creek Avaition Ltd., R.R. # 1, High River, Alta., TOL 1B0	F		(1) Piper PA-25
Touchette, Andre, St. Malo, Man., R0A 1T0	F		(1) Piper PA-25
Unity Spray Service Ltd., P.O. Box 3, Unity, Sask., S0K 4L0	F		(1) Grumman G164A
Valley Helicopters, 1 Lombard Pl, 30th Flr., Winnipeg, Man.	H		(1) Bell 206B (1) Bell 47G-4A
Varjassy, J.A., Meadow Lake, Sask., S0M 1V0	F		(1) Cessna 188
Wheeler Northland Airways Ltd., P.O. Box 217, St. Jean, P.Q.	F		(1) Boeing A75N1

Registered Owner	Equip.	Lic.	Aircraft Type & Number
Wittwer, John & Margaret, P.O. Box 988, Stettler, Alta., TOC 2LO	F		(1) Piper PA-25

Table 4a): SUPPLEMENTAL LIST AMENDING ' TABLE 4': ADDITIONAL OWNERS OF CESSNA MODEL 188 AGWAGON/AGTRUCK

Registered Owner	Equip.	Lic.	Aircraft Type & Number
Ayotte, A. and Opocensky, G., Letellier, Man. ROG 1CO	F		(1) Cessna A188B
Bethune, R.J. and Sawicki, W.J., Box 712, Melfort Sask. SOE 1AO	F		(1) Cessna A188B
Collins, W.J., Box 170, Grp. 261, R.R. #2, Winnipeg, Man.	F		(2) Cessna A188
Foreman, Brian Spring Valley, Sask., SOH 3XO	F		(1) Cessna A188A
Gobert, R.G., Box 14, Grp. 37, SS5, Winnipeg, Man.	F		(1) Cessna A188B
Groeneveld, D.J., R.R. #3, High River, Alta. TOL 1BO	F		(1) Cessna A188B

Registered Owner	Equip.	Lic.	Aircraft Type & Number
Hewitt, L., Box 596, Carlyle, Sask. SOC ORO	F		(1) Cessna A188B
Lacasse, G., 219 Duncan Rd., Estevan, Sask., S4A OA3	F		(1) Cessna A188B
Lange, N., Rosser, Manitoba, ROH 1EO	F		(1) Cessna A188
Letkeman, J., R.R. #1, Austin, Man., ROH OCO	F		(1) Cessna A188B
Schick, J., Spring Valley, Sask., SOH 3XO	F		(1) Cessna A188
Schmit, J.P. Box 494, Davidson, Sask., SOG 1AO	F		(1) Cessna A188B

Registered Owner	Equip.	Lic.	Aircraft Type & Number
Springbank Aviation Ltd., Box 4, Site 16, R. R. # 2, Calgary, Alta.	F		(1) Cessna A188
Williams, Ivan, Box 192, Virden, Man. ROM 2CO	F		(1) Cessna A188B
Yaworski, A., Box 130, Viscount, Sask. SOK 4MO	F		(1) Cessna A188B

Table 5: GOVERNMENT AGENCIES OWNING AND OPERATING AIRCRAFT

Agency Name	Lic.	Key Personnel	Aircraft Type & No.
Alberta, Prov. of, Air Div., 11940 - 109th Street, Edmonton, Alta., T5G 2T8			(4) Bell 206B (2) Bell 47J-2 (1) Beech 200 (1) Beech 100 (1) Beech 70 (2) Dormier DO28B1 (1) Douglas DC-3C
Alberta, Prov. of, Lakeland College, Vermillion, Alta., TOB 4MO			(2) Bellanca 8GCBC
British Columbia Department of "Com Trans Commu", 2631 Douglas St., Victoria, B.C.			(2) Beech D18S (2) Beech 200 (1) Beech 3NM (3) Cessna 500 (1) DHC-2 Beaver (1) DHC-3 Otter
British Columbia Dept. of Education, 3650 Willingdon St., N. Burnaby, B.C., V5G 3H1			(1) Cessna 172H (1) Cessna 180G
British Columbia Hydro & Power Auth., 970 Burrard St., Vancouver, B.C.			(1) Mitsubishi MU2B20

Agency Name	Lic.	Key Personnel	Aircraft Type & No.
British Columbia Telephone Co., 768 Seymour Street, Vancouver, B.C. V6B 3K9			(1) Cessna 500
Canadore College of Applied Arts, & Technology, Box 5001, North Bay, Ontario P1B 8K9	7RF 7FT		(1) Bell 206B (1) Bell 47G-4 (7) Bell 47G-2 (1) Bell 47G
College d'Enseignement General, et Professionnel de Chicoutimi, 534 rue Jacques-Cartier, Chicoutimi, P.Q.	7FT		(1) Bell 47G-4A (1) Beech A24R (4) Beech 19A (1) Beech B23 (1) Beech 9585B (1) Cessna 185 (1) Cessna 172
Churchill Falls Labrador Corp., Box 256, Churchill Falls, Labr.	5		(3) Bell 206A (1) Bell 205A (1) Hawker Siddley DH125
Energy, Mines & Resources, Dept. of, 601 Booth St., Ottawa, Ont.			(1) Bell 47G (1) Beech 65B80 (2) Douglas DC-3C (1) Mystere 20C (1) Short & Harland SC7
Environment, Dept. of 25 Pickering Place, Ottawa, Ont.			(1) Cessna A185E

