AIR POWER

NAVAL, MILITARY, COMMERCIAL

BY

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"THE STORY OF THE AEROPLANE," "THE AEROPLANE, PAST, PRESENT, AND FUTURE," "HEROES OF THE AIR," "WITH THE AIRMEN," "THE AEROPLANE IN WAR," "AVIATION," "THE AIR KING'S TREASURE," "AIRCRAFT IN THE GREAT WAR," "THE INVISIBLE WAR-PLANE," "LEARNING TO FLY," ETC.

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PREFACE

The greatest lesson of the war is this: that in the future a nation which dominates the aerial highways will dominate also those of the land and sea; that a dominion of the air must mean, ultimately, the dominion of the world.

CLAUDE GRAHAME-WHITE.
HARRY HARPER.

London,
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[Depicting various stages in the construction of a modern-type aeroplane, secured specially for this book from photographs taken in the factory of the Grahame-White Aviation Company, Ltd., The London Aerodrome, Hendon, N.W., by Mr. F. N. Birkett, 97 Percy Road, Shepherd's Bush, London, W. The frontispiece by Messrs. Elliott & Fry.]

AIR POWER

PART I

THE WAR BY AIR

SOME CONCLUSIONS, WITH THEIR PROBABLE INFLUENCE ON THE FUTURE

I

The Offensive

IN viewing the lessons of this war, as they are likely to throw light on the future of the aeroplane, either as a vehicle for transport or as a weapon, it must be understood that this campaign by air, in the sequence of its phases, offers little or no guide to the trend of an air war of the future. The next great war, should it come, will begin by air where this leaves off; and all its subsequent stages, so far as any one air service is concerned, must be governed by the success or failure of that service in its first offensive by air—an offensive which, following instantly on a commencement of hostilities, will need to be delivered with a maximum possible force and speed.

"Strike quickly; strike hard"—this must be the watchword in aerial war. There can be no question of playing a waiting game, of staving off an enemy's offensive while one is making preparations which should have been made before a war. Everything must be staked on a rapid blow—a blow so staggering that the enemy cannot recover from it.

It was not until after two years of fighting, not until the summer campaign of 1916, that this war by air reached definitely the phase which, in theory, should have marked its commencement. This was the stage in which one flying corps, by constant fighting, was able to force its opponent to act constantly upon the defensive—driving and keeping him behind his own lines; attacking his machines with armed patrols as they rose from their aerodromes and before they could gain altitude; breaking up his squadrons of scouting and fighting craft when they attempted a reconnaissance in force: securing for themselves, indeed, such a mastery of the air, not only above their own lines but also above those of the enemy, that they were able to carry out without more than spasmodic interference, thanks to the screens provided by their fighting craft, all those daily tasks which form the routine of flying in war—scouting, strategical and tactical; the photographing from above of enemy positions; the constant range-finding for the artillery; and the formation of machines into squadrons, for bomb-dropping raids, so as to ttack the communications of the enemy, where-ever such an attack may prove most damaging to him.

The air service which can do all this work successfully from day to day, and at the same time prevent the enemy's flying corps from doing likewise, is carrying out in actual practice what was no more than a theory before the war: to blind your opponent, that is to say, by air, while retaining yourself the power of aerial vision—the power to scout constantly over and beyond his lines, and the power also of dropping bombs on his railways, supply depots, and munition factories.

II

An Incomplete Power

But in this war, at the moment it began, no decisive action was possible by air. There were not sufficient pilots or machines—to say nothing of the land personnel and general organisation—to permit aerial fighting on anything save a haphazard and inconclusive scale. No fighting aeroplanes, of anything like an effective type, existed indeed at the outbreak of war; though the courage and ingenuity of individual pilots, who went up in scouting machines and fought with rifles and revolvers, enabled them to wage a sporadic and guerilla form of war; in which, occasionally, when they could get to sufficiently close quarters, they crippled and brought down enemy machines. There was no possibility, however, in this first and critical stage of the war, when the armies were mobilising and taking up their positions, of one air service being able to blind the other, and so rob the enemy headquarters of its news by air. Save for haphazard contests, and the occasional bringing down of a machine by land-fire, the air lay free and uncontested to both the flying services; to the aeroplanes of the Germans, that is to say, as well as to those of the Allies. Hostile scouts watched, and reported from day to day, the chief movements of our armies; and the airmen of the Allies did the same, in regard to the main dispositions of the enemy. Both sides scouted. Neither could prevent the other from scouting. Thus we, and the enemy, were robbed at the beginning of this war of that full and complete power which should result from the use of aircraft—the power first to defeat your enemy by air, to scatter and disorganise his service, to blindfold him right at the outbreak of hostilities; and then to profit, all over the field of war, and in the movements and dispositions of your troops, by your power to see constantly by air, and as constantly to prevent the enemy from seeing.

It is difficult enough, with the comparatively slow movement of a vast modern army, to strike any blow that is in the nature of a complete surprise. But all hope must be abandoned of so doing if your enemy is free to send his aeroplanes above you, wherever and whenever he chooses. If you can prevent him doing this, if you can establish such a screen—after a first victory by air—as he finds it impossible to penetrate, and if your cavalry screen on the land is effective also—then, and then only, can one hope to effect a surprise.

The factors which governed the use of aircraft as scouts were, in the opening stages of the war, such as to prevent one from forming any very definite conclusions. Owing to a lack of craft, scouting was more or less intermittent, instead of being regular. In areas where a number of machines had been concentrated, the troop movements of the enemy were reported admirably; but in other districts, owing to the fact that flying could not be systematised, movements were made which escaped detection by air. Where country is wooded, or otherwise difficult from the point of view of the observer, it may be necessary to send several machines over some given route before information is obtained which is adequate and reliable. To trust to one pair of eyes is often inadvisable—especially when the owner of these eyes has, through an insufficiency of aircraft, to make a long and tiring observation over a wide tract of land. And there is the human element to be reckoned with. Some men are by instinct observant; they see just the things it is important for them to see. Others, though lacking nothing in training, are less successful: they remain mediocre, that is to say. Even if you send a man up in an aeroplane, and give him the view as though from a mountain-top, he must have the instinct and keenness of a scout if he is to make the best use of his opportunities.

Aircraft as machines for reconnaissance were on their trial in this war—the first big war in which they had been employed. And though they suffered in the early stages from a lack not only of numbers but of organisation, they did work which was invaluable, and which showed what they could accomplish when machines were available in more adequate numbers (as they were later in the campaign) and when their use had been systematised by experience.

III

Aerial Fighting

It will not serve our purpose, here, to examine in detail, or in chronological order, the progress of the campaign by air. We are concerned merely with large general issues, and more particularly with the influence on the future of such lessons as may be learned already from this campaign. One may, for example, take the question of speed in flight, which is of outstanding importance, and trace its influence in aerial fighting.

It was shown, even in the earliest stages of the war, that aerial fighting was to be something more than a mere figment of the imagination; and this even though experts had contended it would not be worth while for hostile air services to fight each other; that, in the vastness of the air space, such contests would prove inconclusive;

and that the main business of the aviator was, after all, to scout and not to fight.

Before the war, aerial fighting had been considered no more than speculatively; in the abstract rather than in the concrete. It had been argued that it would be years before aircraft would gain sufficient power, either in engine-power or armament, to render them in any way formidable as aerial fighters. And another fact—one which helps to explain the unpreparedness of the flying corps for fighting—was that the military conditions which have actually prevailed during this campaign, and which have affected so profoundly the use of aircraft, had not been accurately forecasted. Armies were regarded, before this war, as being essentially mobile forces; and it was assumed that aircraft, when on reconnaissance, would be engaged mainly in long-distance flights over wide areas—work which would not bring hostile machines into more than occasional contact, and which would be unlikely to cause any general fighting. The long periods of trench warfare which have been a feature of this campaign, with armies immobile from month to month, and with aircraft working ceaselessly over the same restricted areas, being brought thus into daily conflict with enemy machines, had not been in any way foreseen. Nor, for the matter of that, had the influence on aerial fighting of artillery-control by aeroplane.

The Germans, owing to an initial superiority in numbers, and to diligent practice before the war, were able to institute immediately, and very appreciably to the advantage of their artillery-fire, a system of co-operation between their air-craft and the batteries behind their lines. Hostile aeroplanes, flying in constantly over our trenches, signalled their positions to the German gunners. In its early form, this method of co-operation was effected by the dropping of smoke bombs from aeroplanes when they were above the target to be fired upon. Another method was for the pilot to make his machine turn or dive in some unmistakable fashion, and thus convey a signal to those who were watching him. Messages, from an observer to his battery, were also dropped in bags, to which coloured streamers were attached so that they might be easily seen. But the method of communication which gave best results—and was adopted as soon as specially-equipped craft were available—was by wireless telegraphy.

It was the artillery control of the German airmen, which they persisted in despite the land-fire that was directed against them, which led to the first of the aerial fighting.

IV

Guerilla Tactics

Our aviators, as well as those of the French, undeterred by the fact that there were practically no armed aeroplanes, at this early stage of the war, which were in any way worthy of the description, ascended without hesitation in scouting machines, taking up as their weapons rifles and revolvers, and attacked at close quarters the range-finding German aeroplanes; seeking, indeed, to do what the land-guns had failed to do, and this was either to destroy these range-finders or drive them away. And these pilots of ours, by their courage and promptitude in this emergency, were able to give an indication—the first of many, as time was to prove—of the capacity for improvisation, and the spirit of adaptability which, apart from any question of bravery, have been displayed so conspicuously by the air services of the Allies.

V

Lack of Armed Machines

The lack of fighting aeroplanes was due mainly to the fact that, before the war, designers and builders had been concerned mainly with scouting craft. And why this was so may be readily understood. Here, in reconnaissance, lay the first and most important use for aeroplanes; one the value of which could be gauged accurately. Peace manœuvres, for instance, as well as a tentative use of aircraft under war conditions in Tripoli and the Balkans, had left no doubt as to the value of aerial scouting. But no light at all had, as yet, been shed on the question of aerial fighting, which was regarded indeed as a problem of the more distant future. Constructors were, besides, in the period just before the war, occupied mainly in building scouting machines. What was revealed by such experiments as were made with armed craft in the years which preceded the war, stating the case generally, was that an aeroplane when it was equipped with a gun lost so much of its speed, owing to the extra weight it had to carry, and the added head resistance, that it would have little chance of overtaking, or engaging effectually, the machines which it would be one of its chief duties to attack; the scouts, that is to say, which an enemy would send in reconnaissance above its lines. This is an important point. Armed craft must have speed and must be built to manœuvre rapidly. If they are rendered slow-flying and sluggish by a weight of armament, their pilots may be unable to get them into the position from which their gunners can do effective work.

The inability, at this period, to build armed aeroplanes which should be fast in flight, was, apart from the fact that no very vigorous efforts were made to grapple with the question, due chiefly to a lack of aero-engines of sufficient power.

VI

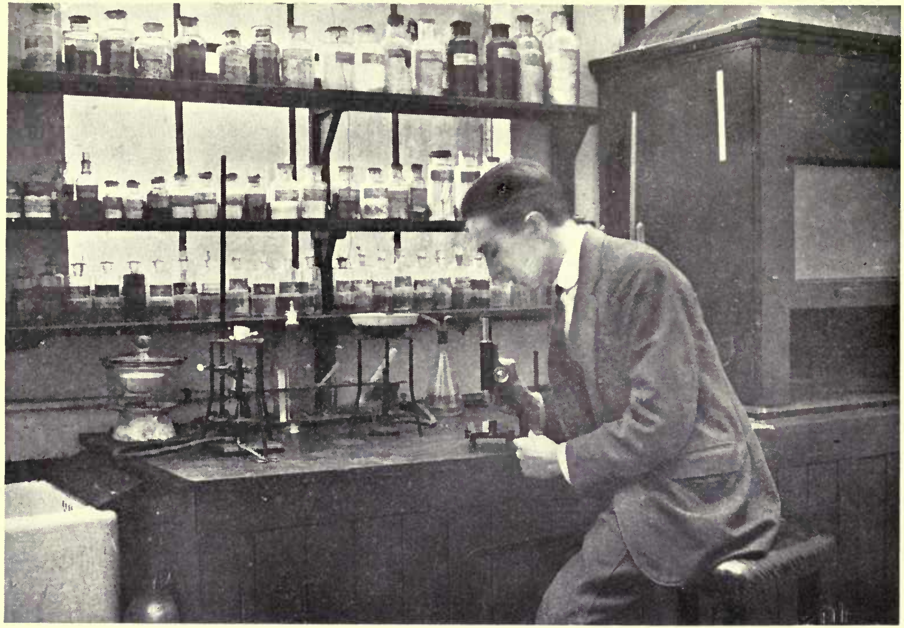
Fast Craft for Fighting

Our aviators, undeterred by the want of aeroplanes built specially for fighting, chose light, single-seated scouting craft, and used these in their attacks on the enemy's artillery-control machines. These single-seated aeroplanes, setting aside for the moment the skill and courage of their pilots, played an important part in our first successes by air. And the chief value of such aeroplanes, of which we should have had more, lay in the rapidity of their flight. They were, indeed, the fruit of our having realised—though realisation had not been followed by a sufficiently vigorous action—the main qualities of an aeroplane for use in war, which are speed in flight, allied to a power for rapid climbing and manœuvring.

One should mention that these single-seated machines had been designed not for fighting, but for rapid, general reconnaissance; to fly over some enemy territory, gain a general impression as to positions and numbers, and then to return quickly to headquarters. Speed, in obtaining news by air, is frequently of extreme value. Speed, also, enables a scout to elude the enemy's armed patrols. Speed renders it a more difficult target, also, for land guns, and enables it to run, with the least risk of injury, the gauntlet of an enemy's fire. Speed, too, permits a machine to make such headway against an adverse wind that it can carry out some errand even when conditions are unfavourable; while, in an aerial combat, the pilot whose craft has the greater speed can manœuvre most successfully for position, and can force an enemy to conform to his tactics—choosing his own moment and method for a swift, accurately-timed blow. Individual pilots, the men who have to run the risks of war, prefer almost always a fast machine. This is what they ask for—speed. They know, from experience, its value when they are above the enemy's lines. But in writing thus of speed one should not, of course, decry the value of such slower-flying machines as are employed for various forms of detailed observation. They, like other craft, play their useful part. Certain tasks must be undertaken for which high speed would prove unsuitable; but in the main it is speed which is invaluable, and must be striven for.

Our aviators, flying their single-seated machines, found themselves opposed, as a rule, by German aeroplanes carrying two occupants; machines which had been built not for speed, but for reliability and safety. The Germans, in the years just preceding the war, had occupied themselves in creating as large a service as possible of purely scouting-type machines. They had endeavoured, more or less, to standardise aeroplanes which would fly for considerable distances without alighting, and which were inherently stable. And such stability meant that they could be flown, even in high winds, by pilots of no more than average skill. These machines were admirable for their purpose; but they were distinctly slower in flight, and less easily manœuvred, than the fast, single-seated machines in which our aviators attacked them.

Germany had been slow in a sense to recognise the value of the aeroplane; she was more concerned in pioneer days with the construction of large airships. It was not really until the



F. N. Birkett.

A modern aeroplane factory has its own laboratory, in which the materials used in construction are tested scientifically, so as to make certain that every part of a machine, large or small, has a high factor of structural strength, and contains no blemish or flaw. Steels have to be analysed; wooden spars and ribs tested; the ingredients of dopes and varnishes examined.

autumn of 1909, when aeroplanes were used with success in the French manœuvres, and pilots made long flights across country, that the German authorities began to interest themselves keenly in the heavier-than-air machine. And, even so, it was not until a year or so before the war that high-pressure measures were adopted which began to produce aeroplanes in hundreds, and which sent large batches of young officers to the schools. Travellers who returned from Germany, particularly during 1913, brought striking tales of the rate at which aeroplanes were being built and delivered, and of the pressure which was being maintained at the schools. This increase of activity was significant: it showed that military and political Germany, seeking to read the course of events within the next few years, had decided that at almost any moment their chance for a blow might come.

Deliberate aerial fighting, persisted in from day to day, was a surprise undoubtedly to the Germans, as it was to others. And it was surprising, too, in its results. Though many combats were inconclusive, still our aviators, out-manœuvring their antagonists as their machines drew together, managed to cripple or shoot down an appreciable number. And even in cases where they could not damage an enemy craft, or cause it to descend, they so harassed its occupants with their bold attacks that they were prevented frequently from co-operating with their guns, or from securing any information in their scouting flights.

VII

Superiority of our Pilots

One should note, at this juncture, a fact which became significant. Having once been out-fought, though only in guerilla fighting, and on no scale that could be described as decisive, the German air service—when viewed as a certain number of human units, rather than as an organisation—appeared unable to throw off the influence of these first and unquestioned reverses. The aviators of the Allies were able in fact to establish, almost at once, a marked ascendancy. Not that the German air service had been rendered impotent; such was far from being the case. But their operations by air ceased in a general sense to be offensive.

Our preliminary advantage in fast machines was not sufficient in itself, though in the early stages it was extremely useful, to account for the success of our pilots in such a large proportion of their contests. That the superiority of our aviators was human, indeed, and not mechanical, was shown when the Germans, quick to realise the necessity of providing themselves with fast-flying armed machines, reaped the reward of a pre-war encouragement of their engine industry. What the Germans had actually done, for several years prior to the war, had been to adapt, and render suitable for use in aeroplanes, the racing motor-car engines of which they had developed several very well-known types. And as a consequence of this forethought they were able to obtain, immediately they required them, motors that permitted them to build aeroplanes which were for a time formidable; machines which, thanks to the power of their engines, and even when carrying a pilot and two passengers —both of whom operated machine-guns—would fly rapidly and climb fast. But even with such machines as these, which were for a time superior to any we possessed—and this through our lack of high-power motors—the Germans waged what was essentially a defensive form of warfare; patrolling mainly behind their own lines, and penetrating far less frequently above ours than we over theirs. Our pilots, indeed, though they were called on frequently, during the time the Germans had some advantage in fighting machines, to attack craft armed more powerfully, and in some cases flying more rapidly, than their own, still managed to win combats and to carry out their daily work by air; though the Germans, operating as they were defensively with their patrols, inflicted for a time many casualties among our scouting craft.

It should be remembered that an air service, if it is to work with high efficiency, must do the greater part of its flying not over its own territory but above that of the enemy. When scouting, photographing, range-finding, or dropping bombs, aircraft must run the risk of flying constantly above hostile ground. This means that casualties are unavoidable, and that they may occasionally be heavy. The point of view from which they must be regarded is this: does the work that is being done by air justify the losses which are entailed—every effort having been made, naturally, to minimise them? One can scarcely expect results of a high military significance without having to pay some price for them.

The advantage of the human factor, of the skill and initiative of the men in the machines, was ours from the first; and this will be an advantage for us, too, not only in this war, but in any future war, and also in the commercial development of the aeroplane. The Briton has taken to the air, and to the handling of aircraft, with an altogether remarkable facility—with a facility so inherent, and at the same time so exceptional, that it won the admiration, away back in pioneer days, of such a fine judge of an aviator as the late Wilbur Wright.

VIII

Temperament and Tradition

The temperament of the Briton, which has sent him adventuring through the world for centuries, and combines judgment and shrewdness with a spirit that is unquenchable, proves almost ideal for flying. It contains, for instance, an extremely rare mingling of those two qualities which are more valuable than any others—courage and caution. The Englishman, one should note, makes a fine horseman; and horsemanship and airmanship have certain points in common. The fine horseman, for example, is conspicuous in his riding for what is called "hands"—for the suppleness and power with which he controls his horse; and in the manipulation of an aeroplane there is a constant need for delicacy and for strength, for precision and for swiftness of action, and yet not for abruptness—for a hand of steel in a velvet glove.

It is a fact also that the Briton, when flying either in peace or war, does so with a personal and sporting zest which is almost unknown, for instance, to the German. The latter—one writes of course generally—flies in a spirit of duty. But the young Englishman flies an aeroplane as he would ride a horse to hounds or in a steeplechase, or sail a yacht in a freshening wind. It is sport to him—an adventure; something to be enjoyed rather than to be done as a duty. And it is this spirit, allied to his temperamental advantages—to the caution and judgment that leaven his daring—which render him invincible in the air; as he has been, for centuries, on the sea.

The Briton has qualities, innate in him for centuries, which have rendered him supreme as a seaman. He is a born sailor, and has the traditions behind him of a seafaring ancestry. And much that appertains to the sea appertains also to the air—a knowledge of winds and weather, a faculty for navigation, an instinctive alertness of mind, and the power of a quick, unflurried decision. Flying is ideal work for sailors. Therefore the whole tradition of the British nation, with its great sea history, tends to produce fine airmen. And it should be gratifying to us to think that, however keen may be the race for aerial supremacy in the future, we shall be able to produce men of the best kind to handle the machines which will be built by our constructors. Our ocean supremacy is due largely to our magnificent seamen; and we shall be able to find the men who will give us the supremacy of the air.

IX

The German

As to the German aviator, one may say that his military training, with its rigid discipline and suppression of individuality, is adverse to the production of a really first-class pilot; one who must, above all else, be a man of individuality, ready to act promptly in an emergency, and to rely on his own judgment. The German system has produced a large number of aviators who have shown a high average of skill, and who have been thoroughly competent both as pilots and observers when on reconnaissance. And if nothing more than this had been required of them, they would have emerged with entire credit from the ordeal of war. But under the test of aerial fighting, a test as severe as one can imagine both of brain and nerve, they have been found wanting not in courage but in initiative; in that mental elasticity which, even in moments of the acutest strain, has rarely failed the British or the French. Exceptions to this rule, as in the case of the German champions Immelmann and Bölcke, go merely to prove it. The German has shown himself a good pilot, but nowhere near as good a fighter.

X

The Struggle for Supremacy

As operations by air, in common with those by land, became steadily more intensive, fighting grew daily more frequent; and this being so our superiority in men, in the human factor, became more and more conspicuous—particularly when, as time went on, we were better provided with machines, and with the ground organisation and personnel which go so far towards victory in modern war. It was not, however, until the summer campaign of 1916 that the Allies were able to concentrate successfully on a struggle for air supremacy—for a supremacy, that is to say, which should be constant rather than intermittent, and should extend over the whole of the battle area.

In this air offensive, pursued as indefatigably as that on land, we attacked the enemy in squadrons, giving him as little rest as possible from day to day. Such machines as he endeavoured to send in reconnaissance above our lines we engaged promptly; while our own patrols, flying above his lines, swooped down on enemy craft which could be seen ascending. We also dropped bombs constantly on German aerodromes, destroying sheds and war material.

What this offensive yielded, in our power to invade the enemy's air space, and to prevent him from invading ours, may be gauged from a short and yet significant extract from the Headquarters report of September 18, 1916—

"During the past week, in the battle area, only fourteen hostile aeroplanes have been reported as crossing our lines, while our machines have made between 2000 and 3000 flights across the enemy's lines."

XI

Speed and Striking Power

What needs emphasis is the fact that such a result, amounting from the military point of view to a mastery of the air, had been achieved only by the fiercest and most protracted aerial fighting; also that the aeroplane which proved of most value, during this determined offensive, was the machine which combined successfully the attributes of speed and striking power. In aerial warfare, already, a lesson is being taught which is familiar to naval strategists. In the naval actions of this war, for instance, the vessels which have proved most effective are those which have been able to steam fast, and, when they have brought their enemy to action, deal rapid and heavy blows.

But in designing any war craft which shall be both powerful and mobile, a very careful discrimination is required. Armament spells weight, and weight tells against speed. The necessity for combining these two qualities must, therefore, result in a compromise. A certain amount of speed must be sacrificed to armament, and a certain amount of armament to speed—the aim being to have vessels which at any given time are faster, and are armed more powerfully, than those possessed by an enemy. That is the naval ideal; and it must form also, in the future, the ideal of the air service.

XII

One Machine, One Task

In designing aeroplanes for use in war it is unwise, as it would be in naval construction, to endeavour to produce one craft which shall carry out a number of separate tasks. A machine so designed, though it may be generally efficient in a moderate sense, will not prove particularly good in any of its roles. In this war, for example, there has been a tendency, with theoretical science playing so large a part in design, to seek to embody too many different qualities in one machine. What one requires in war is not an aeroplane which will do a number of things fairly well, but a craft which will do one thing superlatively well—a craft so specialised for its task that, when it is brought into conflict with some machine built by the enemy for this particular purpose, it will be certain of a definite superiority. It is unreasonable, for instance, to expect that a machine which acts as a scout should prove also a good fighter. It should not, as a matter of fact, be necessary for the scout to fight at all. The fighting machines which co-operate with the scouts, and act as escorts for them, should so clear the air that the observing machines can do their work uninterrupted; or, assuming that a scout is on occasion attacked by a hostile armed patrol, it should be able to escape by reason of its speed.

The policy of an air scout, as of a scout on land, must be to work quickly and unobtrusively; and when the air scout is detected, and things become too hot for him, he must trust mainly to his speed to extricate himself—as the land scout trusts to the speed of a car or of a horse, or of his own legs. The air scout, if he waits to fight, may be winged and brought to earth; and then the news he may have gleaned will be lost to his headquarters. His purpose must be first to obtain news, and then to get back with it: he must run away rather than fight.

The aim in the construction of war craft should be to design one given machine for one given task, and to make it as efficient as is humanly possible for that one task. It is not feasible now, nor will it be in the future, to produce any machine which shall represent the ideal, or anywhere near the ideal, in more than one respect. In a modern navy there are dreadnoughts, battle-cruisers, light cruisers, destroyers, torpedo-boats, and submarines, and each of these craft has its specified task.

XIII

Aerial Scouts, Cruisers, and "Dreadnoughts"

In an air fleet, so far as the immediate future is concerned, the need is indicated for several machines of a specialised type. Importance should be attached always, of course, to the production of high-speed scouts—machines capable of flying considerable distances without alighting, and at high average speeds. It should be the aim of each great nation to make their machines of this particular type the most efficient in the world. Observing machines are also needed, of course, for detailed reconnaissance; and for co-operating with artillery.

Then machines will be required of what may be called the cruiser type, in which speed and radius of action are prime considerations, but which are sufficiently well-armed in addition to render them formidable. Probably several machines of this type will need to be developed, differing in speed, radius of action, and armament.

Sound discernment will be required in deciding the compromise which shall be arrived at between the claims of speed, armament, and radius of action. A machine will have to fly so many miles without need for alighting; it will require to maintain a high average speed; and, when the moment for striking comes, it will have to hit hard and often, and at long range.

There must be special coast-defence craft; machines which, seeing that their radius of action can be limited, should be armed very powerfully, and should prove dangerous adversaries, owing to their speed and power, for any raiding or invading craft—heavily-loaded as these would need to be in order to travel long distances to and from their bases.

And from such machines one moves, naturally, to the battle-plane proper; an aircraft which is as powerful as it is possible, at any given time, for science and construction to make it; in fact an aerial super-dreadnought.

XIV

Safety and Efficiency

There is a point in this connection which should be noted specially. A desire to build machines which have high factors of structural safety must not obscure the prime need of obtaining the greatest possible war efficiency. Here we may learn a lesson from the war. A tendency has existed, undoubtedly, to insist on factors of structural safety so high that dead weight has had to be carried to such an extent that it has prejudiced the speed and manœuvring capacity of the machine, and also its load-carrying capacity; to say nothing of the head resistance which is caused inevitably by a large amount of wiring.

A constructional strength many times greater than is needed to withstand the ordinary strains of flight can only be secured, in fact, at the expense of weight and speed. Such a safeguarding of the aviator, when he is flying in peace, is of course admirable. The disadvantages it entails—a certain loss of speed, of general efficiency, and of ascensional and carrying power—may under conditions of peace flying be very reasonably incurred. In ordinary flying, in fact, the first consideration should be the safety of the aviator. But it is quite another thing in war. One might, for example, have the safest machine in the world, one so strong that it would survive any structural strain, no matter how abnormal; and yet this machine, meeting in combat some craft which, though its inferior in structural strength, was capable of flying a certain number of miles an hour faster, might be out-manœuvred and shot down, and its occupants killed, simply through its failure to fly sufficiently fast, or to manœuvre with sufficient rapidity.

War flying is essentially dangerous, and can never be anything else. This fact, though a platitude, needs constantly to be remembered. An aviator must be willing to take risks in war, and do so constantly, that would be altogether unreasonable in times of peace. His dominant thought is not his own safety. He flies with the desire to strike down an antagonist, to hit if possible the first blow, to make his onslaught with the maximum possible effect. If a gain in structural safety, in the mere passage of a machine through the air, and in relation to the strain imposed on it by the wind, or by the handling of its pilot, depreciates the efficiency of the machine as a fighting craft, then some of this margin of safety must be sacrificed.

What must be striven for is a machine which, while it is not heavy, will still be sufficiently strong—owing to the skill employed in its design and construction, and to the care taken in the choice of materials—to withstand only such strains, under war conditions, as experience proves it essential to guard against.

The governing aim, always, must not be to save men's lives but to win the war. With aircraft, for example, the vital consideration is not so much to protect a machine or its occupants against an enemy's fire, as so to equip the craft that it will out-manœuvre an antagonist, and hit him with a shell before he can retaliate.

XV

Armoured Craft

The armouring of aircraft, to protect them against hostile fire, involves questions of considerable difficulty, remembering how weight tells in the air. Until experience had been gained in this war, little or nothing was done to armour machines. What was found, when practical experience had been obtained, was that aviators who had to pass through zones of fire were killed sometimes, or wounded, by bullets which struck upward through the floor-boards of their machines. On reconnaissance, for example, when there was a mist, or low-lying clouds, pilots needed to descend so near the ground when they were scouting that they came within range of rifles and machine-guns. Bullets through their planes were ineffective, unless spars were so weakened by punctures that they collapsed. The sustaining surfaces themselves—the fabric of the planes—might be riddled with shot without bringing a machine to earth. But hits in the mechanism might stop the motor, pierce a petrol tank, or sever control wires; and there was also the definite risk that a bullet, or bullets, penetrating the hull, might reach the occupants as they sat in their seats.

What this led to was the introduction of thin sheets of bullet-proof steel below the seats of the pilot and observer. And after this, as aeroplanes became available—owing to increases in engine-power—which had a greater weight-lifting capacity, the armouring was continued up round the sides of the hull, so as to protect the occupants of a machine, when they were fighting in the air, from bullets fired at them horizontally.

The aeroplane is, however, an essentially vulnerable machine—to any direct hit, that is to say, from a shell or heavy missile; and it is never likely to be anything else. All that it seems possible to do, either now or in the future, is to take what may be called the vitals of a machine—its occupants, engine, fuel tanks, and controls—

and protect these from anything save direct hits from shells. It will not be feasible, even in the future, to build aeroplanes which are armoured heavily. In the air, a medium of such small density, light systems of construction are essential if craft are to remain efficient.

An aeroplane, when it is hit direct by a shell, may generally be reckoned out of action. It is unreasonable to expect that a machine with widespread, delicately constructed wings, can be rendered invulnerable to shell-fire. One may, for example, take the case of a direct hit from a shell on the wing of a machine. Such a wing, even when metal takes the place of wood, must remain vulnerable; its construction cannot make it otherwise. But even when one of its planes was hit and damaged it might be possible, of course, for a machine to continue in flight. What is more probable, though, is that if one plane was damaged at all seriously this would involve injury also to struts and other gear, imperilling thereby the strength of other planes, and rendering a machine uncontrollable.

In aerial battles of the future, when machines attack each other with powerful guns, it is reasonable to assume that a large percentage of craft will be put quickly out of action. A vessel on the water, even when it is badly hit, or its machinery so damaged that it loses the power of movement, can still put up something of a fight. But an aircraft when winged at all seriously is likely to become uncontrollable; and this will mean that it must abandon the conflict and descend.

A protective measure it is very necessary to take—one which, while implying no great weight, must add appreciably to the safety of an airman when he is under fire—is to duplicate his controls. Machines will fly on, often, when struts have been broken: even when main spars have been shot through. But if a pilot's controls are severed, and they are not in duplicate or triplicate, then he is helpless.

Apart from the duplication of wires, a factor which spells safety is the arrangement of the controls of a two-seated aeroplane so that either the pilot or passenger can take charge of it independently of each other. In war flying, when a pilot is killed or wounded while above hostile territory, and the craft has dual control, the observer can place himself in command, and bring it back to the safety of his lines.

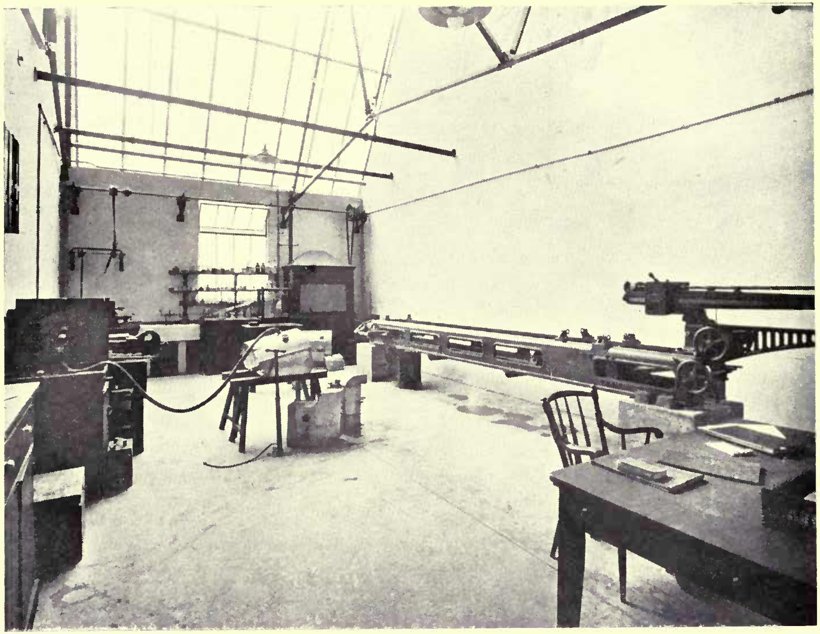
There has been a tendency among pilots to object to dual control, mainly on the ground that a passenger might take it into his head to interfere at some critical moment with the flying of the machine, with an accident as the possible result. But the system can be arranged in such a way that the pilot, by the movement of a lever, can render inoperative the passenger's controls, and prevent any interference with the handling of the machine should he consider this unnecessary or likely to cause an accident.

In cases where dual control has not been fitted, and in craft in which pilot and passenger sit some little distance apart, the death or injury of the pilot may cause the machine to fall, involving the passenger as well as the pilot in disaster. It is possible for a passenger who has exceptional nerve and agility (and who has learned to fly), to make his way from his own seat to that of the pilot, even while a machine is falling, and to take over the controls in time to prevent the machine being wrecked. Dual control is, nowadays, a standard fitting of the fighting machine.

XVI

Offensive Armament

What we have written, so far, goes mainly to prove the value of speed. But another question of supreme importance is that of offensive armament. A machine such as the aeroplane, fast in flight but vulnerable, must be given weapons so powerful that it will be able to engage opponents at long range, relying on rapid and accurate gunnery to cripple these adversaries before they can come within a range that will permit them to use with effect their own guns. The success of such tactics, given an aerial gun of a specialised type, would depend of course on the skill of the gunner—not forgetting the co-operation of the pilot. The task of gunners in the future, as they are called on to use heavier guns, and are required to hit enemies at long ranges, will be one of exceptional difficulty, needing incessant practice,



F. N. Birkett.

A general view of the laboratory in which materials of construction, as used in an aeroplane, are subjected to their tests. In the centre of the photograph are fuel tanks which are being tested under pressure.

and also a natural aptitude. From a machine moving at high speed they will fire at some hostile craft, also in rapid motion, which may not only be a considerable distance away from them horizontally, but which may also—during the time it is under fire—be ascending rapidly, or diving to reach a lower altitude; and this will introduce complications, in finding a range and getting quickly on to a target, with which naval gunners, difficult though their task is, have not at the moment to contend.

XVII

Land-Fire

In the early stages of the war the guns carried by aircraft, and also those used against aircraft from the ground, were not only insufficient numerically, but inadequate in their power and range. In regard, for instance, to land-fire against aeroplanes, the few anti-aircraft guns which were available threw small shells at comparatively short ranges; with the result that the early scouting by air was done without any great interference from the ground.

But more guns were soon provided, and guns also of a higher power, which threw shells to an altitude greater than that at which an aeroplane would need to fly when the observer in it was on reconnaissance. And this meant that aviators were compelled to fly through, and not above, such areas of land-fire. But the aeroplane, by reason of its small size and the speed at which it flies, is an elusive target; and it may be rendered more so by rapid changes of altitude and direction, as effected by its pilot when he finds he is under fire. And there is also the point that, even if a shell bursts near a machine, and it is struck, say, by shrapnel, this may cause no vital injury. The case may be cited of one machine, in the vicinity of which a shell burst; but though the craft was pitted with holes, several hundred punctures being counted on its planes and hull, the pilot managed none the less to fly back to his starting-point. In another case a machine was hit by the base of a bursting shell. This tore a large hole in one of its planes, and then went through the hull, just behind the pilot's seat. But by skilful flying, though his machine threatened to collapse at any moment, the aviator was able to regain his base.

