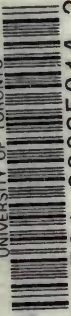


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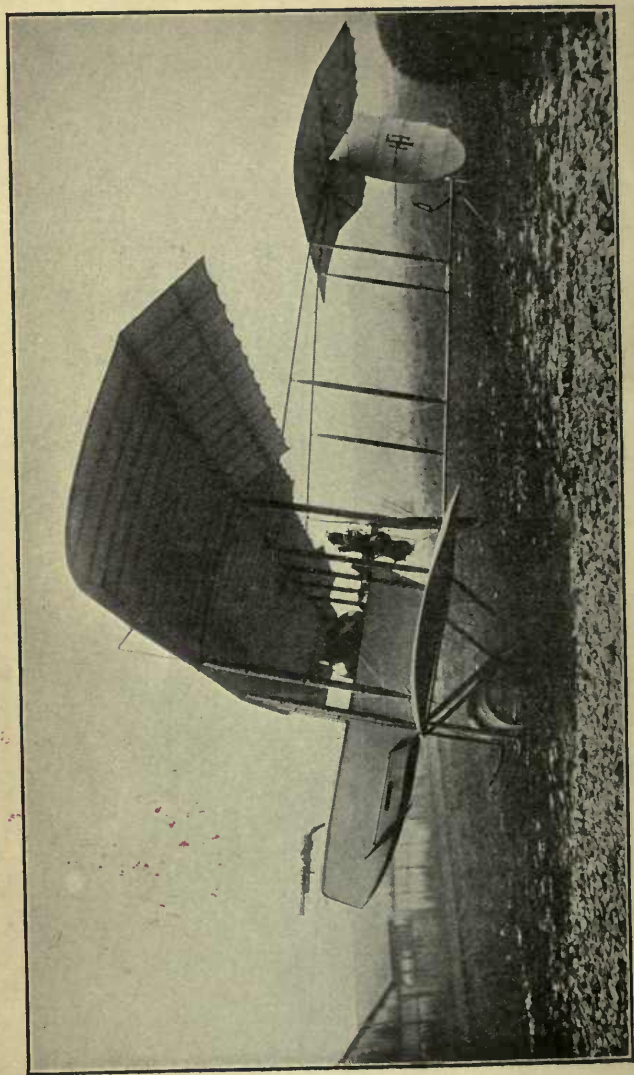
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The Daily Telegraph

WAR BOOKS

AIRCRAFT IN WAR



A FARMAN ARMED SCOUTING BIPLANE, showing gun mounted in position, Gnome motor, ailerons on upper plane, rudders at rear (see Chapter VII.). [Topical Press.]

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AIRCRAFT *in* WAR

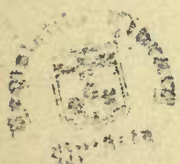
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By

ERIC STUART BRUCE, M.A. Oxon.

*Fellow of the Royal Meteorological Society; late Honorary Secretary
and Member of Council Aëronautical Society of Great Britain;
Vice-President of the Aërial League of the British Empire;
Membre d'Honneur of the Aëro Club of France*

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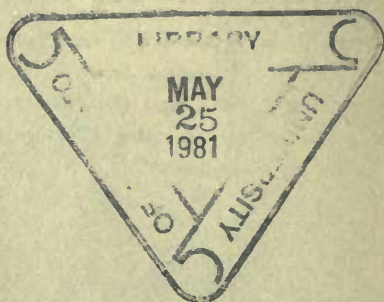


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TO MY WIFE,

who during the eight years of my Honorary Secretaryship of the Aëronautical Society of Great Britain incessantly and most materially aided me in my efforts to secure the united interest of the British nation in the mastery of the air, I dedicate this little volume.

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INTRODUCTION

WHEN years ago we read in Tennyson's " Locksley Hall " the following lines :—

Heard the heavens fill with shouting, and there rained a
ghastly dew

From the nations' airy navies grappling in the central
blue—

we little dreamt that not very far from the beginning of the twentieth century the fancy of the poet would become the fact of reality ; that in the great European war in which the nation is so strenuously engaged, " the wonder that would be " would come to pass.