Agency Name	Lic.	Key Personnel	Aircraft Type & No.
Forest Protection Limited P. O. Box 1030, Fredericton, N.B., E3B 5C3		H. J. Irving - Manager	(25) Grumman TBM3
Manitoba, Province of, Air Div., P.O. Box 39, Lac du Bonnet, R0E 1A0	7 AAM	J. MacDonald - Dep. Min. Transp.	(3) Cessna 180H (4) Cessna 337 (6) DHC-2 Beaver (5) DHC-2 Turbo Beaver (2) DHC-3 Otter (1) MU2B35 (5) Piper PA-23 (2) Piper PA-30
Newfoundland & Labrador, Govt. of, Confederation Building, St. John's, Nfld.			(1) Beech A100 (4) Consol. PBY5A (1) Consol. 285ACF (1) Piper PA-18
New Brunswick, Prov. of, Centennial Building, Fredericton, N.B.	4 9-4		(1) Beech 200
National Research Council of Canada, Montreal Rd., NAF, Ottawa, Ont.			(1) Bell 206A (1) Bell 205A (1) Bell 47G (1) Bell 47G-3B-1 (1) Beech 3NM (1) Canadair DC-4M (2) Canadair T-33 3 (1) Convair 580 (1) DHC-6 Tw. Otter (1) Harvard IV

Agency Name	Lic.	Key Personnel	Aircraft Type & No.
Nova Scotia Power Corporation, P.O. Box 910, Halifax, N.S.			(2) Hughes 500
Nova Scotia, Province of, Dept. of Lands & Forests, C.P. 23, R.R. #1, Waverly, N.S.			(2) Bell 206B (3) DHC-2 Beaver (2) Piper PA-18
Ontario Ministry of Natural Resources, P.O. Box 310, Sault Ste. Marie, Ont. Queens Park: (416) 965-2781 S.S.Marie (705) 949-1231	4 9-4 7AC 7AAD 7APS 7AP 7AIRA	W.B. Cleaveley - Exec. Dir., Fld. Svcs. Div. I.C. Cook - Dir, Air Svc. Branch	(1) Beech A100 (1) DHC-2 Beaver (21) DHC-2 Turbo-Beaver (10) DHC-3 Otter (3) DHC-6 Tw. Otter (6) Grumman CS2F
Ontario Hydro, 2450 Derry Road E., Mississauga, Ont. L5S 1B2	7AAM	S. King - Supt. Hel. Sect. A. Campbell - Ch. Engr.	(3) Bell 206B (1) Bell 47G-2A (1) Bell 47G-4 (2) Bell 47G-4A (1) Hughes 500 (2) Sikorsky S-58T
Ontario Provincial Police		E.S. Loree, Asst. Comm., Special Svcs.	(2) Bell 206B

Agency Name	Lic.	Key Personnel	Aircraft Type & No.
Quebec, Govt. of, Ministry of Transport Airport Quebec, Ste. Foy, P.Q., G2E 3L9		B. Ste. Marie - Dir. L. Desaulnier - Ch. Pilot G. Smith - Ch. Engr.	(5) Bell 206B (15) Canadair CL215 (6) Comsol. PBY5A (2) DHC-2 Beaver (1) Douglas DC-3A (2) Fairchild F27F (1) H.S. DH-125 (1) Hughes 500
R.C.M.P. Air Services, International Airport, Ottawa, Ont. K1A 0R2		W. Peid - Ch. Supt. Air Div.	(3) Bell 206B (1) Bell 212 (4) DHC-2 Beaver (2) DHC-2 Turbo-Beaver (6) DHC-3 Otter (7) DHC-6 Tw. Otter (1) Grumman G21A
Saskatchewan, Prov. Of Rm. 203, C.I.S. Bldg., Regina, Sask.	4 9-4	A. Davis - Ch. Pilot	(2) Beech 95B55 (3) Cessna 185 (1) Cessna 195 (1) Piper PA-23 (1) Piper PA-31 (1) Piper PA-31T

Agency Name	Lic.	Key Personnel	Aircraft Type & No.
Transport, Ministry of			(10) Bell 206B
P.O. Box 819,			(10) Bell 206A
R.R. #5,			(4) Bell 212
Ottawa, Ontario.			(6) Bell 47G-2
			(6) Beech A100
			(1) Beech 56TC
			(2) Beech 65-90
			(6) Beech 65A90
			(8) Beech 65B80
			(7) Beech 95B55
			(1) Cessna 337C
			(5) DHC-2 Beaver
			(2) DHC-6 Tw. Otter
			(2) Douglas C47A
			(4) Douglas DC-3C
			(4) Lockheed 1329
			(1) Sikorsky S-61N
			(1) Viscount 737
			(1) Viscount 797
			(3) SA316C Al. III

Table 6: FORESTRY AND RELATED INDUSTRIES PRIVATELY OWNING AND OPERATING HELICOPTERS ONLY (H) OR HELICOPTERS AND FIXED-WING AIRCRAFT

Company Name	Equip.	Key Personnel	Aircraft Type & Number
Ainsworth Lumber Co. Ltd. P.O. Box 67, 100-Mile House, B.C.	HF		(1) Bell 47G-3B-2 (1) Cessna 185
A & L Lafreniere Lumber Ltd., P.O. Box 340, Chapleau, Ont., POM 1KO	HF	L. Lafreniere - Pres.	(1) Bell 47G-2 (1) Fleet 80
B.C. Forest Products Ltd., 1050 Pender St., W., Vancouver, B.C. (604) 682-1444	HF	H. Dembicki - V.P. Logging & Wood Supply.	(1) Bell 206A (1) DHC-2 Beaver (1) Lear Jet 25B
Hrbinic Logging Ltd., P.O. Box 4533, Quesnel, B.C. V2J 3J8	H		(1) Bell 47J-2
Irving, J.D. Ltd. (Irving Oil Transp./ Forest Patrol Ltd.) P.O. Box 157, Saint John, N.B.	HF		(1) Bell 206B (4) Aero Comm. S2R (1) Aero Comm. 500S (1) Douglas B26C (1) H.S. DH 125