What one may say by way of summary, in regard to land-fire against aeroplanes, is that while a certain number of machines have been hit—and winter with its fogs and mists, necessitating flights at low altitudes, has brought the gravest risks—this land-fire has never proved sufficiently effective to curtail, in any material way, the work of the air services in reconnaissance.

XVIII

Guns in Aeroplanes

As to the guns fitted in aeroplanes, and used by aviators against each other, there soon came a stage, after the first impromptu use of rifles, revolvers, and automatic pistols, when machine-guns were employed. The machine-gun enables an aviator, by allowing him to fire a stream of bullets at an enemy, to make more certain of hitting, at any rate with some of these bullets, the rapidly-moving target at which he aims. But still a machine-gun, using rifle ammunition, remains a weapon far from the ideal; and for the reason that, even if a number of hits are made on a hostile craft, most of the bullets which do reach their mark, passing harmlessly through the planes, or some other yielding surface, of the machine, will have no effect.

By degrees, however, as the campaign advanced, and as more powerful engines were used in aeroplanes—permitting machines to carry heavier loads, and to be built to withstand greater structural strains—guns of a higher calibre began to be fitted; guns which would throw small shells instead of ordinary rifle ammunition; and these shells, when they struck enemy craft, proved naturally more destructive.

But the science of aerial gunnery is still in its infancy; and it is one which must be studied with the utmost care. The production of guns for use in aircraft must be the subject of continuous experiment and research, for which money must be forthcoming in adequate sums. A weapon that seems to approach the ideal is a quick-firing gun which will throw a stream of shells at a fairly long range, each shell being fused so sensitively that it will detonate even when in contact with a light and yielding surface.

Modern warships, with their batteries, seek to overwhelm an opponent right at the beginning of an action, and strike so hard and so often that this opponent is crippled and demoralised before he can retaliate effectually. And in the air, when large craft are in action, the value of the first blow, or blows, will be even greater.

XIX

Land Defences

A factor that must be reckoned with, on looking into the future, is that land defences, by guns and other means, will be improved very greatly against air attack.

We have seen, for instance, in this war, what can be done against airship raids by an organised defensive—incendiary shells being used from guns, and bombs dropped on airships from aeroplanes. But one must remember, in this regard, the vulnerability of an airship such as the Zeppelin. Apart from its immense size, it carries its own destruction within its hull in the form of vast quantities of a highly inflammable gas. It also flies comparatively slowly—for an aircraft, at any rate.

There are possibilities, in land defence against aircraft, which still need the test of practical experiment. It may be found possible, for instance, to cause atmospheric disturbances, very prejudicial to aircraft, by the discharge on a large scale of high explosives; while the possibility has been discussed, scientifically, of so charging the air with electricity, over certain areas, that an interference would be caused with the electrical ignition on the engines of hostile aircraft.

Though it is too soon to discuss such schemes more than generally, it may be taken for granted that, in the future, earth folk will protect themselves more effectually against air attack. And they will certainly need to do so. The raids of this war are nothing to what they may be in the future.

XX

Long-Distance Raids

In making a long-distance raid by aeroplane, under present conditions and with existing-type machines, there are several factors to which attention must be directed. The aeroplane has, of course, certain definite advantages. It flies fast and it offers a difficult mark for hostile gunfire. But until designers have had time to overcome the difficulties which face them in converting aeroplanes from small light craft into large weight-carrying machines, driven by engines developing thousands of horse-power, the airship will be able to raise a heavier load of bombs than the aeroplane, and carry its load a greater distance. But against the weight-lifting capacity of the large airship must be set its extreme vulnerability.

It is possible, already, to build large aeroplanes driven by several engines; and these machines, even when they carry fuel for a long flight, can still raise bombs of a sufficient weight to cause considerable damage when they are dropped on suitable targets. But at the present time, and until construction enters an improved phase, a heavy load can be carried only at a sacrifice of speed. Under peace conditions this means, of course, nothing worse than delay in reaching some destination; but in war, if a machine which has had its speed reduced is sent over hostile territory, this loss of speed may lead to its destruction.

The main factor which has to be remembered, when long-distance raids are in contemplation, is that when an aeroplane has to carry bombs for a considerable distance without alighting, it needs to be burdened so heavily—with its crew, fuel, and load of explosives—that its flying speed is very much less than that of any defending craft which is required only to make a short flight, and which can therefore be lightly loaded.

The heavily-laden bomb-dropping machine, when it passes in above enemy territory, is liable of course to attack from hostile craft; and here lies its danger. The raiding machine, weighted with a heavy load, cannot fly so fast or manœuvre so quickly as the lightly-laden craft which attack it, and which have no long distance to fly, for they are operating above their own territory. The defensive machine, in fact, which may require only to ascend and patrol in the neighbourhood of its own aerodrome, is at a very considerable advantage. It can be built for speed; it needs only a minimum of fuel; what weight it does carry can be devoted mainly to its offensive armament. And so the heavily-loaded bomb-dropping craft, while on a long-distance raid over enemy territory, may be engaged at any moment by machines which are quicker probably in flight, and also in manœuvring; and such an advantage is of course of the utmost importance.

What it is possible to do, and what is done, to minimise the risks of the bomb-dropping machines, is to escort them, when they set out on a raid, with a certain number of fighting aeroplanes. But these fighting machines, if they are required to make a long non-stop flight while acting as escorts, must have a heavy load of fuel, in addition to the weight of their crew, guns, and ammunition; and thus the problem which arises is to give them their proper equipment and still ensure that, when they reach their objective in enemy territory and are engaged by hostile craft, they shall be on a reasonable equality with the latter in speed.

Another difficulty which is encountered when bomb-dropping and fighting machines are sent on a raid which entails a very long non-stop flight, is that of keeping the machines together during their flight, and in effective touch with each other should an attack be made upon them. Weather conditions may be met with, for instance, which cause machines to become scattered or lose their position. Grave anxiety must attach itself, in fact, to the sending of aeroplanes on long-distance raids. Such raids can be made, of course, and are made; but the question which has to be considered very seriously is whether the losses in men and machines are not greater than the damage which is inflicted by the dropping of bombs.

It is quite possible to use aeroplanes in night raids: the airship has no monopoly of night flying. But the difficulty with an aeroplane, when it has to fly a long distance by night, is to steer an accurate course, and also to identify the target on which bombs are to be dropped. This may lead to a haphazard and ineffective bombardment, such as has occurred when raiding airships have failed to pick out any definite mark, and have dropped bombs at random.

In a short-distance aeroplane raid, when no excessive loads of fuel have to be carried, and the machines of a squadron are better able to keep in touch with each other, the risks and difficulties are reduced. Even in long-distance raiding the problems encountered are no more than temporary. With engines of greater power becoming available, and with design and construction improving, it is possible to increase the speed of raiding machines. But such improvements tend to cut both ways. Defending craft can also be rendered more efficient.

XXI

Silence and Invisibility

Developments are possible, in the construction of raiding craft, which will aid them materially when attacking land positions. The raiders of the future are not likely, for instance, as has been the case in this war, to herald their approach by a heavy drone of engines. Their motors will be so silenced that at anything like a high altitude the machine will be inaudible from the ground. It may be found possible also—though problems of complexity are involved—to treat the surfaces of a machine so that, when it is at any distance from the ground, it is practically invisible against the background of the sky.

If raiding machines which are both silent and invisible can be produced—and it would be foolish to use the word impossible in any such connection—then the destructive power of an air attack, if made ruthlessly by numbers of machines, operating in squadrons over an enemy's territory, is better imagined than described.

XXII

Safeguarding the People

It is interesting to note, in this regard, that it has been suggested already, as a precautionary measure against the air attacks of the future, that Government and administrative buildings, together with arsenals and large stores and factories, should be housed below ground; also that by degrees, and as opportunity offers, most of the other important buildings in large cities should follow this example, and go underground. The suggestion has been made, too, that large underground shelters should be provided, in all thickly-populated areas, where people could seek protection when an air raid was in progress.

This whole question, as a matter of fact, which concerns not only the safeguarding of the populace but the protection also of vital means of communication, will need the closest study. The main purpose is to obtain an efficient defensive organisation, both by air and on land. But in addition to this, and as a further safeguard against the penetration by surprise of hostile craft, favoured perhaps by atmospheric conditions, it has been suggested that certain vital means of communication—such for example as lines of railway which have a strategic and military value—should be rendered immune from air attack by being run below-ground.

XXIII

The Problem of a Quick Decision

The aim in future must, beyond all else, be to win a war quickly. The burden of conflicts on a vast scale becomes insupportable if they are long-continued, with the result that the victor may emerge as badly off, economically, as the vanquished. A way will have to be found, if war on the vast modern scale is to be worth while, of gaining rapidly some unqualified success; a success so decisive that even the most stubborn of enemies must realise that it is fatal to him. Where lies the hope of speedy victory? Can it be gained, say, on land?

In this war we have seen a military machine, the greatest in the history of the world, strive month after month, even year after year, to gain a signal victory somewhere—to put at least one of its adversaries out of action. And we have seen victory elude it, not once but time after time. And there is no ultimate value in a paper victory, or in a strategic or political success, if the army of the enemy is still in existence as a fighting organisation and is ready to carry on the war. In warfare, if one's enemy is determined, one cannot win on "points," as a boxer may in the prize ring. There is nothing to be done, in fact, but to go for a "knock-out." But when your adversary is equipped properly, and his forces are led with even moderately good generalship, and remembering the comparatively slow movement of vast masses of men, this much-desired knock-out appears extremely difficult to obtain.

What, as a matter of fact, does such a victory imply? It implies nothing less than the decimation of a huge and well-armed force; the scattering of it in confusion; the stamping out from it, while it is in flight and in disorder, of any such spirit of resistance or of cohesion as will lead to its re-formation as a fighting force. Can this be done? It would be unwise, naturally, even after what we have seen in this war, to state definitely that it cannot. But it is reasonable, certainly, to assume that any great struggle of the future, if it is waged on land, may be so long-drawn-out, each army and each nation fighting to the point of exhaustion, that the victor will be robbed of the fruits of his victory.

Obviously there is the factor of generalship to be reckoned with. It may happen in the future that a super-Napoleon will arise—a man towering, in the power of his strategy, above all others. But such a great commander would be faced, inevitably, by this difficulty: that whereas Napoleon achieved his coups with armies of moderate size, moving these rapidly to the confusion of his opponents, any commander of the future will find himself embarrassed—as has been more or less the case in this war—by the need to manipulate vast masses of troops, which cannot be moved with rapidity; and whose movements, when they are made, may be watched from day to day by enemy aircraft, and so become known to an enemy staff. And such conditions do not favour a great or surprising coup—the arrival, say, on an enemy's flank, as in Napoleonic times, of some attacking force which, after days of forced marching, appeared apparently from nowhere, and proved sufficient in itself to turn the tide of battle.

As regards the future of naval warfare,

the factors seem more obscure. It appears certain, however, that, if a fleet which is superior numerically, and in weight or armament, can once come really to grips with an antagonist, and can prevent that antagonist's retreat into protected waters should he attempt to break action, then a blow can be struck which is decisive. But if one fleet does not choose to give action, if it is content to seal itself up within protected waters and to conduct a guerilla war with the object of weakening its opponent's forces, then sea warfare, like land warfare, may enter on a phase which offers no hope of a quick and telling blow.

XXIV

The Medium for a Decisive Blow

This brings one to the fact that there is another element, the air, which an ambitious nation may seek to dominate, and in which, if its desires are not realised by peaceful means, it may endeavour to gain that quick, crushing victory which can no longer be relied upon by land or sea.

The aim of the future will not be so much to strike at a nation through its fleets or armies as to strike directly at the nation itself; to strike a blow, so to say, at its very vitals; paralysing its nerve centres, and robbing it of its power of internal action. And here lie the possibilities of an air attack, unhampered by the natural barriers either of land or sea.

With aircraft, remembering the huge speeds they will attain, and the almost unlimited power of destruction which they will possess, there lies a very clear promise in the future—granted the use of machines in sufficient numbers—of being able to force a speedy victory. Once having gained by aerial fighting some initial superiority, an enemy will endeavour to make life intolerable in the country with which it is at war. It will deliver attacks constantly by air, seeking to harass and confuse its adversary in all his warlike operations; in the mobilisation and movement of his troops, or in the transport of his supplies. It will endeavour also to cause such damage, by the constant dropping of incendiary bombs and high explosives, as will cripple and disorganise the civilian activities of the nation which is attacked. The powers of perfected aircraft, when such machines are employed mercilessly, may grow, indeed, so terrible that they will seem almost superhuman. A ruthless enemy, waging war without mercy, may seek to spread pestilence by aeroplane; or he may endeavour to destroy the inhabitants of an enemy country by means of poisonous or suffocating gases, released from raiding craft. And such death from the air, sweeping a country from end to end, may come, perhaps, without a formal declaration of war. The blow may be struck suddenly by an enemy who attacks at night, using thousands of machines, and seeking to lay waste a country between dawn and dusk. The fate awaiting a nation which lags behind in the race for aerial power may, indeed, prove terrible. It may find itself ravaged, defeated, and rendered helpless, in a conflict which lasts not a year, or a month, or even a week, but as the result of a blow which is struck and completed within a few hours.

The point has been raised that the aeroplane should be regarded as having an extraordinary power only so long as it remains a new weapon; or so long, say, as one antagonist, having a superiority in men and machines, can strike against an opponent a bold and successful blow. But what about the future? Will it not be the case again, one is asked, of move and counter-move; of one weapon being forged only to be negatived by another; with the result that in time, even in the air, something approaching stalemate may be reached?

Here, though, there are factors which need remembering. In the next great war the rival air fleets, though they may be numerically large—with little to choose between them, perhaps, in this respect—will be embarking on a form of organised war which will be new to them. Their strategy and tactics, when large squadrons of fighting craft have to be manœuvred in action, will be based on theory and not on experience. They will be using, also, new forms of armament. And under conditions such as these, with so much that is experimental to be reckoned with, there is naturally a far greater risk of error, of things happening not as they were expected to happen, than there is, say, with the well-matured plans, based on years of experience, which are employed in land or sea warfare. It is reasonable to argue, in fact, that in any war of the future, when aerial forces meet for the first time in action on a grand scale, one such air fleet, handled perhaps more dexterously than its rival, or with its armament more destructive, may inflict on its opponent a defeat which is conclusive.

One should bear in mind that in this war, though there has been organised aerial fighting, with machines operating in squadrons, all such actions and formations have been on a small scale. Machines and weapons, too, have been of low power; while strategy and tactics have been elementary.

XXV

The Handling of Air Fleets

In the future the commander of an air fleet will, of course, have a large number of machines under his command; big, heavily-armed craft, flying at high speeds, and capable not only of manœuvring either to and fro, or from side to side, as on the sea, but capable also—say prior to an action—of ascending to high altitudes, or of diving at immense speeds to gain a tactical advantage. The handling of an air fleet, extraordinarily mobile, and moving at speeds unknown on land or sea, must introduce problems of strategy and tactics which will prove difficult of solution even by the most ingenious brains. On sea or land, strategy seems to have been worked almost threadbare. But in the air, should some struggle of the future come, there will be opportunities that are vast and far-reaching for the commander of genius; for the man who, adapted temperamentally to these new conditions, and with a mind capable of making rapid, unswervingly accurate decisions which will be necessary in the air, has been able to grasp also, more completely than any opponent, the first main principles which will govern the use of aircraft in fleets rather than in units or squadrons.

The nation will be fortunate and also well-advised which, having found such a man, gives him the amplest resources and the fullest scope.

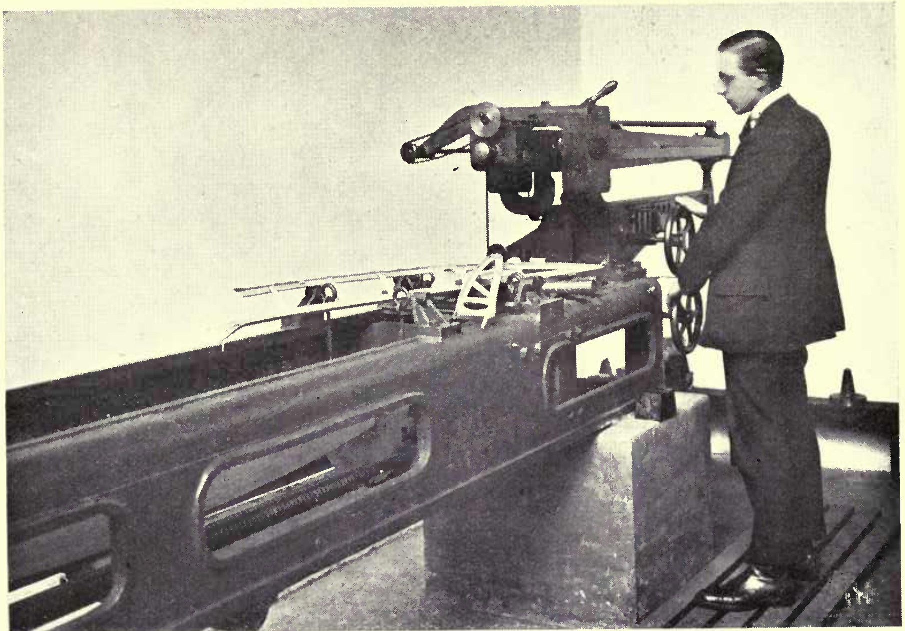
One may assume, for the sake of argument, that two nations each equip themselves, after a determined effort, with large and efficient air fleets. What will prove decisive, should these fleets meet in action, will be the way in which they are handled in what must prove, from the point of view either of strategy or tactics, a new and highly complicated form of war. It will be the mental dexterity behind an air fleet which will prove important. To concentrate forces, to have them in the right place at the right time, when there is the vastness of the air space to be reckoned with, will be in itself a problem of immense difficulty. There will be questions of speed, too, which will require exhaustive study. When oceans can be crossed by an air fleet in a matter of hours instead of days, the minds which plan a campaign, and estimate with accuracy these new problems of time and distance, will need an exceptionally rapid grasp of the situation. It will be necessary, as a matter of fact, in the first great battle of the air, to grasp these new factors by intuition rather than by experience.

XXVI

Troop Transport

A matter that needs attention is the possibility, in the future, of transporting troops by air—the bringing of reinforcements, for instance, to any line that is hard pressed, or the landing of bodies of troops for a flanking movement. By using air transport it might be possible to turn an enemy position in a way that would be impossible by any movement on land. It should be possible, also, to transport machine-guns and light artillery by air. This war has come too soon for aviation in many of its aspects.

The problems of an air invasion, of an army landed by aircraft in a hostile country, duplicate in some respects those of an invasion by sea. But an invading force, when it comes by air, is not restricted to a landing along any specific stretch of coast, or on any particular beach. The invading aircraft could land troops at any point within an enemy's territory which might appear most suitable, and which was least defended;



F. N. Birkett.

Occasionally, in testing materials, the ribs or spars of an aeroplane (and metal parts also) are subjected deliberately to such strains that they fracture—the actual breaking strain being recorded for the information of the technical staff. In the picture above, a wing rib is seen which has just been tested to destruction.

while the lines of communication of these troops, and their supplies, could be maintained by air.

But aircraft which act as transports must suffer from much the same vulnerability as do transport vessels on the sea. If they are to raise a number of men, they will be comparatively slow-flying; and, in order to carry a maximum of useful load, they cannot be armed more than superficially, or their hulls protected. They must therefore be susceptible to attack, and might fall easy victims to hostile warplanes, unless guarded effectually by a screen of fighting craft.

A point to be considered, when studying the tactics of defence, is the speed at which aircraft will fly. Learning, for instance, by wireless that a surprise landing was being attempted on any part of its territory, the country which was menaced could send fighting aircraft to the spot with great rapidity; and the aerial transports of the enemy, while alighting and discharging their troops, might run a heavy risk of destruction, even when there was an effort to screen them by means of armed escorts. To land in an enemy's country by air would be all very well if that country was weak in its defences. But in future contests between nations, each provided adequately with aircraft, it would seem necessary for one or the other to win an aerial victory before attempting an invasion by air—any invasion, that is to say, which was on a large or definite scale. Isolated raids there have been, and will be, aircraft being ideal weapons for such guerilla operations.

But in any world campaign, with countless millions being spent, and blows planned and delivered on a shattering scale, all minor forms of offence must lose their significance. It will not be sufficient to harass an enemy, or wait for his exhaustion : he must be hit so hard that he will collapse quickly.

PART II

PROBLEMS IN CONSTRUCTION

PAST, PRESENT, FUTURE

I

The Initial Problem

THERE were, in the evolution of the aeroplane, three main problems to be solved—

1. To obtain wings, or planes, which would bear through the air the weight of a man, and of the engine which drove his machine.

2. To control and balance such an apparatus when it was in flight.

3. To discover some form of engine which should be sufficiently light, and at the same time sufficiently powerful.

Nature gave men guidance in the building of sustaining planes. The wing of a bird arches upward from front to back, most of the curve taking place near the forward edge. The effect of such a curve, when a plane shaped on Nature's model is moved rapidly through the air, is two-fold. The plane, as it moves forward, divides the air which impinges on it into two currents. One sweeps above the plane, and the other below.

The current that passes below, following the curve of the plane, is thrust downward, and, while being so acted on, imparts an upward lift to the plane. The air current which moves above the plane, rushing up as it does over the arch we have mentioned—and which occurs, it must be remembered, near the forward edge—is deflected upward with such force that it cannot descend again immediately, or follow the downward curve which takes place towards the rear of the plane. What happens, therefore, is that, between this current of air and the curve of the plane, a partial vacuum is formed; and this vacuum draws upward on the plane, which gains support not only from the air passing below, but also from that which sweeps above it, the latter influence being the more powerful.

II

The Power of the Air

Such a plane is inoperative unless it is in fairly rapid motion, or unless a current of air is blowing on it. The air, being an element of such small density, will yield support only when it is struck quickly by some large, light surface which has been built specially to act upon it. If you stand and open an umbrella on a calm day, and hold it above your head, you feel no aerial influence at work at all: neither the umbrella nor the air is moving. The power which lies in the air when it is in motion, or when some object is moved through it, is in this case dormant. But if you run forward with the umbrella, even on a calm day, you soon feel the drag of the air upon it; or the effect will be the same, on a windy day, if you stand still, and the air itself beats on the umbrella. In the one case you provide the motion which allows the air to act on the umbrella; and in the other the wind itself, owing to the fact that it is in motion, reveals its hidden power.

This power, what one might call the unsuspected solidity of the air, intangible though it seems, one can gauge when one stands on a hill, in a sixty-mile-an-hour wind, and feels the striking power of gusts which, though they are invisible, drive one a step backward. At such a moment, if one imagined oneself holding in the stream of the wind a large curved surface such as we have described, it would not seem difficult to believe that this surface, acted on powerfully by the wind, would bear one upward. What happens with the aeroplane, what explains the fact that it flies, is that the engine and propeller of the machine, driving it forward through the air at, say, sixty miles an hour, create a pressure on its planes just as powerful as one may feel when standing on a hill-top in a gale of wind. In one case it is the air that is in motion, in the other the machine; but the resulting pressure is the same. And it is this air pressure, converted into a lifting influence by the curve of the planes, which supports an aeroplane in flight. It is the speed of the machine, the forcing of its planes against the air, which enables it to support itself. It must preserve this forward motion, the pressure on its planes must be maintained, or else it will cease to bear its load.

The weight that any given plane surface can carry through the air will vary according to the speed at which it is moving, the curve that is imparted to it, and the angle at which the plane strikes the air. In the earliest gliding machines, in which men passed down through the air from the tops of hills, using gravity as their motive power—"coasting on the air," Wilbur Wright called it—the planes bore a load of not more than about a pound per square foot. Then, with power-driven aeroplanes, moving more quickly through the air and with their surfaces more skilfully designed, it became possible to carry a load of two or three pounds per square foot. And this was soon improved on. Nowadays the load that each square foot of surface will raise is, say, six, seven, or eight pounds. The lift that can be obtained from the air, small as its density is, has been shown by the fact that the planes of racing monoplanes, machines flying at a very high speed, have borne through the air a load of nearly twenty pounds per square foot.

III

British Pioneers

More than a hundred years ago a British engineer, Sir George Cayley—one of the great pioneers of flight—was explaining the lifting power of curved surfaces. More than sixty years ago Stringfellow, another Englishman, had built a model aeroplane, driven by steam, which employed such curved planes and which actually flew—proving beyond question the support that could be obtained from the air. And Stringfellow did more than this. He had sought and found—apart from the building of a tiny steam-engine which weighed about thirteen pounds and which would develop one horse-power—a means of employing this power effectually in driving his model through the air.

Here it should be explained that, while men can imitate successfully the wing-curve of a bird, they cannot, or at any rate they have not so far, found it practicable to imitate the wing-flapping method by which the bird moves through the air. To obtain this wing movement, which is so powerful and at the same time so supple, the bird has been given by Nature a wonderful system of muscles—delicate, perfect for their purpose, light and yet tremendously strong. To make the wings of an aeroplane flap like those of a bird has been found so complicated, owing to the mechanism necessary, and the difficulty of transferring the power from the engine to the wing-gear, that much of the power is wasted. This does not mean, though, that any such system is abandoned finally; further experiments should prove interesting and instructive. Wing-flapping systems have, however, proved themselves so far to be unsatisfactory. The wings of an aeroplane are therefore built rigidly, being outstretched like those of a bird when it is in soaring flight; and the machine is driven forward through the air, not by any wing movement such as a bird employs, but by means of revolving propellers, which act on the air like the propellers of a ship in water.

Stringfellow, in his model which was so important a link in the chain of progress, used a couple of two-bladed propellers. They were very large, remembering that the density of the air is small; and it was necessary to drive them at high speeds before their blades would act with sufficient power on the air. Each of the curved blades of an aeroplane propeller may be likened, in a sense, to the sustaining planes which support the machine. Whereas the sustaining planes, when they are moved rapidly through the air, bear the weight of the machine, so the blades of its propellers, revolving at high speed, act on the air powerfully owing to their scientifically-designed surfaces, and screw forward as they turn, like those of a ship's propeller in water; or of a gimlet as you twist and force it into a piece of wood. And so the propeller or propellers of an aeroplane, their curved blades boring their way into the air, either draw or push the machine forward, and maintain that constant pressure under its sustaining planes which supports it in flight. The engine and propeller of an aeroplane are likened to the string of a kite. Only when its string is pulled, and the air made to act on its surfaces, will the kite rise and hold itself in the wind. If the string is cut, the kite drifts away before the wind, and sinks quickly. And the sustaining surfaces of an aeroplane, unless its engine and propeller drive it forward through the air, or its pilot—deprived perhaps of his engine-power through a breakdown—brings gravity to his aid and maintains the speed of his machine by a glide earthward, have no power of continuous flight.

Stringfellow, in his famous model, did even more pioneer work than we have described. He showed, for instance, how an aeroplane could be steered from side to side, when it was in flight, by the movement of a vertical rudder, in the same way as a ship is steered in water. And he showed also how a horizontal tail surface, placed behind the sustaining planes of the machine, would tend to give it stability when in flight by checking any pitching or diving movement.

IV

Factors which Delayed Progress

Here, indeed, more than sixty years ago, though in no more than a model form, was a machine which anticipated, in many ways, the modern man-carrying, mechanically-propelled aeroplane. Stringfellow's machine, if it had been built on a large scale, and if it had been fitted with a sufficiently powerful engine, and if a man had been found who could control it in flight, and take it into the air and alight again without accident, might undoubtedly have flown. But these "ifs" were very important; so important, indeed, that more than fifty years had to elapse between the flights of this model machine and the first ascent of a practicable, man-carrying aeroplane.

Hampering progress, for one thing, was the lack of a suitable motor. The petrol engine, perfected subsequently at the expenditure of many thousands of pounds for use in the motor-car—and developing, as the late Sir Hiram Maxim put it, "the power of a horse with the weight of a common barnyard fowl"—was still a thing of the future. The steam-engine, it is true, when it became available, was seized upon eagerly by certain of the pioneers. Sir Hiram Maxim, building a large experimental aeroplane at Baldwin's Park in 1893—a machine which he confessed afterwards was too large, in view of the limited manœuvring space at his disposal—employed two light compound steam-engines, developing a total of 362 h.p. But the quantity of water consumed was so great that the machine could not have remained in the air more than a few minutes. This machine, however, before it was destroyed in an accident, proved on a large scale what had been demonstrated previously with models. By the use of check rails, mounted above those on which the machine ran, and permitting a certain upward movement, Sir Hiram Maxim had been able to gauge the lifting power exercised by the planes of his machine when it was in rapid motion.

And it was found that at a speed of about forty miles an hour the machine would lift not only its own weight, and that of its engine and fuel, but also that of three men.

V

The Problem of Equilibrium

But in the building of such a large machine Sir Hiram Maxim—and Clement Ader also in France, who was experimenting at about the same time with steam-driven aeroplanes—was faced by a problem even more grave than that of getting a machine to leave the ground. What the inventor had to do, to use Sir Hiram Maxim's own words, was "to learn the knack of balancing it in the air." Here, indeed, was a difficulty which appeared for a time insuperable. There was no man living who, even if this machine had flown, as it showed itself capable ot doing, would have been able to control it in flight. To place in charge of such a craft a man who knew nothing of the navigation of the air would have been worse even than putting a man who knew nothing of steam-engines in charge of an express train.

It is not difficult to imagine the perils which would have faced a man who attempted to take this big machine into the air. It would have risen, no doubt; but how could a man who had never flown before gauge with precision the angle of his ascent, and prevent his craft from rising, say, so steeply—as an aeroplane may unless well handled—that it checks its own speed by the heavy pressure on its planes, with the result that it may come to a standstill in the air instead of moving forward, and then fall backwards towards the ground? And even if he had risen successfully and made a flight, the pilot would have been faced—a complete novice—by the task of bringing his craft back to earth, of making that contact with the ground which, even to-day, requires constant practice before a pupil can master it. Apart from this, too, the pilot would have been faced while in flight by the effect on his machine of sudden wind-gusts. These, striking against his planes and causing unequal pressures, would have threatened to swing over his craft and rob it of equilibrium. And, remembering his inexperience, he would have known none of the correcting movements which would have been necessary.

This problem of learning to balance an aeroplane, and bring it safely to earth when it had made a flight, seemed for a time so hopeless of solution that it threatened to check all progress, and bring experiments entirely to an end. And the difficulty was rendered all the greater, in view of the fact that the air is in constant and sometimes violent motion; is full, indeed, of such gusts, and eddies, as imperil constantly the balance of any machine that is moving through them. And such gusts are invisible. Unlike an ocean wave, which he can see bearing down upon him, the navigator of the air is struck constantly by waves the approach of which he has no chance of detecting.

VI

Gliding

How, then, were men to learn to fly? They could only do so, certainly, in the air. Yet to launch themselves boldly, handling levers in the use of which under flying conditions they were unfamiliar, meant nothing less than the wreckage of their machine, and perhaps the loss of their own lives. And to build a series of machines, one after another, until at last a pilot became proficient, was, even granted he escaped from his accidents with his life, a proposition so costly that it was impracticable.

Common sense, allied to the power of observation, solved this problem. Otto Lilienthal, a German engineer who from his youth had studied the flight of birds, saw that even when provided by Nature as they were with a perfect flying apparatus, the birds had still to learn patiently to use this apparatus. They could not merely leap into the air and fly. Lilienthal, watching young storks on his lawn, saw how they practised from day to day in the use of their wings, running forward a little way into the wind, flapping their wings rapidly once or twice and skimming a short distance forward, then losing their balance, perhaps in a sudden gust, and reaching down quickly to the ground with their long, cautious legs.

Could not a man learn thus to balance himself in the air, using some apparatus in which he could skim close to the earth, and in which, even if he lost control, he would be so near the ground that he would be able to alight without injury? This was the question Lilienthal asked himself, and he answered it by building a machine which we now know as a glider. It consisted of two light wings, resembling those of a bird, and containing sufficient surface to bear its owner's weight through the air. At the rear of the machine was a tail, again in imitation of the bird, which would tend to prevent it from pitching or diving. So light was this apparatus that Lilienthal, taking his place between the wings, could lift it to the level of his shoulders and run forward with it. His method of practice was to stand on the top of a hill, and run against the wind. The speed of his own movement, and the thrust of the wind, soon brought a pressure under the wings of the machine which was sufficient to support the weight of the man and the apparatus. Lilienthal would then draw up his legs and glide free of the earth, gravity providing him with his motive power, and permitting him when conditions were favourable to move through the air down the side of the hill, only a few feet from the ground, and yet in actual flight, and with an opportunity of practising those balancing movements which it was his aim to acquire.

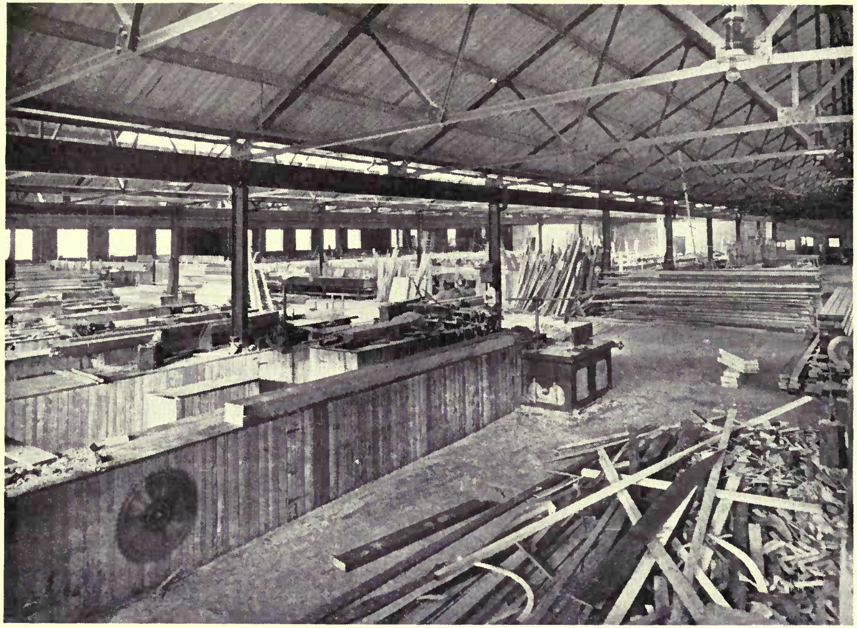
For five years, before he met with his death through a fall, Lilienthal practised the art of balancing himself in the air. And he learned, merely by movements of his body as he passed through the air—inclining his weight either forward or backward or from side to side—to combat the overturning influence of wind-gusts, and to glide without losing his balance for distances that sometimes reached 1000 feet. He showed indeed, for the first time, that a man who was patient and willing to learn might make himself at home in this element, the air, and might acquire the art—though his mechanism was crude in comparison with theirs—of balancing himself in flight even as did the birds.

VII

The Wrights

There were other pioneers who carried on Lilienthal's work: Pilcher, for instance, in England; Chanute in America; and Ferber and others in France. And then in 1900, after studying the experiences and the writings of the earlier pioneers, came Wilbur and Orville Wright. They built gliders larger than had been used before, in order to pass longer distances through the air; and these gliders being too large to be balanced by the simple method Lilienthal had adopted—that of swinging his body to and fro or from side to side—the Wrights made use of a system of auxiliary surfaces and flexible plane-ends by means of which the operator of the machine, remaining himself motionless, might steer up and down or from side to side, and also prevent his craft from heeling too far sideways under the influence of wind-gusts. To make their craft rise or descend they fitted in front of it, on outriggers, a small horizontal plane, which was so pivoted that it could be held either in a horizontal position or inclined upward or downward, presenting its surface at either a steep or a moderate angle to the air.

The operation of this elevating-plane—which is now adopted universally, being fitted either in front of or behind the sustaining-planes—was as follows: when the pilot tilted the plane upward, to ascend, the pressure of the air on it caused the whole of the front of the machine to assume a steeper angle to the air; with the result that the main sustaining-planes, assuming also a steeper angle, had their lifting power increased accordingly. Whereupon, at an angle determined by the inclination of the elevating-plane, the machine would rise into the air. A reverse movement of the plane, tilting the machine downward, would cause it to descend. Of course an elevating-plane, like any other of the surfaces of a machine, is operative only when a stream of air is acting on it; when the machine, that is to say, is in forward motion. The action of the controlling surfaces of an aeroplane may be likened, in a sense, to the action of the rudder of a ship. Unless a ship has steerage-way—is moving, that is to say, at a pace which allows its rudder, when shifted over, to act with suffi-



F. N. Birkett.

The wood-working department in an aircraft factory. So long as aeroplanes are machines of a short life, with types changing constantly, it is more convenient, and less expensive, to use wood in construction, than would be the case with metal. But in the future, as construction develops, tubes of a high-grade steel should, to a large extent, take the place of wood.

cient power on the water streaming past it—the vessel is not controllable. And it is the same with the governing surfaces of an aeroplane.