Though happily, at present, in these isles the din of war is unheard, yet a semi-darkened London and bright searchlights playing on the skies

tell the tale of prudent foresight against the advent of the enemy's airfleet. From the battlefields there daily come the reports of actual battles in the air, sometimes betwixt aëroplane and aëroplane, sometimes between the lighter and heavier than air craft. Often such encounters are death-grip duels. Such conflicts of the air are the direct consequence of the great and important use of both airship and aëroplane as aërial scouts. These are the eyes of encountering armies. To destroy as far as possible this penetrating vision of the enemy and restore to him the fog of war is the untiring aim of either side.

During those first anxious days of the present war the public anxiously awaited news of the doings of the Royal Flying Corps, as well as those of the aviators of our Allies. Expectation was satisfied in the reading of Sir John French's report to Lord Kitchener, dated September 7th, 1914. Speaking of the use of the aëroplane in the war he says :—

I wish particularly to bring to your Lordship's notice the admirable work done by the Royal Flying Corps under Sir David Henderson. Their skill, energy, and perseverance have been beyond all praise. They have furnished me with the most complete and accurate information, which has been of inestimable value in the conduct of the operations. Fired at constantly both by friend and foe, and not hesitating to fly in every kind of weather, they have remained undaunted throughout.

Further, by actually fighting in the air, they have succeeded in destroying five of the enemy's machines.

For those brave heroes of the air our hearts beat with fervid admiration. In accomplishing their all-important tasks they have not only to fear disaster from shot and shell of the enemy, but from the mistaken fire of their comrades and the very forces of nature. These latter, owing to the imperfections of the flying machines, do not entirely spare them; the Royal Flying Corps, in order to become competent to perform the work it is now doing for King and country,

has had in manœuvres at home to pay a high price in the sacrifice of human life.

It may, indeed, be reasonably thought that the knowledge of the vast utility of aircraft in the present conflict will dispel the last remnant of prejudice in this country against the development of aërial navigation, and the grudging of a liberal national expenditure on the service of the air. It was, perhaps, this ignoring of practical utility, so vigorously combated by the pioneers in this country, that caused Great Britain to be the last of the Great Powers to seriously take up aircraft for military and naval use. Our delay had been a wonder to many, since theoretically in the past this nation had been to the fore. Nearly half a century ago it led the way of the air by being the first country in the world to found a society for the encouragement of aërial navigation—the Aëronautical Society of Great Britain. It is no exaggeration to say that many of the great principles of human flight were formulated and discussed at the earlier

meetings of that society. The late Mr. Wilbur Wright, when he came to this country to receive the gold medal of the society, in his speech testified to the substantial help he had received from the study of the transactions of the oldest aëronautical society in the world. As the pioneer in laying the foundations of aërial science, this country is not without honour amongst the nations.

CHAPTER I

THE EARLIER AËRIAL SCOUTS

PATRIOTISM has been the most powerful factor in developing aërial navigation. Montgolfier experimented with his paper balloons filled with heated air in the desire that his invention might be of use to France in her wars, and throughout the history of both balloons and flying machines we find that it has been the desire to employ them as instruments of war that has most fostered their progress.

Very soon after Charles invented the gas balloon the latter was pressed into military service for the very same purpose of reconnaissance for which airships and aëroplanes are now being used. At the time of the French revolutionary war an aëronautical school was founded at Meudon under the control of Guyton

de Morveau, Coutelle, and Conté, and a company was formed called Aërostiers.

Captive balloons were used by the armies of the Sambre and Meuse, of the Rhine and Moselle. Just before the battle of Fleurus, 1784, two ascents were made, and the victory of the French was attributed to observations made by Coutelle. At that time several ascents were made from Liège with a spherical balloon and one of cylindrical shape. This latter appears to have anticipated the well-known German kite-balloon.