Company Name	Equip.	Key Personnel	Aircraft Type & Number
Kimberly Clark of Canada Ltd., Terrace Bay, Ont., POT 2W0	HF	G. L. Puttock - Pres. D. Penna - V.P. Ops. B. Davis - Pilot	(1) Bell 206L (1) Piper PA-23
L. & K. Lumber Co. (N.S) Ltd., P. O. Box 86219, N. Vancouver, B.C.	H		(1) Bell 206B
Malloch & Moseley,Logging Co. Ltd., 2610 Sooke Rd., Victoria, B.C.	H		(1) Bell 47G-2
Milne, J.F. & Sons Lumber Co. Ltd., P.O. Box 237, North Bay, Ont. P1B 8H2	H	J.W. McNutt - Pres.	(1) Bell 47G-2
Normick, J.H. Inc., P.O. Box 2500, La Sarre, P.Q., J0Z 2M0	HF	M. Perron - Pres. F. Burrows - Wdlds. Mgr.	(1) Bell 206A (1) Bell 476-4A (1) Piper PA-18S
Norie Bros. Logging Co. Ltd., P.O. Box 217, Campbell River, B.C.	HF	H.C. Norie, Pres.	(1) Bell 206B (2) Bell 47G-2 (1) Republic RC3

Company Name	Equip.	Key Personnel	Aircraft Type & Number
Nova Lumber Co. Ltd. 200 Bridge St., N. Vancouver, B.C.	HF		(1) Bell 206B (1) Cessna 185
Nudanmyra Clearing Contr. Ltd., 7-7319 Monte Cito, Burnaby, B.C.	H		(1) Bell 47J-2
Pallan Timber Products Ltd., P.O. Box 47, Campbell River, B.C. V9W 4Z9	H		(1) Bell 47G-2
Proctor & Gamble Company of Canada Ltd., 2 St. Clair Ave. W., Toronto, Ont.	HF	R.N. O'Brien - Woodlands Mgr., Grande Prairie, Alta.	(1) Bell 206B (1) Helio H295
Williams Logging Co. Ltd. P.O. Box 6, Yale, B.C. VOK 2SO	H		(1) Bell 47J-2

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APPENDIX E

GENERAL SUMMARY OF FIXED-WING AIRCRAFT IN CANADIAN FOREST PEST MANAGEMENT, 1927 - 1975

APPENDIX E - GENERAL SUMMARY OF FIXED-WING AIRCRAFT IN CANADIAN FOREST PEST MANAGEMENT, 1927 - 1975*

Year	Prov.	Aircraft	Equip.[3]	Acreage[1a]	Insect	Chemical[4]	Cost/Ac.[2a]
1927	N.S.	Keystone Puffer			Spruce budworm	Calc. arsen. dust	$ 6.00
1928	Ont.	Keystone Puffer			Spruce budworm	Calc. arsen. dust	6.00
		DH-61			E. hem. looper	Calc. arsen. dust	
1929	B.C.	Boeing Flying Boat		45	W. hem. looper	Calc. arsen. dust	10.50
	Ont.	Ford Tri-motor		N/A	Spruce budworm	Calc. arsen. dust	6.00
		DH-61		1,000	E. hem. looper	Calc. arsen. dust	
	Que.	Ford Tri-motor		1,500	E. hem. looper	Calc. arsen. dust	6.00
1930	B.C.	Boeing Flying Boat		1,600	W. hem. looper	Calc. arsen. dust	8.00
1944	Ont.	White Standard	S.D.	N/A	Spruce budworm	DDT	
1945	Ont.	White Std. Canso	G.O.P.	65,000	Spruce budworm	DDT	
		Waco custom		N/A	Spruce budworm	DDT	
1946	B.C.	Canso	G.O.P.	12,500	W. hem. looper	DDT	1.53[2b]
	Ont.	Canso	b & n	23,700	Spruce budworm	DDT	
1950	Ont.	Piper J3, Seabee, Cessna T50		N/A	Forest Tent Caterpillar	DDT	5.00
1951	Ont.	Piper J3, Seabee, Cessna T50		N/A	Forest Tent Caterpillar	DDT	5.00
1952	N.B.	Stearman, DHC-2		200,000	Spruce budworm	DDT	2.51
	Ont.	Piper J3, Seabee, Cessna T50		N/A	Forest Tent Caterpillar	DDT	5.00
		DHC-2 Beaver	b & n	10	E. hem. looper	DDT	
		Piper J3 Cub	b & n	100	Eur. pine sawfly	Virus (NPV)	
		Douglas DC-3		N/A	Spruce budworm	DDT	
	Que.	DHC-2 Beaver		8,000	Spruce budworm	DDT	
1953	N.B.	Stearman		1,800,000	Spruce budworm	DDT	1.38
	Que.	Stearman		1,000	Spruce budworm	DDT	
1954	N.B.	Stearman		1,100,000	Spruce budworm	DDT	1.05
	Que.	Stearman		318,000	Spruce budworm	DDT	
	Sask.	Piper J3 Cub	b & n	N/A	Larch sawfly	Malathion	
1955	N.B.	Stearman		1,100,000	Spruce budworm	DDT	.84
	Ont.	Piper J3 Cub		20	E. hem. looper	DDT	
	Que.	Stearman		1,040,000	Spruce budworm	DDT	