Steering from side to side the Wrights achieved by means of a vertical rudder, such as we have mentioned already; while for maintaining the lateral balance of their machine they devised a system—imitating so far as was possible in wood and canvas the delicate movements of a bird's wing — whereby the rear extremities of their sustaining-planes could be warped, or rendered flexible, and could be moved a certain distance up and down. The effect of such an action, which is obtained more generally to-day by a movement up and down of auxiliary surfaces at the rear edges of the main-planes, which are known as ailerons, may be described thus: should a wind-gust swing the machine over sideways, the pilot warped down his plane-ends on the side of the machine which was tilting downward. The result, seeing that the movement caused the plane-ends to assume a steeper angle in their relation to the air, and exercise thereby a momentarily greater resistance, was to raise the side of the machine which had been tilted down, and restore the craft to a normal position. By inter-connecting the control wires, this balancing action could be exercised with a double force: when one wing was warped down the opposite one could be warped up; and so, while the side of the machine that had been tilted down was caused to rise, the opposite plane-ends, which had risen, were acted on reversely, and a forcing-down pressure applied to them. To facilitate turning also, and to correct the drag or resistance to forward motion which might be caused by the action of the wing-warp, the Wrights inter-connected this warp with the control actuating the rudder, and were able to operate both by a movement forward or sideways of a single lever.

The general system of control is worth remembering, because it forms the basis of operation of the aeroplane to-day: the elevating-plane for rising or descending; the vertical rudder for steering from side to side; the wing-warp, or ailerons, for preserving lateral balance. These actions, with an engine and propeller to drive the machine, and give its sustaining-planes their lift, comprise indeed the equipment of the aeroplane; not forgetting, of course, the human element, the guiding hand which controls and steers the machine when in flight, and brings it safely to earth again when its journey is done.

VIII

The First Practicable Aeroplane

For three years, without serious accident, the Wrights practised the art of gliding flight, learning to control a machine even in high winds, and with perfect ease. Then, the development of the motor-car having brought a petrol engine within the bounds of possibility as a motive-power for aeroplanes, they built themselves a light, fourcylinder motor in their own workshop, and fitted it to one of their gliders so that it would drive two propellers by chain gearing. And here one reaches a salient point. Thanks to their experience with gliders, and the knowledge they had gained, the Wrights were able to take this power-driven machine into the air—piloting it in turn—and to make a series of short flights entirely without accident. It was in December, 1903, that the first power-driven flight was made; and a couple of years later, in 1905, the Wrights were flying for more than half an hour without alighting, during which they climbed, dived, and circled in the air, showing indeed that they had a complete control over their machine.

And so now the three main problems were solved. Men had wings that would bear them through the air; they had motors which were sufficiently light, and sufficiently powerful, to propel their machines; and they had learned, when such machines were in the air, and were being driven by their motors and propellers, to guide them in any direction they wished, to resist the influence of gusts, and to make a landing safely.

Not that the conquest of the air was as yet complete. It had, in fact, only just begun. The first aeroplanes were frail and low-powered. They flew too slowly, and needed too constant a manipulation by their pilots, to enable them to combat high winds. The engines, too, which drove them, being crude and purely experimental, and needing to run at high speeds, delivering their full power in order to keep a machine in the air, were breaking down constantly. It was also a fact that the aviators who were then flying, having had so little experience, and being as yet uncertain in the handling of their machines, felt justified only in ascending when weather conditions were favourable.

But, the main problems once solved, the rest was a question of development and refinement: of an assiduous perfection of detail, and of that gradual gaining in experience, obtained by constant flying, which brought aviators an increase not only of skill but of personal confidence. Machines were built more strongly; motors were rendered not only more reliable but were given a greater power, and this enabled men to fly faster, and to combat higher winds.

IX

Wind Flying

To fly, though, for several hours, under adverse conditions, was found to entail for the pilot, apart from any question of nerve strain, a considerable physical effort. He had to make a constant and rapid use of his controlling surfaces; and the movement of these surfaces, effected by hand or foot levers acting through wires, might need in a heavy wind a strong muscular effort. Pilots found indeed, often, after an hour or so's flying in bad weather, that it was physical exhaustion which compelled them to alight, rather than their inability, at any given moment, to resist the attacks of the wind.

In early-type aeroplanes, it should be noted, the comfort of the pilot was not studied as it is now, and he had to sit often in such a cramped position that, quite apart from any muscular effort he might have to make, he soon felt stiff and fatigued; while if the weather was cold, and even granted he was warmly clad, his hands and feet became painfully numbed. His controls were not placed so accessibly as they are to-day; while his compass and other instruments were fitted wherever it might be convenient to fit them, and not where it was most easy for him to see them. All such disadvantages as these, though they were minor ones, proved detrimental to the making of long cross-country flights.

X

Inherent Stability

It was found possible, in order to render aerial navigation generally more safe (and with the greater engine powers which became available giving considerably higher flying speeds), to design aeroplanes which had an inherent stability. One reaches, here, a question which is interesting, and at the same time technical and somewhat involved. It is possible, however, to attempt an explanation in this form. First one must bear in mind that an aeroplane which is not inherently stable, which cannot adapt itself automatically to such fluctuations in air pressure as it may encounter, needs the personal manipulation of its pilot to maintain it in equilibrium when it is passing, say, through a gusty wind. And it may happen that such a machine, if struck by an exceptionally heavy gust, swings over so far sideways—failing to respond to its pilot's controlling movements—that it assumes an angle so acute it begins to side-slip, skidding in a sense like a motor-car instead of continuing to move forward. The pilot, should this happen, is for the time being helpless. His controls are only operative so long as his machine is moving forward through the air in normal flight. While it is side-slipping, its forward speed gone, he can exercise no effective controlling influence. All he can hope for is that, during its fall, and before it strikes ground, the craft may attain such a momentum that its controlling surfaces will again become operative. He may be able to convert the side-slip into a dive, and this will restore power to his controls. But unless the machine is flying fairly high at the moment it side-slips, there is a risk that while still out of hand it may strike the ground and be wrecked.

Science, after a study of wing-shapes, with their curves and angles, and of such methods of gaining stability as result from a tilting up or sloping back of planes, can indicate now how planes may be built which, even without any controlling movements on the part of a pilot, will themselves resist while in flight the tendency to lose equilibrium which may be set up by wind-gusts and eddies.

To describe minutely the theory of inherent stability, remembering we are writing for general readers, would be to enter into questions of an abstruse technique. But this much may be said. It is possible, merely by shaping and placing at certain angles of the sustaining-planes of a machine, and by a scientific and carefully studied relation between these main-planes and their subsidiary surfaces, to produce an aeroplane which, when a wind-gust strikes it and it threatens to heel over, will itself apply, by aid of the positive and negative pressures which are set up automatically on its surfaces owing to their change of angle and relative position as the machine begins to roll, a self-righting influence which is inherent and unfailing. A wing that is tilted upward by the wind may for instance have imparted to it, solely by the way in which the air now impinges on it, a distinctly negative or down pressure, instead of a lift—and this will tend, naturally, to force it back to a normal position; while a wing that has been depressed may, on the other hand, just through its being in this position, and through the action of the air on it while it is tilted downward, be given such an enhanced lift as will tend to thrust it upward.

It is in this way that compensating or opposite forces, derived from the action of the air striking at various angles on specially-designed surfaces, may permit a machine when it is in flight, and so long as it is moving at a pace which renders its surfaces operative, to preserve constantly its own stability; not only laterally or sideways, but also—owing again to the shaping and placing of its surfaces—in a longitudinal or fore-and-aft direction.

To obtain such aeroplanes, inherently stable, is a step, naturally, of the highest importance. It means that once a machine is free of the ground, and at a fair altitude, it may be flown without danger of becoming uncontrollable, and steered through any wind, no matter how violent, that its engine gives it the power to make headway against. Such a result may also be obtained, it is true, with an aeroplane that is not inherently stable, granted its pilot is sufficiently skilled, and can himself apply unerringly, in his own controlling movements, what the craft that is inherently stable will do without assistance. But even so, and assuming his skill, one must remember the fact that, owing to the fatigue of his constant movements, the pilot in the machine which is not inherently stable may be able to fly for only a few hours before he is obliged to descend. In an inherently stable machine, on the other hand, an aviator of no more than average skill will be able to make a long flight in even a high and boisterous wind without any fatigue, or need for alighting.

It is possible for the pilot in an inherently stable machine, having gained a sufficient altitude, to take his hands from the controls, and allow his machine to fly itself; provided he keeps it on its compass course by an occasional touch on the rudder, and attends also to the running of his motor.

The value of inherent stability, in reducing the risks of flying, and apart from special problems which are introduced by the use of machines in war, can scarcely be over-estimated. The fact that such stability cannot as a rule be gained, at any rate in our present stage of knowledge, without entailing for various reasons some slight loss of lifting power or speed, or both, is not a drawback that is vital in peace flying, though it may be in war. The advantages of stability, in ordinary flying, may be said to outweigh any of its disadvantages; and even these disadvantages, which are purely technical, may, it is reasonable to assume, be eliminated as time goes on.

People who have no more than a nodding acquaintance with aviation imagine often, when they see an aviator aloft in his machine, that he can only maintain himself in flight, and prevent his machine from overturning, by a constant action of his controlling levers. They regard him indeed as a sort of aerial gymnast, a man whose skill alone, as he balances his craft, stands between him and a fall. Yet how different is the reality. A modern-type aeroplane, inherently stable, will recover itself from any position in the air, no matter how abnormal, and resume of its own accord its ordinary flying path. If such a machine was launched, say, from a height, upside down, it would swing over and assume its proper position in the air. If the pilot, by way of testing its stability, should deliberately force it over sideways until it began to side-slip, the machine would yield for a moment only to bring itself back to a safer angle. If the aviator drove it up so steeply that it lost forward speed, and began to fall tail-first, it would come to a momentary standstill in the air, and then, inclining its bow downward, would begin to move forward again in a dive which, as soon as the machine had gathered sufficient pace, would be converted automatically into horizontal flight.

It is, in a word, impossible for the wind, or for a pilot even by a deliberate mishandling, to force such a machine more than temporarily from its normal flying position. Given only sufficient air space, the craft will recover itself. But when in a heavy and dangerous wind, with its equilibrium assailed constantly, the machine may yield for a moment, heeling or diving under the onslaught of an abnormal gust, before its self-righting power can be exerted. And this is due to the fact that, unless a machine is in forward motion, flying at approximately the speed at which it was designed to fly, its inherent stability and self-righting power, generated by its planes when the air is acting on them, cannot be exercised properly. If, for example, a machine is robbed for the time being of its forward speed, and is forced over at the same time to a critical angle, it may need to drop some short distance through the air, recovering thereby its momentum, before the air pressure on its planes is sufficient to allow them to reassert their stabilising function.

XI

Safety in Altitude

Height is essential to safe flying, even with an inherently stable machine. And here another comparison is possible between the navigation of air and sea. It is when he is near a coast-line that the sea-captain posts his outlook men, and has his moments of anxiety. Not until he is well away in mid-ocean does he feel really comfortable. And with the aviator, when he sets out on a flight, the farther he leaves the earth below, the more secure he feels.

It is at the moment after leaving the ground, or just before alighting, should the wind be heavy and fluctuating, that a pilot runs most risk. While still near the ground, in ascending, if his machine is caught by a rush of wind which has a downward trend, he may be swept back to earth with a damaging impact, before the stabilising action of his machine has had time to be effective. And when descending after a flight, should he come suddenly within the influence of a heavy air trend, he may be carried abruptly to earth—again before his machine can recover itself—and with injury perhaps to himself and his craft. But with machines having ample engine-power, and when flying is conducted from large aerodromes, free so far as is possible from awkward ground currents, even this danger is practically eliminated.

Descending into a small landing-ground with an aeroplane, when the wind is high, is like trying to bring a ship, during bad weather, into a small and awkward harbour; and one should not forget that even to-day, after years of organisation and a perfection of detail, it happens not infrequently—owing to stress of weather—that large and powerful steamships are unable to enter the harbours for which they are bound. It is scarcely surprising therefore that, in high and gusty winds, and with machines small and low-powered, and with landing facilities imperfect, risks should have to be run at the moment of rising and alighting—though skilled piloting will do much to avert them.

There are certain conditions, during heavy gales, when it is impossible to get an aeroplane from the earth into the air; impossible, that is to say, without grave risk for the pilot. One may, perhaps, though the simile is not perfect, liken the position to that in which it is sought to launch a small boat on a rough sea. The moments of peril for the boat, as for the aeroplane, come just after it has left the one element and before it has embarked fairly on the other. The boat, lifted on some wave before it is in deep water, may be dashed down again, and brought into a violent contact with the beach. And the aeroplane, rising through a heavily-disturbed air, may be caught by one gust, only to be swept back to the ground again by another, before it can gain an altitude which would spell safety. The boat, once free of the breakers, may ride out the waves that lie beyond. And with the aeroplane, once given height and an engine of sufficient power, running well, there is practically no wind, however strong, that it cannot weather in safety; though of course, if the speed of the wind is greater than that of the machine, it may be forced backwards through the air instead of making progress towards its destination.

So long as aeroplanes remain small, and with low engine-power, they cannot be said to have conquered the wind, even though they have reached, as they have, the stage at which, once well aloft, the wind has lost its power to rob them of equilibrium. The criterion by which they must be judged is their ability to travel from point to point against the wind. One might, for example, have a small boat which was so seaworthy it would ride out any amount of rough water; but such a boat, if its motive power was so low it could make no reasonable headway against wind and sea, would not be much use, say, for crossing the Atlantic. Aeroplanes of to-day, even the largest, represent nothing more, if contrasted with machines of the future, than the smallest of steam-tugs, when seen in comparison with one of the largest of ocean-going liners. The ability, however, to render machines inherently stable, even the small and comparatively slow-flying machines of to-day, strengthens our confidence in the machines of the future. The large, high-powered aeroplane we shall have in a few years' time, with its inherent stability and the speed at which its motors will drive it through the air, will be able not only to resist but to make headway against even the strongest of gales.

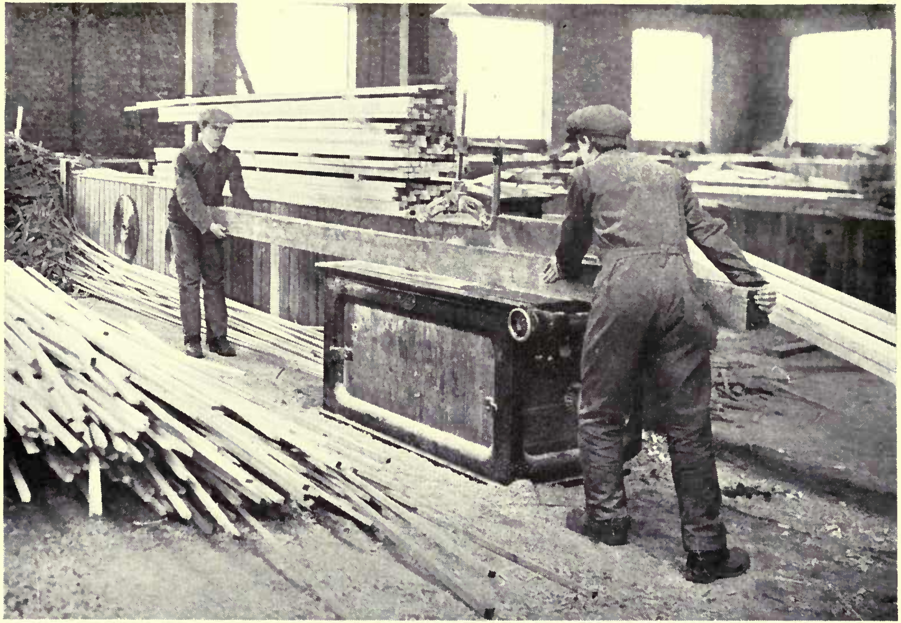
XII

The Increase of Speed

In the work of the immediate future, so far as naval and military aeroplanes are concerned, a machine which will require skill in its design and construction is the high-speed scout.

In future, should nations meet in war, rapid aerial scouting will have an importance even greater than has been the case in this campaign. An air fleet, ascending for action after a declaration of war, and seeking an immediate engagement with the fleet of the enemy, will send out in advance of it a number of these high-speed scouts. They will have to fly long distances without alighting, each of them following some specified route. In this way it should be possible, within a few hours, to obtain news of an enemy's movements over a wide area of land or sea.

These scouts will require a wireless installation of high power, capable of sending messages a distance of hundreds of miles to a receiving station. Their crew need not comprise more than one or



F. N. Birkett.

A length of silver spruce, a wood employed largely in aeroplane construction, is shown as it is being sawn into sections to form the spars of a wing.

two men; the fewer the better, because all weight thus saved would mean an increase of speed and of radius of action. The machines might carry perhaps three occupants—two pilots, both skilled in observation, and a wireless operator. Such scouts would be the eyes of a nation when at war. On their preliminary scouting—on their success in locating and keeping in touch with an enemy's air fleet—the success of an action might depend.

The importance of speed in such machines would lie in the fact that it would be their speed, and their speed alone, which would permit them to penetrate above hostile positions when on a scouting flight, and return with their news to headquarters without being intercepted and shot down by hostile patrols, or hit by enemy land-fire. The faster the machines are, the greater boldness they will be able to display in passing over enemy territory; and this will mean, of course, that their news is so much the more valuable. Their policy will not be to fight, but to run away. Immediately hostile patrols sight them, and begin to close in on them, they will have to rely on their speed to keep them beyond the range of the enemy's guns.

By building scouts purely for speed, and by studying every factor which may increase this speed, it should be possible to have machines capable of dashing in above an enemy's territory, eluding his patrols, making a rapid, general observation, and escaping again without being brought to earth. Great personal skill will be necessary in handling these machines, and the observers in them will require to be picked men, capable of gleaning a maximum of information during the short time they will be over an enemy's lines. Such men and such machines will not, of course, be risked indiscriminately, or without good purpose. The gauntlet of fire they may have to run, both from earth and air, will be so severe on occasions that some of them will fail to return. It will only be when important news is urgently required that these high-speed scouts will be called on to run the gauntlet, penetrating above positions which are defended heavily. Atmospheric conditions may of course help them considerably. They may be able to approach their objective hidden by cloud, and then dive suddenly into clear air, making a quick survey and then ascending again to the shelter of the clouds.

A question arises whether it is possible, in designing such scouts, and other machines also, to increase to any material extent the speeds obtained to-day. Of course the faster the machines could be made to fly, the more valuable they would be. In this war there are single-seated machines in use which fly at more than a hundred miles an hour—some, indeed, at speeds which are reported to be as great as 150 and even 160 miles an hour. But under present systems of construction such very high speeds can be gained only by building a machine which requires such dexterity in handling it, particularly in effecting a landing, that only a pilot of exceptional skill can be placed in charge of it; and even then, unless he has a surface of an almost billiard-table smoothness on which to alight, the speed at which he has to make his contact with the ground may cause his machine to overturn, or may break some portion of its landing gear.

Scouting and fighting machines are in daily use at the front, and can be landed on an ordinary aerodrome surface with a fair amount of safety, which reach flying speeds of slightly more than 100 miles an hour. And this represents a limit, with machines constructed as they are to-day, unless a landing can be made on a specially prepared surface, and one which offers also a large and unobstructed space.

When a flying corps is on active service, under present conditions, it is not possible to obtain specially prepared aerodromes for the alighting of high-speed machines. As an army moves, during, say, an advance, the flying corps bases have to be moved with it. And this means that there can be no special aerodromes. What is done is to select the largest and smoothest field which can be found in the neighbourhood where a landing-place is required. But the surface of such a field is, of course, in the majority of cases, far less suitable for the alighting of high-speed machines than would be that of a permanent aerodrome.

XIII

Flying Speed and Landing Speed

An aeroplane is not in the position of a ship, which, once it is launched on the water, lives on that element continuously, except for brief periods when it may be docked for repairs. An aeroplane, having risen into the air for flight, must return again to earth when its journey has been made, alighting at a pace which—at the present time and with present methods of construction—is governed by the maximum speed at which it flies. Aeroplanes have to be built for use not in one element, as with the ship: they must be able to manœuvre on the land as well as fly through the air. This means that they must be given a landing-chassis, with its supporting struts, shock absorbers, and pneumatic-tyred wheels. And the aeroplane, apart from using this chassis when it is moving along the ground, or is in the act of ascending, must carry it up with it when in flight—in spite of the fact that it spells weight and wind resistance—in order to be able to alight on the chassis again when the aerial journey is at an end.

Aeroplanes, when they are designed and built, are given a certain amount of wing-surface according to the loads they will have to carry at the speeds they are designed to attain. A machine flying at say 100 miles an hour as its maximum speed will alight (to state an average) at about 40 miles an hour. What this means is that 40 miles an hour is the slowest pace at which the planes of the machines will bear their load through the air. If the pilot reduces his speed below this point the machine may dive or side-slip, passing out of control.

When its normal flying speed is greatly reduced, an aeroplane becomes what is called "sloppy" on its controls. The machine is designed so that its control surfaces are efficient when it is in flight at its maximum speed, and any reduction of this maximum speed impairs the efficiency of the controls, because the air is striking on them at a lower velocity, with the result that they exercise a less perceptible influence on the course of the machine. With well-designed surfaces, there is naturally an appreciable latitude. An elevating-plane which gains its maximum efficiency at 100 miles an hour will still be sufficiently operative, for all practical purposes, when a pilot is making a landing at 40 or 50 miles an hour. Its movements at the slower speeds will naturally require to be accentuated. Whereas at high speed the very smallest movement up or down will affect the flight of the aeroplane, the pilot will find it necessary, after he has slowed up his machine, to push or pull over his lever much further in order to gain a corresponding result.

There are machines to-day which are perfectly satisfactory in their control when they are moving at high speed. But when you try to land them slowly they are dangerous. They have not enough aileron or elevator surface to give their pilot a proper control over them when he attempts to alight slowly.

There are other factors which govern the alighting speed of a fast machine. If such a machine is lightly loaded with fuel, say for only an hour or so's flying, this has a favourable influence on its landing speed. The lighter the weight it carries, the slower the speed at which it can be landed. But if a high-speed scout is loaded heavily with fuel for a long flight, and if the pilot has to bring it back to the ground for some reason within a few minutes of starting out, and before his fuel load has been lightened, he may have to make a landing at a dangerously high speed.

Then there is the individual skill of the aviator to be reckoned with. There is a certain small scouting craft, of a type used at the front, which attains a maximum speed of 120 miles an hour. This machine, when in the hands of an expert pilot, can be landed at a speed of 30 or 40 miles an hour. The pilot lets the tail of his machine down, just before landing, and presents his main-planes at a steep angle to the air—checking forward speed in the same way that a bird may be seen to employ, turning back its wings and making them act as a brake, when it wants to bring itself to rest quickly on some given spot. But the percentage of very highly-skilled pilots—men able to land fast machines at slow speeds—is small. A pilot of ordinary skill, in alighting with the 120-mile-an-hour machine we have mentioned, might perhaps make contact with the ground at about 60 miles an hour, and this might prove a dangerous speed if the landing took place on any average surface.

The aim with aeroplanes for use in war should not be to obtain a machine which will do wonderful things in the hands of a specially-skilled man, but one which will yield good service when flown by an average pilot. An aeroplane which can only be handled successfully by one man in a hundred is not the machine that is wanted on active service.

It should be understood that an aeroplane, when it alights, does not do so with anything in the nature of a dead-weight impact: if such was the case, no chassis would stand the strain. What happens is that the aviator, when he decides to alight, switches off his motor, and then begins to glide down at a gently-sloping angle. A well-designed machine, when it is gliding, will descend on a gradual path say of one foot in six or one foot in eight—that is to say, it descends one foot perpendicularly for every six or eight feet that it moves forward horizontally.

Just before his eye tells him that the landing-wheels of his machine are about to touch ground, the aviator makes a movement of his elevator which checks the downward glide of his machine, and causes it to move through the air in a horizontal position, the landing-wheels being only a few feet above the surface of the ground. The forward speed of the machine now lessens appreciably, its dive having been checked, with the result that its planes begin gradually to lose their lifting power, and allow the machine to sink until its landing-wheels make their first contact with the ground. In this first impact only a small percentage of the total weight of the machine has to be borne by the wheels. The machine is still moving forward at some speed; therefore its sustaining-planes are still bearing a large proportion of their load. At this first impact the wheels should touch so lightly that they seem merely to skim the ground. As soon, however, as the wheels are in definite contact with the ground, the machine begins rapidly to lose its forward speed, with the result that the total weight of the machine is soon transferred from the planes to the landing-wheels. But this transference is sufficiently gradual to prevent there being an abrupt shock. It is difficult sometimes for a passenger to judge the precise moment at which the machine in which he has made a flight actually touches ground. His first indication that he has landed is often the up-and-down motion of the machine as it runs forward on the ground after the moment of contact, and before it comes to a standstill.

To learn to make a smooth and correct landing, and to do so time after time without error, represents one of the most difficult stages in the instruction of a novice. Sometimes a man will "flatten out" his machine quite correctly; but instead of being just on the point of touching ground when he does so, he will still be at some little altitude. This is due, of course, to an error on his part in judging distance. He sees the ground nearing him as he descends, and—often from nervousness more than anything else—brings up the front of his machine a second or so too soon. What happens, as a result, is generally disconcerting. The machine, having been checked in the glide which is preserving the lifting influence of its planes, comes almost to a standstill, and then drops perpendicularly on to its chassis, which suffers as a rule—as well perhaps as the propeller and other parts. The pilot, however, escapes generally with nothing worse than a shock; and the remonstrances of his instructor.

Occasionally, instead of being too soon to check his glide, a pupil will be a second or so too late. Remembering his instructor's warning to keep his machine well down after he has shut off his engine, and to glide at a speed which will ensure him a full control, the pupil will delay too long the moment when he draws back his lever slightly and changes the vertical descent into a horizontal glide. The result may be that the machine strikes ground heavily while still moving at some speed, and breaks its alighting gear.

But the remarkable fact in connection with the flying schools is not the accidents which happen, because these are extremely rare, but the fact that thousands of men can be trained to fly, as they are, with nothing more than an occasional breakage of some part of a machine.

Fatalities among pupils are very rare indeed; even a trifling personal injury is unusual. This immunity from accident is due mainly to the skill and thoroughness of instructors, and also to the fact that the pupil passes through a carefully graduated series of tests, and is not allowed to handle a machine alone until he has become thoroughly accustomed to being in the air. Accidents which happen during the early career of a pilot occur as a rule after he has left the care of his instructor and has begun to fly on his own account—making journeys across country from point to point, and facing such risks as were absent entirely from his trips above the aerodrome. It is in this stage, when he is free from the advice and control of an instructor, that the temperament of the young pilot may begin to reveal itself strongly. If he is cautious in a reasonable way, remembering his own lack of experience, all may be well; but if he is hot-headed and impatient, and if he fails to appreciate how little he knows, then a smash may lie in wait for him.

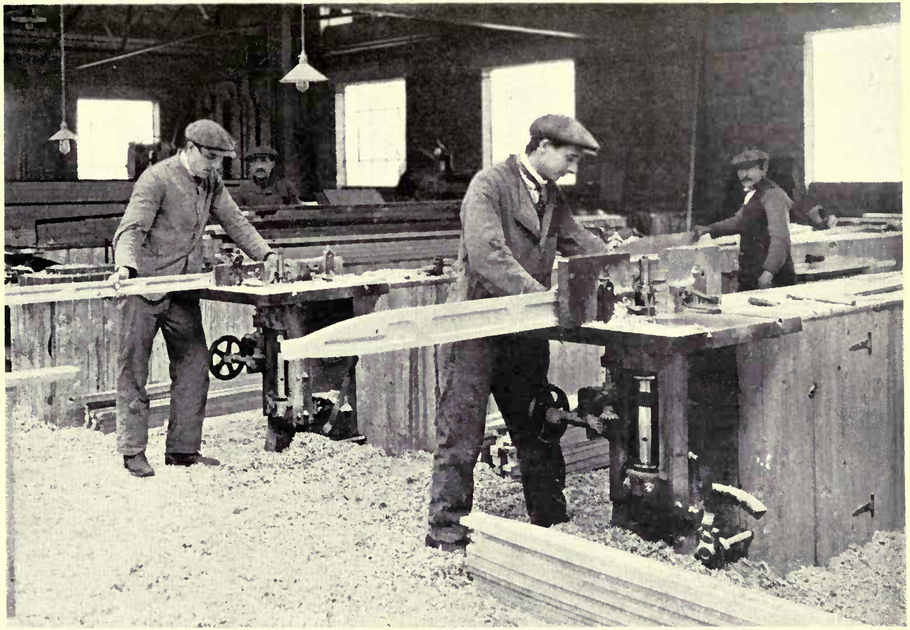
Perfect landings are only possible at reasonable speeds. In the case of a racing monoplane, built to take part in an international contest, the wing surface of the machine had been so curtailed that the pilot found he had to alight at a speed of nearly ninety miles an hour. And though the landing was made on the smooth surface of a carefully-prepared aerodrome, the machine sprang upward again after the first impact, and moved on through the air for some distance before it lost its impetus sufficiently to bring its wheels in contact with the ground again. And even then, though the aeroplane was flown by a pilot who was an expert in handling high-speed machines, it made another leap upward before coming to rest.

The chief difficulty of alighting, in one of these high-speed racing machines, is that their wing area, being heavily loaded in the endeavour to use a minimum of surface, gives a very small latitude in flying speed. The machines will bear their loads only so long as a high speed is maintained. In alighting, when a pilot attempts to slacken speed, the wing-lift diminishes so rapidly that the machine may tend to drop like a stone, and has no such gliding angle as is the case with a machine the planes of which are lightly loaded. If a pilot in a fast machine should encounter any furrow, or inequality in the ground, when he attempts to alight, his machine may spring into the air again after its first impact. And what he has to fear, then, is that the speed of the machine will have become so reduced, by the time it has exhausted the momentum of this upward spring and the moment comes for a second contact with the ground, that its wings will be bearing so little of the weight of the machine that this contact will be made heavily, with the result that the chassis of the machine may collapse. It happens often, when a pilot tries to alight with a racing aeroplane, that the machine springs again into the air in the manner we have described. Whereupon, rather than wait for a second and more violent impact, the aviator will switch on his engine again and make another circuit of the aerodrome. Then, when he makes another attempt at landing, he may be fortunate enough to encounter an absolutely smooth piece of surface, with the result that he will be able to keep his machine on the ground after its first contact, and prevent a dangerous rebound.

An aviator who flies a very fast machine across country, and has to descend involuntarily on a surface that is not perfectly smooth, may find it almost impossible to make a safe landing. If the wheels of his aeroplane encounter any furrow or roughness in the ground either at the moment of alighting or just afterwards, the machine may pitch forward on its nose, or perhaps turn right over in a somersault; and this will mean, at the speed at which it is travelling, that it is badly damaged or perhaps completely wrecked; while the pilot will be lucky if he escapes unhurt.

The problem of the relation between the flying and landing speed of an aeroplane is one of the utmost importance. Unless a machine can be made to alight slowly, as well as to fly fast, it will be impossible in the future to attain speeds as high, say, as 200 or 250 miles an hour—though these should be possible if only a slow landing speed can be made to accompany a high maximum speed.

An aeroplane with a fixed amount of plane area, built for a certain maximum speed, cannot reduce its alighting speed beyond a certain limit;



F. N. Birkett.

Above are seen the spindling machines in the wood-working department. The machine in the foreground is hollowing out sections from a wing-spar in order to lighten it.

and if its maximum speed is high, then (one writes of present conditions) its landing speed must be high also.

XIV

The Variation of Plane Surface

To overcome this difficulty, aeroplanes may be designed which have the power of altering the area of their wings while they are in flight.

An alternative method, which has already been tried but which can hardly be expected to give the wide variations in speed which will be required in the future, is to alter the angle of incidence of the planes. This means that the sustaining-planes are attached to the hull in such a way that the pilot can alter the angle at which they present themselves to the air. The planes, that is to say, can be constructed so that they will rock slightly, presenting themselves either at a steep or a fine angle to the air. When at a high speed, the planes are set so that they have a very fine or flat angle, thus reducing their lift, and also their drift or head resistance, so as to meet the conditions which exist at high speed. When he wants to fly slowly, say at the moment of alighting, the pilot can arrange the planes so that they are at a steep angle to the air. This gives them more lifting power, and enables them to bear the weight of the machine at a reduced speed; while the resistance they offer to the air, when at a steep angle, makes them act in the same way as would an air brake, slowing up the speed of the machine.

To alter the angle of incidence of a plane is more simple, mechanically, than to devise a means of varying the amount of surface which it presents to the air. But, when very high speeds are contemplated, to alter the angle of incidence is not likely to provide a sufficiently wide variation between high speeds and low.

If a successful method of varying plane area can be obtained, it will mean that in ascending, as an aeroplane moves forward across the ground at moderate speed, it will present its full wing surface to the air—gaining in this way a maximum lift, and leaving the ground quickly and climbing fast. Then, when the aviator has gained his required altitude, and wishes to fly forward at a high speed and not to climb, he will begin to reef or furl his wing-surface, reducing gradually the full area which had enabled him to ascend quickly—but some of which is now superfluous, and is hindering the rapid movement of the machine. In this way, as his craft begins to move forward more quickly through the air—its ascent having given place to horizontal flight—the pilot will continue to reduce his plane area until he reaches the point when the machine is exposing just sufficient surface, and no more, to bear it through the air without any tendency to lose altitude. And when this point is reached it will mean that the machine has attained a maximum speed, having regard to its engine-power and load.

With machines which have no power to vary their wing area, and which must sustain themselves in flight with one given surface, whether they are flying rapidly or at only a moderate speed, it means that when a very high speed is attempted the planes of the machine exercise such an increased lift—owing to the action on them of the more rapid air stream—that their tendency is to force the machine upward rather than to bear it forward horizontally. This tendency to rise a pilot must check by setting his elevating-plane so as to keep the machine down. But this action sets up friction and unnecessary resistance, and robs the machine of speed.

When the pilot in a variable-surface aeroplane has reached the end of his journey and wishes to alight, he will begin to throttle down his engine and unfurl again his wing-surface, exposing more and more surface as the speed of the machine slackens. By obtaining a large wing area again, when he needs it, he will be able to make contact with the ground at a speed slow enough to permit him to land without accident in a restricted space, or on rough ground.

An aeroplane which had the power to vary its wing area might attain, say, a maximum speed of 150 miles an hour, and yet be able to land at 20 or 25 miles an hour.

XV

Steel Construction

With present systems of aeroplane construction it would be difficult in the extreme, if not impossible, to provide any successful method for varying wing surface. The wings of the present-type aeroplane are built up as a rule with long, light wooden spars, across which wooden ribs are fixed, the framework thus formed being covered by a tightly stretched surface of cotton fabric. In the case of biplanes or triplanes, these planes are fixed one above another in a box-girder method of construction, being connected by a system of inter-plane struts and bracing wires. To adopt reefing or telescoping in planes of this construction, and to maintain at the same time rigidity and strength, would be a matter of almost insuperable difficulty.

Before a practical system of wing variation can be designed, it seems necessary that metal, instead of wood, should be used in construction. The main-spars of a wing, instead of being of wood, must be hollow tubes of high-grade steel, which can of course be made immensely strong. These tubes would be telescopic, one section moving within another. The surface of the wing would comprise a number of light metal plates which, in the outer sections which would need to contract or expand with the movement of the telescopic spars, would be made to slide one within another. The main-spar tubes would be so strong that towards the extremities of the planes, where the reefing of the surface would be effected, neither inter-plane struts nor bracing wires would be required.

Through the sliding of one section into another, when the main-spars were being telescoped, they would have a maximum strength, in their resistance to the pressure of the air, just when the machine was moving at its highest speeds, and was being subjected to the heaviest strains.

In front of the machine, projecting from the hull, a spar might be needed which would be the equivalent of the bowsprit of a ship. Cables would run from this spar to the extremities of the wing-spars, so as to take the drift or backward strain on the wings when the machine was at high speed. These cables would adjust themselves automatically to the moving in or out of the plane-ends, so that they would always be in tension.