There is a tradition that in those early days of the balloon the French were possessed of a varnish which satisfactorily held the hydrogen gas, but that the secret was lost—a grave loss indeed, if the tradition has truth in it. The secret was never refound. A really gas-proof varnish is unknown.

In the course of the American Civil War of 1861 captive balloons were again employed with important results.

During the Franco-Prussian War of 1870 three captive balloons were installed in Paris, the "Nadar" on the Place St. Pierre; the

The Earlier Aërial Scouts 3

“ Neptune,” manned by Wilfred de Fonvielle, at the gasworks at Vaugirard ; and the “ Celeste ” on the Boulevard des Italiens.

Thus long before the advent of airships and flying machines the use of altitude for military reconnaissance was realised. A great disadvantage of the captive balloon was its stationary nature. It was not prudent to ascend in it very close to the enemy, as there was not the same chance of escape as when the aërial observer is in mobile aircraft.

Though rifle fire has over and over again failed to bring down a captive balloon owing to the upward pressure of the hydrogen gas, still, artillery fire has been known to have very destructive effect.

Undoubtedly, the best use that has been made of the captive balloon was in the Boer War. The British observation balloon equipment, which under the unceasing labours of Colonel Templer had reached a state of considerable perfection, then proved to be highly efficient. But in the light of modern aëronautical progress its doings were merely the fore-

shadowings of the achievements the aviators in the present war are daily carrying out.

Perhaps the most important feature of the balloons in the South African War was the material of which they were made—gold-beaters' skin. We are all more or less familiar with this substance, for we use it as a plaster when we cut our fingers. We should scarcely think that so apparently fragile a substance was strong enough to form the envelope of a balloon. It is, however, an admirable substance for the purpose on account of its lightness and capacity of holding the gas, and the desideratum of strength can be obtained by combining layer and layer of the substance to any desired thickness. By the use of gold-beaters' skin it became possible to have much smaller balloons for a given lifting power than when varnished cambric or silk was employed. If made of the latter materials a captive observation balloon had to be at least 18,000 cubic feet to be of any service. Gold-beaters' skin reduced the volume to 10,000 cubic feet, or even less.

The only disadvantage of gold-beaters' skin

The Earlier Aërial Scouts 5

for the envelope of balloons and airships appears to be its very great expense. This, in the case of a large airship, is formidable. It should be mentioned, however, that it has sometimes been used for the separate gas compartments which, as will be seen, are a feature of the Zeppelin airship.

As regards the actual achievements of the balloon in South Africa, one section did excellent work at Ladysmith. In the words of Colonel Templer, "it not only located all the Boer guns and their positions, but it also withdrew all the Boer fire on to the balloon. Several balloons were absolutely destroyed by shell fire."

One of the balloons was burst at a height of 1,600 feet, and came down with a very quick run, but the staff officer in the car was unhurt. At Ladysmith, by means of the balloon, the British artillery fire was made decisive and accurate.

With General Buller at Colenso, and up the Tugela River, Captain Philips' balloon section was very useful. Splendid work was done

at Spion Kop. There the whole position was located and made out to be impregnable. It has been said that the British Army was then saved from falling into a death trap by the aërial reconnaissance. Captain Jones' section went up with Lord Methuen on Modder River. His observations continued every day. It was considered there was not a single day that they were not of the utmost importance.

Again, Lord Kitchener and Lord Roberts used balloons. From the information they obtained from them they were enabled to march on to Paardeburg. At the latter place itself they were able to locate the whole position. Another section went to Kimberley and on to Mafeking. A very important observation was made at Fourteen Streams. There a balloon was used continuously for thirteen days without the gas being replenished. By its means the Boers were prevented from relieving Fourteen Streams.

It has been pointed out by Colonel Templer that one of the great difficulties connected with the use of the comparatively small balloons in

the South African War was the heights the armies went over.