Year	Prov.	Aircraft	Equip.[3]	Acreage[1]	Insect	Chemical[4]	Cost/Ac.[2a]
1956	B.C.	Stearman		360	W. black-headed budworm	DDT	6.33[2b]
		Stearman		200	Phanton hem. looper	DDT	
	N.B.	Stearman		2,000,000	Spruce budworm	DDT	.82
	Que.	Stearman		400,000	Spruce budworm	DDT	
1957	B.C.	Grumman TBM	b & n	156,000	W. black-headed budworm	DDT	1.62
		Stearman		275	Phantom hem. looper	DDT	
	N.B.	Stearman		5,200,000	Spruce budworm	DDT	.65
	Ont.	Fixed-wing		33	White pine Weevil	DDT	
	Que.	Stearman		1,255,000	Spruce budworm	DDT	
1958	B.C.	Fixed-wing		N/A	Striped ambrosia beetle	BHC	
	N.B.	Stearman, TBM		2,600,000	Spruce budworm	DDT	.61
	Que.	Stearman, TBM		760,000	Spruce budworm	DDT	
1959	B.C.	Grumman TBM	b & n	550	W. hem. looper	DDT	
1960	B.C.	Grumman TBM	b & n	31,500	W. black-headed budworm	DDT	1.94
		Grumman TBM	b & n	N/A	W. black-headed budworm	BT	
		Grumman TBM	b & n	1,800	Saddle-backed looper	DDT	
	N.B.	Stearman, TBM		2,600,000	Spruce budworm	DDT	.56
		Stearman	b & n	60	Spruce budworm	BT	
	Que.	Stearman		33,000	Spruce budworm	DDT	
		Fixed-wing		2,055	Gypsy moth	DDT	1.25
		Stearman	b & n	N/A	Swaine jack pine sawfly	Virus (NPV)	
1961	N.B.	Stearman, TBM	b & n	2,200,000	Spruce budworm	DDT	.60
	Que.	Stearman		77,000	Spruce budworm	DDT	
		Fixed-wing		1,600	Gypsy moth	Sevin 85 P	4.40
1962	B.C.	Stearman		N/A	Doug. fir tussock moth	DDT, Malathion	
	N.B.	Stearman, TBM	b & n	1,400,000	Spruce budworm	DDT	.63
		Stearman	b & n	50	Spruce budworm	B.T.	
	Que.	Stearman		69,000	Spruce budworm	DDT	
		Fixed-wing		1,600	Gypsy Moth	Sevin 80S	3.84
1963	N.B.	Stearman, TBM	b & n	700,000	Spruce budworm	DDT, Phos.	.62
	Que.	Fixed-wing		2,000	Gypsy moth	Sevin 80S	3.45
1964	Man.	Fixed-wing		N/A	Fall cankerworm	DDT	
	N.B.	Stearman, TBM	b & n	2,000,000	Spruce budworm	DDT, Phos.	.73
	Que.	Fixed-wing		2,000	Gypsy moth	Sevin 80S	3.13
		Stearman	b & n	4,000	Swaine Jack pine sawfly	Virus (NPV)	

Year	Prov.	Aircraft	Equip.[3]	Acreage[1]	Insect	Chemical[4]	Cost/Ac.[2a]
1965	Man.	Piper J3 Cub		250	Fall cankerworm	DDT, Dylox, Matacil	$
	N.B.	Stearman, TBM		2,100,000	Spruce budworm	DDT, Phos.	.81
	Que.	Fixed-wing		900	Gypsy moth	Sevin 80S	2.63
		Stearman	b & n	150,000	Swaine jack pine sawfly	Phos	
1966	N.B.	Stearman, TBM		2,000,000	Spruce budworm	DDT, Phos.	1.00
	Que.	Fixed-wing		300	Gypsy moth	Sevin 80S	3.47
1967	Man.	Piper PA-25	b & n	1,580	Jack pine budworm	DDT, Aminocarb, Fenit.	
	N.B.	Stearman, TBM		1,000,000	Spruce budworm	DDT, Phos., Fenit.	.94
	Que.	Fixed-wing		18,000	Gypsy moth	Sevin 80S	2.81
		Stearman	b & n	90,000	Swaine jack pine sawfly	Phos., Fenit.	
1968	N.B.	Grumman TBM		500,000	Spruce budworm	DDT, Phos., Fenit.	.92
	Nfld.	Grumman TBM		431,000	E. hem. looper	Phos., Fenit.	.95
		Stearman		N/A	Balsam fir woolly aphid	Baygon, Dursban, Diazinon, Furadan	
	Ont.	Stearman	b & n	280,000	Spruce budworm	Fenit., Phos.	.90[2c]
		Stearman	b & n	4,000	Jack pine budworm	Fenit.	
		Stearman, Grum. 164A	b & n	1,410[1b]	White pine weevil	Methoxychlor	
	Que.	Fixed-wing		15,000	Gypsy moth	Sevin 80S	2.59
1969	N.B.	Grumman TBM		3,100,000	Spruce budworm	Fenit. Phos.	.54
		Stearman		240	Spruce budworm	BT	
		Grumman 164A	b & n	17,000	SBW (Adult Moths)	Phos.	
	Nfld.	TBM, DC-3, Pilatus Porter		2,054,900	E. hemlock looper	Fenit., Phos.	.70
	Ont.	Stearman	b & n	26,000	Spruce budworm	Fenit., Phos.	.90[2c]
		Stearman	b & n	10,800	Jack pine budworm	Fenit.	
		Stearman, Gum. 164A	b & n	1,410[1b]	White pine weevil	Methoxychlor	
	Que.	Fixed-wing		6,000	Gypsy moth	Sevin 80S	2.59
1970	N.B.	Grumman TBM		4,200,000	Spruce budworm	Fenit.	.50
	Ont.	Stearman, Grum. 164A	b & n	23,250	Spruce budworm	Fenit.	.90[2c]
		Fixed-wing		6,000	Gypsy moth	Sevin 80S	3.14
		Stearman, Grum. 164A	b & n	2,250	White pine weevil	Methoxychlor	
	Que.	Stearman		24,300	Spruce budworm	Fenit.	
		Stearman	b & n	2,700	Jackpine budworm	Fenit.	
		Fixed-wing		1,000	Gypsy moth	Sevin 80S	3.14