In the pioneer days, sufficient attention was not paid, sometimes, to the drift or backward strain on a plane which is set up when it is in rapid motion. Constructors were more concerned with giving planes strength to meet the air pressures on them from above and below. But after accidents had happened in which planes had folded back and broken, a system of drift wiring was adopted. These wires, extending from the front of the machine on either side, and being attached to the wings at their forward edge, took up the drift strains. But such wiring should be eliminated, if possible, owing to the fact that it sets up resistance to forward progress when a machine is flying fast. To-day, with a greater science in wing construction, these drift-wires may be discarded without risk of structural weakness. In the design of a wing, and in its internal construction, an allowance can be made for drift strains, so that the wing will withstand such strains without the assistance of external wiring. But with the extremely high speeds of the future, and with the use of movable extensions unsupported by inter-plane struts, it may be found necessary to employ drift wires, passing from the front of the machine to these extensions.

When the sustaining planes of a machine are reefed it will be necessary, in order not to impair the equilibrium or controllability of the craft, to vary either the surface of its subsidiary planes, or to alter their angle of incidence. The control surfaces of a machine, if designed to be efficient when the craft was flying fairly slowly, and with its full wing area exposed, would exercise too powerful an influence—when the machine had reefed its main surfaces and was at high speed—unless they could be moderated either in surface or angle. It will probably be found convenient, and sufficiently effective, to alter the angle of incidence of these control surfaces. To attempt to vary their area, in conjunction with that of the main-planes, might prove too complicated.

In varying the area of sustaining-planes, it may be possible to perfect some system on which the machine itself should, by an automatic action, expose just what surface was required for any given speed. As speed increased, for example, and the pressure of the surfaces grew heavier, these might be constructed so that they would reduce themselves automatically, adapting themselves to the higher rate of speed, and providing only just sufficient surface to maintain the machine in horizontal flight. And by a reverse action, when the motors were throttled down and the speed began to lessen, more surface could be exposed, automatically, so as to sustain the machine when it was making, say, a slow descent on to a small or roughly-surfaced alighting ground.

XVI

Variable Pitch Propellers

In order that the propellers of an aeroplane should be efficient, when they are required to drive a machine at widely varying speeds, it will be necessary to give their blades a variable pitch, or angle, in relation to the air stream in which they work. A propeller with blades having one fixed or given pitch must be designed specially for the speed at which the aeroplane to which it is fitted is intended to fly. The designer of a propeller, being acquainted with the horse-power of the engine which will drive it, and the number of revolutions per minute made by the engine (say 1200), designs the blades of the propeller in such a way that, absorbing this engine-power when turning at 1200 revolutions a minute, they will screw themselves forward through the air a certain number of feet a second—this rate of forward travel represents the speed that has been chosen for the aeroplane. In the case of a tractor propeller, the machine is drawn forward by its propeller, which is placed in front; while in the case of a pusher, the screw is at the rear of the machine, and forces it forward.

A propeller designed to deal with the air efficiently, when revolving at a given speed, and moving through the air also at a given speed, will churn up the air and slip, without dealing with it efficiently, when moving at a speed which is much less than its designed speed. It is the same with the propeller of a ship. When a ship is moving slowly through the water, at far short of its full speed, the propeller churns and beats up the water, instead of dealing with it smoothly. But as the speed of the ship increases, and the blades of the propeller begin to work through the water at more nearly their designed speed, this turbulent and slipping action ceases.

It is not difficult to construct propellers with variable-pitch blades; but mechanism is of course necessary to gain the movement required, and this mechanism entails weight. And at the present time, when there is no extreme variation in the flying speeds of aeroplanes, the disadvantage of the additional weight, in using a variable-pitch propeller, more than outweighs the advantages. The use of a variable-pitch propeller, in place of one with an unvarying pitch, may add a few miles an hour to the speed of an aeroplane; but the difference is not sufficient to justify the additional weight and complication of mechanism. In the future, when speeds are increased, and there is a wide variation between high speeds and low, it may become essential to have variable-pitch propellers.

XVII

One Propeller behind Another

Much more needs to be known about propeller design, though scientific research is constantly bringing facts to light. It used to be considered that one propeller, if placed behind another, and revolving in the air stream thrown back by the propeller in front, would have its efficiency prejudiced owing to the fact that it had to work in a disturbed air stream. But experiments have shown that a propeller, provided that it is designed specially to work under such conditions, may be placed behind another—granted it is not immediately behind it—and still remain efficient.

The factor which has to be considered is that the first propeller, acting on the air its blades encounter, accelerates this stream of air until it is travelling at a high rate of speed. And it is in this accelerated air stream that the second propeller has to operate. What is done is to calculate the rate of acceleration of the air, as between the speed at which it meets the first propeller—this speed being the flying speed of the aeroplane—and the speed at which the first propeller throws it on the second. The blades of the second propeller are then given a pitch different from those of the first, so that they may work efficiently in an air stream which corresponds not with the speed of the aeroplane, whatever this may be, but with the additional speed imparted to the air by the action on it of the first propeller.

It may prove convenient, in building large aeroplanes, to be able to place one propeller behind another, and to do so without any appreciable loss of efficiency. It would be possible, for instance, to have one screw, working as a tractor, in front of a plane, and another one behind, at the rear edge of the plane, operating as a pusher, the two being divided by the chord or width of the plane, which might be assumed to be, say, ten feet.

XVIII

Future Speeds

If a successful method for varying plane area can be devised, and when variable-pitch propellers are employed there seems no reason why future speeds by air should not reach 200, 250, or perhaps even 300 miles an hour. At such speeds, with machines rushing through the air like projectiles, a very small amount of sustaining surface would be required. Machines would reduce their wing area gradually, as they increased their speed, until they were flying, so to say, almost under bare poles.

The question of wind resistance at high speeds—the resistance the machine itself offers to its own passage through the air—requires to be studied very closely. By a careful stream-lining or tapering of hulls, and the reduction so far as is possible of inter-plane struts and wires, wind resistances have been lessened already to a marked degree. But here there is an important field still for laboratory research. The aim, in the words of a constructor, is to build the hull of an aircraft of such a shape that " the air does not know how big it is."

XIX

Alighting Gear

The landing-chassis of an aeroplane, which cannot be discarded, will have to be improved considerably in the future; and the improvement must lie in simplifying the construction of the chassis, so that it represents a minimum of dead weight when a machine is in the air, and in arranging it so that it offers the least possible head resistance.

It may be assumed that the machines of the future which are intended to be flown from one country to another, passing above stretches of water while in flight, will be amphibious. They will, that is to say, be given a chassis comprising wheels and floats, so that they can alight either on the ground, or support themselves on the water. A chassis of this type offers no great difficulty. The aim must, of course, be to keep down weight and head resistance. In one design the landing wheels are made to disappear inside the floats when the machine is in flight, or is about to descend on the water; the pilot being able to lower the wheels into position, by a lever action from the driving-seat, when he needs to make a landing on the ground.

In the system of construction most general to-day, a machine must be given a chassis which allows it to stand up fairly high off the ground, this being necessary to provide clearance for the propeller, which is coupled directly to the engine, the engine being placed within the hull of the machine. To obtain this clearance entails the use of long chassis struts projecting below the machine, and these struts have to be braced with wires. The result is that, when a machine is in flight, there is a structure projecting below its hull, comprising struts, wires, and wheels, which is not only so much dead weight, but which offers also a constant head resistance.

If the chassis could be brought close up under the hull, eliminating struts and wires, then head resistance as well as weight could be lessened; but, as it is, the difficulty is that of propeller clearance. In large machines of the future, however, which will have duplicate engines driving propellers through gearing, it will be possible to raise these propellers higher above the ground; and this will mean that the landing wheels, instead of projecting some distance below the hull to give propeller clearance, can be brought close up under the hull.

In this way, when a machine is in flight, nothing more than the lower half of the landing-wheels need be exposed to the air, and this will mean a considerable lessening of resistance.

It should be possible also to devise a form of disappearing chassis, should this be found necessary. The landing-wheels could be attached to a lattice-girder structure, which could be made to close up under the machine when it was in flight on a system similar to that of a lift gate. But with a chassis so simplified that nothing except the lower portions of the wheels projected below the hull, it would hardly be found necessary to have disappearing mechanism. One might have a hull with, say, four wheels placed close up under it, more or less like the wheels of a motor-car: these wheels would be well sprung, of course, and would be fitted with large pneumatic tyres.

XX

Air and Ground Brakes

When a low landing speed is possible, as with a variable-surface machine, the chassis can be greatly simplified. And to obtain landings at slow speeds it is possible to use a form of air brake, in addition to the reduction in speed which can be gained by an increase in wing surface. These air brakes are obtained by hinging rear sections of the main-planes so that they may be tilted upward. As a machine glides down, and just before its contact with the ground, the hinged rear surfaces are tilted up so that they act on the air, causing a drag or resistance which slows up the machine; and, when a machine has once touched ground, the brakes tend to hold it on the ground, checking any tendency to rise again.

An air brake is useful also, on occasion, when an aviator in a machine with a fine gliding angle requires to alight quickly on some suitable ground which he sees almost immediately below. It may happen, for instance, that a motor fails suddenly, and that a pilot sees a field just below which is the only one in the neighbourhood offering a safe landing. With a machine which glides at a fine angle, the aviator might run the risk of over-shooting this mark, or of having to make circles above it as he descended, with the result that the wind might carry him away sideways and prevent him from reaching it. But with an air brake, once the pilot has his position in relation to the landing-place below, and has measured the distance with his eye, he can slow up with his brakes the forward motion of his machine, and land just at the point he has decided on. Such air brakes require skill in their application: the speed of the machine must not be reduced to such an extent that its planes threaten to become inoperative.

To check the run of an aeroplane along the ground, after it has alighted, brakes can be operated on its wheels, in the same way as on the wheels of a land vehicle. It should be possible with variable surface, and with the use of air and wheel brakes, to alight not only at a slow speed in a small space, but also to prevent a machine running forward any appreciable distance after it has made contact with the ground.

A number of accidents have been caused by aeroplanes running forward after they have alighted and colliding with some obstruction. Unless a pilot has a brake which he can apply to the running wheels, it is impossible for him to check this forward run. In a case which illustrates this risk a pilot landed in a field with a decided slope, which he had been unable to detect from the air. What happened was that the aeroplane ran down the slope after it had landed, the aviator having no brake with which he could check it, and crashed into a wall, though the pilot escaped unhurt. A brake will only come into effective operation when the planes of a machine have ceased to lift, and its weight is bearing on its wheels. A special form of chassis needs to be used, also, to prevent a machine pitching forward on to its nose when the brake is applied.

XXI

Engines

The motor which drives an aeroplane has been described as the heart of the machine. It will be essential in the future, when large weight-carrying craft are designed, that their motors should give more power for a given weight than is the case to-day. In the improvement of aero-engines, and in the construction and testing of new designs, lies a most important field for research.

The first engines used in aeroplanes may be described as motor-car engines which had been robbed of most of their strength, and of their reliability, in order to gain lightness. And these motors, after having been thus weakened, were subjected to strains of a severity which no motor-car engine could have been expected to survive. In order to maintain in flight the aeroplane to which they were fitted, the motors which had been adapted to flying needed to run continuously at high speeds, with no slackening or respite; working in fact under conditions which were the equivalent of driving a motor-car at high speed up a never-ending hill. It is not surprising therefore that these first aero-motors should have broken down constantly. Parts which had been lightened collapsed, while engines over-heated and lost their power. No motor-car engine is expected, hour after hour, to develop its maximum power. In going down-hill you take out your clutch; while during an average run, on an ordinary road, the engine is slowed down for one reason or another say twenty times an hour. To transform a motor-car engine into an aeroplane engine it is necessary—in view of the strains to which the latter is subjected—to devise among other things a new method of lubrication, and to adopt bearings of a special type.

Matters became better certainly for the pioneer aviators when they were given a rotary, air-cooled motor, which was not a lightened motor-car engine, but one designed specially to meet the conditions of flight. This engine, however, had its drawbacks; but it ran with sufficient reliability to allow long flights to be made, and considerable experience gained. This engine, indeed, gave pilots the chance of becoming acquainted with the air.

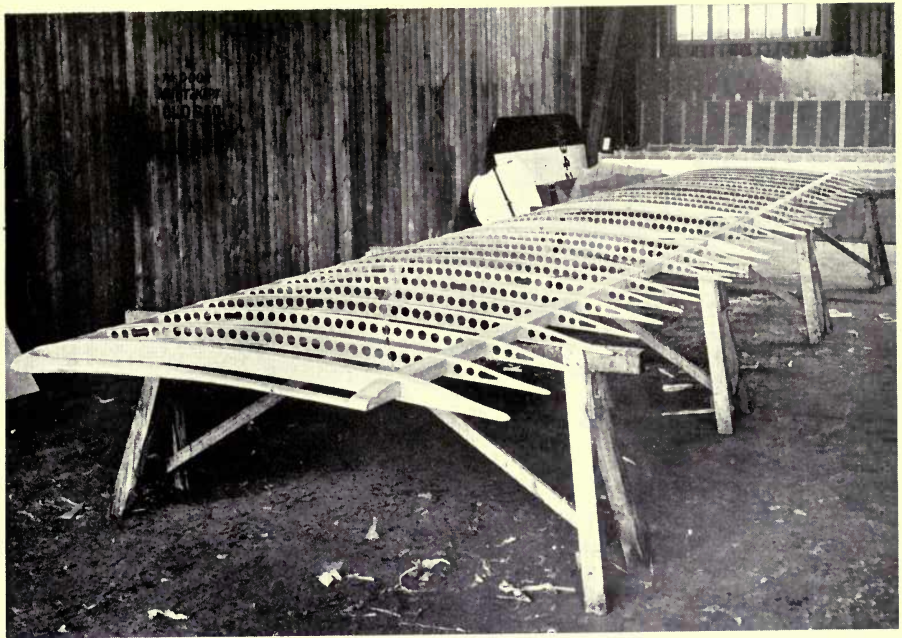
XXII

Breakdown

One of the troubles with aero-engines has been caused by coupling them direct to a propeller, with no system of gearing between the two; with the result that the motor has had to be run always at high speeds, throwing a heavy and continuous strain on its reciprocating and other parts.

In the past there has, of course, been much to commend the direct coupling of a propeller to the engine. Engine-powers have been so low that it would have been a serious matter to have been deprived of even the small percentage of power which might have been lost in the use of a gear. By a direct coupling, also, the weight of a gearing was saved. But the drawback of direct coupling lay in the fact that a motor was expected to run, perhaps for a number of hours, at a very high speed, delivering its full power under conditions which were most exacting. To turn an aeroplane propeller hour after hour at say 1000 revolutions a minute, with the propeller blades acting on the air in a way which calls for a constant and heavy output of power, throws on an engine a very severe and continuous strain. It is scarcely surprising, therefore, that breakdowns have been frequent. What has been surprising has been the reliability which engines have actually shown, even when required to work under such adverse conditions.

Some pioneer aviators, realising the strain which was imposed on their engines, and desiring to lessen this as far as possible, were in the habit of " nursing " their engines with assiduous care—and with results, it may be mentioned also, very satisfactory to themselves. In one of the early contests, a long-distance flight across country, practically all the competitors were using water-cooled motors of a certain type. One aviator, whose machine was a lightly-built biplane which had a large plane-area, found after a series of experiments with propellers that he could maintain himself in flight, though at no great speed, when his motor was throttled down to about 900 revolutions a minute. Other competitors, flying machines of different types, were running their engines at full throttle and at 1200 or 1400 revolutions a minute. The aviator who was able to throttle down and " nurse " his engine made a cross-country flight lasting more than three hours—a record at the time. None of the other competitors did anywhere near so well, their motors giving constant trouble. The pilot who made the long flight, and won the prize, attributed his success almost entirely to his ability to relieve



F. N. Birkett.

A section of an aeroplane wing after its spars and ribs have been assembled, and before it is covered with fabric. An idea can be gained of the method of construction by which lightness is made to accompany strength. Both the forward and rear main spars are made in two sections, each hollowed out so as to lighten it, without robbing it of strength, and are then glued together.

his motor of the heavy and incessant strain of running for hour after hour at full throttle.

In motor-boating in its early stages, as in aeroplaning, engines were coupled direct to propellers and run at high speeds, with the result that they were frequently breaking down. But when gears were introduced between the engine and the propeller, permitting engines to run at more reasonable speeds, a greater reliability was at once obtained. And with aeroplanes it promises, under certain conditions, to be the same—though of course the last thing one should do, in the light of our present knowledge, is to dogmatise.

XXIII

Petrol Turbines

Aero-engines in use to-day, greatly though they have been improved, do not represent anything like a limit of efficiency in the power which they develop for any given weight. New systems are already being experimented with, among them being that of the high-speed petrol turbine; and there seems nothing, in the process of time, to prevent this being developed successfully. A great deal of experimental work still needs to be done, however, and for this large sums of money are required. It is very costly to produce and perfect a new type of engine.

The turbine principle should be one of the most suitable for driving an aeroplane propeller, imparting a smooth, even thrust; exerting a continuous impulse instead of a series of impulses, as with a four-cycle motor. With a turbine, also, it should be possible to obtain high power for a very small weight. At the present time, with one of the lightest four-cycle aeroplane engines, a horse-power of energy is obtained for a weight of about two pounds. With the turbine it may be possible to get the weight down as low as half a pound per horse-power.

XXIV

Weight-carrying Aeroplanes

The war has brought designers and constructors face to face, for the first time, with the structural problems which are involved in changing the aeroplane from a small, light machine, raising one or two occupants, into a large, heavy craft, capable of lifting weights which would have been almost undreamt of before the war. And as a definite instance of what war can do to stimulate constructional progress, it may be mentioned that there are machines in existence already which have engines developing hundreds of horse-power, and which have been proved capable, when carrying fuel for short flights, of ascending with a pilot and more than twenty passengers.

It is possible, to-day, to build large aeroplanes and to make them efficient for a few hours' flying; but it is another matter to design large machines which shall fly for a number of hours without alighting, carrying a heavy load of fuel in addition to their crew, and being loaded also perhaps with guns or bombs. The difficulty is not the actual building of a large aeroplane, or in making it fly, but in rendering it efficient when it is in the air. It must carry fuel to enable it to fly long distances; it must raise the weight of a crew; it must, if it is a war machine, carry in addition the weight of certain war material. And it must be able to ascend rapidly, even when so loaded, and to fly fast.

XXV

Strength and Efficiency

The chief problem, in the construction of very large aeroplanes, is to obtain an adequate structural strength without the weight which this entails rising to such a point that it impairs the flying efficiency of a machine; that is to say, its speed, radius of action, and weight-carrying power. But this problem is by no means insurmountable. It represents merely the difficulty of the moment in moving from small aeroplanes to large. It would be altogether absurd to say, as is said sometimes, that aeroplane construction has reached anything like a final stage. On the contrary, it is just beginning, and has all its important work before it; and there are no problems, in the building of large machines, that time and experiment will not solve.

In spite of heavy drawbacks, and of a lack of support both official and public, the aviation industry in this country went ahead with remarkable strides before the war—thanks to the indomitable spirit of those who were associated with it, and to whom time and money meant nothing so long as they could forward the science to which they were content to devote their lives. If such progress was possible before the war, when the industry was badly organised, and without anything like adequate funds, we may anticipate extremely rapid developments after the war—when the industry will not only be organised, but will possess a financial strength which should permit machines to be built which would have been impossible, owing to their cost, before the war.

Aeroplanes in use to-day are generally in the form of biplanes, one wing being fitted above another. This is an advantageous form of construction, for many reasons, when building machines of moderate size. But when a large aeroplane is designed, a machine capable of raising a heavy load, the extra lifting surface which must be provided may mean that the span of the wings has to be increased to such an extent—assuming the machine to be a biplane—that adverse factors are introduced. It should be explained that, in disposing of a large amount of additional plane-area, it is not possible to increase beyond a certain definite limit the chord of a plane, or its width from front to back. Therefore the main increase must be in span, or width from side to side. It is because the chief lifting power of a plane is obtained near its forward, or entering edge, that it is necessary to use planes which have a narrow chord: if they were built wide from front to back, in order to dispose of additional surface, their rear sections would be inefficient.

With planes of a wide span it is necessary to use heavy spars, in order to obtain strength; and it may be found necessary, with planes of a very wide span, to employ some cantilever system of construction. This means not only an increased weight, but an added head resistance. Heavier construction, all round, is in fact entailed by the use of wide wing-spans. And the trouble is that this factor of increased weight, which must be incurred to gain strength, may rise at such a ratio that it impairs seriously the efficiency of a large machine when it is in flight.

XXVI

Multiple-Plane Machines

Several new methods of construction, by which the drawbacks of a wide wing-span may be obviated, already suggest themselves. Design and construction must, indeed, now enter on a new phase. Present systems of construction have reached almost a limit, so far as the size of a machine is concerned. They were conceived and adopted for the building of small aeroplanes, with everything on a small scale; but now we are faced by the problem of designing and constructing really large aeroplanes, and new methods must be adopted for meeting new difficulties.

In making any radical departure from methods which have been proved successful in small machines, the designer of a large aeroplane may be faced by a whole series of new problems—the disposition of the load the machine must carry; the placing of the motors; the system of gearing between these motors and the propellers; and then the placing of these propellers themselves. All these problems have not only to be considered afresh when a large multiple-engined machine is designed, but the advantageous settlement of one question may react disadvantageously on another. In the end, of course, there is a compromise, the best all-round result being obtained. But to reach this point of equilibrium, when one factor is balanced as well as it can be against another, may represent in the evolution of a new machine not only a period of delay, but an expenditure of a very large sum of money on the construction of experimental types.

One way of overcoming the drawback of wide wing-spans is to employ a system in which a number of sustaining-planes are used, each of them being of a moderate span, and superposed one above another in a manner rather suggesting a venetian blind. This is not a new idea; it was suggested and discussed in the pioneer days. But in those days, when small machines were being built which had no great amount of surface, the idea had not so much to commend it as is the case now.

Already, in the design and construction of triplanes—machines which have three surfaces one above another—one sees the tendency to adopt a multiplane system. In the use of the triplane, another idea is revived from pioneer days. But in the early triplanes, which were crude machines, there were certain constructional difficulties which could not be overcome. Nowadays, however, owing to the increase of knowledge, both theoretical and practical, such disadvantages as exist in this method of construction may be very greatly minimised.

The interference between planes when they are one above another is an objection which has been raised to the triplane or multiplane construction. A plane, in order to gain its full efficiency, must act in a uniform, smoothly-flowing stream of air. If the air-stream is disturbed, or broken up, a plane cannot extract from this air-stream its full amount of lift. Planes which are placed only a short distance apart, and directly one above another, do interfere with each other, with the result that there is a loss of efficiency.

But steps can be taken to lessen this interference. The planes of a machine may, for example, be set some distance apart when they are superposed; or they may be staggered—which means that one is set some little distance in front of the other. In a triplane of modern design, for example, all three planes are so staggered that not one of them is immediately above or below another. By such means, while interference is not altogether eliminated, any disadvantage it entails is outweighed by the convenience of this system of construction.

Here one has a case, again, of the compromise which is essential in designing an aeroplane, or almost any other piece of mechanism. The designer of an aircraft has to choose, often, the lesser of certain evils. When he is told that his machine must carry more and more weight, and must fly longer distances without alighting, and yet must attain a high average speed, he has to work patiently in order to get the best concrete result from these requirements, conflicting as they often are.

A point of distinct value, in the use of a number of planes, is that each of them can be given a narrow chord; and this, as has been explained, is a definite aid to efficiency.

The main fact, in regard to multiplane machines, is that this method allows a large amount of plane area to be used without an unwieldy wing-span, and that it tends to keep weight within a reasonable limit, and to provide a rigid construction. Space is saved, also, in housing machines.

XXVII

Metal *v.* Wood

By the time we are using large multiplane machines, metal will be used in construction instead of wood—a high-grade steel, built in the form of hollow tubes, and shaped specially for use in aircraft. With a fine, high-grade steel, when it is used in the form of a specially-designed hollow tube, one could obtain great strength for a comparatively low weight.

The designing and building of aeroplanes will, in future, become one of the most highly specialised and technical of engineering enterprises. The construction of an aeroplane will, indeed, become an engineering job, just as is the building of a motor-car.

Metal is not used to any great extent in present construction because the aeroplanes built to-day, becoming so rapidly obsolete, are not required to last any length of time. A month or so, perhaps, represents the life of a machine on active service. If it has not been destroyed in that time, or lost its efficiency through wear and tear, it will probably have become out-of-date. Constant changes are being made in design, and this renders wood more suitable at the moment than steel: wood is also less expensive to work than metal. If a machine was required to last a long time, metal would of course take the place of wood. But the position to-day is that the life of a machine is not sufficiently long to justify the use and extra cost of metal. War machines at the present time require only such a constructional strength as will allow them to be used with safety during the short period that will elapse before they are superseded by something better: to build them so strongly that they would survive a long period of active service would be a waste of time and material.

In aeroplanes for use in tropical countries metal has taken the place of wood because wood is eaten into by worms and insects, and is warped also by extreme heats.

The use of metal, instead of wood, in building the nacelles or hulls of aeroplanes, offers a greater safety for the pilot in the case of accident. Wood may break and splinter, and perhaps penetrate the pilot's body; but with metal, while it will kink or bend, it is not so likely to break and form jagged projections.

PART III

OUR POLICY AFTER THE WAR

I

Britain to Lead the World

THE war will have a vast influence on the future of flight—not only constructionally and financially, but in the attitude of nations towards aviation, and also in the outlook of individuals. Mental sluggishness, after the war, should have to a great extent departed. The ordinary citizen, after the awakening which has come to him, should be quicker to see a new idea; and after the organising we have had to do in the war, under extreme difficulty, it should be possible to improve very greatly our methods in the encouragement of new industries. Therefore the path of aviation should be far easier, when we have passed through these times of crisis, than it would otherwise have been.

Immediately the war is over, and the pressure in maintaining the supply of present-type machines has decreased, it must be the task of the aviation industry in this country to make the fullest possible use of the lessons which have been taught by the war. Large multiplane machines must be designed and experimented with, and the closest attention paid to the fitting of several motors in a machine, and the transmission of the power from these motors to the propellers—the aim being of course to obtain gearing which shall transmit the power from the engines to the propellers with the smallest percentage of loss.

The ambition we must set ourselves is to lead the world in aerial progress. Our science and constructional skill, as well as the natural aptitude of our aviators, must be given the fullest possible scope. The war has shown us what fine pilots we have, and that the aeroplanes we are building now are second to none. All that we must make sure of doing, particularly in the next few years, is to avail ourselves of the talent of the nation in research or designing, and in the construction and flying of machines.

As soon as the war is over, and the lessons it has taught can be studied more fully than is possible to-day, it will be realised that aeroplane construction stands, so to say, at a parting of the ways. It will be seen that the day of the small, low-powered machine is gone (except for scouting or pleasure flying), and that dominion of the air will go to the nation which can develop large aeroplanes, capable of flying thousands of miles instead of hundreds without alighting, and of carrying such loads, and at such speeds, as will make them of immense importance commercially, as well as weapons of war.

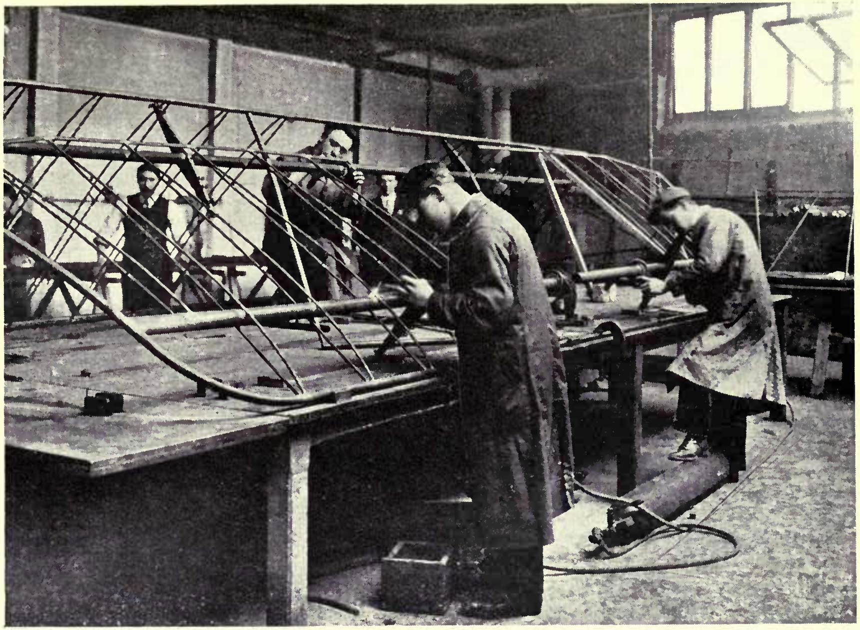
II

Subsidising the Industry

The aircraft industry will be unable to advance with sufficient rapidity, in the period of experimental construction which should follow the war, unless it is subsidised by the Government: some Government subsidy will, indeed, be absolutely essential. The next few years of development will be most critical; on them will be based the future progress of the industry—the evolution of the large war machine, as well as the building of craft for carrying passengers and mails. Unless we progress rapidly, and at the same time surely, from small aeroplanes to large, we shall find ourselves left behind in that race for aerial power which will follow the war.

It cannot be expected that the aviation industry should bear by itself the whole cost of such experimental construction as will be necessary. To design, build, test, and gradually improve a new type of aeroplane is a most expensive undertaking: a series of machines may have to be scrapped before anything like an efficient model is produced. And during the next few years, until something more like standardisation is possible, a constructor who has built a new machine which does what he claims for it cannot hope to recoup himself, merely by the sale of this machine, for all the time and money he has devoted to its production: the orders he will obtain will not prove sufficient. In years to come, when certain types of proved efficiency are standardised, it will of course be different. But for some time to come, until machines can be produced in quantities without any fear of their becoming quickly obsolete, it will not be good policy for War Departments (we are writing now of times of peace) to buy more than a certain limited number of any one make of machine. And this is of course all the more reason why the Government should subsidise the industry. They will reap the advantage of the experimental work which is done by private constructors, and they should be prepared to pay for the privilege. It is found advisable to subsidise the shipbuilding industry; and it should be even more necessary, during a period of experiment and research, to subsidise the aircraft industry.

The German Government was sufficiently astute, before the war, to see the necessity for an encouragement of its aviation industry. The financial assistance it extended to aircraft constructors, and also to the constructors of aero-engines, enabled the Germans to go into the war with an industry which was on a sound and practical footing, capable of turning out numbers of machines, not only to put in use at the commencement of the war, but also to replace the machines which were destroyed or rendered useless while on active service. In England, on the contrary, owing to the fact that the authorities had left aircraft constructors to struggle along as best they could, no organised industry existed



F. N. Birkett.

Metal has begun, already, to play some part in aeroplane construction. Above, in the process of being oxy-acetylene welded, is the all-steel frame of a tail-plane.

at the outbreak of war. When aeroplanes were required urgently, in the critical days immediately following the outbreak of war, they could not be obtained; while the aero-engine industry had been so neglected that it was a long time before the navy or army could secure, even in small quantities, the high-powered motors which the war showed to be essential. Our unpreparedness showed itself, also, and in an even more critical sense, in our lack of pilots. To train an aeroplane pilot so that he shall be thoroughly competent when on active service, and ready and able to carry out any task that may be assigned him, is a matter of time—and also of money. The period of training cannot be hurried or curtailed. A couple of months should, as a rule, be set aside to learn to handle an aeroplane. And after he has completed this stage, being able only to make simple evolutions above an aerodrome, a naval or military pilot has further stages through which he must pass before he is considered ready for active service.

III

Lessons from the Past

Our general attitude as a nation, before the war, was shown by the way in which we treated aviation. Aeroplanes were regarded as ingenious toys: their inventors and users were considered harmless cranks, whom it was thought might have been better employed doing something useful. The public went as an amusement, and out of curiosity, to see aeroplanes fly; but the nation as a whole was almost completely indifferent when those who had realised our peril urged the Government to recognise the important part that aircraft would play in any European war, and to develop and foster the industry before it was too late.

We did not seem so much to lack imagination as to be the victims of a persistent mental laziness. The ordinary citizen put a certain amount of energy into the task of earning his living: afterwards his main desire was to be amused. To speculate on the future of aviation, or to attempt to master even the rudiments of this new science, was too much like work to find favour with him.

We lulled ourselves into a false sense of security by believing that no great war was coming; and this idea we were all the more ready to accept because of our antipathy towards problems which may call for initiative. It was impossible, in fact, in view of the complacent attitude which existed almost everywhere, to arouse any sustained interest as to the use of aircraft in war; or, for the matter of that, in a discussion of any instrument which was intended for use in war. People simply did not want to talk about such things, much less believe in them as realities.

Britain as a nation was engrossed before the war with questions of home comfort—of ameliorating the general conditions of life; questions which were national, not imperial. Our attitude might be likened to that of a prosperous business man who, after years of competition, finds himself at the head of some great organisation. Whereupon, human nature being what it is, he turns his attention to life in its pleasanter and less strenuous aspects—to the decoration, say, of his home, or to such details of his affairs as he would have passed over without comment in days of ambition. But as a disturbing note in this placid atmosphere there is the existence of rival concerns—organisations of a steadily growing power which are restless for achievement, and bent upon extending their influence and trade. But the controller of the business which has succeeded, and who has little more to hope for in his extension of trade, is loath to turn his mind again to those old ruthless days, when he was ceaselessly plotting and scheming. He does not want to sit in his office again, late at night, and work out some plan to cut the feet from under a competitor. So he prefers to make light of the determination of his rivals; he refuses to look at things from their point of view; he blinds himself deliberately to their strength and power.

This was the attitude of Great Britain. We did not want war; we did not want to talk about war. The problem of the aeroplane, and the whole question of aerial navigation in its relation to war, was regarded as one of those disturbing topics which misguided enthusiasts were trying to thrust between us and our enjoyment of all that centuries of conflict had obtained. It seemed to the majority of people most inconsiderate, most unjust in fact, that there should be any nation which was not content to let things be as they were; which wanted to disturb and upheave the balance of power, and which was unwilling to settle down quietly and cease to envy its neighbours.

We are writing, of course, in no way as a palliation of German brutalities. They are inexcusable —world-condemned. The Germans have chosen to blacken their hands; and they themselves can see, already, the penalty they will pay for ignoring treaties and the rules of war. But if a nation, having ambition for world power, cares to saddle itself with the burden of armament which this must entail, other nations cannot very well complain. None of the nations inherit the earth, or have a right to any part of it save their power to hold what they possess. The world has seen a succession of efforts for dominion, and it will no doubt see more. It is the penalty of any great nation, having achieved conquests, and owning possessions which are coveted by others, that it may have to hold itself ready, at any time, to fight for its ownership of these possessions. The struggle for world dominion is not a struggle that can be made to cease automatically as soon as one or other of the competitors has secured what he desires. It is a continuous struggle, and will last probably as long as the world lasts; and a nation cannot, as can an individual, invoke any law which shall prevent its property from being taken from it by a stronger rival. Each nation must, in the world struggle, hold its possessions by force; or, if it is a small nation, by the favour of some friendly power. Force is, in the end, the determining factor.

We have made this point because it explains our pre-war attitude towards flying. When the idea of war is repugnant to an entire nation one cannot very well expect a Government which has been put into power by the nation, and represents its views, to betray lively interest in a new weapon of war, or to be prepared to vote large sums of money for the development of such weapons. That we had such aircraft as we did possess, when the war came, was due solely to the ceaseless efforts of a few enlightened men.

A contrast may be drawn, to our detriment, between our attitude towards flying and that of the French. Everywhere throughout France, in the years prior to the war, a keen and intelligent interest was taken in aviation, not only among cultured people but among all classes. Even the humblest of people had a good general notion of the problems of flight, and of the main difficulties and risks which had to be encountered. But in England it was no uncommon thing before the war—or even to-day—for people to be ignorant of the difference between a biplane and a monoplane, or to regard all machines which fly as "airships," whether they are lighter than air or heavier than air. And it was an utterly thankless task, before the war, to endeavour to combat such ignorance, because it was based on the idea that a study of any such new-fangled subject as flying was a waste of time. When questions were raised whether we were spending sufficient money on aircraft, the general attitude was that it did not matter much one way or the other.

As a contrast to this there was the action of the French people, who, besides giving their authorities the most enthusiastic encouragement in all their plans for an air service, subscribed promptly and willingly to funds which were started so that machines might be purchased to amplify the official programme.

Another contrast to our indifference was provided also by the enthusiasm of the German public in the development of large airships. When after a series of disasters Count Zeppelin was on the point of abandoning the construction of the rigid-type airships which bear his name, the German public subscribed for him £300,000; and the German Government, when it decided a year or so before the war to increase by millions of pounds the vote for naval and military aircraft, had behind it the wholehearted support of the people.