On the march to Pretoria there were hills 6,000 feet above the sea, and to make an observation from these hills it was necessary to go up 1,500 or 2,000 feet, so that the barometrical height was hard work on the buoyancy of the balloon, because the barometrical height then became 8,000 feet—the 6,000 feet altitude above the sea-level, and the 2,000 feet it was necessary to go over the hills—that was about all our balloons would do.

That was a disadvantage of the captive balloons which would not have been felt if the observers had been on aëroplanes !

Certainly, the excellent gas retaining power of gold-beaters' skin was well put to the test in the South African War. The thirteen days' work with one charge of gas mentioned above was a fair trial for a balloon of such comparatively small size ; but Captain H. B. Jones gave a still more striking experience of the value of gold-beaters' skin as a gas-holder. Speaking of the Bristol war balloon of 11,500 cubic feet capacity, he says :—

It was used at the engagements at Vet River and

Land River, and arrived at Kroonstad on May 12th. The balloon was kept in a sheltered place near the river till we marched again, on May 22nd, and was not emptied till after we had crossed into the Transvaal at Vereeniging on May 27th. To keep a balloon going for thirteen days at one station is a good test; but in our case the Bristol was filled for twenty-two days, and did a march of 165 miles with the division.

The system of filling the balloons from steel cylinders in which the hydrogen gas had been compressed, so well exemplified in the Boer War, was a great improvement on the older methods of manufacturing the gas on the spot. Speed in filling balloons is a desideratum for their use in war. By the cylinder method, owing to the great pressure under which the gas escapes from the cylinder, the inflation of the observation balloons became a question of minutes instead of hours. The necessity of speed applies to the inflation of airships also.

Although the present volume is designed rather to speak of the aëronautical appliances of the present than those of the past, the above-mentioned facts concerning aërial reconnaissance in the Boer War have been included, as

the value of the air scouts at the time was hardly known and appreciated by the general public, whose mind in those days was not constantly being directed to aërial matters as it is at the present time. The knowledge of what just a few well-contrived and well-utilised balloons could then do in the way of aërial scouting must lead to the thought how the Boer War might have been shortened had we then possessed the squadrons of fast-flying aëroplanes that are taking part in the present war. To know, indeed, what a very few aërial observers could do may enhance our estimation of the possibilities of the squadrons of the flying machines of the British and allied armies in the present war as they dart in search of information over the lines of the enemy.

In the course of some articles on the subject of the new arm of war, which contain many apt statements, Mr. F. W. Lanchester gives the opinion that the number of aërial machines engaged in the war is a negligible quantity. We might, indeed, well say the more the better, provided they are on the Allies' side; but no

aëronaut or aviator will allow the number is negligible. The writer compares the supposed number of aëroplanes the Germans possess with the cost equivalent of scouting cavalry. The comparison is not a happy one, on account of the tremendous advantage of altitude and, consequently, long range of vision possessed by the aërial scout. We have seen that in the Boer War one observer at Spion Kop from his height and super-sight saved the situation, and rescued our army from possible crushing disaster.

What might not even one shrewd British observer in a swift-moving modern aërial craft accomplish at a critical moment in the present conflict ?

CHAPTER II

THE DEVELOPMENT OF THE AIRSHIP

BEFORE free balloons were successfully motor driven and steered, stern necessity had pressed them into the service of war. During the siege of Paris, in 1870, when the Parisians were cut off from all means of escape, there were only a few balloons in Paris ; but the successful escape of some aëronauts in them was considered encouraging enough to establish an aërial highway involving a more wholesale manufacture of balloons than had been accomplished before. The disused railway stations were converted into balloon factories and training schools for aëronauts. In four months sixty-six balloons left Paris, fifty-four being adapted to the administration of post and telegraph ; 160 persons were carried over the Prussian lines ; three

million letters reached their destination ; 360 pigeons were taken up, of which only fifty-seven came back, but these brought 100,000 messages, by means of microphotographical despatches. In these a film 38 by 50 mm. contained 2,500 messages. The pigeons usually carried eighteen films, with 40,000 messages.