Year	Prov.	Aircraft	Equip.[3]	Acreage[1]	Insect	Chemical[4]	Cost/Ac.[2a]
1971	N.B.	Grumman TBM		6,000,000	Spruce budworm	Fenit.	.42
	Ont.	Stearman	b & n	81,000	Spruce budworm	Fenit.	.90[2c]
		Fixed-wing		8,000	Gypsy moth	Sevin-4-oil	3.14
		Stearman, Grum. 164A	b & n	1,460	White pine weevil	Methoxychlor	
	Que.	Grumman TBM		2,116,376	Spruce budworm	Fenit.	
		Grumman TBM	b & n	200	Spruce budworm	BT	
1972	N.B.	Grumman TBM	b & n	4,600,000	Spruce budworm	Fenit., Phos.	.43
		Stearman	Micr.	16,000	SBW (Adult Moths)	Fenit., Phos.	
	Ont.	Stearman, Grum. 164A	Micr.	46,500	Spruce budworm	Zectran	.90[2c]
		Stearman	Micr.	2,000	Spruce budworm	Fenit.	
		Grumman 164A	Micr.	480	Spruce budworm	BT	
		Grumman 164A	Micr.	1,920	Spruce budworm	Virus	
		Stearman	Micr.	360	Spruce budworm	Mbl.+ Chem. Insd	
		Grumman 164A	Micr.	1,800	Jackpine budworm	Zectran	
		Fixed-wing		12,000	Gypsy moth	Sevin-4-oil	2.44
		Stearman, Grum. 164A	Micr.	1,900	White pine weevil	Methoxychlor	4-5.00
		Piper PA-25	b & n	500[1c]	White pine weevil	Methoxychlor	
	Que.	TBM, DC-7B	b & n	1,672,600	Spruce budworm	Fenit., Matacil, Zectran	
		Grumman TBM	b & n	10,300	Spruce budworm	BT	
		Grumman TBM	b & n	19,560	Jackpine budworm	Fenit.	
		Grumman TBM	b & n	425,000	E. hemlock looper	Fenit.	
				17,585	Sw. jack pine sawfly	Fenit.	
1973	B.C.	Grumman TBM		28,800	W. black-headed b.w.	BT	1.37
		Cessna 188	b & n	275	W. false hem. looper	BT	
	Man.	Cess. 188, PA-25	M,bn	8,125	Spruce budworm	Fenit., Sevin-4-oil	
		Cessna 188	Micr.	200	Spruce budworm	BT	
	N.B.	Grumman TBM	b & n	4,200,000	Spruce budworm	Fenit., Phos.	.43
		Grum. 164A	b & n	1,625	Spruce budworm	Growth reg.	
		Grumman TBM	b & n	340,000	SBW (Adult Moths)	Phos.	
	Ont.	Stearman, Grum 164A	Micr.	88,300	Spruce budworm	Zectran	.90[2c]
		Stearman, Cess. 188	Micr.	5,750	Spruce budworm	Fenit.	
		Stmn., C188, G164A, PA-25	Micr.	3,420	Spruce budworm	BT	
		Grum. 164A	Micr.	735	Spruce budworm	Virus	
		Stearman, PA-25	Micr.	525	Spruce budworm	Mbl. + Chem. Insd	
		Stmn, G164A, PA-25	Micr.	3,000[1c]	White pine weevil	Methoxychlor	
		Stearman	Micr.	1,300	Oak leaf shredder	Sevin-4-oil	2.37
		Fixed-wing		3,500	Gypsy moth	Disparlure	

Year	Prov.	Aircraft	Equip.[3]	Acreage[1]	Insect	Chemical[4]	Cost/Ac.[2a]
1973	Que.	Grumman TBM	b & n	300	Spruce budworm	BT	
		CL-215	b & n	10,300	E. hem. looper	Fenit.	
		DC-68, TBM, CL-215, LPV-2, L749, L1049	b & n	9,882,000	Spruce budworm	Fenit., Phos., Matacil	
1974	B.C.	Cessna 188	b & n	90	False hem. looper	BT. Juv. hormone	
		Cessna 188	b & n	25	Doug. fir tuss. moth	BT. Juv. hormone	
	Man.	Piper PA-25	b & n	1,850	SBW, jack pine BW	Fenit.	
	N.B.	Grumman TBM		3,892,000	Spruce budworm	Fenit., Phos.	
		Grum. G164A		33,000	Spruce budworm	Dylox	
		Cessna 188		600	Spruce budworm	CGA 13353	
		TBM, DC-6B		2,000,000	SBW (Adult Moths)	Phos.	
	Ont.	Stearman, G164A	Micr.	48,000	Spruce budworm	Zectran, BT	
	Que.	DC-6B, L-1049, L-749, CL-215	b & n	6,350,000	Spruce budworm	Fenit., Matacil, Zectran, BT	
1975	Man.			50	Spruce budworm	Fenit.	
				1,280	Jack pine budworm	Fenit. Mal.	
				2,780	For. tent caterpillar	Malathion	
	N.B.	TBM, Cess. 188	b & n	6,600,000	Spruce budworm	Mat., Fenit., Phos. Dylox, BT	
		Thrush Comm.	b & n	752,000	Spruce budworm	Fenit. Phos.	
	Ont.	Stearman, G164A	Micr.	33,400	Spruce budworm	Dylox, Fenit.	
	Que.	DC-6B, DC-4, L-749 L-1049	b & n	7,133,700	Spruce budworm	Fenit., Mal., Phos., BT, Zectran, Dylox, Dim.	