IV

Military and Other Views

Our military attitude towards aircraft, in years preceding the war, was conservative and un-

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Some of the lathes used in an aeroplane factory for shaping such parts of a machine as are already made of metal; and the number of these metal parts is increasing constantly.

imaginative. There was the feeling, from the first, that nothing should be added to the impedimenta of war unless it could prove its value to the hilt. But with the aeroplane in its pioneer days there was a very obvious need to take it a little on trust; to judge not so much by its performances at the moment as by its future promise. This, however, our military authorities — with certain exceptions—were unwilling to do. What was said in effect to the struggling inventor was this: Bring us finished machines, perfectly reliable and capable of flying in high winds, and we will buy some of them. But this was not a reasonable attitude. The industry, such as it was, was starving; it needed support before it was in a position to produce a perfected machine.

To make matters worse, there was a reluctance to spend money on any such new and untried weapon. This attitude was illustrated by the experience of one pioneer who, carrying out some tests under Government supervision, asked that the low-powered motor which had been lent him might be exchanged for one of a considerably higher power. He was told, however, that if aeroplanes required such expensive engines as these, there would be very little chance of their adoption on an extensive scale. And yet only a few years were to elapse before the authorities were searching the country in an endeavour to obtain engines of many times greater power, and infinitely greater cost, than this pioneer had asked for. The few men who, in the early days, were allowed to work with Government funds were brought constantly to a standstill, or had to modify or partially spoil their schemes, owing to the fact that money was begrudged always, and that they were given sixpence, so to say, when they asked for a shilling.

The industry in this country laboured under the further disadvantage that the majority of business men could see no future for flying, and were unwilling to invest money in it. In France, as a contrast, there were financiers who were perfectly willing to assist experiments and tests; while wealthy sportsmen came forward and helped enormously with the construction of experimental craft. Here, however, in this country, even among people of intelligence, the attitude was one of an amused scepticism.

In this war we have been shown the folly of being indifferent to great issues and new ideas. And we must disabuse our minds of the notion that we can afford to neglect flying again, after the war, as we neglected it before. Unless we keep abreast of development from year to year we shall find ourselves in a condition of extreme peril, with enemies only too ready to take advantage of our weakness. Money, even when at a crisis it is spent like water, cannot buy experience—cannot create at a moment's notice a great and smoothly-working organisation, operated by a trained personnel. This is a work not of weeks or months, but of years. Who can estimate the millions that our unpreparedness has cost us in this war?

From the Sunday morning in July 1909, when Bleriot flew from Sangatte, a few miles from Calais, to the cliffs by Dover Castle, Britain was no longer from the military point of view an island: the twenty-one miles of water had been crossed by the airman in his flight from France to England, just as easily as though they were dry land. But there is a difference, obviously, between the peaceful arrival on one's shores of a small monoplane, and the coming of a fleet of hostile airships, each carrying with destructive intent a ton or more of bombs. The first makes its appeal only to the imagination—a quality which has been shown in the mass of men, and particularly in the mass of Englishmen, to be varying and uncertain. But when airships appear on a raid, and civilians are killed and houses blown to pieces, then a universal and a very startled interest is aroused. Here is something tangible; something threatening which needs to be combated. The sense of security possessed by non-combatants, so long as their country escapes invasion by land or sea, has already in this war been very rudely dispelled.

To Britain this new menace has been peculiarly disturbing, remembering that there is an instinct which has come down to its inhabitants as islanders, from the days when they were raided cruelly by barbarians, that they should be prepared at all costs against invasion.

Hence, naturally, the strengthening and rendering dominant of the British navy. And until the advent of this war the enemies of Britain, if they sought to invade her, had no choice but to come at her across the water, with the barrier of a great sea fleet lying between them and their goal. But now, and the peril must grow inevitably from year to year, and affect not only Britain but every other nation, there are enemies to be resisted who approach in numbers by the aerial highway. And so defence must be carried, quickly and efficiently, into a new element.

V

No Slackening of Effort

After the war, no matter how we may be engrossed for a time by national problems and readjustments, and no matter how loud may be the cry for retrenchment, we must provide without hesitation every penny of the money which will be necessary for the development of aviation. We are reminded constantly that we are fighting this war not only for ourselves but for posterity; and this should be our view-point, also, when we spend the money of the nation on the perfection of the aeroplane: the future security of the Empire rests on our energy in developing flying within the next few years.

The industry must have funds which will permit it to experiment freely. Each of the chief firms must maintain a well-staffed experimental department; and here designs must be prepared for machines which are outside the routine production of the moment, and which embody such improvements as experience may suggest from day to day.

There should be a closer co-operation in the future between private constructors and the National Physical Laboratory. The valuable research work of this laboratory must be available for the constructor with less delay than has been the case in the past. And apart from our own national research work we must be in a position to know constantly, and by means of some reliable organisation, what other nations are doing in the perfection of the aeroplane. Information of this nature during the next few years, when great nations are endeavouring to profit by the lessons of the war, will be of special importance to the industry in this country, which should have full access to the data which the authorities may obtain.

The research work of science, in a struggle for command of the air, will, when such research is continuous and well directed, play an unusually important part. The science of flying, still of course in its infancy, has developed hitherto on fairly well-anticipated lines; and it may continue to do so in the future. But there are many possibilities which, scientifically, are still unexploited. It is conceivable that some discovery might, entirely without warning, revolutionise the problem of aerial navigation: no country, therefore, though its machines may to-day be all they should be, can rest secure unless its scientists are constantly at work.

VI

The Air Age

Another task, in some respects the greatest we can undertake, is to teach the rising generation the importance of flying. The youth of the nation must be made to understand, by methods which cannot fail to impress them, that not only our prosperity, but also our security, depend on our obtaining a dominion of the air. A national institution should be formed, after the war, to further the interests of this great movement. Art and music have their national organisations and headquarters; and aviation must have some central rallying point—a centre from which knowledge must be made to radiate among the people, and which shall ensure that public opinion keeps abreast of development, instead of lagging far behind, and hampering our progress.

A general knowledge of aviation, and of its growing importance in the world's affairs, should be taught in our schools, and prizes and scholarships should be given to promote knowledge of this, the greatest of the achievements of mankind. Grown-up men and women, whose minds have lost their elasticity, find it hard to realise that the aerial age is just about to dawn; but the children, familiar as they are becoming already with the sight of aeroplanes overhead, have no mental inertia to overcome. And it is the young people of to-day who will, to-morrow, be using the air as a regular highway. We should, therefore, do everything we can to stimulate their interest in flight; while parents, seeking some career for their sons which offers a rapid progress, and a wide scope, should remember that the industry of aviation, developing so enormously, is crying aloud for men of initiative and ability—and particularly for young men who will throw themselves heart and soul into the movement, and devote all their thoughts and energies to its advancement.

PART IV

FACTORS OF SAFETY

I

Organisation

In the old coaching days a business man who wished to travel from Edinburgh to London was able to make the journey in eight days: this was considered a fast piece of travelling, and could only be hoped for—in the words of an old poster—"if God permits." To-day, when made by express train, the journey lasts about eight hours. Beaumont and Vedrines, flying from London to Edinburgh in the Circuit of Britain race in 1911, covered the distance in less than six hours; and in the future, by passenger air service, the journey should be done in less than three hours.

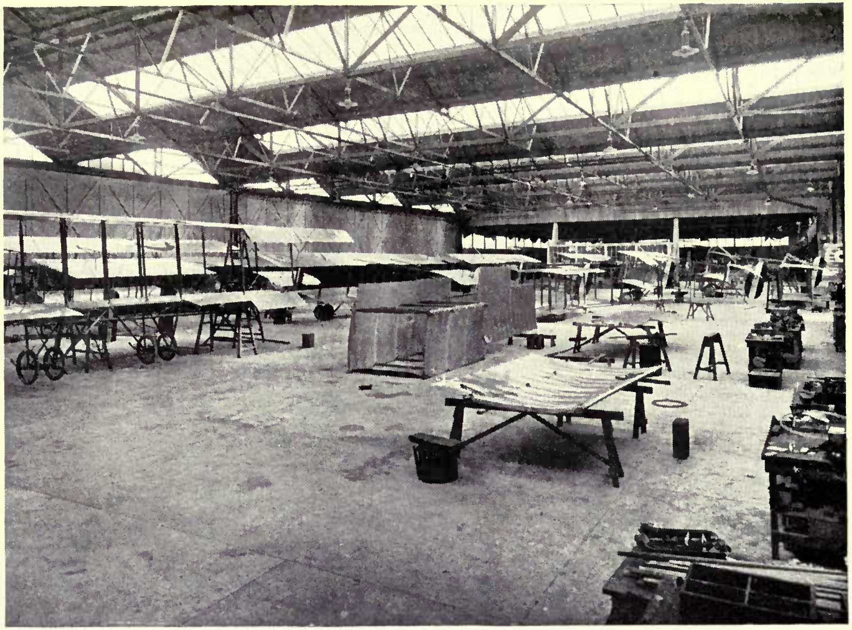
But we cannot hope to pass at once into the aerial age. The inauguration of regular passenger services by air will be possible only as a result of experiment, experience, and organisation. It is only after years of experience, and by a very gradual development of their organisation, that the railways have attained such efficiency as they can boast of to-day; and they still have ample room for improvement. It is not reasonable, therefore, to expect that air travel can become possible, on any extensive scale, without painstaking effort and the most careful organisation.

At a London terminus, recently, one of the earliest railway carriages run by the company owning this station has been on exhibition. The carriage is small, cramped, and uncomfortable, with springs in their crudest form; and it would have been impossible to have run it at anything like high speed. An instructive contrast may be drawn, in a study of railway progress, between this first carriage and one of the dining-car or sleeping-car coaches which this same company is running on its express trains to-day. And in the future, when people see in some museum an early-type aeroplane, and compare it in their minds with the great aerial liners which will then be in operation, they will have an illustration even more striking of our progress towards an ideal form of transit.

Greater experience is what is required in aviation, also a steadily improving organisation. Organisation tends always towards safety. In the early days of railway travelling risks were run from horses and cattle straying on the line in front of the trains—which had not then been protected, as of course they were later, by an adequate fencing. This point is a small one, but it shows the risks that may arise from an imperfect organisation. The safety of railway travel has been made what it is to-day as a result of experience. And aerial safety will be a very different matter when the organisation of air traffic has reached the point that has been attained by railway traffic. At present air travel is almost completely without organisation; or it would be more accurate perhaps to say that its organisation is not as yet linked up in any way or rendered complete. There may be organisation in one place, but not in another; efforts are spasmodic and not properly unified.

The risks of flying are nowhere near so grave as people are apt often to imagine. The earliest of the pioneers, men using the crudest of apparatus, and navigating an element which was unknown to them, managed to fly thousands of miles without losing their lives—such men as the Wright brothers, Farman, and Bleriot. A distance of more than 30,000 miles was flown by air, with the first experimental aeroplanes, at a loss of only three lives. The idea that flying must always be unsafe, because a machine is passing through the air at some height above the ground, and is not in contact with the surface of the earth as a train would be, arises from a lack of knowledge.

A large proportion of the accidents which have marred the progress of flight have been due to the fact that men have not taken their task seriously enough; that they have failed to realise—as the great pioneers realised—that one cannot afford to make mistakes in the air, and that a foolish action may cost a man his life. The pioneers, who perfected at extreme peril to themselves the machines with which they were at length able to



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The erecting shop, where the various parts of an aeroplane are brought together, and in which they are assembled. In view of the size and wing-span of the machines, a very large amount of space is—as may be seen—required. The shop illustrated is 500 feet long by 160 feet wide.

fly, learned in the school of experience to respect the air. They learned to fly cautiously, and yet with determination—to take no risks that it was possible to avoid. But the men who came after them, and found they had not to design and build an aeroplane, but could buy one ready-made, did not pass through any of the phases which imbued the pioneers with their caution. And so they made flights which the pioneers would have condemned as dangerous—and which led in fact to accidents.

But there were other factors, besides human error or indiscretion, which led to a growth of accidents in the stage which followed that of the first pioneer flying. Men of all types began to take to aviation; machines of many different makes were put on the market; and the fact which was perhaps most significant of all was that aviators began to desert the neighbourhood of aerodromes, where the early flying was done, and to make flights across country from point to point. And to the risks of such cross-country flying, with the necessity perhaps of descending involuntarily on dangerous and unsuitable ground, were added those of a sudden-arising wind, or those incurred by ascending deliberately when atmospheric conditions were unfavourable. But the silver lining to the cloud, even at a time when accidents were so frequent that people began to wonder whether the conquest of this new element was not costing us too much, was that experience was being bought, and that it was being profited by; that the skill of designers and constructors, and the growing knowledge of the pilots, were tending always to reduce the elements of risk.

II

Air Travel and Land and Sea Travel

It will be some time, naturally, before people are accustomed in their minds to the idea of using the air as a regular medium through which to travel. One needs to recall the timidity of the first travellers on the sea, also the risks of ocean travel in its early days. Ships were frail, then, and at the mercy of storms instead of being superior to them : but in ocean travel, as in travel by land, the factors of safety were constantly increased.

Air travel in the future will become safer in certain respects than land or sea travel. An aircraft when high above the earth does not run the risk, as does a ship, of colliding, say, with some drifting iceberg, or of encountering some derelict floating awash, or of being driven on a dangerous shore. Nor will there be the risk with a high-speed aircraft, as with an express train, of an engine or coaches leaving the line when running at high speed, or of being derailed through encountering some obstruction on the line. With a high-speed aircraft, also, seeing that it moves entirely free of any earth contact, there will not be the risk, as with high-speed vehicles on the earth, of a wheel or axle giving way, under the strain of speed, and leading perhaps to a disaster.

The risk of collision, when large numbers of aircraft are in use, will be rendered negligible by the adoption and enforcement of a series of rules of the air, to which we shall refer later; also by the fact that on the main aerial routes machines travelling in one direction will fly at a certain given height, while craft on the same route, but travelling in an opposite direction, will fly at a different altitude.

With land and sea travel the existence of fogs is a frequent cause of accident, and also of delay; but aircraft will be able to ascend above fog-belts, and pursue their course in clear air without any slackening of speed or risk of accident. There will be rules as to changes of altitude, when weather conditions demand them, so as to avoid any risks of collision. Aircraft will of course be in wireless communication with each other.

In discussing the safety or peril of aerial navigation, it is necessary to approach the question logically, and without any preconceived notions or prejudices. What are the perils of the air, compared with those of land or sea? An aeroplane gains no support from the air unless it is in motion through the air. But as long as it is in motion it is fully and perfectly supported—supported just as safely and surely as is a railway train on its metals. This fact must be borne in mind. The wings of an aeroplane, designed to carry through the air a certain given load, can be relied on without fail to support that specified burden, in the same way as the axles of a train or motor-car are designed to carry whatever may be the weight and load of the vehicle.

The aviator in his aeroplane, passing high above the heads of spectators on the ground, and through a medium so impalpable, is borne forward on a cushion of air which is supporting the weight of himself and his machine just as effectually as would the wheels of a land vehicle by their contact with the surface of a road. It is only if the forward speed of the machine should (say as a result of engine failure, or perhaps through some error of judgment on the part of the pilot) fall below the minimum at which its wings will bear their load that it fails to gain a full support from the air; and even then there is no question of the machine falling. Inherently stable aeroplanes, such as are already in use, and will become universal, will themselves restore their requisite flying speed, should this fall for any reason below the minimum required for horizontal flight.

III

Engine Failure

A misapprehension one finds often in the minds of those who are not fully conversant with the conditions that govern the flight of an aeroplane, is that when the engine of the machine fails, the craft must fall helplessly to the ground. This idea has become fixed in the public mind very largely through brief and inaccurate newspaper reports of aeroplane accidents. When the motor fails there is no need whatever for an aeroplane to fall, or for its pilot to be in any way endangered. So long as the machine is in forward motion it is supported by the air. And when his motor fails there is another force that a pilot can bring to his aid to permit him to maintain his forward speed, and thus preserve the lifting power of his machine; this force is that of gravity. The aviator inclines his machine downward when his engine fails, and begins to glide towards the ground; and that this descent need not be precipitate is shown by the fact that a pilot who is a mile high when his motor fails will be able to glide a distance of eight or ten miles before he reaches the ground. He can circle while descending, or steer from side to side: he is, in fact, in perfect control of his machine, except for the fact that he has to descend gradually all the time, in order to maintain the support of his planes.

There may be a danger for the aviator in unduly prolonging a glide. A machine moving through the air so slowly that its planes only just prevent it from falling is sluggish in its response to the movements of its control surfaces. It is susceptible to the sudden impact of a wind-gust, or to any upward or downward trend in the air. An instance may be cited of an aviator who, after the failure of his engine, was prolonging his glide to its utmost in order to pass over some trees and reach an unobstructed stretch of ground which offered the only landing-place in the vicinity.

After the aeroplane had passed over the trees, and was gliding so slowly that the pilot barely had control of it, it came under the influence of a heavy downward trend of wind, and was swept to the ground and wrecked.

Though engine failure while in flight entails as a rule nothing worse than a compulsory descent, it does happen occasionally that a machine gets out of control, and is wrecked, owing to the stoppage of its motor. But in such cases there is usually some special reason which explains the accident. Pilots have taken the risk, sometimes, of ascending when their engines were not running well; then, while they are in the act of climbing, and while still near the ground, their motors have stopped suddenly, and the pilot has found it impossible, with the machine pointing upward, to get it forward and downward into a glide. The result has been that the machine has stood still in the air, and has then fallen to the ground either in a side-slip or a tail dive. Errors have been committed also by pilots who have not been quick enough when their engines have failed, and before the machines have lost flying speed, to incline them downward in a glide. With certain early-type biplanes, which had large and heavy tail surfaces, the air stream thrown back by the propeller, acting on these rear surfaces, helped materially to keep them at a proper flying angle. But if the motor failed suddenly, and this propeller-blast on the tail-planes ceased, they were apt to droop suddenly, and place the machine at a critically dangerous angle. The pilot moved over his elevator and tried to get the machine into a glide; but the droop of the tail-planes prevented this; while the main-planes, being now at a steep angle to the air, brought the machine very quickly to a standstill—with the result that it became uncontrollable and fell.

The fact was that some of these machines were not balanced properly for gliding: their tail-surfaces were over-weighted. The late Cecil Grace, while making trials with such a machine at Leysdon in the Isle of Sheppey, had his motor stop suddenly while he was in flight. He found it impossible to get the machine forward into a glide: it slowed up, came to a standstill, and then fell. Luckily it was at a low altitude. The chassis and other gear were smashed, but the pilot escaped injury.

When there is only one engine in an aeroplane there is always the risk of some breakdown, though improvements in construction have decreased this risk very considerably. One may instance the amount of cross-Channel flying that has been done in single-engine machines since the outbreak of war. Constant flights are taking place, as a matter of routine, between England and France, and it is a rare thing for an engine to fail while the cross-Channel passage is being made. Yet in early days the cross-Channel flight was regarded as an undertaking of the greatest danger. Bleriot, with his little 25 h.p. air-cooled motor, considered himself extremely lucky when this motor worked uninterruptedly for thirty-six minutes, and carried him from Calais to Dover. It may be remembered that Latham, his rival, fell twice into the sea through engine failure.

The chief risk with single-engine machines is that some quite trifling breakdown of the engine, something that can be repaired in a few minutes when the machine is on the ground, will occur at an awkward moment during a flight, and compel a pilot to descend when he is above bad country, or over a thickly-populated area.

IV

Multiple-Engines

Machines are in use in the war which are driven by two or more engines; but the system is still so experimental that the best results cannot as yet be expected. An instance, however, will show how valuable a twin-engined machine may be when it is flown in war. A French aviator was piloting a biplane so equipped above the German lines when the machine was hit in several places by shrapnel, and one of the engines so damaged that it stopped at once. But the second motor still ran on, and the pilot was able to get his machine back to its base, flying, of course, at a reduced speed. In this case, if the machine had been fitted with only one motor, the aviator would have been obliged to descend in enemy territory and be made a prisoner.

V

Risks of Engine Failure in War

How serious may be the result of engine failure, when it takes place in war above hostile territory, has been shown by the fact that it has lost the Allies some of their finest aviators. There is the case, for example, of the French airman Garros, one of the most expert monoplane pilots in the world. After an arduous spell of active service in the French air corps, during which he flew high-speed fighting monoplanes, and brought down a number of German aeroplanes which ventured over the French lines, Garros was dispatched one day on a bomb-dropping raid within the enemy's territory. After attacking a train, on which he dropped his bombs, he was returning in the direction of his base when his motor failed suddenly and refused to start again. Garros was too far from the French lines to reach them in a glide; so there was nothing for him to do but descend in German territory. This he did, and after destroying his machine he attempted to hide and wait for darkness. But he was discovered by German soldiers and made a prisoner.

Another well-known French aviator, Gilbert, after dropping bombs on the German airship factory at Friedrichshafen, was returning to his base near the French frontier when engine failure brought him down in Swiss territory. Nobody was in the neighbourhood where he landed, and he tried to get his engine going again, and re-ascend. But before he could do this a party of Swiss soldiers came up, and the aviator was taken prisoner and interned. His attempts to escape, in the third of which he succeeded in getting across the frontier, were typical of the ingenuity and determination which have been shown by aviators whose misfortune it has been to have their engines fail. On one occasion Gilbert, having disguised himself in woman's clothes, had actually reached the frontier and was about to cross it, when his walk aroused the suspicions of a sentry, and his identity was discovered.

Guidner, another French pilot who fell into German hands, lowered one of the windows of the train in which he was being taken from Lille into Germany, and managed to slip down on to the permanent way, during a moment when the train came to a standstill, without being detected. Then, hiding by day and travelling by night, he succeeded in regaining the French lines.

Pracomtal, another French aviator, after having been wounded in the leg, was captured and taken into Germany. He escaped once, but was re-taken, being tracked by police dogs. After this he was moved to another fortress, and placed for a time in solitary confinement. In company with three companions, however, he managed to escape again. But there was an unfortunate accident in connection with this escape. One of the party, while crossing a moat, fell and broke his leg, and had to be abandoned. Pracomtal and the others, walking across country by night, and hiding by day, travelled a distance of 180 miles before they reached neutral ground. They were able after this to make their way to Paris.

Didier and Martini, two other Frenchmen who were compelled to alight on ground that was in German possession, managed to escape and to elude recapture for thirty days, during which they made their way back by slow stages to the French lines.

There is the case also of the late Captain Mapplebeck, R.F.C., who was forced to alight behind the German lines. He managed to conceal himself so that the German soldiers could not find him, and afterwards spent nearly three weeks in a house in Lille, being sheltered by a Frenchman whose chivalry and kindness cost him his life, the Germans finding out subsequently what he had done, and causing him to be shot. Captain Mapplebeck, awaiting a favourable opportunity, and aided by this Frenchman, managed to regain the British lines. A rather similar experience was that of the aviator Fréville. He lost his way while in a fog, alighting inadvertently behind the German lines and being made a prisoner. About a week after he had been captured he succeeded in eluding his guards and making his way to the shelter of a friendly farm-house, situated in a village which was in German hands. The plans he made to steal back from this village to his own lines were anticipated by the fact that the French, in a sudden advance, recaptured the village, with the result that Fréville was able to regain his comrades without further risk.

VI

The Elimination of Breakdown

In the future, when it is probable that a series of engines will constitute the power-plant of large machines, any one engine which breaks down or gives trouble will be cut out temporarily from the series, and repaired by mechanics, while the machine continues its flight under the power of its remaining engines. The passengers on a modern Atlantic liner, having become accustomed for these great ships to run with the regularity of an express train, would be surprised and indignant if they found that a vessel was brought to a standstill in mid-ocean by any complete breakdown of its machinery.

In the early days of the steamship, craft were built with one shaft and propeller; and if anything broke they were helpless. But as design and construction improved vessels were given two, three, or four propeller shafts; and in this way they were able to steam on, and reach their destination, even after suffering a partial breakdown of their machinery. It happens not infrequently that one of the propeller shafts of a ship will seize and stop. What the engineers of the ship do in such a case is to cut out temporarily the unit which is giving trouble, and run on with the other engines until, say, a hot bearing has cooled. All that this means is a somewhat reduced speed. The passengers would hardly notice that anything had happened—except that perhaps, for a time, there might be a little more vibration.

The motive power of the aeroplane of the future will be as reliable as that of a steamship, or of a railway engine. It will be impossible, of course, to eliminate completely the risk of breakdown. Even after years during which its machinery has been perfected, a ship's engines still fail it at times; while occasionally a railway engine comes to a standstill. Even a motor-car engine of the best type, though it may run thousands of miles without needing repair, may develop suddenly some small defect which will bring it temporarily to a standstill. One cannot obtain absolute dependability with any mechanism; but a breakdown can be rendered so unlikely that the risks attached to it are negligible.

If it is assumed for the sake of argument that the entire motive power of a passenger aircraft should fail suddenly, while the machine is in flight, the passengers need be in no danger. All that would happen, if the defect could not be remedied quickly, would be that the machine would glide to the nearest aerodrome and alight for repairs.

VII

Landing-Grounds

One takes it for granted that a machine would be flying high enough at such a moment to permit it to travel some distance in a glide after its engines had failed; also that by the time passenger aircraft are in regular operation there will be landing-grounds within a short distance of each other all over the country. The provision of such aerodromes will form an important part of the organisation which will add so greatly to the safety as well as to the convenience of flying. No such organisation of landing-grounds exists to-day, though the naval and military authorities have increased very considerably, since the war began, the number of their air stations in various parts of the country. But the aviator who is on a cross-country flight at the present time, and whose engine fails him, may be unable to reach any landing-ground before he is compelled to alight, even though he may have been flying high at the moment his motor stopped. In such a predicament, when the aviator has to pick out the most likely-looking spot for a landing on the country he sees below, the question is one largely of luck, and also, of course, of personal skill. In the majority of cases the pilot should make a safe landing, even when he is unable to reach an aerodrome. But it may be his misfortune to be over very rough or broken country at the moment his engine fails, and then it may be difficult for him to find, even within an area of a number of miles, any reasonably smooth spot on which to bring his machine to earth. A field which looks suitable from a height of a thousand feet or so may be found to have an awkward or uneven surface when the pilot actually makes contact with it.

In the future we shall have main flying routes—north, south, east, and west. And along these routes or airways, every few miles, there will be landing-grounds. Some of them, those in the neighbourhood of important towns or cities, will be large and well-equipped aerodromes. Others, acting merely as links in the chain of landing-grounds, and being near no large centre of population, will need only a simple equipment—a sufficiently large and open space, well situated and with a smooth surface; sheds in which aircraft may be housed; and mechanics and a machine-shop so that repairs can be effected in the case of any craft which may need them. Telephones and other such facilities would be required also; and there would need, of course, to be supplies of petrol and oil.

VIII

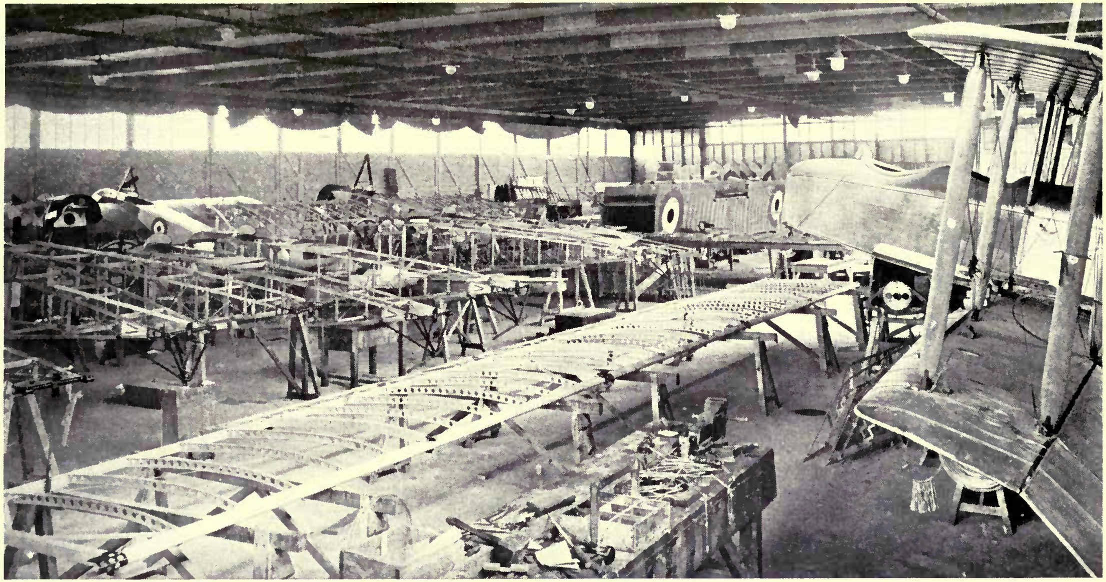
Night Signalling

At night-time the stations along the airways, being illuminated, would act as a guide for the pilots of aircraft.

Lighthouses will be used probably along the airways, showing revolving coloured signals with so many flashes indicating certain points. The system adopted, with modifications, will no doubt be that which is used to indicate land positions to a seaman. The navigator on the sea, approaching a coast, may see perhaps two flashes in four seconds, then a pause of five seconds, and then two more flashes. Turning to his log-book, he will look up this sign, and identify the place on the coast he is approaching. And the aviator of the future, as he nears some town or city, will look down and identify it by the number and timing of the flashes he sees below.

The blending of coloured lights will be used, no doubt, for purposes of identification. One might, for instance, have a green and a red flash, then a certain number of seconds interval, and then a blue and a white one. Various combinations will be required to identify different points on the airways. The landing-grounds will be illuminated in a way which will make it easy for pilots to glide down and land on them, and it is probable that each aerodrome will have an illuminated identifying number, displayed so conspicuously that it will be possible to see it distinctly from the air, even when at a considerable distance. There will be a system of night signals, also, between aerodromes and machines above, so that the latter may be notified when all is clear for them to make a landing.

A great element of safety, in cross-country flying, would be introduced by the existence of landing-grounds. An aviator who is in any trouble with his mechanism will always be in a position



F. N. Birkett.

A corner of the erecting shop, showing the wooden skeleton of a main-plane before it is covered with fabric ; also (to the right) a machine partly assembled.

to glide down to one or other of these aerodromes, and make a safe landing on a smooth and unobstructed surface. The organisation of such a system of aerodromes will, in fact, eliminate the risk, which exists to-day and is serious, of a pilot making an involuntary landing on bad ground, wrecking his machine and perhaps losing his life.

It is not difficult to see how, by the improvements in organisation we have mentioned, and also by such mechanical improvements as the use of multi-engined machines, the factors of safety in flight can be increased very considerably. To-day, if a single-engined machine breaks down, an accident may follow through a bad landing. But the use of duplicate engines will render improbable any breakdown in flight; while, if such a breakdown should occur, owing to some quite unusual cause, it will mean nothing more for the aerial traveller of the future than the delay of gliding to the nearest aerodrome and waiting for repairs.

IX

Amphibious Craft

Large aircraft which are built to fly above oceans will be either flying ships, with hulls resembling those of sea-going craft, or will be fitted with a system of floats, which will permit them, when necessary, to descend on, and ride upon, the surface of the water. Such machines, if brought down by mechanical trouble while on an ocean flight, and if it is found that repairs cannot be effected quickly by the mechanics on board, will send out a wireless message for assistance; and, in view of the fact that over-sea flying will be made along specified routes, it may be assumed that there will be some other craft within no more than a short flying distance, which will come up and take off, if necessary, the passengers of the crippled machine. But, as we have said, it will be a very unlikely thing for there to be a breakdown of the whole of the plant of a large multi-engined machine. In the majority of cases, when mechanical trouble of any kind develops, the mechanics in charge of the engines will be able to deal with it successfully without there being any need for a machine to descend, and with no more inconvenience than a temporary loss of speed, due to losing for the time being the power of one or other of the motors.

It seems probable that the large naval aeroplane of the future, a machine developing thousands of horse-power, will be a veritable flying ship, discarding any system of floats, and having a hull substantial enough to enable it to withstand heavy seas when it is on the water. Such craft may be built with wings on either side of the hull which can be made to telescope completely within the hull when the machine is on the water. In this way, after it has drawn its wings within its body, the machine should be able to navigate and make headway against heavy seas. When it requires to take the air again, its planes will be moved out from the hull until a sufficient surface is exposed to lift it into the air. By a development of such a system we might obtain large, powerful, sea-going aircraft, capable of making long voyages, and of remaining away from their bases even in bad weather.

X

The Influence of the Wind

It has often been declared that the wind, and particularly the sudden springing up of a high wind, will be a peril always for the aviator. But an important safeguard in this respect is, as we have explained, the ability to construct machines which are stable and fast-flying. In the early days, when aeroplanes were in use which were far from stable, a machine might be forced to such a critical angle under the pressure of a wind-gust that its pilot lost command of it, and was unable to regain control, even if the craft was at a high altitude and had a long way to fall. One may instance the case of a military pilot who, while flying an early-type biplane over the eastern counties, was assailed by a whirlwind and had his machine overturned. This occurred at an altitude of about 1500 feet—a height which would have provided ample air space, with an inherently stable machine, for the craft to have regained its equilibrium. But in this case the machine remained uncontrollable. It descended, upside-down, in a series of zig-zag curves. The pilot, who did not lose his presence of mind, jumped clear of the machine just before it struck a field, and escaped with nothing worse than bruises and a general shock. With an inherently stable biplane, had it been overturned by any abnormal rush of wind, the machine would have righted itself immediately, even without aid from the pilot.

Though it is a fact that high and gusty winds have already lost their peril for the aviator, except when he is near the ground, there still remains the need for a more accurate knowledge of the structure and trend of winds, and of the general condition and movement of the air in its relation to navigation. The air is far from being a smooth or evenly-flowing element. It contains gusts, eddies, and upward and downward trends. The sun, drawing moisture off the land, causes gusts and eddies; while the configuration of the earth's surface, with its hills and valleys, sets up aerial disturbances which, when a high wind is blowing, may extend to a considerable height above the ground. Aviators have found, when flying daily over the same districts, that eddies and disturbances in the air are to be encountered regularly above certain spots, these being due to the motion imparted to the wind by its contact, say, with some hill or valley.

XI

Meteorological Investigation

In the future it will be necessary to have an organisation which will supply frequent weather forecasts to all aerodromes throughout the country. In this way, when an aviator is about to make a long cross-country flight, it will be possible for him to learn beforehand whether he is likely to pass through any area of disturbance; while by means of foreign meteorological stations, acting in conjunction with our own, it will be possible to give a warning to aerial travellers when some gale threatens to sweep over England, say, from the Atlantic.

By a study of storm stratas, and of the areas in which they occur, it may be possible for the aerial travellers of the future, even though they may enter some such disturbed area when on a long flight, either to ascend higher and pass out of it, or to descend lower and find themselves in a normal stratum of air. This ability of an aviator to seek favourable conditions either high or low is one that will be of immense value to him; and it is one that cannot be claimed either for land or sea travel.

The importance of collecting meteorological information, in connection with aerial navigation, and of studying and classifying such data, has been recognised by the Royal Flying Corps, which has appointed an officer (Major G. I. Taylor) specially for this duty. Military pilots who encounter in flight some unusual atmospheric condition will report their experience to this officer, who will be able in course of time to amass data which should prove of considerable interest.

It will not be possible in the future, any more than it is at present, to navigate small, light, pleasure types of aircraft through extremely bad weather. The speed of such machines will not be sufficient to enable them to make headway against the heaviest gales. One would not think of putting out to sea in a small light boat when there was really heavy weather; and it will be the same with small aircraft. But with large high-speed machines, no wind, not even a gale, will have any more influence on them than a certain reduction in their speed when they are moving against a head-wind. The wind will have no perils for such machines, and will be unable to rob them even temporarily of their equilibrium. They will be able to weather the heaviest gales without need for alighting. An unusual spell of bad weather will of course delay a cross-Atlantic aircraft, as it would a cross-Atlantic liner, but not to the same extent, because the aircraft will have such a greatly superior speed.

XII

Sea Sickness and Air Sickness

Travellers by air, in bad weather, will suffer far less personal inconvenience and discomfort than is the case with ocean travel. A ship rides on the water and is subjected to all its surface disturbances. But an aircraft may be likened to a submarine. It does not ride on the air but in it; and the large aircraft of the future, flying fast and at high altitudes—avoiding thereby the fluctuations in pressure which are more liable to occur at low elevations — will pass through gales of wind without any of the heavy rolling and pitching which is so distressing for passengers in a vessel on the sea.

Variable surface machines such as we have described, when they are at their highest speed, will have reefed their wing area to such an extent that there will be only a very small amount of surface on which the wind can act. There will, therefore, be little to set up any oscillating movement. The speed and momentum of a big ocean liner, when it is steaming fast, help to drive it through the waves instead of yielding to them, in the same way that a torpedo-boat destroyer, when at full speed, cuts through waves instead of rising to them. And the high-speed aircraft, moving at a pace greater than that of wind-gusts it may encounter, will drive through them without a tendency to swing or dive.

It is a fact to be remembered, that with aeroplanes which are small, and of a low power, a high wind may cause them to pitch and toss so badly that the pilot or passenger suffers occasionally from air sickness, which is quite as unpleasant as the nausea caused by the motion of a ship.