At this time the French Government attempted to produce a navigable balloon, and employed Dupuy de Lôme on the task of designing and building it. This was to be driven by hand power, the screw being driven by eight labourers. The balloon was actually made and tested. Considering the h.p. was 0.8, it is needless to say it was not successful.

It was during the siege of Paris that Krupp constructed the first special gun for attacking balloons, a relict which has been preserved at Berlin.

If such was the utility of balloons that merely drifted at the mercy of the aërial currents they encountered, it was not to be wondered at that, soon after the Franco-Prussian War, new attempts were made to make them navigable. Though

The Development of the Airship 13

the term airship might reasonably be applied to all the forms of navigable aircraft still in this country, it has been applied in a less wide sense to those machines that are lighter than air. In these pages the term will be used in this connection.

The effort to navigate balloons almost dates back to the invention of the balloon itself. It was, indeed, early realised that the spherical shape of the ordinary balloons that drift with the winds would be unsuitable for a craft that would have to travel against the wind. In 1784 Meusnier designed an elongated airship, in which the brothers Robert actually ascended. It is noticeable that in this early design of Meusnier was the now well-known ballonet, or inner balloon, which forms an essential feature of modern non-rigid and semi-rigid airships for preserving the rigidity of the outer envelope and facilitating ascent or descent.

If we except the effort of Dupuy de Lôme, the next remarkable attempt at airship construction was in 1852, when the Parisian Giffard made his steam-driven elongated balloon, with

which he made two experiments. These merely proved that successful navigation against a wind would require much larger motive power than his Lilliputian steam-engine of 3 h.p. Giffard, however, was the pioneer of the airship driven by other than hand power. The following are the dimensions, etc., of what will ever be an historic balloon :—

Length	44 metres
Diameter	12.00 metres
Cubic capacity	2,500 cubic metres
Horse power	3.0
Estimated speed per hour ..	6.71 miles

The experiments of Krebs and Renard in 1885 were noteworthy. They were the first in which direct return journeys were made to the place whence the balloon started.

These experiments showed the importance of the military factor in the development of aërial navigation. Krebs and Renard were the officers in charge of the French Military Aëronautical Department at Meudon, and they applied national funds to the construction of an airship. It was the development of the electrical industry

and the production of electric motors at that time which stimulated the experiments. The brothers Tissandier had, in 1883, propelled an elongated balloon against a wind of some three metres a second by means of an electric bichromate battery which supplied the power to an electric motor. It was thought that those experiments had been sufficiently successful for further trial of the powers of electricity.

Renard made profound and exhaustive researches into the science of the navigable balloon. To him we are, indeed, indebted for the elucidation of the underlying principles that have made military airships possible.

The navigable balloon "La France" was dissymmetrical, being made very much in the shape of a fish or bird. Its master diameter was near the front, and the diameters diminished gradually to a point at the back.

The following were the dimensions of the envelope :—

Length	50.40 metres
Diameter	8.40 metres
Length in diameters	6.00 metres

The airship was remarkably steady on account of the minute precautions taken to counteract the instability produced by a somewhat excessive length. Any device which modifies pitching at the same time lessens the loss of speed resulting from the resistance of the air when the ship is moving at an angle. A direct means of reducing pitching is the dissymmetrical form given to the envelope by placing the master diameter near the front. The resistance of the air falls on the front surface, which in this dissymmetric form of envelope is much shortened, while the compensating surface at the back is augmented. Many experts are of opinion that in this form of envelope Krebs and Renard came nearer perfection than any other navigable balloon constructor.

Like the brothers Tissandier, they used an electric battery and motor to drive their screw, their motive power being 9 h.p.