Explanatory Notes

1. a) Acreage refers, in each case, to the total area treated and does not reflect the fact that some areas may have been treated more than once for the same pest during the same year.

   b) A total 2810 acres were treated during 1968 and 1969 in connection with the same programs, but no annual breakdown was available. Therefore this was divided equally between the two years for the sake of convenience.

   c) A total of 1,000 acres were treated during 1972 and 1973 in connection with the same program, but no annual breakdown was available. This was divided equally between the two years for convenience sake and, for 1973, the 500 acres was added to a separate 1973 project which involved 2,500 acres, using the same chemicals and equipment to control the same insect.

2. a) Cost per acre is shown where available. Most costs shown represent operational programs.

   b) Does not include salaries of permanent staff of participating government agencies or forest industry.

   c) Average cost during the course of the program.

3. Equipment Abbreviations:

SD	- Spinning disc apparatus
Gop	- Gravity-feed, open pipe
b & n	- Boom and nozzle
Micr.	- Micronair, air-driven, spinning cage

4. Chemical Abbreviations:

Calc. arsen	- Calcium arsenate dust
NPV	- Nuclear polyhedrosis virus
BT	- Bacillus thuringiensis
Phos.	- Phosphamidon
Fenit.	- Fenitrothion
Mbl	- Microbial
Chem. Insd.	- Chemical insecticide
Mal.	- Malathion
Dim.	- Dimethoate

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* In the compilation of this table, general and specific reference was made to those authors, given as references in the general References list of this report, who contributed Chapters concerning the various insects and treatments indicated in this Table in 'Aerial Control of Forest Insects in Canada', M.L. Prebble, Editor, D.O.E. C.F.S. Publ. No. F023/19/1975.

APPENDIX F

CLASSIFICATION OF AIR CARRIERS AND AIRCRAFT GROUPS

APPENDIX F: CLASSIFICATION OF AIR CARRIERS AND AIRCRAFT GROUPS

I. CLASSIFICATION OF AIR CARRIERS

(a) Class 1: Scheduled commercial air service, being a service that is operated wholly within Canada and that is required to provide public transportation of persons, goods or mail by aircraft, serving points in accordance with a service schedule at a toll per unit of traffic;

(b) Class 2: Regular Specific Point commercial air service, being a service that is operated wholly within Canada and that is required to provide, to the extent that facilities are available, public transportation of persons, goods or mail by aircraft, serving points in accordance with a service pattern at a toll per unit of traffic;

(c) Class 3: Specific Point commercial air service, being a service that is operated wholly within Canada and that offers public transportation of persons, goods or mail by aircraft, serving points consistent with traffic requirements and operating conditions at a toll per unit of traffic;

(d) Class 4: Charter commercial air service, being a service that is operated wholly within Canada and that offers public transportation, on reasonable demand, of persons or goods from the base specified in the licence issued for that commercial air service of the base declared by the Committee to be the protected base for that commercial air service at a toll per mile or per hour for the charter of an entire aircraft, or at such other tolls as may be allowed by the Committee, and includes recreational flying;

(e) Class 5: Contract commercial air service, being a service that is operated wholly within Canada from the base specified in the licence issued for that commercial air service, that offers transportation of persons or goods solely under contracts of carriage with users with whom the air carrier has a substantial relationship through corporate structure or financial control and that does not hold out to the general public, or a class or segment thereof, the offer of transportation by air;

(f) Class 6: Flying Club commercial air service, being a service that is operated wholly within Canada from the base specified in the licence issued for that commercial air service and that provides flying training and recreational flying to members of a flying club incorporated as a non-profit organization;

(g) Class 7: Specialty commercial air service, being a service that is operated from the base specified in the licence issued for that commercial air service for any purpose not provided for by any other class of service and, without limiting the generality of the foregoing, for any of the following purposes:

(i) "aerial application and distribution", being the application of chemicals or distribution of other materials from aircraft to

(A) inhibit and destroy insect life and other forms of organism injurious to plants, crops and forests, or

(B) foster the growth of crops, forests or fish

including agricultural flying, aerial pest control, spraying, seeding and reseeding, forest cultivation and fish cultivation;

(ii) "aerial construction", being the use of rotating wing aircraft in construction work, including aerial hoisting, mountain tram line construction, aerial pole setting and aerial power line construction;

(iii) "aerial control", being fire suppression, fire or frost prevention or altering the normal processes of weather, including aerial fire control, forest fire protection, firefighting, forest firefighting, forest protection, water pumping, forest control, hail suppression, aerial frost control, rain making, fog dispersal and cloud seeding;

(iv) "aerial inspection, reconnaissance and advertising", being

(A) the reporting from aerial observation upon events, natural phenomena related to man-made objects, or

(B) the providing of visual messages in the atmosphere, including aerial patrol and inspection, ice reconnaissance, seal spotting, forest inspection and administration, forest pathol, pipeline patrol, powerline patrol, news service and aerial advertising;

(v) "aerial photography and survey", being

(A) the taking of photographs or the recording in other tangible form of phenomena on, under or above the earth's crust by a carrier using a camera or other measuring or recording device mounted in or attached to the carrier's aircraft and under the carrier's control, and

(B) the eventual delivery of the photograph or other record to the client in finished, semi-finished or other tangible form, including aerial photography, scintillometer survey, aerial prospecting and geophysical survey;

(vi) "aerial photography restricted to scenics", being the recording of scenes only and not involving any interpretive services or the creation of maps of any kind;

(vii) "flying training", being an air service for the purpose of instructing a person in the art and science of pilotage and the operation and navigation of aircraft; and

(viii) "recreational flying", being flights that originate and terminate at the same place without landing at any other place for purpose of taking on or discharging passengers and that are

(A) flown over a standard course that has been advertised by the carrier.