In this connection a story is told. An aviator on a long cross-country flight, having lost his way, descended near a village to locate his position. But the instructions of the villagers, who were endeavouring to tell him how to steer in order to reach the town which was his objective, were so incoherent that the aviator could not understand them. The rustics were in fact so excited by the arrival of the aeroplane that they were plunged in a state of mental confusion. At last the aviator, impatient of delay, picked out the most intelligent-looking of the men who surrounded him, and asked him if he would ascend with him as a passenger in the aeroplane, so as to be able to point out, from the vantage-point of a higher altitude, the actual line of country over which the aeroplane should fly. The rustic agreed with alacrity, proud of the distinction of making an aeroplane flight.

As it happened, however, a gusty wind had sprung up, and the machine rocked and swayed as it climbed. The higher it ascended the rougher became the wind, and the more disconcerting the motion of the machine. At length, having gained what he considered a sufficient altitude, the aviator turned to his passenger and asked him to point out the route. But the unfortunate villager, huddled in his seat, and clasping the nearest struts with the desperation of a drowning man, was in the throes of such a violent attack of air sickness that the aviator could get nothing from him at all, and was in fact afraid every moment that the man would collapse and fall out of the machine. All the pilot could do, indeed, was to glide down as quickly as he could, and place the sufferer once again on solid ground.

The aerial passenger of the future need fear no such discomforts as these. The machines then in operation, large and metal-built, will move at such speeds that their weight and momentum will carry them through the heaviest winds without the inconvenience to their occupants of any perceptible oscillation. Machines will in fact drive through gusts and eddies with a momentum like that of some huge projectile.

XIII

The Luxury of Air Travel

A fact which has not yet been realised is that the air travel of the future will have a luxury and comfort which are unknown, and indeed impossible, on either land or sea. We have not yet realised, in fact, a hundredth part of the benefits and conveniences which the conquest of the air will bring. One may take, for the purposes of comparison, the present-day form of travel by means of an express train. With a train when it is at high speed there is a perceptible and sometimes unpleasant oscillation, even in the case of the best-constructed rolling stock. There is also the constant grind and roar of the wheels in their contact with the metals; while the coaches swing and lurch when they round a curve.

In air travel there will be none of this. The passengers will, in the first instance, be so placed in a machine that there will be no vibration from the machinery.

Even nowadays, when a 250 h.p. fixed-cylinder engine is running at high speed in a machine in flight, and no absorbers are used, there is an almost total absence of vibration. And in the large passenger aircraft of the future, when turbines or other improved types of engine are in use, running in an engine-room isolated from the passenger saloons, vibration will be eliminated completely. The power plant will be so silenced, also, that no sound from it will reach the passengers' ears.

The noise made by the air, as it rushes past the polished hull of a machine when it is at high speed, will be sufficiently deadened not to prove irritating. It will be possible, for example, to have layers of felt or other sound-absorbing material between the outside hull and the passenger saloons. In this way the noise of the wind, even when a machine is travelling at high speed, will be so deadened that it will reach the ears of a passenger as a faint, continuous drone which will pass unnoticed after the machine has been for some time in flight.

There will, of course, be no feeling whatever of earth contact, as is the case with a train on its metals. An aircraft moves on a cushion of air so perfectly resilient that its contact with the machine gives no suggestion whatever of any such friction as is the case with a vehicle on land.

With an aircraft at high speed there will be no grinding of wheels, or clamour and roar of passing under bridges or through tunnels: the aircraft will rush through the air with a perfect steadiness, and there will be no tiring sense of movement for the eyes, as in the case of trains, when objects are seen streaming constantly past the windows. Flying at high altitudes when on long journeys, passenger aircraft will often be at an altitude greater than that of the clouds, and there will be nothing of the earth to be seen below—nothing in fact which will tell the eye that the craft is in motion. The machine will seem under such conditions to float in pure space, and it will be difficult for its occupants to appreciate that they are moving swiftly from point to point.

XIV

Structural Breakage

A danger in flying to which an exaggerated importance has been attached is that of the breakage of a machine when in the air. Sometimes, for example, one hears it said—

"In a motor-car or train, when something breaks, people are at least on solid ground; but in the air, if anything goes wrong, there is nothing below but so many thousand feet of empty space, and you have no chance at all."

Such a view shows a misapprehension, however, of certain essential facts. To be moving across the surface of the ground in any vehicle, when something breaks, is a disadvantage often rather than an advantage—as the occupants of any such vehicle may find when, a wheel or axle breaking and the vehicle overturning, they come into a sudden and violent contact with the unyielding surface of the ground, breaking perhaps a limb or sustaining injuries even more severe. The breakage of any essential part of a land vehicle, if such a vehicle is moving at the moment at anything like high speed, will in fact in the majority of cases cause injuries to its occupants. With a motor-car, for example, the steering-gear may possibly go wrong. Whereupon the machine may swerve off the road and crash perhaps into a wall, or overturn in a ditch. A railway engine, breaking an axle or a connecting-rod, may be the means of bringing a whole train off the line, with the result that there will be a disaster. The risk in land travel, when some essential part of a vehicle collapses, is not only that the occupants of the vehicle may be brought into a violent contact with the ground, but that the vehicle itself, passing out of control, may crash into some obstruction.

An aeroplane, if it develops some defect which places it temporarily out of control, may swerve or dive some distance through the air without sustaining any damage, or endangering its occupants. There are no obstructions in the air with which it can come in contact; nothing which can damage it as it swerves or falls. And it would be unusual, even when some part of a machine broke in the air, for a pilot to be unable to regain some sort of control over it during a fall, say, of several thousand feet — a control sufficient, that is to say, to enable him to land the machine without injury to himself or his passengers. It is certainly not the case, as has been imagined, that if some small structural breakage takes place in an aeroplane, the machine will fall at once, completely beyond control. The war has disproved this on many occasions. Machines, even when they have been badly damaged by shell-fire, have remained sufficiently under control to allow their pilots to get them back to the ground without a smash; or, even if the landing has been a bad one, the occupants of the machine have escaped unhurt. It has been remarkable, in fact, the amount of damage a machine can sustain and still remain navigable.

A fact which has prevented many aeroplane accidents from having serious consequences is that a machine may strike the ground when moving at high speed, and damage itself very badly, without its occupants sustaining injury. This is due to the light materials of which the machine is constructed, and to what may be called its natural elasticity. When the machine comes in contact with the ground there is no violent, unyielding shock, as there would be if the machine was a solid construction, with no "give" in it. What actually happens is that one part after another breaks, each absorbing something of the shock, and lessening the main force of the impact. One may take the instance of a machine which side-slips and falls on one wing. The wing has to break up completely, or telescope, before the shock of the fall reaches those in the hull. And if a machine should dive to the ground there is the landing chassis and other gear which must break before the force of the impact is communicated to those in the hull.

This absorption or deadening of the first impact with the ground, when a machine falls, has saved the life of many pilots. The death-rate in aviation would, in fact, have been much higher than it is were it not for this. Pilots have emerged with nothing more than shock from accidents in which, to an onlooker, it appeared certain that the occupants of the machine had been killed. From machines which have fallen to the ground from some altitude, and have been so badly damaged that they were complete wrecks, aviators have managed to crawl with nothing worse than cuts and bruises.

The value of this cushioning effect, in a fall, is that the bodies of the occupants of a machine are not brought suddenly and violently to a stop, after moving at high speed, as they might be if the machine struck the ground with a dead, heavy impact. The sudden bringing of the human body to a standstill, after it has been moving at high speed, may have fatal consequences even if there is no actual impact. If a man is strapped in a machine so that he cannot be flung out of it, or against any obstruction, and this machine comes into a violent and unbroken impact with the ground, the immense strain thrown on the human tissues by the sudden arresting of the forward motion of the body, may set up internal hemorrhages which prove fatal. It happens sometimes that a pilot who is strapped in his machine, and who makes a bad landing, or who may have his machine nose-dive and alight heavily, suffers severely from pains and swellings in his neck muscles—due to the fact that when his body is brought to a standstill, after moving at high speed, his head jerks forward in a way which, if the force of the impact is sufficiently violent, may lead to a dislocation of the neck.

People generally imagine, owing to their unfamiliarity with the conditions which actually govern flight, that the chief peril lies in a machine being high in the air. But altitude, instead of being a danger, constitutes one of the chief elements of safety. One may mention the case of an aviator in the war who was shot and rendered unconscious when the machine he was piloting (which had not dual control) was at a height of about 10,000 feet. The aeroplane began to fall, its descent accelerated by the fact that the pilot had been unable to switch off his engine before he lost control. The machine fell several thousand feet in an uncontrolled dive; but then the observer, managing to move back to the pilot's seat and reach the controls, switched off the motor and was able to get the machine into a normal glide, with the result that a descent was made safely. In the case of a motor-car moving at high speed, assuming the driver has suddenly lost control, through some indisposition, there is no such element of safety, no such latitude for a swerve and fall, as exists in the air. One swerve, after the driver's hands have left the steering-wheel, and the car will run off the road and probably overturn; and it is hardly likely that any of the passengers will be able to get to the steering-wheel, and check the swerve, in time to prevent an accident.

Naturally, when one puts such a machine as an aeroplane into the hands of a pilot, one has to reckon with the human element—with the various temperaments and inclinations with which men are endowed. One of the difficulties of men who have gained experience in flying is to induce young aviators to curb their ambition, and to proceed cautiously in that critical stage which follows their first handling of an aeroplane, and before they have learned to appreciate the dangers which lie hidden in the air. Learning to fly is in a sense too easy. Nowadays, in favourable weather, and with a suitable machine, the novice finds everything so simple that he may feel tempted to emulate some crack pilot who knows every "trick of the trade." And then, while he may be in perfect control of his machine one moment, and with the fullest confidence in his powers, he may overstep an instant later the hidden danger-line, placing his machine at such an angle that it side-slips, perhaps when near the ground, with the result that he finds himself involved in what may prove a serious accident.

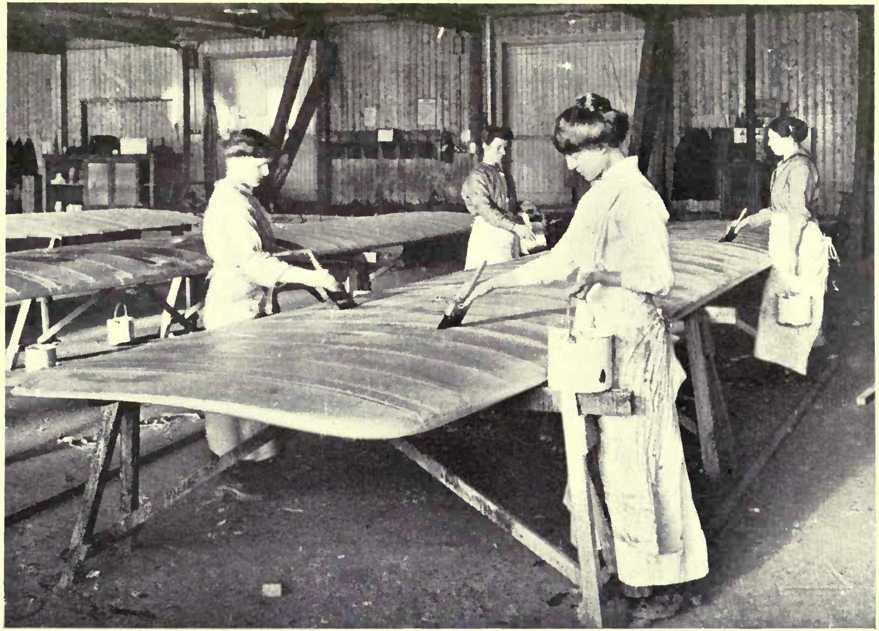
In this question of the temperamental balance of a man, of his judgment and discretion, there exists, of course, all the difference between safety and peril. A man can go into a shop and buy a gun, and there is nothing on earth that will prevent him from shooting himself with it. A man can go into a shop, also, and buy a fast motor-car which will kill him just as surely as a gun, if he persists in taking risks. A man who is not evenly balanced, mentally, and who cannot be made to realise the risks he runs by doing foolish things, may kill himself with an aeroplane, just as he might with a motor-car or a gun; but a man of sound judgment will, in the future, be able to fly an aeroplane with the same absence of risk as he drives a car.

The breakage of any part of an aeroplane when it is in flight is a risk which has already been obviated very largely; and in future, with steel construction, aided by the data gained from experience, the risk will be lessened still further. There is no reason why a properly constructed aeroplane should collapse, any more than one would expect the collapse of a well-built vehicle on the land. For certain reasons, indeed, among them being the fact that an aircraft escapes the constant earth vibration and friction which affects any land vehicle, an aeroplane should be less likely to develop flaws which might lead to a breakdown.

XV

In Early Days

An aircraft when it is travelling at high speeds is subjected, of course, to the heavy strains of air pressure; but the extent of these strains is no longer uncertain. Designers are able to calculate them accurately, and to allow a sufficient margin of structural safety to meet the strains imposed by any given speed. It was the accidents which occurred in the early days of flying which gave the public an exaggerated notion of the perils of a structural breakage or collapse. These early accidents were due often to the fact that constructors, having as a rule only low-powered engines with which to drive their machines, and desiring to gain the maximum speed possible for any given power—so that they might win the races which were then the vogue—were apt sometimes to reduce the strength of their machines until a dangerous point was reached. The competitions to encourage flying were generally in the form of races, the winning machine being the one which flew fastest, irrespective of any other quality or defect which it might possess. Regret has been expressed that so many of the valuable prizes in the early days were given merely for races from point to point, which meant the use of aeroplanes in which the speed at which they



F. N. Birkett.

Women, since the beginning of the war, have been employed in aeroplane factories in rapidly increasing numbers. Four are seen above doping and varnishing a main-plane. These dopes and varnishes are used in order to preserve the fabric of the plane against damp and other weather conditions. They also render the fabric air and water proof, and at the same time keep it taut.

would fly was the main consideration; and to obtain this speed the weight had to be so cut down that the machines had only a small margin of strength available with which to withstand any of the abnormal strains to which they might be subjected. It would have been better, it has been argued, if more of the money prizes had been offered to encourage stability, reliability, and general efficiency. Had more prizes been offered to encourage structural safety, the list of early fatalities might, it is contended, have been far less heavy than it was. But in the case of newspapers, which offered handsome prizes for aeroplane races, something spectacular to interest their readers was of course required; and a race proved more exciting than a reliability contest, or one for stability.

One must remember that the universal cry to-day on land and sea, and in the air, is for speed; also that these great races, stimulating as they do both design and construction, and making it imperative to build machines which will survive the heaviest possible strains, have an important influence on the development of an industry. One may take as an example the motor-car. Here the great road races which were organised, and which were so often condemned for the loss of life they entailed, had an enormously beneficial influence upon the improvement of cars. As many as half a dozen men were, it is true, killed in one of these races, and the fact should be deplored; but on the other hand we have the fact that the motor-car industry could never have developed at the rate it did had it not been for the stimulating effect of these contests. And with flying races it was much the same. They led to accidents, but they led also to rapid progress. There might not have been so many deaths, had there not been this era of races, with the types of machine which were encouraged; but if it had not been for these races, even though they meant accidents, the industry could not have gone forward so quickly.

That heavy risks were run sometimes in such contests cannot, of course, be denied. One actual occurrence may be cited. A monoplane which had been entered for one of the early races was found on the day of the contest to be a certain number of miles an hour slower than a rival craft against which it would have to fly. Whereupon, before the race began, the constructor reduced still further the already small wing area of the machine, hoping that the speed would be increased in consequence—as in fact it was. The monoplane certainly flew faster; but by the clipping of its wings it had been rendered almost uncontrollable. While rounding a pylon at a low altitude, it side-slipped and struck the ground with great violence. But the pilot, thrown out across one wing and rolling clear of the wreckage, escaped any serious injury.

That the risks run by pioneer aviators were far greater than is the case to-day might be proved by many instances. There is, for example, the case of an early-type machine which, after having been built to carry a low-powered engine, was fitted with one of a considerably higher power, so as to increase its speed. The aeroplane was strengthened in certain ways to bear the strain of the higher speed; but this strength proved insufficient. While the machine was being flown in a gusty wind, one of its wings collapsed, with the result that it fell, its pilot being killed.

The pioneer aviators ran heavy risks also when flying machines of an entirely new or experimental construction. The designers of such machines, proceeding often by rule of thumb, and having no very great knowledge or appreciation of the strains on a machine when it was in flight, provided factors of safety which were insufficient. There is the case of an experimenter who built a light type of single-seated biplane, and was told by experts that the strength of his main-planes was inadequate. The machine flew safely, however, on several occasions when the weather was calm; but one day, when at some altitude, it was caught in a gusty wind; and, as had been predicted, one of the main-planes broke and the machine fell, its pilot being killed.

It is encouraging, as a proof of the structural strength which may be imparted already to an aeroplane wing, that a plane which is built of such far from perfect materials as wood, wire, and cotton fabric can be made to withstand the strains imposed by a speed through the air of more than a hundred miles an hour. If such a strength can be obtained with flimsy materials, there is little need to fear the future, when extremely light, high-grade steels take the place of wood. The aeroplane may be said, indeed, to have passed through its dangerous stage, so far as structural weakness is concerned.

PART V

POPULARISING TRAVEL BY AIR

I

Touring

An important task after the war, for those interested in aviation, will be the popularising of flight. The war, with its gallant aerial exploits, and the important and continuous influence which aviation has had on strategy and tactics, has led the public to become far more interested in flying than was the case before. This interest must be stimulated in every possible way. It will be most necessary, for example, after the war, to encourage aerial touring and the purchasing of aircraft by private owners.

A promising fact which must be recorded is that a large number of passengers have come forward, since the beginning of the war, to book flights in aeroplanes at the London Aerodrome, Hendon; and these passengers, apart from enjoying their flights, show a distinctly clearer grasp of the importance of aviation, and are eager to discuss its future. Since the war began, in fact, there has been a rapidly widening interest in flight. Apart from the admiration which has been aroused by the work of our naval and military pilots, it must be remembered that flying is becoming familiar in thousands of homes throughout the country owing to the fact that one or other of the sons of the house has joined the air service, and writes to his relatives telling them of his experiences and adventures. It is in this way that people who had no more than a vague interest in flying before the war are now keenly alive to its possibilities, and are eager themselves to make a flight, in order that they may enjoy the sensations which are described by the sons, brothers, nephews, or cousins who are in the air services.

Each of the thousands of young men who have come forward to serve their country in the air are spreading throughout their home circle, and also among a wider circle of friends, a knowledge and an appreciation of the importance of flight. This education of the public, which is going on constantly, and which brings home the lesson to them in a personal way which cannot be ignored, is exercising a greater influence from day to day. More men are joining the flying services, and the work they do is of increasing value. In this way, like a snowball grows as it is pushed along, a knowledge of what flying means in war, and a growing belief and interest in its future, are being instilled almost imperceptibly into the minds of the people. The full value of this work of education will not reveal itself until after the war.

There was a certain amount of aerial touring before the war; but it lacked facilities or organisation. After the war the energies of clubs and other institutions, working in co-operation with the industry, must be directed particularly towards this aspect of flight. The development of civilian flying, leading as it will to a demand for touring and pleasure-type aeroplanes, will have a most beneficial influence on the progress of the industry. It will open up a branch in design and construction which will have an almost unlimited scope, which will be apart altogether from the building of war machines, and which should serve as a convenient stepping-stone between present-type aeroplanes and the larger machines which will be used for carrying passengers and mails.

To accustom people to being in the air, either as pilots of their own machines or as passengers in machines owned by friends, will be of the highest importance as a preliminary to the commercial era of aviation. After men and women have flown a certain number of times, and have come to realise the possibilities of aerial travel, they will be ready to respond when the time comes, as it will in a few years, for the establishment of the first of our passenger services by air.

II

The Ideal Form of Travel

Aerial touring, once it is established and is gaining headway, will be found so pleasurable that its subsequent progress should be rapid. Touring by air represents indeed a form of travel from which all such inconveniences and discomforts have been eliminated as afflict the tourist who travels by land or sea. In aerial touring, as contrasted with motor-car touring, there is an absence of dust or vibration; the air breathed is pure and invigorating; while the effortless speed of flight gives a sense of exhilaration stronger than is the case with any other form of travel: and, when the aerial tourist is above picturesque country, a magnificent panorama lies thousands of feet below him, and as far as the eye can reach.

Aerial tourists, driving their own machines, will not be subjected to the nerve-strain which attends driving a motor-car along one of our main roads, with the vigilance necessary to avoid running over pedestrians, children, or straying animals, or of colliding with some badly-driven vehicle. In the air the tourist flies serenely and with ease, chained in no way to a narrow or crowded track. Rules in piloting will have to be observed, of course: with these we deal later.

Doctors have noted already the beneficial results of flying. Instead of breathing into their lungs a mixture of dust and petrol fumes, as do travellers in a motor-car on a main road, the aerial tourists, owing to their altitude above the earth, breathe an air which is equivalent in its purity to that on a mountain-top.

Business men who feel the nerve-strain and lack of air which follow, say, a strenuous week of work in a crowded city, will find aerial touring a magnificent restorative. Hitherto such men have motored at week-ends; but flying will have benefits which are incomparably greater.

III

A Day in the Air

As an instance of the possibilities of a day's pleasure flying, one might map out a trip as follows. The tourists, who garage their aeroplane at the London Aerodrome, Hendon, motor to the flying-ground in the early morning, ascending for, say, an hour's flight before breakfast, steering for the seaside aerodrome at Shoreham, near Brighton. Here they breakfast, and then make a coastal flight, passing seaward of Beachy Head, until they reach the flying ground at Eastbourne. From here, after a halt to look over their machine, they continue along the coast to the aerodrome at Dover, the French coast visible away to their right, should the weather be clear. After lunch at Dover, they make a flight to the aerodrome at Eastchurch, on the Isle of Sheppey; and from here, after an interval for tea, they steer back to Hendon—having visited four aerodromes during their day's tour, three situated on the sea-coast, and having flown a total distance of a little over 200 miles. Many other such excursions could be arranged, of course, the one mentioned being given merely by way of illustration.

Foreign tours by air will be possible to an extent, and with an enjoyment and convenience, which cannot be obtained by any present modes of travel. Using amphibious machines, capable of alighting on land or water, the tourist will be able to visit coastal towns abroad as well as those inland—going just where he pleases either by land or sea—combining in fact the pleasures of yachting and motoring, and in a more exhilarating form. The whole of the continent will lie open to him; he will have a complete freedom of choice as to his route from day to day. None of the restrictions of railways or roads will apply to the tourist who travels by way of the air.

IV

Touring Aeroplanes

In designing a touring aeroplane, the features to be considered must be those of safety, reliability, comfort, and ease of control. The designer will not aim so much for speed as for a high all-round factor of safety. Such machines must not be sensitive on their controls; they must offer as wide a latitude as possible for any error on the part of their pilot; and they must also have a slow minimum speed, so that they can be landed without risk of accident when handled by pilots of average skill.

It should be one of the first aims of designers and constructors, after the war, to produce two-seated and four-seated machines of a purely touring or pleasure type, and for all those connected with the industry to promote and popularise their use.

Designers will find that the planning of a touring machine offers less difficulty than is the case with craft which are required for use in war. In a war craft it is necessary as a rule to carry huge loads of fuel, so as to allow the machines to remain for long periods in the air; and this weight of fuel must be carried in addition to the load represented by bombs, guns, and other warlike equipment. But with a touring machine all such excessive weighting may be eliminated. The craft will be built to carry, say, a three hours' fuel supply. This will be sufficient because the aerial tourist will have landing-grounds at frequent intervals on which he will be able to alight, and at which he will refill his petrol tank. A three hours' journey, non-stop, should represent the limit required for ordinary touring, seeing that with a sixty-mile-an-hour machine a distance of 180 miles could be traversed during such a flight. With a moderate load of fuel, and with a maximum speed of sixty miles an hour, the designer should be able to plan a machine fitted with, say, a 100 h.p. motor, which will carry several people across country with efficiency and safety. It is when, as in a war machine, the designer is required to build a craft which shall fly fast and carry a heavy load, and possess at the same time a wide radius of action, that his difficulties begin.

V

The Cost of Aerial Touring

A question that arises naturally is as to the cost of aerial touring when compared, say, with touring by car; but it is not possible yet, nor would it be advisable, to enter into a detailed comparison: the data available are insufficient. What can be said, however, with confidence is that as soon as touring aeroplanes can be produced of approved types, and there is a demand for them in any numbers (thus permitting a certain standardisation), it should be possible to produce and sell a high-class touring aeroplane at a price no greater than would be paid for a first-class car. And it may be stated with equal confidence that as soon as flying is organised the running costs of a touring aeroplane will be no more than those of a touring car: it is likely, indeed, that they will prove less.

The most important item of expense in motoring is, of course, the wear-and-tear of tyres. But with aeroplanes this item of expense will be negligible. The wear on aeroplane tyres, during the brief periods a machine is moving across aerodromes, is so slight that a set of tyres, when properly inflated, should last almost as long as an aeroplane itself.

Of importance in the development of aerial touring will be the establishment of a system of landing-grounds such as we have described. They will serve the aerial tourist in the same way as the garages along our main roads serve the traveller who journeys by motor-car.

One of the results following the introduction of privately-owned aeroplanes, when they are used, as they will be, in the same way as a motor-car, is that the environs of a great city like London will cease to be residential, and will be given over more and more to workshops and factories. People who travel to and fro each day between their offices and their homes will be able, owing to the speed and other facilities offered them by aircraft, to live either at the seaside or in the heart of the country, and still reach their offices in good time each morning, travelling quickly and comfortably by way of the air.

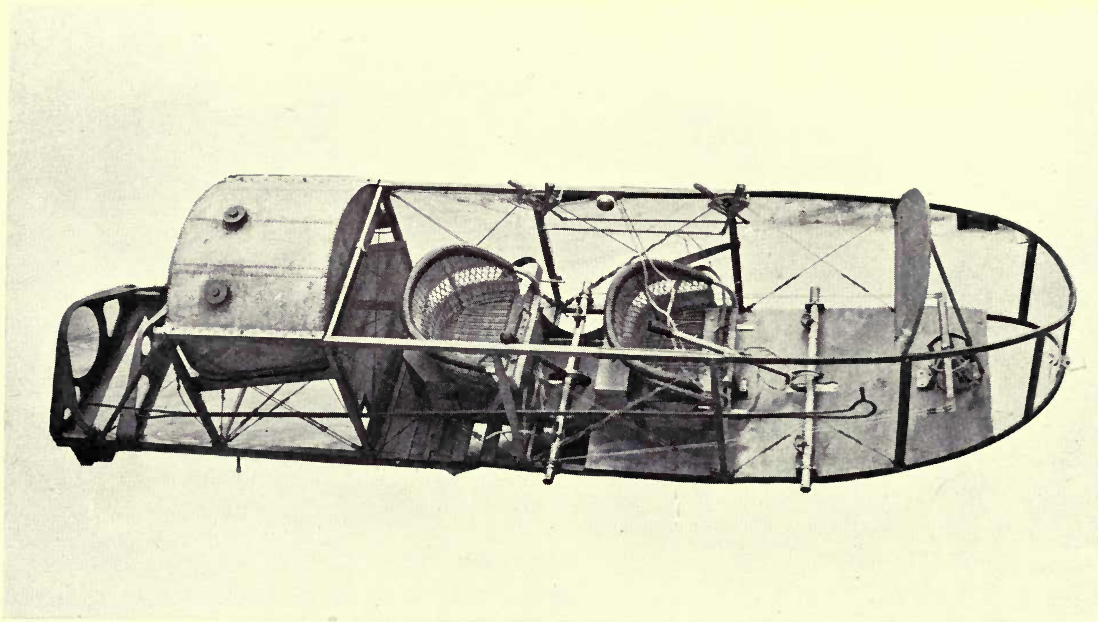
The opportunity which air travel will offer a man of living much farther from his work than is possible to-day, will have a very important influence, in time, on the health, habits, and lives of the people. It will no longer be necessary for great masses to congregate in one locality, with the disadvantages which this entails, not only in health, but also in high rentals and the other costs of living. The coming of the air age will enable us to distribute our population more evenly. Districts which lie at some distance from great towns, and which are at present unoccupied and untilled, will be transformed gradually into residential areas, in which the cost of rent and living will be so much reduced, as compared with life on the outskirts of a city, that the workers will be well able to afford the cost of the aerial transport which will bear them to and from their work. In this way the city worker will be able to enjoy a country life, greatly to the benefit of his health. He will be able to have a garden—land in these country districts being cheap—and this will not only give him exercise, but will enable him to grow his own vegetables and keep his own poultry, and so reduce his living expenses.

VI

Training Aviators

The effort to popularise aviation cannot succeed unless some general scheme is devised, and carefully carried out, to provide well-trained and reliable pilots for aeroplanes which pass into private hands. Most private owners will learn no doubt to drive their own machines, but they will not always wish to do so; hence they will need the services of a pilot. And there will probably be people who will buy aeroplanes for touring without learning to fly them, and who will rely entirely on the pilot they engage.

On the skill and discretion of the first pilots who fly privately-owned aeroplanes a great deal must depend. Their training will require to be thorough in every respect, and must be carried out under careful supervision. Unsuitable men must be rejected without compunction before they have had a chance to disgust, and perhaps en-



F. N. Birkett.

A view from above of the nacelle or body of an aeroplane, before it has been attached to the machine, and showing how it is built up as a self-contained unit. The aeroplane, being intended for instructional purposes, the system of controls has been duplicated, so that either pilot or passenger may, while the machine is in flight, take charge of it in turn, and without changing seats. The nacelle is shown before it has been enclosed by its covering of fabric.

danger, some new aeroplane owner who may have been induced to employ them.

It is here that we can learn a lesson from the early history of the motor-car. There were far too many men who, after buying a motor-car in the pioneer days, had the misfortune to be driven so badly, by an incompetent or imperfectly-trained chauffeur, that they abandoned motoring, and sold their cars, just at a time when their support of the industry was urgently required. It was through a lack of organisation that we failed to produce, either in sufficient numbers or at the right time, the fully-qualified and picked chauffeurs who should have handled the first motor-cars which were bought by members of the public. The right men could not be found when they were wanted; there was no organisation or recognised system of training; expensive cars had to be placed in the hands of men who were incompetent to drive them, with the result that accidents occurred, and motoring acquired a bad name, just at a time when it was most necessary to avoid accidents, and to impress people with the safety of this new method of travel. The use of inexperienced drivers also meant heavy running costs.

These mistakes must be avoided with the aeroplane. It will be fatal to progress if an attempt to popularise aviation should coincide with a list of accidents, caused by careless, incompetent, or inconsiderate flying. The public is already apt to dwell too much on the risks of aerial travel;

and if newspapers have a number of accidents to report, immediately private owners begin to buy and use aeroplanes, it will have a disastrous influence upon development.

The tests a man must undergo, before he is given a certificate which will entitle him to pilot an aeroplane, must be made so severe that none but perfectly suitable men, physically and temperamentally, will be able to pass them; and the tests imposed must be so graduated, from aerodrome flying to flights across country, that it may be taken for granted that the man who passes them, and gains his certificate, will not be found wanting in any of the emergencies which may arise during a flight, and which can only be dealt with successfully by a pilot of experience. The present certificate of proficiency, as granted by the Royal Aero Club, is a guarantee merely that a man can handle an aeroplane in flight, and ascend or descend safely, when flying over an aerodrome under favourable conditions. His cross-country experience (also his experience in flying under bad weather conditions) has to be gained after he has taken his certificate. Existing tests will be quite inadequate in the future. Unfortunate experiences with bad pilots must not be allowed to rob aviation of the support of those who buy touring machines.

It is very necessary, during the early training of an aviator, to prevent any accident which may impair his nerve. If a man goes through his period of tuition without a smash, and learns to control a machine without loss of confidence, and is willing to gain experience gradually, then he is on the road to becoming a good pilot.

A man who decides to learn to fly does so generally with a certain inward trepidation. But his first experiences in a machine, and particularly his first attempts at controlling it, fill him as a rule with astonishment that the thing should be so easy. His trepidation leaves him, being replaced by enthusiasm and confidence. The problem is to carry him through his tuition, and make him a pilot, without allowing this feeling of confidence to lead him to a foolish action; and also without opening his eyes too soon—through the rude shock of an accident—to the fact that underneath the apparent easiness of flight there are a host of hidden dangers, and that just when all seems plain-sailing something may happen which will call for an instant readiness both of judgment and nerve.

Flying is easy only so long as conditions, atmospheric and otherwise, prove favourable. Where the risk lies is that the fine-weather flier, the novice who has not yet been faced by any serious difficulty, may begin to feel so sure of himself that he over-estimates his powers. While he is in this frame of mind, should he over-step the boundary line between safety and danger, and involve himself and his machine in an accident, the effect on his nerve and confidence may be extremely bad. He may lose faith suddenly in his own powers, and by a process of reaction become timorous and hesitating. And such an attitude of mind is worse than over-confidence. This is why it is so necessary, at a flying school, that instructors should be chosen with special care. They must be something more than good pilots. They must be men of sympathy and understanding, capable of an estimate of character; and they must have a sufficient interest in their work to treat each pupil individually. Flying brings out a man's temperamental peculiarities. One may be extremely cautious; another foolishly daring. One may be slow and disappointing in getting any sort of a "feel" of his machine; another may pick up the whole business with facility. But the instructor need not feel disheartened by any apparent stupidity, nor over-elated when a pupil is unusually quick. Often a man who is slow in the early stages will turn out in the end a sound, reliable pilot; while the pupil who is very quick in learning to handle a machine may be found to lack the judgment and discretion which are essential.

A large proportion of the accidents which have marred the progress of flight have been due to the fact that men have gone ahead faster than their experience has justified.

VII

Physical Fitness

A question which needs to be taken carefully in hand is that of the physique of men who wish to become pilots. No man should be in charge of an aeroplane unless he is absolutely sound, and in normal health in every way. To ensure such fitness, and to prevent any man of doubtful physique from evading medical detection, it will be found necessary no doubt to adopt a rigid system of examination by doctors appointed by the Government; men who have made themselves familiar with aviation, and can be relied on to pass no man unless he is unquestionably sound. The eyesight of an aeroplane pilot needs of course to be perfectly normal; he must have no organic defects such as latent heart trouble, or any weakness of the lungs; his nerves must be sound and in a normal condition; the muscular action and movement of his limbs must be quick and unhesitating. Awkwardly built, ungainly men, with limbs of an abnormal length, are not likely to make good pilots; nor are men who are slow in their mental processes. Lightly-built, intelligent men, naturally quick without being jerky or excitable, and who are not of a worrying or anxious temperament, represent the type that must be sought for. Aeroplane owners, if they are supplied with such men, well-trained and reliable, must be prepared to pay them good salaries.

The importance of a rigorous medical examination, for all men who wish to pilot aeroplanes, is emphasised by the fact that there have been cases already in which the circumstances made it clear that a man was flying, and met with an accident, at a time when his physical condition was such as would render him unfit to be in charge of an aeroplane. But the physical strains of flying will, in the future, be very much less severe than has been the case in the past.

A fact that should not be forgotten, either, is the way in which men have adapted themselves already to the new conditions they have to encounter when navigating the air. It was declared in the early days of flying that it would be only one man in a thousand who would have the qualities necessary to handle an aeroplane. But this was disproved before the war, and has been disproved even more conclusively during the progress of the war. One can take any young man to-day, normal in physique and nerve, and teach him to handle an aeroplane in a few hours; while in three months he will be sufficiently experienced to pilot aeroplanes in cross-country flights. If this is possible to-day, when flying is still in its infancy, it suggests that the people of the future will take to the air just as naturally as to any other form of travel. Mankind will adapt itself to aerial locomotion in the same way as it has adapted itself to the conditions of modern life.

Our forefathers would have considered it impossible to live at the rate we live to-day—with telephones, fast motor-cars, and all the facilities which enable us to get so much more done, in a given time, than was possible in the past. And with the coming of flight there will be another great speeding up. We shall live at an even greater pace, doing still more in any given time than is the case to-day. But as in the past, and as now, there will be pessimists who will say that mankind cannot stand the strain—that our physique and nerves will be ruined irretrievably. And yet, ignoring such lamentations, the world will adapt itself almost unconsciously to the new rate of speed. Of course there is a limit which must be reached, so far as concerns the endurance of the human physique and nerve. But, though it is the habit to deplore the wear-and-tear of modern life, that limit is not as yet in sight. There is the elasticity of the human organisation to be taken into account. A normal man has to over-drive himself terribly before he breaks down. A man who takes care of himself, who rests when he can—who does not, in the time-honoured phrase " burn the candle at both ends " —will live even at the highest pressure which attains to-day, and still feel he has something in hand.