It was claimed that out of seven journeys, the airship returned five times to the place whence it started. As an example of these journeys, on September 22nd, 1885, a journey was made

The Development of the Airship 17

from Meudon to Paris and back again. On this day the wind was blowing at a velocity of about 3.50 metres a second—what we should call a calm. Few, perhaps, who saw the small naval airship, the "Beta," manœuvring over London this autumn realised that a navigable balloon, not so very much unlike it in form, was speeding its way over Paris as long ago as 1885. The advent of the first at all practical military airship was forgotten because the experiments, comparatively successful as they were, suddenly ceased. They came to an end because it was found that though electricity as a motive power could afford an airship demonstration, it was unfitted for serious and prolonged use.

One industry has often to wait for another—the world had to wait for the missing link in aërial navigation. That was the light petroleum motor. With its coming came the era of airships and aëroplanes.

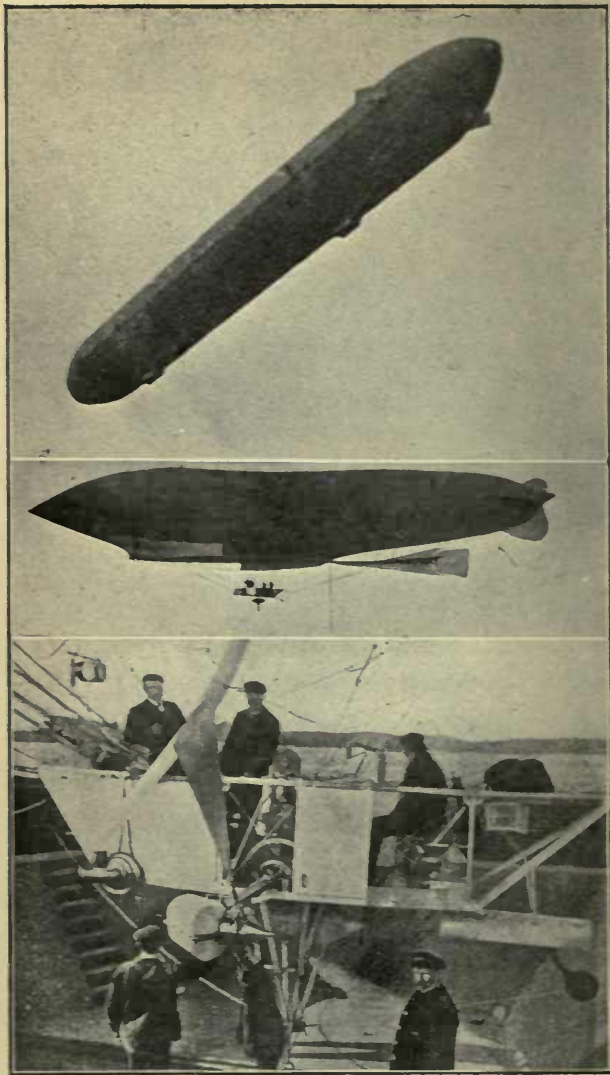
CHAPTER III

TYPES OF MODERN AIRSHIPS

WITH the new century came the modern military airship—to stay, at any rate, until the heavier-than-air principle of aërial navigation has so developed as to absorb those features of utility the airship has and the aëroplane has not.

During the fourteen years which have seen the construction of practical airships, three distinct types have been evolved—(i.) rigid, (ii.) non-rigid, (iii.) semi-rigid. In considering the airships of Great Britain, France, and Germany, I propose to class them together as to types rather than under nationalities.

Each type has its own peculiar advantages. The choice of type must depend upon the circumstances under which it is proposed to be employed.



Top : SNAPSHOT OF ZEPPELIN IN MID-AIR.

Centre : MILITARY LEBAUDY AIRSHIP, showing fixed vertical and horizontal fins at the rear of gas-bag, vertical rudder, and car suspended from rigid steel floor underneath gas-bag.

Bottom : CAR OF A LEBAUDY AIRSHIP, showing one of the propellers.