(B) conducted for the sole purpose of the recreation of the passengers, and

(C) charged for at a rate per seat per unit of time, including sightseeing, barn storming and parachute jumping;

(h) Class 8: International Scheduled commercial air service, being a service that is operated between points in Canada and points in any other country and that is required to provide public transportation of persons, goods or mail by aircraft, serving such points in accordance with a service schedule at a toll per unit of traffic;

(i) Class 9-2: International Regular Specific Point commercial air service, being a service that is operated between points in Canada and points in any other country and that is required to provide, to the extent that facilities are available, public transportation of persons, goods or mail by aircráft, serving such points in accordance with a service pattern at a toll per unit of traffic;

(j) Class 9-3: International Specific Point commercial air service, being a service that is operated between points in Canada and points in any other country and that offers public transportation of persons, goods or mail by aircraft, serving such points consistent with traffic requirements and operating conditions at a toll per unit of traffic;

(k) Class 9-4: International Charter commercial air service, being a service that is operated by an air carrier using

a) Group A, B or C aircraft, or

b) subject to obtaining a permit as required by Part IV, Group D, E, F, G or H aircraft,

from the base specified in the licence issued for that commercial air service and that offers public transportation, on reasonable demand of persons or goods between places in Canada and places in any other country, at a toll per mile or per hour for the charter of the entire aircraft, or at such other tolls as may be allowed by the Committee; and

(l) Class 9-5: International Contract commercial air service, being a service that is operated between Canada and any other country from the base specified in the licence issued for that commercial air service, that offers transportation of persons or goods solely under contracts of carriage with users with whom the air carrier has a substantial relationship through corporate structure or financial control and that does not hold out to the general public, or a class or segment thereof, the offer of transportation by air.

II. AIRCRAFT GROUPS ACCORDING TO WEIGHT

The groups for commercial air services based on the weight of the aircraft used in the operation of the service are as follows:

(a) commercial air services operated with fixed wing aircraft,

(i) Group A, having a maximum authorized take-off weight on wheels not greater than 4,300 pounds,

(ii) Group B, having a maximum authorized take-off weight on wheels greater than 4,300 pounds but not greater than 7,000 pounds,

(iii) Group C, having a maximum authorized take-off weight on wheels greater than 7,000 pounds but not greater than 18,000 pounds,

(iv) Group D, having a maximum authorized take-off weight on wheels greater than 18,000 pounds but not greater than 35,000 pounds,

(v) Group E, having a maximum authorized take-off weight on wheels greater than 35,000 pounds but not greater than 75,000 pounds.

(vi) Group F, having a maximum authorized take-off weight on wheels greater than 75,000 pounds but not greater than 150,000 pounds.

(vii) Group G, having a maximum authorized take-off weight on wheels greater than 150,000 pounds but not greater than 350,000 pounds, and

(viii) Group H, having a maximum authorized take-off weight on wheels greater than 350,000 pounds, and

(b) commercial air services operated with rotating wing aircraft,

(i) Group A-RW, having a maximum authorized take-off weight not greater than 4,000 pounds,

(ii) Group B-RW, having a maximum authorized take-off weight greater than 4,000 pounds but not greater than 7,500 pounds,

(iii) Group C-RW, having a maximum authorized take-off weight greater than 7,500 pounds but not greater than 18,000 pounds,

(iv) Group D-RW, having a maximum authorized take-off weight greater than 18,000 pounds but not greater than 35,000 pounds,

(v) Group E-RW, having a maximum authorized take-off weight greater than 35,000 pounds but not greater than 75,000 pounds, and

(vi) Group F-RW, having a maximum authorized take-off weight greater than 75,000 pounds.

NOTICE

"The above description of aircraft groups has been taken from The Canada Gazette, published May 5, 1972, which promulgated Air Carrier Regulations establishing, amongst other things, new aircraft groups based on new weight ranges. Licences issued before May 5, 1972 make reference to aircraft groups which do not correspond to the above description; they will gradually be converted to the new aircraft groups but, before this has been completed, they are shown in the Directory under the old aircraft groups. To avoid confusion we have indicated by an $^{(n)}$ where the group indicated refers to the new group; e.g., Group A$^{(n)}$, Group B$^{(n)}$. Holders of the Directory are advised that, for the present, caution should be exercised in determining the weight of the aircraft the licensees are authorized to operate."

III. ABBREVIATIONS AND THEIR MEANINGS

RF	Recreational Flying.
FT	Flying Training.
AP	Aerial Photography restricted to Scenics.
APS	Aerial Photography and Survey.
AAD	Aerial Application and Distribution.
AIRA	Aerial Inspection, Reconnaissance and Advertising.
AC	Aerial Control.
A. CONST.	Aerial Construction.

IV. ADDITIONAL INFORMATION

1. Services

Air carriers are required to publish and file with the Committee General Schedules for Class 1 and 8 services and Service Patterns for Class 2 and 9-2 services. Details of the Actual Schedules of Services operated may be obtained from the carrier at any of its principal offices.

2. Charges

Air carriers, except those in Classes 5, 6 and 7, which are subject to the Committee's tariff filing requirements, must publish and file with the Committee tariffs of rules, fares, rates and charges applicable to the type of traffic they are licensed to carry. Such tariffs are required to be available for public inspection. Information in this connection may be obtained from the carrier at any of its principal offices.

From Canadian Transport Commission, Air Transport Committee. 1976. Directory of Canadian Commercial Air Services, 116th Revision, August 15, 1976. DSS, Ottawa, Canada.

APPENDIX G

PERFORMANCE COMPARISON OF FIXED-WING AIRCRAFT AND LIGHT TURBINE HELICOPTER FOR AERIAL APPLICATIONS

APPENDIX G

PERFORMANCE SUMMARY

FIXED WING vs LIGHT TURBINE HELICOPTER[1]

Assumptions:

Five (5) gallons per acre application rate. One-half mile swath length.