A point to be noted is that certificated aviators, after having passed the doctor, will need to report themselves periodically for re-examination, so that there may be no chance of their having developed any defect, since their first examination, which might involve them, and others, in a smash.

VIII

Flying Clubs

A feature in the popular development of aviation which should be encouraged is the formation of flying clubs. A certain number of people, forming themselves into a club, may decide to acquire their own flying ground, buying what aeroplanes they require, and employing their own engineers and mechanics. The formation of such clubs should do much to promote the sporting and competitive aspects of flying. They should lead to inter-club contests; and there is the possibility of organising international meetings, in which aviators of various countries engage in a series of contests. Events of this kind should prove attractive to the public; and they should certainly have a stimulating influence on the construction of new types of aeroplanes, seeing that the rivalry between aviators would be shared also by designers and constructors.

IX

Need for Organisation

Though progress in the directions we have indicated should be rapid after the war, nothing must be done which is haphazard or badly organised. There is a lesson in this regard to be learned from the first flying meetings. These, with few exceptions, were so hastily and imperfectly organised, and with such a lack of regard for the convenience of spectators, that a bad impression was created on the public mind. The desire to make money quickly out of flying defeated in fact its own purpose. Great crowds of people were brought together to see aeroplanes fly, many of them coming from long distances, at a time when all aeroplanes were so inefficient, and their pilots so inexperienced, that even a moderately high wind was sufficient to prevent any flying from taking place. Many thousands of people were disappointed in this way, and felt that their ignorance had been exploited; with the result that for years after these early failures the aeroplane was regarded by the majority of people as being a purely fine-weather machine, and this even at a time when flights were possible in high and gusty winds. The first impressions of the public, so far as spectacular or competitive flying was concerned, were certainly unfortunate; and the influence of these early disappointments is felt to-day.

What we must strive to do, in aerial touring and pleasure flying, and later on in commercial flying, is to prevent the public from being disappointed by unsatisfactory machines, or by a lack of safeguards or conveniences when they fly such machines from point to point. Machines, aerodromes, and all the necessary organisation, must be thought out carefully and placed in readiness before any general campaign is embarked on to popularise the aeroplane. Spasmodic efforts will do more harm than good; while rash or ill-considered enterprises, which individuals or concerns may attempt to launch who have no proper organisation behind them, and no knowledge of the special requirements of aviation, will need to be suppressed for the common good by a firm action on the part of the whole industry.

PART VI

LAWS OF THE AIR

NAVAL, MILITARY, INTERNATIONAL, CIVIL

I

The Hague Convention

In 1899, at the Hague, the nations agreed to prohibit the discharge from aircraft of projectiles or explosives: but later, when this rule came up again for consideration, several nations, including Germany and France, declared they could no longer agree to it; and the reason for this change of attitude was not hard to find. Aircraft, improving rapidly, promised to be effective machines in the making of raids across hostile frontiers; and neither France nor Germany, with the possibility of war always in their minds, felt that they could deprive themselves of such a weapon.

After the refusal of Germany and France to sign this rule, matters were arranged as follows: those countries which still consented to be bound by it—and they included Great Britain and America—agreed that, in any war in which they found themselves opposing each other, they would not use aircraft for bomb-dropping; but that if they were called on, say, to fight Germany or France, and these countries used aircraft in destructive raids, then they would hold themselves free to retaliate. This rule, as a matter of fact, after countries like Germany and France had withdrawn their consent to it, became practically without force. The whole question was left in abeyance, with no fixed or definite rule to guide the action of any combatant. The problem was, of course, one of unusual complexity; and this was recognised by the international aeronautical congress which sat at Nancy in 1909, and which decided that " only warfare can reveal what abuses are to be checked."

There remained, however, as a general guide, the article of the Hague Convention which read: " It is forbidden to attack or to bombard, by any means whatever, towns, villages, habitations, or buildings, which are not defended." This rule, however, as it stood, did not provide adequately for such special contingencies as might arise in connection with raids by air—remembering that raiding aircraft, being unchecked by land obstructions or defences, have the power to reach vital points, and damage communications behind a battle-front, in a way that would be impossible with any other weapon. Such questions arose, therefore, as this: Under what conditions is a town to be considered defended, when use can be made of aircraft for the purposes of destruction? The presence round a city of anti-aircraft guns, or of patrol aeroplanes, or the power an attacking airman might possess of destroying with bombs some building of military importance within the confines of a city, such as an arsenal or munition factory, raised points that were not covered by the rule we have quoted, and to which, prior to the war, there were no authoritative or definite answers. No law, indeed, existed, and therefore there was no law to be broken.

The use of aircraft, it must be realised, brought up problems which were entirely new. If an army possessed a gun of such power that it would throw a shell with accuracy for a distance, say, of fifty miles, and it was possible to train this gun on some railway junction used by an enemy for the transport of troops, it would be a permissible act of war to bombard this station, even if it was far behind the fighting line and there was nothing else in the vicinity of military importance. Raiding aircraft, armed with bombs, may be likened to a gun which has a range of hundreds of miles—a gun capable of placing a shell on some railway depot or junction which lies deep within an enemy's territory, and which could not be attacked by any other means. And it is only natural, such a new and powerful weapon becoming available, that it should be used. If the rules of war do not, at any given time, cover the use of a new weapon, they should be modified so as to do so. It is certain that no weapon would be discarded, if it was powerful and promised well, simply because provision had not been made for its use at some earlier Hague Conference. The science of war is progressive; the rules of yesterday cannot cover to-day, nor those of to-day to-morrow.

II

Aerial and Naval Bombardment

It was considered reasonable, though there was no formal agreement between nations to this effect, that aerial bombardment should be governed by the international code which concerns naval bombardment. This lays it down that any structures or buildings may be bombarded which can be held to be of definite use to the enemy in providing for the needs of his fleet and army; anything, in fact, which comes under the heading of material of war. And under such a heading are placed docks, harbours, railways, and all warlike stores and military establishments. What this means, really, is that an aircraft, when flying over hostile territory, is entitled to aim bombs at any railway station its occupants see below, even if there is nothing else in a town, except this railway station, which merits the description of war material. The airmen, discharging their bombs at the railway station, can argue that this station, with its buildings and rolling stock, is of military importance to the enemy, seeing that it may be of use to him in the transport of his troops or supplies. And nowadays, of course, with munition factories everywhere, one can see how universally might be extended this right to attack war material from the air. Almost everywhere throughout this country, for instance, we have had factories and other buildings engaged directly on military work, which an enemy could argue he had a right to attack.

The position amounts, in a word, to this: not only navies and armies, but entire nations, fight nowadays. The whole of a country has to be organised to supply war materials, seeing that such vast quantities are required. And if hostile aircraft fly over such a country, and drop their bombs, it is practically impossible to frame any rule as to where bombs are permissible and where they are not. The nation is in arms for the prosecution of the war; all the national organisation is directed towards that end.

In the past such conditions have not existed; wars have been more localised. Armies have fought without there having been an upheaval in the whole lives of the nations at war. But in warfare on its modern scale, almost every man in a country, and a large proportion of women, are doing war work, and are combatants in the sense that if it were possible for the enemy to kill them with a bomb from the air, their death would have an effect more or less prejudicial on the output of some war munition, or in the product of foodstuffs, or in the business of transport and supply.

Aerial bombardment, of course, even assuming it is governed by the rules of naval bombardment, offers possibilities of destruction which are far more serious. A warship, approaching a hostile shore, can only reach with its shells some town or position which is on the coast, or a given number of miles inland. But an aircraft, flying in over the shore, can reach cities which are far inland: it can, indeed, granted it has a sufficient radius of action, drop its bombs anywhere and everywhere.

Natural barriers mean nothing to raiding aircraft. They pass with equal facility above land or sea, forest or mountain. And in this fact, coupled with their speed, lies their immensely destructive power.

A point that is of importance, in contrasting bombardments from the air and from the sea, is that it is laid down in regard to naval bombardment, with a view of course to saving the lives of non-combatants, that an attacking squadron should give notice to the city it proposes to shell, in order that civilians may withdraw to some place of safety. But with this rule, as with others in war, conditions may arise which render its observance impossible. In aerial bombardment, for example, in practically all cases, the observance of any such rule would rob an attack of its chief hope of success—would eliminate, that is to say, the factor of surprise. Even an hour or so's notice of any raid would permit guns and defending aircraft to be brought into position. A blow by air must be struck swiftly; it must come, if possible, without warning: to give any notice, therefore, before a city was attacked, would be simply to play into the hands of the enemy.

Here one comes again to the essential fact that, owing to the power of raiding aircraft to penetrate within a hostile country, and to drop bombs on military centres, railway junctions, or munition works, there is now a risk for civilians which has not had to be faced in any previous war. It is a risk which must grow and which must be made the best of. War has ceased to be an affair in which a certain number of men fight, watched by a host of spectators—the people who stay at home. Onlookers as well as combatants find themselves involved in the titanic struggle. In future wars, as a matter of fact, there are not likely to be any onlookers at all—either among individuals or nations. Every man and woman will be given some war task; while it will be almost impossible for any nation to remain neutral, owing to the vast and complex interests which will be involved. The war of the future will not be fought between individual nations: it may be a conflict in which one half of the world finds itself ranged against the other.

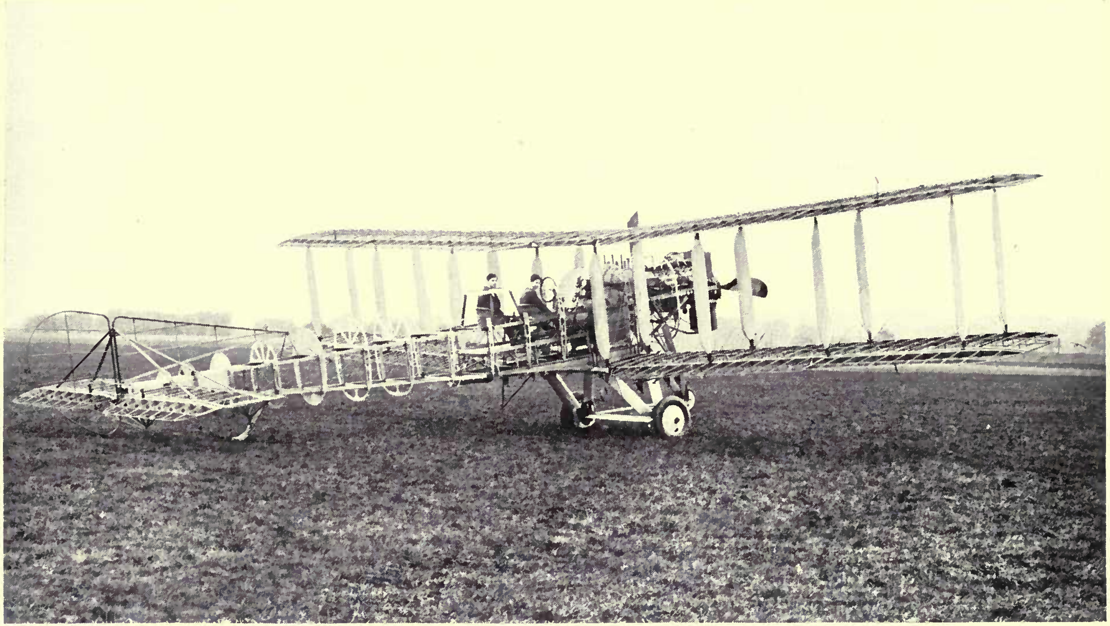
III

At the Outbreak of War

The position between nations as to aerial bombardment, when the war came, was practically this: any country was entitled to send its aircraft over hostile territory, and to drop bombs on railways, harbours, or military stores, or any other buildings engaged in war work. But if any country did so—and here was the point that was important—it might incur odium, and the condemnation of neutrals, if the bombs from its aircraft fell wide of their mark, as they were quite likely to do, and killed non-combatants, or destroyed private property, instead of reaching the targets at which they were aimed. Would any country use this new and dangerous weapon indiscriminately, or would it confine its attacks so that non-combatants ran the least risk of injury? This, rather than the observance of any rules, was the question that war was to solve.

Germany, as we have seen, has provided a grim answer. Throwing aside the restraints of humanity, and using her airships and aeroplanes as weapons of sheer terrorism, she has flouted the good opinion of the world, and has turned a deaf ear to the protests of neutrals. She has sent airships over England by night to scatter their bombs haphazard; making, indeed, scarcely a pretence of aiming at a definite target, but merely throwing out their bombs when they imagined, groping as they were above a darkened countryside, that they were over some town, railway, or human habitation.

The action of Germany need not be argued now, or even considered, from any such aspects of humanity, in its application to war, as were entertained before this campaign. War has entered upon a new phase: all previous land-



F. N. Birkett.

A Grahame-White biplane (type 18) fitted with a 250 h.p. engine. The machine is seen in skeleton, before receiving its covering of fabric, so as to give some idea of aeroplane construction. The passenger, seated behind the pilot, has round him the framework of the revolving turret on which an automatic machine-gun will be mounted.

marks are gone. We must face the position actually as it is; and this means that one great nation, directing every ounce of its energy to the defeat of another—converting itself, in fact, into a huge war organisation, in which civilians as well as combatants play their appointed parts—will strike at the enemy with every weapon that comes to hand; and strike him not only in the battle area, or on the seas, but at any points, and under any conditions, where damage may be done, or the courage of his people weakened. And this means that it will be impossible, in the future, to protect non-combatants from risk of injury or death.

IV

What the War Teaches

Any nation which is chivalrous, which seeks to fight cleanly according to the traditions of the past, is at a disadvantage, naturally, when opposed by an enemy who is unscrupulous. In a fight between pugilists in a prize ring, which is governed by certain rules, the man who breaks a rule, who seeks to gain some unfair advantage over his opponent, is brought to task by the referee. The referee represents a power that the offender cannot ignore—a power stronger than himself. However evil may be his intentions, therefore, he has to fight fairly, as his opponent fights, or the contest will be declared against him. But in the fighting between nations where is the referee who, condemning an unfair blow, can enforce on the transgressor an observance of the rules? It was said, before this war, that neutral opinion would take the place of a referee; that no country would wage a war of terrorism, or of brutality, because it might fear what neutral countries would say, or what action they might take, either during the war or afterwards, to express their disapproval. But that argument, like a good many others, has gone completely by the board. Germany has shocked neutral opinion, not once but a hundred times. The protests of neutrals have been simply disregarded. What we have seen, indeed, in this war—and it is a lesson that should imprint itself indelibly on our minds—is first the striking of an unfair blow, not inadvertently but with premeditation, and then an apology for it afterwards—completely insincere—when the effect has been gained, and the damage done. This is the policy Germany has pursued deliberately; and she has not even taken the trouble to apologise unless it has been for some good reason of her own, or in order to quieten temporarily some neutral whom she has thought it judicious to soothe.

In this war, owing to the imperfection of aircraft as weapons of destruction, a policy of terrorism has failed because it could not be pursued with sufficient rigour. Germany, by adopting the policy she did, suffered all the reprobation with practically none of the results. But the point to be remembered is that such a campaign of terrorism has actually been attempted and that—for any combined effort the world has made to prevent it—it might have succeeded.

With an individual, should he break the law, there is the power of the State to punish him; a power he cannot question, and before which he is helpless. But with a great and powerful nation, when it decides to break international law, and cares nothing for the discredit of so doing, where is the power, save a force greater than its own, which can bring it to account? A powerful group of nations may, certainly, form themselves into a tribunal, and enforce by their combined strength an observance of certain laws. But the effectiveness of any such action depends on the strength of the combined nations being greater than that of any country or countries which may decide to break the law. And it is impossible to make certain that, among the nations forming a tribunal, there shall remain always a complete agreement. Dissensions may arise; the balance of power may change. It is impossible, indeed, that it should remain stationary. Nations, as well as individuals, rise and fall. New conditions have constantly to be faced—conditions which may change friends into rivals, and even enemies.

If every country in the world were to agree to certain laws governing, say, the conduct of war, there is the restless ambition to be reckoned with which is a part of human nature. The control of some great country may pass into the hands of men whose ambition is so strong that, as soon as they find they are not moving fast enough towards their goal by legitimate means, will turn without scruple to means that are illegitimate. Would anybody have thought, before the war, that Germany would have done what she has done? No. But a nation, like an individual—human nature being what it is—will go to any length to gain some end, provided that its desire is sufficiently strong. Germany wanted world power; she had thought of little else for forty years; and she was ready to do anything to get it. And as with a nation, so with an individual. A man who wants money, whose obsession it is to gain money, who thinks of money day and night, and who loses his sense of proportion in so doing, will steal if he cannot get it any other way.

This war, from the point of view of flying, is merely a prelude to that great air war of the future which must come, almost inevitably, unless the nations agree without reserve to lay aside their arms. But will they do this? It seems at least improbable.

"There will be no future war," one hears it said. "This is the last great war."

Well, if this war should alter, at a stroke, the entire basis of human nature, it will have done something so extraordinary as to be almost beyond belief. If the lion does lie down with the lamb, and with nothing but peaceful intentions, well and good. But until that phenomenon actually does take place before our eyes, and is seen to be a state of things likely to endure, it is for us to remember that this world, like this life, is built up of rivalry and struggle.

One sees this everywhere, of course, not only in war but in peace. There are fights to the death in trade, one great organisation seeking to crush another, with the livelihood of hundreds or perhaps thousands of people depending on the struggle. And what takes place in civil life, and in times of peace, takes place also on a more terrible and lurid scale when nations go to war. A powerful business concern, failing to make a sufficiently rapid headway by the normal processes of trade, may start a price-cutting campaign against some rival, seeking to deal this opponent a death-blow by robbing it of its customers. And a powerful nation, feeling that under peace conditions it cannot expand with sufficient rapidity, may decide to take up and use the weapons for which it has paid hundreds of millions of pounds, and to strike suddenly at some rival with its fleet and army. With ambitions high and ruthless, and with human life so brief, it is not surprising that short cuts should be taken to power, either by waging a trade war or by a war of arms.

V

A Puerile Suggestion

The proposal has been made that flying should be put a stop to after the war; that all countries should agree not to build any more machines or train any more aviators; that this great new science, the greatest and most important in the world, should be deliberately suppressed. And this merely because aircraft are powerful instruments of war. The suggestion is ludicrous. Flying has a purpose far greater, in the end, than the destruction of cities, or the killing of men in war. It will, when machines are perfected, provide the world with its swiftest and most delightful form of travel. It will open up a new era; it will give men, ultimately, the complete mastery of a new element. The conquest of the air, when it is absolute, will have a more important influence on civilisation—and a greater influence for good — than any other conquest man has made. To renounce this conquest, to abandon the navigation of this new element, which will reduce journeys of weeks to days, and those of days to hours, would not only be illogical in the extreme, but would be to deny the world a means of transit by which, in the future, there will be the greatest chance of spreading civilisation, and of strengthening the bonds of good feeling and understanding between one nation and another.

None but those who take a narrow view, and who fail to realise the vast future which lies before aviation, would suggest for a moment that flying should cease. Such an error, if made by the world under the influence of panic, would be a pitiable confession of weakness and of short-sightedness. That an aircraft is a weapon of war is incidental: its great rôle—the rôle of the future—is not as an instrument of destruction but of construction; an instrument which, coupled with the use of a universal language, should do more than anything else to render war impossible.

When a man can travel into another country just as quickly as, to-day, he travels between one city and another in his native land; and when he finds in that other country a people who no longer speak a foreign language, but who can talk with him in a universal tongue, it will need an extraordinarily powerful influence to set these men of different nations at each other's throats—men who have become friends instead of strangers, and who have talked with each other heart to heart.

In the air there are no frontiers. Aircraft of the future, linking not only countries but continents, will break down prejudices and false assumptions. The nations of the world, brought together as they will be by air travel, will get to know each other intimately instead of superficially. All earthly barriers, such as exist now, will be removed. People will begin to understand that they are the inhabitants of one great globe, instead of being a series of separate communities. The rôle of the aeroplane in the future is to make men realise that they do not belong to any one city, or country, or continent, but are merely citizens of the world. Nothing can do this so effectually as can aircraft, because nothing else can break down in the same way all existing barriers, natural and artificial.

But will men learn this great lesson in time to prevent another war? That is the question, and who can answer it? But this at least we can say, and remind ourselves of it constantly. Air power alone, the power of dominating the aerial highways, the power of striking and defending, will prove our safeguard in the years to come.

Hundreds of millions of pounds might, of course, be saved each year in the cost of armaments if nations would agree to settle their differences by the use of a certain number of picked men, employing no weapon other than the sword, who would fight hand to hand until one side or the other was defeated. But the tendency has always been in the past, and will be the same probably in the future, to make use of every new weapon which comes to hand, no matter what its cost. When guns were invented the nations might have agreed not to use them in war, but to content themselves with bows and arrows. But they were only too glad to seize this new and more powerful weapon—as they were when submarines and aircraft became available.

VI

Laws after the War

A task which will face the nations after the war will be to frame and enforce laws, international and civil, to govern the navigation of the air. Before the war there were comparatively few aviators, while machines were not passing through the air in such numbers as rendered necessary any immediate or detailed consideration of the laws which should control their flight. But after the war, when aircraft are built and flown in constantly growing numbers, and flights are being made daily not only between points inland, but from one country to another, it will be essential that there should be laws which are universally recognised and obeyed.

The interests must be safeguarded of those who use the aerial highways, and also of those on the earth. It will be most necessary to avoid bad feeling between those who use the air and those who remain on the ground. We must avoid in the development of flying any such public outcry as occurred in the early days of motoring, when newspapers were full of complaints against users of motor-cars, many of whom were labelled "road hogs" and regarded as a public menace. Discretion will be needed in framing rules to meet such contingencies as may arise when aircraft are flying in large numbers. There are international rights to be safeguarded; traffic on the airways must be regulated, to avoid accidents and collisions; and there is the question not only of the safety of those on the earth, but also that of preventing their property from being damaged, or they themselves annoyed, when the air is used as a regular highway.

These problems are not new, but they may become urgent after the war owing to the rapid strides which will take place. For several years before the war, such bodies as the International Aeronautical Federation and the International Law Association had been considering the problem which would attend a general navigation of the air, and had framed proposals which had been submitted to various Governments. The Governments themselves had also considered these matters before the war, and certain laws had been placed already on the statute books.

VII

The Freedom of the Air

One of the questions to arise is whether the air should be regarded as entirely free for navigation, or whether nations should have power to supervise and control the traffic which passes above their territory. The argument in favour of the complete freedom of the air, over the whole surface of the globe, is based frequently on the fact that the navigation of the sea is unrestricted, except for the rights of nations over the waters in the immediate vicinity of their shores. But it has been pointed out that a comparison between air and sea is not satisfactory. If a ship sinks, and goes to the bottom of the sea, there are no cities or communities on the sea-bed which might be harmed by the descent on them of this vessel. But if an aircraft falls while flying above the land, its descent may cause loss of life, or damage to property. There is the law of gravity which must be considered always. Though an aircraft is moving free of the earth when it is in flight, it is still under the influence of gravity. If any object is dropped from it, inadvertently, this will fall to the earth and may cause damage. If aircraft were completely free from earth attraction, the question of the rights of those on the ground, when flying becomes universal, would not need, of course, to be studied so closely. But as it is, the comparison between air and sea, for the purposes of a freedom of transit, fails to be convincing on several points. There are, for example, no fortifications or military works at the bottom of the sea which those passing above in ships could spy down on; but with air traffic the problem of espionage is one of the most important.

It is pointed out also, as against the contention that the navigation of the air should be free — provided aircraft maintain a minimum height when passing above the earth—that no comparison in favour of such an argument can be drawn between the navigation of air and sea. The chief danger to a country from the attack of a hostile fleet of warships occurs when these ships move close to the shore and commence a bombardment. But this is not the case with the air. An attacking air fleet, even while maintaining a high altitude, would be capable of attacking and destroying cities by the dropping of bombs. So it would not be a safeguard in the air, as it might be on the sea, to demand that craft should keep any specified distance from the earth.

VIII

Main Problems

The chief questions which have been argued legally, in connection with aerial navigation, are briefly these—

1. That the air should be regarded as being entirely free.

2. That each nation should have complete control of the air traffic passing over its possessions, and should be able to prohibit all such traffic if it desires to do so.

3. That each nation should have such a control of the air space above it as would enable it to safeguard its interests internationally, and also the lives and property of its inhabitants; but that apart from such a control as would be necessary to ensure this protection, aircraft should be given free passage.

It is held as a matter of fact to be essential that a country should have power to regulate the entry above its coasts of foreign aircraft; that it should have power to prevent spying from the air; and that it should be able to prevent the entry by air of undesirable aliens, or guard against the bringing into the country by aircraft of infectious diseases. The question of enforcing Customs regulations we shall deal with later.

In order to obtain control over air traffic entering or leaving a country it was considered before the war that either one of two courses might be taken: (1) That flying should be restricted to certain definite routes or airways; or (2) that landings should be declared compulsory at certain fixed points.

IX

British Laws

The British Government, after consulting naval and military authorities, decided before the war to adopt the second of the two plans just mentioned, and to specify certain areas in which craft which entered from abroad must alight. These rules, which became law in 1913, indicated a certain number of areas on the south, east, and north-east coasts, where it was required that aircraft from foreign countries should be obliged to descend.

The procedure in connection with this rule was as follows. An aviator intending to enter Great Britain from abroad had to give eighteen hours' notice to the Home Office of his flight. On arrival at one of the landing areas prescribed, he filled up an official form and received a permit which allowed him to continue his journey inland; then, before leaving the country, he was required to alight again in one of the coastal areas.

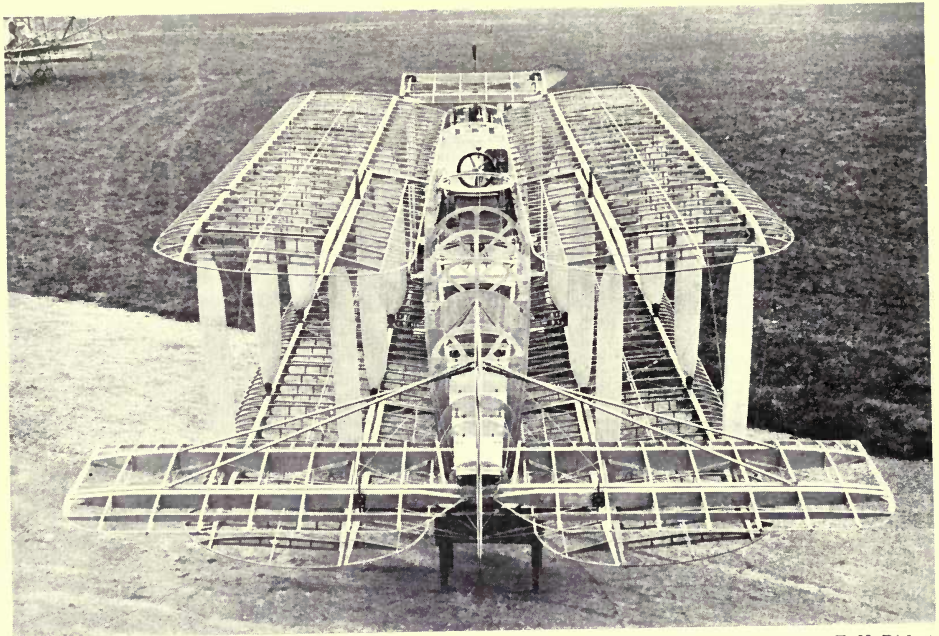
Another law governing aviation which the British Government put in operation before the war was one by which no flying was permitted over certain points of strategic importance. The mouth of the Thames, for example, was closed to aviation; so were fortifications like those at Dover; or dockyards such as those at Portsmouth.

X

International Law

The general position before the war in regard to the establishment of aerial law may be summarised as follows: the nations had not yet agreed to any comprehensive scheme by which the air traffic of the world might be governed, and this mainly because aerial navigation was so much in its infancy that many of the problems which might arise in the future could not be forecasted with accuracy. What had been done was that individual nations had framed regulations which gave them the right to control the flight of aircraft reaching their shores from foreign countries. The advocates of a complete freedom of the air, or those who argue that a nation should be said to own its air space only up to a certain altitude, and that above that altitude aircraft should navigate without restriction, found that when it came to the framing of these first laws the Governments were determined—with certain exceptions—to assert their right to supervise and regulate, but not necessarily to prohibit, the flying which took place above their territory.

It was generally agreed that above the high



F. N. Birkett.

Another view in skeleton—this time from the rear—of the Grahame-White (type 18) biplane. The main-planes are folded back along the sides of the hull so as to facilitate the housing of the machine, and to reduce the space it occupies. This photograph indicates, even better, perhaps, than its predecessor, the large amount of detail work which is involved in aeroplane construction.

seas, or over unoccupied land, aviation should be permitted without restriction; but to allow foreign machines to fly over their territory without any legal or other machinery for establishing their identity, or for examining their papers and discovering the purpose of their flight, was a proposal which failed to find acceptance among nations which had important interests to safeguard. It was considered that an impossible situation would be created if an aircraft could fly without control from its own country to that of some neighbour, passing over strategic points and making whatever observations its pilot might desire, and then returning again without question to its starting-point. Of course, if the nations agreed to abolish war, to discard their burden of armament, and to develop flying for nothing but peaceful purposes, then the position would be different, and aircraft might be given an unrestricted freedom. But as matters stood before the war—and as they are likely to stand after the war—it was held to be essential to national security that air traffic should be supervised and controlled.

XI

Registration

Before air traffic can be regulated, in the way that traffic is regulated by land or sea, it will be necessary to register all aircraft (this has not yet been done) and to compel them to display identifying numbers showing their registration, and also letters indicating their nationality. The International Aeronautical Federation has drawn up a schedule covering such points as these. It is proposed that an international list of aircraft should be prepared, and exchanged between nations, and that it should be kept always up-to-date; also that machines should be marked first with the letters indicating their nationality (such as G. B. for Great Britain and F. for France), and after this the number by which they are registered. These identifying letters and numbers would have to be borne so prominently on an aircraft that they were distinguishable from the earth when the machine was at an ordinary flying altitude.

The point has been raised that a craft coming in over a foreign country, and flying high, might escape recognition owing to the fact that its number was unreadable. But here it must be remembered that all craft will be required by law to alight within specified areas after passing in over the sea-coast or frontier; and if one did not do so, and flew on, infringing the regulations, it is pointed out that an intimation of the fact would be sent at once to various centres inland, and that patrol aircraft would endeavour to intercept the machine and compel it to alight. But there will be the possibility always that a fast machine, when favoured atmospherically, will be able to dart in over a coast-line or frontier and get away again without being identified or stopped. It is a possibility which no organisation can hope to obviate completely. But the risks of aerial spying on an extensive scale, or of the illegal or secret flying of machines contrary to the regulations, can be lessened very considerably by an international system of registration, and also by the establishment of air patrols, which would seek to enforce the landing rules if any craft attempted to evade them, or which would report by wireless the number of any offending craft, and so cause this machine to be identified, and its pilot interrogated, at whatever point he came to land.

A fact which it has been pointed out should aid the regulation of air traffic, and render impossible anything like a systematic avoidance of regulations, is that though a machine might escape identification by flying high, or by shielding itself in clouds, it would be compelled eventually to land somewhere, and submit to an examination of its papers. Of course if a machine capable of a long non-stop journey passes from one country to another, in cloudy weather or under cover of darkness, and returns again without alighting after carrying out some secret errand, it will be impossible in the majority of cases to prevent any such flight. But it must be remembered that the country which sends one of its machines on such an errand over the territory of a neighbour will place itself in an unpleasant position should the craft happen to be identified or forced to land. Such an offence, if it could be proved to be deliberate, might be considered equivalent to an act of war.

XII

Permits to Fly

In regard to the papers which an aircraft should carry, the International Aeronautical Federation suggests that, after a machine has been registered, and the aviator has obtained his certificate of proficiency, he should be required to apply for an official form, which would be known as a "permit to travel." This would contain all details necessary for the identification of the aviator and his craft, and the possession of it would allow him to fly anywhere within his own country. But it would not be available for a foreign journey. Before leaving his own country for another, it is proposed that the aviator should obtain from the authorities a special Customs bulletin. This would specify the nationality of his machine, give particulars of its registration, and provide details as to its passengers, goods, and baggage; also the date and place of its departure from England, with the destination to which it was bound. When he descended on foreign soil the aviator would hand his bulletin to the authorities, and receive in exchange a document showing that the Customs officers had examined his machine, and that he had paid what duty might be claimed on any of the goods he carried. Once he had this Customs bulletin, the aviator would be free to fly where he liked in the country visited.

It is considered that pilots of aircraft, as is the case with captains of ships, should be required to keep an accurate log of their various journeys, which should be brought constantly up-to-date, and should be shown to the proper authorities whenever demanded.

XIII

Smuggling

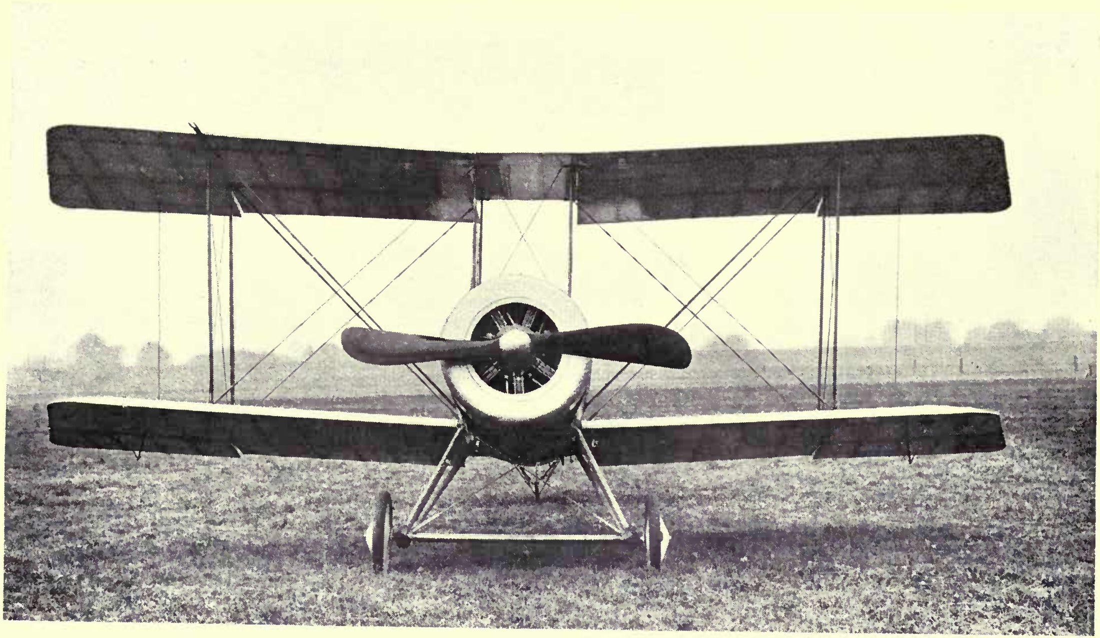
The problem of smuggling by air, and how it is to be prevented when there are large numbers of craft in flight, and long non-stop journeys can be made by multi-engined machines, both by day and night, with small risk of a compulsory descent, is one which will need careful attention. The authorities may specify points where aircraft are to alight, and where they are to be examined by the Customs officials, but the question is: What can be done if aircraft are used with the deliberate intention of smuggling?

Any elaborate organisation, necessitating a constant use of air patrols round the whole of the coastline, say, of Great Britain, so as to endeavour to prevent any smuggling aircraft from creeping through on a dark night, or when the coast was obscured by fog, would entail an expense which would be almost prohibitive. The Customs will no doubt employ a certain number of patrol machines, but it will be impracticable to have such an organisation in constant operation as would prevent any smuggling craft from slipping across the coast inland, provided it flew high, and chose suitable conditions. What Governments will rely on, probably, will be an organised co-operation between the Customs authorities of each country, working in conjunction with the police and local organisations, so as to trace long-distance flights; while the penalties inflicted on aerial smugglers will no doubt be heavy.

A machine which makes a smuggling journey say, to England, and escapes detection when passing above our coasts, would need, of course, to have some point of departure; also some landing-ground to which it could return; and it is argued that, while one or two smuggling flights might be made perhaps without such a machine being traced, it would be difficult to organise any system of aerial smuggling on an extensive scale, because the base used by the smugglers—the spot where they housed their machines, and where they had their mechanics and fuel supply—would be discovered sooner or later by the authorities.

But it should be remembered that with machines of the future any large open space for ascending or alighting will no longer be required. Machines with variable-surface, variable-pitch propellers, and using high-powered engines, will be able to leave the ground so rapidly that it will be possible to ascend from quite a limited space. Aerial smugglers might therefore render their base of operations so inconspicuous that it would be no easy matter to trace them.