Aircraft Characteristics:

	Fixed Wing	Helicopter
Chemical Load	280 gal.	180 gal.
Airspeed	100 mph.	80 mph.
Swath Width	50 ft.	120 ft.
Time to Turn	40 sec.	12 sec.
Ferry Distance	5 miles	1/4 mile
Loading Time	4 min.	2 min.

Spray Cycle - Fixed Wing:

Time in Swath (18 per load)	5.4	min.
Time in Turns	12	min.
Turn Around & Load	10	min.
Total Time Per Cycle	27.4	min.
Area per Cycle	56	Acres (22.7 hectares)
Cycles per Hour	2.2	Cycles
Acres per Hour	122.6	Acres (49.6 hectares)

Spray Cycle - Helicopter:

Time in Watch (5 per load)	1.8	min.
Time in Turns	1	min.
Turn Around & Load	2.4	min.
Total Time per Cycle	5.2	min.
Area per Cycle	36	Acres (14.5 hectares)
Cycles per Hour	11.5	Cycles
Acres per Hour	415	Acres (168.2 hectares)

Conclusions:

The helicopter utilizing field side loading and the wider swath width characteristic of helicopter applications, is nearly 3½ times more productive for aerial applications than a fixed wing aircraft.

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[1] Bell Helicopter Company, Fort Worth, Texas, 1975.

APPENDIX H

MANUFACTURERS OF AERIAL APPLICATIONS EQUIPMENT AND SYSTEMS

AERIAL APPLICATIONS EQUIPMENT AVAILABILITY

The following schedule lists all organizations currently known to be manufacturing and/or marketing aerial applications equipment, especially dispersal apparatus which is suitable for use by helicopters.

Company	Equipment and Comments
1. Agrinautics, P.O. Box 11045, McCarren Airport, Las Vegas, Nevada, 89111, Ph. (702) 736-3794	Manufacturing all types of aerial applications hardware, both components and complete units, including pumps, tanks, valves, and a self-contained spray system for Bell Models 205 and 212.
2. Amchem Products, Inc., Ambler, Pennsylvania, 19002, Ph. (215) 628-1000.	Manufacturing Microfoil and Spra-Disk booms and related nozzles and hardware.
3. Barnant Corporation, 28W092 Commercial Ave., Barrington, Illinois, 60010, Ph. (312) 381-7050	Manufacturer of Masterflex pump heads, tubing and drive systems.
4. Beeco Products Company, Industrial Park, Fort Washington, Penn. 19034 Ph. (215) 646-8440	Manufacturing Beecomist Spray Head and distributing various pumps, valves, tubing, fittings and aircraft mounting brackets for spray head.
5. Bud Palen Helicopter Svc. Scott City, Kansas, 67871 Ph. (316) 872-2172	Manufacturing and marketing the Bud Palen Wet Bucket.
6. Campbell Air Services, Inc., P.O. Box 872, Vivian, Louisiana 71082 Ph. (318) 375-3207	Helicopter operator who manufactures and markets complete spray system for Bell Model 47.
7. Chadwick, Inc., 4375 S.W., 142nd Ave., Beaverton, Oregon 97005, Ph (503) 643-1602	Manufacturing and marketing the Model C-500 Aerial Spray System and various fire suppression and drop-bucket systems.
8. Evergreen Helicopters, Inc., P.O. Box 358, McMinnville, Oregon, 97128, Ph. (503) 472-4151	Helicopter operator manufacturing and marketing the Pace Spreader, a granular fertilizer and seeding dispenser.

Company	Equipment and Comments
9. Rambling Rotors, Inc., Route 2, Box 2744, LaGrande, Oregon 97850, Ph. (503) 963-5644	Helicopter operator manufacturing and marketing a belly-tank spray system for the Bell Model 206A/B, JetRanger.
10. Simplex Manufacturing Co., 5224 NE 42nd Ave., Portland, Oregon 97218, Ph. (503) 281-0039	Manufacturing all types of aerial applications hardware, both components and complete units, including pumps, valves, booms, the Jet II Spray System for the Bell Model 206 and a complete line of liquid and dry buckets for all models.
11. Smithfair Design & Engineering Inc., P.O. Box 134, Kingfisher, Oklahoma, 73750 Ph. (405) 375-4016	Manufacturing and marketing Smithfair Automatic Turret Nozzle.
12. Soilserv Inc., 1427 Abbott Street, Salinas, California, 93901, Ph. (408) 422-6473	Manufacturing and marketing closed pesticide transfer systems and 'nurse rig' equipment.
13. Sorensen Sprayers, Inc., Worthington, Minnesota, 56187, Ph. (507) 376-6230	Manufacturing and marketing fiberglass spray tanks; distributors for several lines of pumps, nozzles, rotary atomizers, parts and repair kits including Simplex, Agrinautics, Spraying Systems, Delavan, Smithfair, Acu-Mist and Beecomist.
14. Transland, Inc. 24511 Frampton Ave., Harbor City, Calif. 90710, Ph. (213) 534-2511	Manufacturing and marketing all types of aerial application equipment, both components and complete units, including pumps, tanks, valves and booms.
15. Turbair Ltd., Britannica House, Waltham Cross, Hertfordshire, EN8 7DR, England. Ph. Waltham Cross 23691	Manufacturing the Turbaero Rotary Atomiser; Canadian distributor is Reginald Bennett Ltd., P.O. Box 99, Station Victoria, Montreal, P.Q. H3Z 2V4 Ph. (514) 631-3093.

Company	Equipment and Comments
16. Williams Flying Service, P.O. Box 38, Lutwiler, Mississippi, 38963, Ph. (601) 345-8395	U.S. distributor for Micronair rotary atomizers.
17. Zero-Max Industries, Inc., 2845 Harriet Ave., S., Minneapolis, Minn. 55408, Ph. (612) 827-6261	Manufacturing and marketing variable-speed transmissions, drives, electric motors and accessories.