They would use aircraft, naturally, in which the machinery had been so silenced that it was



F. N. Birkett.

A single-seated, high-speed biplane of a type which has proved certainly useful, on active service, either in rapid reconnaissance or—when fitted with a machine-gun—as a fighting craft. The machine seen above, built by the Grahame-White Aviation Co., and fitted with an 80 h.p. motor, attains a speed of approximately 100 miles an hour. With a 100 h.p. motor this speed is exceeded.

inaudible when the craft were at any height; while when near their base, say before landing, they would switch off their motors and glide in silence to the ground; and the same plan might be adopted when approaching the English coast—the pilot might rise to a high altitude, that is to say, while passing over the sea, and then switch off his motors as he neared the coast-line, gliding inland without a sound to reveal his passage to those below.

It has been argued that the landing of a smuggling aircraft, in order to unload its cargo of contraband, would lead to its detection; but a plan might be adopted which made it unnecessary for a machine to alight. Confederates in a motor-car could proceed at night to some lonely point agreed upon, and, at the hour which had been specified, shine a light skyward to act as a guide to the pilot who was bringing over the smuggled goods. This light would not need to be brilliant, and it could be screened so that its ray was invisible to any one on land.

Those in the aircraft, having located by this light the position of their confederates, would attach their contraband goods to parachutes, drop them overboard without descending, and then return through the darkness whence they had come. The motor-car party, having retrieved the parachutes, and taken the goods on board their car, would then drive away, leaving no trace when daylight came of what had occurred. The receiving-point could be varied constantly to avoid attracting attention locally—any open or sparsely populated stretch of land being suitable for the purpose. Such a scheme would hardly be profitable unless goods were smuggled on which the duty was high—such for example as saccharin, a large quantity of which can be stored in a small space, and on which a high duty has to be paid.

The scheme indicated is merely one of many. A problem of exceptional difficulty may in fact face the Customs authorities as the volume of air traffic grows, and as machines become more reliable and capable of longer non-stop flights. It has been argued indeed that the application of the Customs regulations to aircraft will eventually become so difficult that, in order to save endless complications and the expense of an elaborate organisation, all air-borne goods will be allowed to go duty-free. But this is a proposal which raises large issues, and will require detailed consideration before (if ever) it can be adopted.

XIV

The Rights of Landowners

Apart from the international laws which will govern flying, or the enforcement of Customs regulations on air-borne traffic, there is the question of civil law in its application to aerial navigation; the rights, for instance, of landowners above whose property an aircraft flies. By the old Roman law, which has come down through medieval times, it is held that the owner of any stretch of land owns also the air space above it. This law, if rigidly applied, would give any landowner who had a prejudice against aviation the right to prevent aircraft from passing above his property.

An expert, writing in the *Law Magazine*, has held that the flying of an aircraft over private land is an act of trespass because it comes under the heading of what is known as "constructive entry," which in its legal definition includes "every interference or entry other than actual or physical entry." But it has been argued that if a landowner who had a prejudice against aviation brought actions for trespass against every aviator who passed through the air above his property, he might be called on by the defence to prove his occupation of the air. To his land he can of course prove occupation, seeing that his house is built on it, and that he moves about on it, and employs others to work for him on it. But it might be difficult for him to prove his occupation of the air in a legal sense, or up to any such altitude as that at which an aircraft would fly: he does not go up in it, or carry on any work in it, or employ others to make use of it for him in any way.

In a case before the war in a local police court, a landowner was sued for the value of certain pigeons which he had shot as they flew above his property. His solicitor, by way of defence, contended that the birds were committing an act of trespass while passing above his client's land, and that there was justification for shooting them; but the magistrates would not accept this view, and called on the landowner to pay the value of the birds he had shot.

XV

The Legal View

The law, being impartial, is prepared to consider the rights of aviators as well as those of landowners; and the legal opinion at the present time (stating the case, of course, generally) is that while an owner of land is held to own also the column of air above it, he has no right to prevent an aviator from flying through this air space unless he (the landowner) can prove to the satisfaction of the law that the aviator has been guilty of some damage by so doing, or has endangered or annoyed those on the ground. This is the view taken generally by legal authorities, but cases in the nature of tests will come no doubt before the courts as soon as there is a large volume of civilian flying—as there will be after the war.

An interesting case, showing as it did the legitimate grievance of a landowner, came before the French courts some time before the war. Several flying schools had been established in the neighbourhood of this landowner's property, and the damages he claimed were in regard to the operation of these schools. His counsel declared that the hares and partridges on the estate had been driven away by the noise of the aeroplane engines; that crops had been damaged by flying-school pupils who made involuntary descents; and that the landowner had become afraid to walk in his own grounds for fear that some aeroplane might fall upon him.

The court took the view that the landowner had established a claim for damages, and awarded him a sum of about £100. This case was of course exceptional, inasmuch as there were several flying schools in the neighbourhood of the land-owner's property, and novices were passing low over his land, and making descents at points which a pilot of experience would have avoided.

An interesting case, brought against those who were controlling a large permanent aerodrome, was that of the proprietor of a nursing home, whose establishment was near the flying ground. The complaint was that the noise of the aeroplane engines, as pupils made their practice flights, disturbed and caused inconvenience to the patients who were in the home, particularly in the early hours. For certain reasons, however, this case did not come before the courts.

XVI

A Minimum Height

The mere passage of an aircraft over private land, provided the machine is at a reasonable altitude, cannot be claimed to be a cause of annoyance, or of danger, to those on the earth. It will be necessary, of course, in the framing of detailed rules to govern aerial traffic, that a minimum height should be specified below which it is not permissible to fly across country. It has been contended that an aircraft when flying low may be said to interfere with the privacy of people on the land. Legal experts argue, for instance, that an aeroplane which passes low over a man's garden—so low that those in the machine may be able to look down into the garden and see what its occupants are doing—is guilty of an act of annoyance sufficient to give the owner of the garden a right to take action.

XVII

Falling Objects

Among questions rather similar to this there is that of objects which might be dropped by accident from an aircraft, and cause damage when they reached the ground. A problematical case is that of a mechanic in an aircraft who, while repairing an engine when a machine is in flight, drops a spanner which falls with disastrous results through the roof of a conservatory. Here the question is one of identifying the machine from which the spanner fell. If this could be done, the owner or pilot would be responsible for damages.

It will not be so difficult as might be imagined, when air traffic is organised and under supervision, to trace a machine in any such conditions as these. Even if, at the moment of the accident, the registration number of the machine could not be observed, it would be possible, of course, for the police to make inquiries at aerodromes; also to question the occupants and mechanics of machines which had been known to be flying in the neighbourhood where the accident occurred. People who had been in the vicinity might be able, also, to give a general description of the appearance of the machine. The police will be required, no doubt, to familiarise themselves with the appearance of the various types of aircraft in use, and it is suggested that they should be provided when on duty with field-glasses to enable them to read the identifying numbers of aircraft which pass overhead.

An actual case, rather like the supposititious one just mentioned, occurred in connection with one of the early meetings. A lady wearing an expensive cloak was watching the aeroplanes in flight when a splash of lubricating oil, which had obviously fallen from one of the machines, descended upon her cloak. She brought an action for damages against the proprietors of the meeting, but they were able to prove that the motor-car in which she had been seated was outside and not inside the aerodrome; therefore it was decided that no claim could be established against them. After this an attempt was made to claim damages against the aviators taking part in the meeting. Here, however, it was necessary to identify the actual machine from which the oil had fallen; but as there had been several aviators in flight at the time in question, it was found impossible to prove who had been the culprit, and so the case had to be abandoned.

There will be cases, no doubt, in the air, as there are with motor-cars on the land, in which an aviator who has caused injury or damage will make off quickly so as to avoid detection. Such cases should, however, prove exceptional, as they are in motoring; and when an aviator is detected in an attempt to escape the legitimate consequences of an accident which he may have caused, it will be for the authorities to make an example of him, inflicting some heavy penalty.

XVIII

Descents on Private Land

A question which will arise, apart from the actual navigation of craft over private property, is that of the descent of machines, either voluntarily or otherwise, while they are making cross-country flights. It is held that an aviator is a trespasser except when he is alighting on his own property. But it is not likely in the future that there will be much trouble on this score, owing to the fact that aerodromes and subsidiary landing-grounds will become so numerous that it will be a rare thing for machines to descend anywhere except at these appointed places. It must be remembered also that the use of multi-engined machines will reduce very greatly the risk of breakdown, or of an involuntary descent.

It is suggested that if an aviator should make a voluntary descent on private land he should pay a fixed fee for having made this use of private property; while, if any damage should result from his descent, the owner of the land should make a claim which would be settled if necessary by arbitration.

Cases which bear on this have come already before the courts. In America a balloonist who descended on private property was sued by the owner of the land for damages caused by a crowd which broke into his grounds in order to see the balloon. The defence of the aeronaut was that he was not in control of the balloon, which was at the mercy of the wind, and that he was unable to avoid landing where he did. But the court held that the aeronaut knew at the time he ascended that he would be obliged to drift before the wind, and that damage might result from his descent. The court would not, therefore, entertain the plea that the aeronaut was a helpless agent. It was decided that the case was one of trespass, and the aeronaut was held to be responsible for the damage done by the crowd, just as though he had done this himself.

In another case an aeronaut who descended in a parachute on private land, with the result that damage was caused by the crowd which collected, was sued in respect of this damage and held responsible.

XIX

Involuntary Landings

If an aviator who alights on private land can prove that his descent was involuntary, and that his machine was out of control, he may claim that his act was what is known in law as one of "inevitable necessity." Here the aviator can be regarded in much the same light as a shipwrecked sailor, who is held by law to have a right to land on any shore, without the possibility of an action for trespass. The right of the sailor, on account of his extremity, is considered greater than that of the owner of the shore.

An aviator descending involuntarily on private ground, and defending himself against a claim for damages, will have to prove to the satisfaction of the court that his machine was out of control at the time of its descent, and this through no negligence on his part, and that it was impossible for him to reach a proper landing-ground, or to avert in any way what happened. If he can do this, it seems there will be no case in law against him. An illustration bearing on this occurs in the case of a man who was sued for damages caused by the bolting of the horse he was driving. But the court decided that, as the animal was obviously out of control at the time, and as its driver had done everything he could to avoid the accident, he must be exonerated from blame, with the result that the claim against him failed.

A case more directly applicable was that in which an action was brought against an aeroplane pilot who had run among the spectators during an exhibition, and caused certain injuries. For the prosecution it was argued that the accident had been caused by the personal negligence of the aviator; but he, in his defence, declared that a sudden gust of wind had carried his aeroplane over the spectators, and that he was powerless to prevent the machine behaving in the way it did. The court came to the conclusion that it could not be proved that the accident was due to the negligence of the aviator; therefore the case failed.

XX

No Repressive Legislation

What the industry must resist is any attempt which may be made to force the Government to impose legislation which will hamper the progress of flight. There have been, and will be, people who are opposed to the development of aviation, in the same way as there were opponents to the train and the motor-car. The efforts of such people must be watched and combated. Aviation claims the right of legitimate expansion.

There existed a tendency, even before the war, to form leagues and societies in order to impose restrictions on aviators. In France, for example, a league was formed to guard against "excesses in aviation." One of the suggestions of this league was that the speed of aircraft should be limited. The proposal, however, is one which should not be entertained. It may be argued that a speed limit is essential for vehicles passing along a road, in view of the fact that, apart from any risk of colliding with each other, they may endanger cyclists, pedestrians, school-children, or animals. In the air, however, with its freedom from obstruction, conditions are different: the only restriction placed on aviators should be the need to observe the rules as to passing or overtaking other craft; and there should be a heavy penalty for pilots whom it could be proved had flown recklessly or carelessly, thereby endangering other craft.

XXI

Rules for Piloting

The International Aeronautical Federation has already framed rules to govern the navigation of aircraft, in order to avoid accidents and collisions. Two aircraft meeting each other, end on, are required to steer to the right, passing each other at a distance of at least 100 metres (110 yards). An aircraft which overtakes another is held to be responsible for keeping clear, and must not pass directly under or over the other machine. When aircraft approach each other in cross directions, the pilot of the machine who sees another on his right-hand forward quadrant must give way, and the other aircraft must keep on its course at the same level until both machines are well clear. (The right-hand forward quadrant is reckoned from a position straight ahead of a machine to an angle of ninety degrees on the right-hand side.)

For night flying the Federation suggests the following system of lights: a white light showing ahead, a green to starboard, and a red to port, with another white light astern. It is suggested that a pilot flying in the daytime, who desires to alight, should indicate his intention to other aircraft by displaying a red triangular flag; or, at night-time, by waving a white light.

Other and more detailed rules will naturally be required: these are merely by way of suggestion. But, generally speaking, the laws governing the navigation of the high seas will be taken—with certain modifications—as a basis for framing the rules of the air.

PART VII

THE COMMERCIAL ERA OF FLIGHT

I

Exploration

A PERFECTED aircraft, capable of flying long distances without alighting, and with small risk of mechanical breakdown, will be of immense value for exploration, scientific and commercial. Blanks still exist on the map of the world; and it will be one of the tasks of the explorer, preparing expeditions by air when peace has come, to fill these in for us. As the expense attached to such expeditions will be considerable, their organisation must not be left to private individuals, but must be taken in hand by Governments. It should be possible for several nations, each with interests in common in some remote part of the world, to organise a joint expedition by air, and thus reduce the expense involved.

Mountains, forests, deserts—none of these impede an aerial explorer: instead of having to cut his way laboriously through dense undergrowth, he will be able to fly high above it, free from the menace of wild animals or from the possible attacks of hostile natives. For survey work, maps being prepared from photographs which are taken while in flight, an aircraft will offer unique facilities. In a few hours, by air, the explorer should do work which would occupy him days by any other means.

II

Mail-Carrying

One of the first commercial uses for aircraft should be as carriers of express mails and of light, urgently-consigned goods. Aeroplanes should be particularly useful, for example, in carrying mails in localities, and under conditions, which render land or sea transit difficult; in parts of our dominions which are sparsely populated; or in regions where land communication is impeded by rivers, mountains, or forests.

Aircraft must be reliable, of course, before they can be employed regularly in any such work as mail-carrying. The commercial value of a machine lies in its ability to do a certain thing at a certain time, and to keep on doing it without breaking down or giving trouble. This was what people thought the motor-car would never do. When motor-vans and lorries were in their crude stage, for example, there were sceptics who refused to believe they could ever be employed in a service requiring such reliability as that of mail-carrying. But the success of the motor-vans used for this work, and the increase in the numbers so employed, have proved such sceptics to be wrong. They will prove even less accurate if they make light of the possibilities of aircraft for mail-carrying. The commercial use of aircraft is no longer an idle speculation: the question now is merely one of how long it will take, after the war, before the industry can produce suitable machines. That they will be produced there is no doubt: they will be evolved just as certainly as the first crude motor-cars have given place to a perfected, smooth-running, six-cylinder machine.

Certain experiments had been made, before the war, to show the value of aircraft as mail-carriers. At the London Aerodrome, Hendon, as early as the autumn of 1911, a test was made in which the Post Office showed its interest. The object was to carry special letters and postcards, packed in ordinary mail-bags, and placed in aeroplanes piloted by aviators of the Grahame-White Aviation Company, between the London Aerodrome and a landing-ground which had been chosen at Windsor. Though there was a spell of bad weather during the experiments, with rain and high winds, flights were made almost daily by the aerial postmen, who carried from Hendon to Windsor a total of 130,000 letters and postcards.

Business firms should be willing to pay special fees for an express delivery of letters by air between London, say, and the great cities of the continent. A letter might, for instance, be sent by air from London to Paris, or vice-versa, in a little more than two hours, there being a motor or tube delivery from the aerodrome where the machine alighted to the point in the heart of the city where the letter was to be delivered. What all this would mean, in facilitating business transactions, it is not difficult to perceive. A London firm might dispatch in the morning to Paris, by the express aerial mail, a letter containing urgent draft contracts, specifications, or other documents, the contents of which it would be impossible to telegraph (apart from the expense) and might receive a reply by a return air mail which reached London during the afternoon. The value of such a rapid means of communication would be great, particularly in obtaining signatures to documents in cases where these were required urgently.

III

Passenger Machines

From aerial mail-carrying, with the experience which will be gained in the operation of such services, it will be a logical step to the carrying of passengers by air. The first machines used for passenger work may carry either twenty-five or fifty people. How near the industry is to the day when such machines will be practicable is shown by the fact that existing-type aeroplanes, with motors developing 500 h.p., have been able already to raise the weight of nearly thirty passengers. With increases in engine-power, and with improvements in construction which will yield a greater power for a given weight, the institution of the first passenger services should follow within a year or so of the termination of war.

In five years' time, certainly, there should be a service of passenger craft between the chief cities of Britain, and also between London and the Continent; and in, say, ten years' time, granted reasonable progress in construction, we should see the establishment of a trans-Atlantic air service. This era will come all the sooner owing to the fact that, when the war ends, the industry will no longer be suffering from the drawbacks which so hampered progress in pioneer days. Up to the time the war came—with its immense demand for craft of all types—there had been no money behind the flying movement. Scepticism as to its future robbed it of the support of financiers: the industry, such as it was, lived from hand to mouth. Experimental work, on any types of machines other than those which could be sold to navies or armies, was too costly to be attempted, except on a spasmodic and inadequate scale. But after the war aviation should be on a sounder footing, and the chief firms in the industry, who are now building nothing but war craft, should be able to turn their attention to the design of commercial-type machines.

IV

Fares

It is inevitable that, for a time, high rates will have to be charged for transporting passengers by air. Organisation, however, and a growing volume of traffic, should soon permit such rates to be reduced. The pioneers who establish the first services will find, no doubt, that it is difficult to secure a sufficient number of passengers. There will be certain enterprising people who will be quick to make use of this new means of transport; but the inertia of the mass of the population will make it a matter of time and patience before they are convinced that they can travel safely, as well as rapidly, by air. Nothing but facts—the daily records of an actual service—will overcome this natural timidity. Air services will have to be established, and run regularly day by day in all sorts of weather, and without accident, before the mass of the people can be made to realise that the era of aerial transit has actually arrived. The organisers of these first services will have to rely on the patronage of a certain number of enlightened and progressive men—men trained to profit quickly by new methods, and to whom time is money.

It is scarcely to be hoped that the first passenger aircraft will obtain full and regular complements of passengers. Journeys will have to be run no doubt at a loss, even though high fares are charged. Educating the public to the advantages of any new form of transport is notoriously expensive. But somebody must, and will, come forward; a start must be made by some one. And with air travel there will be a considerable prejudice to overcome.

Apart from the question of the expense of instituting the first passenger services, and of educating people to make use of them, air travel must be regarded by the public as a rapid and luxurious means of transit, offering facilities so much greater than those of land or sea that passengers must be prepared as a matter of course to pay special fares. Extra rates, for specially fast and comfortable travel, are charged by railways in connection, say, with Pullman cars, and also in regard to long-distance continental trains. If you can carry passengers by air at a speed twice as great as that of the fastest express train, you are entitled to demand higher fares.

A question arises whether people will be willing to incur the extra expense of aerial transit. A similar question was asked when motor-cabs were first seen on the streets. It was argued that the public would not be willing to pay this extra money—as compared, say, with the charges of omnibuses and tubes—in order to get quickly and pleasantly from point to point. But the motor-cab created its own public—a new public; and so in time will aircraft. As soon as motor-cabs became available, it was found that people were willing to pay several shillings, instead of a few pence, in order to profit by the extra speed and comfort which the taxi offered them. And when travel by air means a saving not of minutes or of hours, but of days, people will be found willing to pay for the privileges which are thus provided. It will be possible to earn larger sums of money, in trade and other ways, if passengers, letters, and light merchandise can be transported more quickly.

It will be unnecessary to attempt to carry heavy goods by air—goods which are not urgently consigned, and which could be carried just as well by the slower means of land or sea transit.

V

The Value of Quick Transit

Those to whom time is money will seek always, and almost regardless of expense, the means of travel which is the most rapid. We have as an instance the railway races which have taken place between London and the great business centres of the midlands and the north. The saving of only a few minutes on a long journey has been sufficient to make busy men travel by the route which offers them this slight economy of time; and it should be remembered that time, valuable enough now, will become steadily more valuable in the future. After the war the nations will be faced by vast tasks of reconstruction, which will occupy them many years; and speed in transit, as between one country and another, will have a vital importance in furthering this work.

Time, in the future, will have an almost priceless value to a man who is a great organiser, and whose energy and personality are so outstanding that he controls enterprises in all parts of the world. At the present time, it is true, such a man can flash his instructions from place to place by cable or wireless; but when he has to travel personally from point to point, as is often the case, he is wearied by the slowness of travel either on land or sea. Such men feel impatient, to-day, even when travelling in a sixty-mile-an-hour train, or in a liner steaming say at twenty-six knots. They know how precious their time is to them, and how it is wasted whenever they take a long journey. It is to obviate this drawback, so far as is possible, that there has been a tendency to fit long-distance trains with telephones and wireless installations, so that busy men may, even while they are *en route*, keep to a certain extent in touch with their affairs. But such devices are nothing more than makeshifts: what the business man wants is to be able to travel more quickly.

To the great organiser, deep in affairs of importance in all parts of the world, air travel will be an inestimable boon. He will be able to contemplate without apprehension, or any disorganisation of his affairs, a journey not merely from one country to another, but if necessary around the world. High-speed aerial transit will represent one of the final conquests of mind over matter, annihilating distance, and opening up for the traveller a completely new era.

An instance of the willingness of men of affairs to pay high rates, in order to travel in speed and comfort, was provided by the construction of certain of the great modern liners. These ships, when they were put into commission, were found to have state-rooms for which as much as £200 was charged for a single journey across the Atlantic. It was declared, though, that only a very few people would be found willing to pay such fares as these, and that the staterooms would be often empty. On the contrary, however, they were almost always occupied.

A comparison is possible in this regard between air travel and sea travel. If a man will pay £200 to be transported in comfort across the Atlantic, in a voyage lasting, say, five days, what will he be willing to pay if he can make the journey, in equal or even greater comfort, and in a voyage lasting no more than thirty-six hours? Would he pay £300? There seems little doubt but that he would; granted, of course, he could be persuaded, by undeniable facts, that he would be carried with as much safety by air as by water.

VI

The Trans-Atlantic Service

To a man whose interests require personal attention, both in America and Europe, the trans-Atlantic air service should prove of immense assistance. Think of the benefit it would be to such a man to be able to travel from New York to London, and back again, within forty-eight hours; a journey which should be possible with the high-speed aircraft of the future. Sometimes a magnate or financier may have to cross the Atlantic merely to append his signature to some important document. What would not such a man pay for the rapid transit offered him by air?

The aircraft of the future will have an effect, indirectly, of lengthening our lives, seeing that long journeys will be reduced so greatly in point of time. This will mean that people will find time to visit places which are inaccessible by any present mode of travel. One often hears the man who is condemned to a city life yearn for a glimpse of the beautiful islands of the South Pacific. These he will be able to visit in the future, by way of the air, even in the few weeks' annual holiday which may be all he allows himself.

By the use of amphibious machines on the trans-Atlantic service—machines capable of alighting either on the sea or land—an aircraft which leaves New York with its passengers and mails will fly right on to within a few miles of London, alighting at some aerodrome on the outskirts of the city. This will obviate the delay which takes place, to-day, when a liner puts into Liverpool or Southampton, and trans-ships its passengers and mails to a train, in which they are borne to London. Travellers in the future will enter an aircraft at New York, and not get out of it again until they reach London, or vice-versa.

As an example one might cite the case of an American business man who, after dining in New York, boards a trans-Atlantic aircraft. Going to his sleeping berth he passes a tranquil night, disturbed neither by vibration, nor by any oscillation or swaying on the part of the machine. He wakes next morning to find himself far out over the Atlantic. After breakfast and lunch on board, and an early tea, he alights during the evening on the outskirts of London, and travels into the city in a few minutes by means of a rapid tube. Thanks to the conquest of the air, a man will be able in the future to dine one evening in New York, and the next in London.

It is difficult to estimate the influence on our lives and habits which will result from an ability to spend a week-end in New York just as readily as, in the past, we have gone for a week-end to Paris. Such are the facilities which the aircraft of the future will offer us.

VII

Operating Costs

In the matter of working expenses, a trans-Atlantic aircraft should have several advantages over the great liners on the sea such as are at present in operation. On an aircraft, when it makes a passage, it will not be necessary to feed passengers for a week—as is the case with the sea crossing—but only for a period of about twenty or thirty hours. Nor will it be necessary for the aircraft to lie idle in port for a week while it is taking on board stores for a thousand or more people. It will only need, before a trip, to take supplies sufficient for a day and a night. It must be remembered also that a passenger aircraft, owing to the speed of its flight, will be able to make several journeys across the Atlantic while an ocean liner is making one.

The initial cost of an aircraft for carrying passengers across the Atlantic would be very considerably less than that of an ocean liner. The crew needed to man an aircraft, even one of large size, would be far smaller also than that required for a big passenger steamer. The engines of the aircraft would be automatic in their action, and no stokers would be required. The lubrication of these engines would be automatic, also, and there would be no need to have oilers and greasers; while one would be able to do without the innumerable stewards, and deck and other hands, such as have to be carried on a large liner. A very small, but a very highly-skilled crew, would be all that would be necessary on an aircraft. The possibility of such economies as these, in working an aircraft service, would compare, of course, most favourably with the huge expenses which are entailed in the operation of modern liners; and this would mean that, as soon as a trans-Atlantic air service was in regular operation, and was patronised adequately, there would be no need to charge fares greatly in excess of those which are imposed to-day by steamship lines.

VIII

European Airways

People who winter in the south of France will find, in the future, that a continental air service will rob their long journey of its wearisome fatigue. By the special *de luxe* services which will be run on such routes as these, an aerial traveller will be able to leave London, say, at noon, and reach Nice in time for tea! What this will mean is that during the cold and dreary winter in England we shall be able to leave London, say, on Friday evening, and spend a week-end in the warm sun of the Riviera, just as readily as we travel to-day for a week-end to our own south coast. To hard-working city folk, who need a brief and thorough change of air, or to those who are recovering from illness and are ordered to seek the sunshine, the airways south will be the greatest boon: they will rob our English winter of more than half its terror.

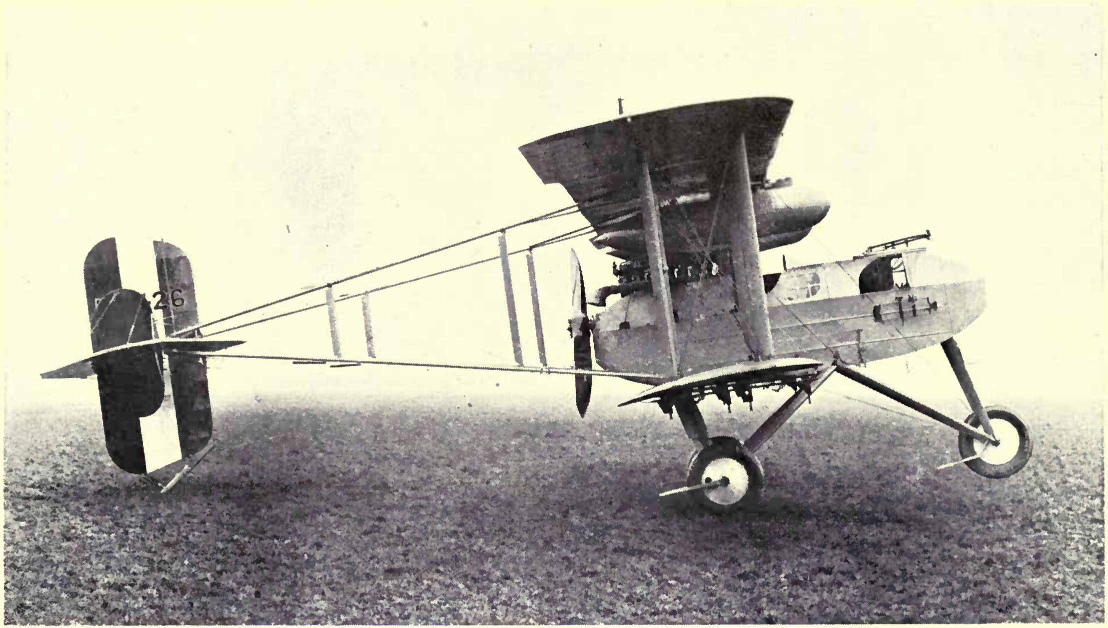
All over Europe, in the future, will radiate a network of airways, which will stimulate our friendly relations with the countries which are our Allies in this war. Russia will no longer be so inaccessible. Instead of the tedious journey which is necessary, to-day, in order to reach Petrograd from London, it will be possible by means of a service of non-stop aircraft to travel between these two cities in a journey lasting no more than eight or ten hours.

Of almost incalculable value, also, will be the shortening of the journey between Paris and London, as effected by a service of passenger aircraft.

On this route, by train and steamer, there is an immense volume of traffic at normal times; and in the future, when peace has come, the pressure will be even greater. But business men who make the journey by rail and sea do so rarely without inconvenience, irritation, or delay. There are the terrors in winter of the Channel crossing. Passengers speculate anxiously while in the train as to the sort of passage they are to have; and, should it prove a bad one, as it often does, business men may reach their journey's end in a condition which makes it impossible for them to attend immediately to their affairs. They may have to go to their hotels and rest for hours before they are ready for business appointments, and these hours of delay have to be added to the time occupied by the journey.

Even if weather conditions are favourable, it is irritating, and a waste of time, to have to get into a train and then out of it into a steamer, and then out of the steamer again into a train. The Channel tunnel, should it materialise after the war, will of course obviate this; but even with trains passing under the Channel the journey will not be possible at anything like the speed attained by air.

Ordinarily, by train and steamer, the journey between the two capitals takes just about eight hours. A fast passenger aircraft, passing as it



F. N. Birkett.

A raiding-type war machine, built by the Grahame-White Aviation Co. It is driven by a 250 h.p. engine, and will carry fuel for a ten-hours' non-stop flight, in addition to the weight of its occupants and bombs. Note the guards, fitted to the landing wheels, to prevent mud from splashing up on to the revolving propeller, and perhaps damaging it, should a machine alight in a ploughed field, or on wet and heavy ground.

will in a direct line between the two cities, should do the journey in a trifle over two hours. The advantage of this to business people need scarcely be emphasised. A city man in London, going to his office as usual in the morning, will be able to deal with his correspondence before he takes the tube to the London Aerodrome, and catches the 11 a.m. air service to Paris. By this he would reach Paris in time for lunch, and would then have all the afternoon for business interviews and calls; returning by an afternoon air service—tea being served *en route*—which would bring him back to London again in time for dinner. Instead of being fatiguing, irritating, and time-wasting, this journey in the future, thanks to aircraft, will become a pleasure.

IX

Government Encouragement

To hasten the coming of the day when all high-speed travel is by way of the air should be one of the chief aims of the Allied Governments after the war. The interest they take in the development of aircraft, and the practical support they give, will be repaid them a hundredfold. An international alliance, when the nations concerned are linked by airway, will be something more for the mass of the people than a mere contract or document: they will have every facility for seeing each other, and for getting to know each other, and this will lead inevitably to a better understanding.

The coming of the air age should have an immense influence on us in England—more perhaps than will be the case with any other country. Our insularity, the product of centuries, will go by the board: we shall have to be prepared to welcome the world in London, and to travel ourselves constantly by air. And this will apply not only to the wealthier classes, but to the whole mass of the people. When aerial navigation is organised, and is operating with an assured success commercially, excursions by air should be possible at rates which will place them within the reach of all.

If a universal peace should become possible, in this world of rivalry and ambition, its advent will be due largely to the development of flying. The opening up of travel by air is the most hopeful augury of the future. Where darkness looms in other directions, here there is already a light so powerful that it is difficult for us to estimate the full benefits it may bring. It should be some consolation to us to think that, on the experience gained in this dreadful war, will be based a future progress which will render aircraft not merely instruments of destruction, but passenger and transport machines of such power that they will have the greatest civilising influence the world has known.

X

Airways in Britain

In comparatively short journeys, as well as in long, the value of aircraft will be apparent. One may take, as an example, the route from London to Manchester, over which there is such a heavy volume of traffic at ordinary times. This journey is accomplished in about four hours by an express train. By express aircraft it should be possible to make the flight in, say, an hour and a half. At normal times, by train, the first-class return fare is £2 9*s*. By air, when a reasonable number of passengers can be obtained, it should be possible, with a service of machines each carrying, say, fifty people, to charge a sum of £3 for the return journey. This would mean, if all the seats were occupied, that those who were operating the service would receive £150 for carrying fifty people (whose total weight may be set down at approximately 3½ tons) for an out-and-return flight lasting a total period of three hours. And there would be fees for the urgently-consigned mails, and light express goods, which the aircraft might also carry.

There should be no difficulty, after a time, in securing a sufficient number of passengers over a route such as this: the advantages of the service would be so undeniable. Instead of having to spend practically a day in travelling, as in the case of a journey between London and Manchester by rail, a merchant would be able to devote all the morning to his affairs in London, and then travel to Manchester by air in the afternoon, allowing himself several hours for business in that city, and still being able to return to London by one of the evening services, so as to be ready to go to his office in London on the following morning. A special fare should be paid willingly for such a service as this; and also for one between London and the cities farther north.

XI

Tubes to the Aerodromes

The point has been raised that travellers might lose time in getting from the heart of a city, where their offices are situated, to the aerodromes which lie on its outskirts. But in the future, as soon as the air services are organised, there will be tubes connecting each of the aerodromes with the heart of the city. A business man in London will, for example, be able to get into a fast passenger tube, and reach the London Aerodrome at Hendon, in much the same time as it takes him, now, to travel from his office to Euston. North, south, east, and west, there will be large aerodromes, each dealing with its separate stream of traffic, and all linked with the heart of the city by a system of high-speed tubes.

XII

Questions of Economy

An important point to be considered, when contrasting the operation of railways and airways, is the economy in certain directions which will be possible with the latter. With a railway it is necessary to construct, and to maintain at a constant expense, some hundreds or thousands of miles of permanent way. But with an aircraft service no permanent way is necessary; the machines provide their own support as they rush through the air. All that they require is a convenient chain of alighting-grounds. The land occupied by these air stations will need, of course, to be acquired from its owners; but this expense will be almost negligible when compared with the costs which have to be incurred by a railway, when it buys the right to lay its metals across hundreds of miles of country.

It will be an advantage for the airway that it will need to employ no huge staffs of permanent-way men. There will be staffs, of course, at the landing-grounds; but the operating costs of an airway will be nowhere near so heavy as are those of a railway. And it must be remembered that the speed in flight of the aircraft will enable large volumes of traffic to be handled without congestion or delay.

When contrasting the operation of railways and airways, one should remember always the natural advantage which will be possessed by the latter through its ability to move with absolute directness from point to point. Railways are diverted, and the length of journeys increased, owing to the existence of natural and other obstacles. But an aircraft, after ascending and reaching its required altitude, will be steered in an undeviating line from point to point, going in each case absolutely the straightest and most direct way in order to reach its destination. Another advantage of the airway over the railway will be that the aircraft, once it is aloft and at a sufficient altitude, will go full speed ahead without slackening until it reaches its journey's end. But an express train must lose time frequently by having to slow up as it goes through big junctions, or when rounding curves. It is liable also to be held up by signals when there is a congestion on the line; but this would be a form of delay which would be obviated completely on the airway.

XIII

The Air—Our Future Speedway

For this and other reasons it is clear that, even if the speed of land travel should be increased in the future, the air will always be the medium for the most rapid form of travel. By the use of mono-rail trains, driven by electricity, it may be possible to increase to a very appreciable extent the speeds at present attained on land. But with

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Another view of the 250 h.p. raiding-type biplane, as shown in the previous illustration. Above the front seat is a revolving turret, so as to facilitate the use of a machine-gun, and give it a wide range of action.

any such services, having regard to the power required to move heavy weights at high speed over the land, and the wear-and-tear involved, the question is whether they would be feasible commercially; whether a profit could be made, even at special fares. When very high speeds are demanded, as they will be in the future, they will be obtainable at less cost in the air than will be the case on land or sea.

XIV

An Imperial Air Policy

The aircraft industry must, now and in the future, receive not only the financial support of the Government, but the moral support and encouragement of the entire nation. The Government, quite apart from buying war machines, must subsidise mail and passenger services, and assist constructors to build experimental craft. No cry for retrenchment after the war, however desirable in other directions, must be allowed to retard the progress of aviation. Money spent on aircraft should be regarded as a form of national insurance—an insurance against our peril should some enemy, striking by air, seek to deliver a blow so sudden and paralysing that the whole nation, crippled and disorganised, would be compelled to sue for an immediate peace.

Our final word is this. The same energy, determination, and grit, which Britain is putting into this titanic struggle, and which we all trust will ensure us victory, must be devoted after the war to securing, and maintaining, that aerial dominion on which the future safety of our Empire will most assuredly depend.

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