Types of Modern Airships 19

I. RIGID TYPE.

(i.) *Zeppelin* (German).—There are not many examples of the rigid type. The most important is undoubtedly the *Zeppelin*. This form of airship before the present war had elicited the interest of the aeronautical world for the long-distance records it had established. Indeed, no little sympathy had been extended to Count *Zeppelin* for his perseverance in the face of the gravest difficulties. Now the *Zeppelin* has accumulated notoriety instead of fame as having been the means of carrying on a form of warfare repugnant to the British nation, and condemned by the Hague Convention. Imagine some seventeen huge bicycle wheels made of aluminium, with their aluminium spokes complete, and these gigantic wheels to be united by longitudinal pieces of aluminium, and in this way seventeen sections to be formed, each of which contains a separate balloon, and it is easy to grasp the construction of the *Zeppelin* airship. It consists of a number of drum-shaped gas-bags, all in a row, held together by a framework of aluminium. They form a number of

safety compartments. The bursting of one does not materially matter—the great airship should still remain in the air. The dimensions of individual Zeppelins have varied to some extent. The largest that has been built (“Sachsen,” 1913) had a cubic capacity of 21,000 cubic metres (742,000 cubic feet), and a length of 150 metres (492 feet). The aluminium framework containing the balloons has an outer covering of cloth. On each side of the frame of the airship are placed two pairs of propellers. In the original airship of 1900 these were four-bladed, and made of aluminium. They were small, being only 44 inches in diameter, but they revolved at a very high speed. In the later airships the screws have been considerably modified in detail, size, and shape. For instance, in the Zeppelin which descended accidentally at Lunéville, in France, it was found that the back pair of the propellers on each side were four-bladed, the front pair two-bladed. The screws are driven by motors placed in the two aluminium cars beneath the airship. These cars are connected by a covered gangway, which

Types of Modern Airships 21

also serves as a track for a movable balance weight, by means of which a considerable change of balance can be effected. The motive power in the first Zeppelin was only two Daimler motors of 16 horse power each. With this low power little success was attained, but gradually the motive power has been increased. We find that in the naval Zeppelin, L 3, 1914. The motive power is three Maybach motors, giving total h.p. 650, whereas in the types building the total h.p. is 800.

The stability of these aërial monsters is attained by the use of large projecting fins. Horizontal steering is effected by a large central rudder and pairs of double vertical planes riveted between the fixed horizontal stability planes. For vertical steering there are sixteen planes provided in sets of four on each side of the front and rear ends of the balloons. These can be independently inclined upwards or downwards. When the forward ones are inclined upwards and the after planes downwards, the reaction of the air on the planes as the airship is driven forwards causes the front part to rise

and the rear part to sink, and the airship is propelled in an inclined direction to a higher level. The favourite housing place for the Zeppelin airships has in the past been on Lake Constance, near Friedrichshafen, so that they could be taken out under protection from the direction of the wind. It is also much safer for large airships to make their descent over the surface of water. It has been estimated that the most powerful Zeppelins have a speed of some fifty miles an hour.

When on April 3rd, 1913, Z 16, in the course of a journey from Friedrichshafen, was forced to descend on French soil at Lunéville, excellent opportunity was afforded the French of a close inspection of its details.

The following were the exact dimensions, etc.:—

Length	140 metres
Diameter	15 metres
Cubic capacity	20,000 metres
Motive power three Maybach motors, 170 h.p. each	510 h.p.
Speed	22 metres per sec.
Height attainable	2,200 metres
Useful carrying power	7,000 kilos.

Types of Modern Airships 23

On the top of the ship was a platform, on which a mitrailleuse could be mounted.

It was only a few weeks before the present war that the new Zeppelin, L Z 24, attained a new world's record of altitude and duration of flight. The height attained was 3,125 metres. The voyage without a break lasted thirty-four hours fifty-nine minutes. On May 22nd, 1914, it left Friedrichshafen at 7.16 a.m. Bâle was reached at 10 a.m. At 6 p.m. it passed Frankfurt, at 9 Metz, at 10.30 Bingen, at 2 a.m. Brême. At 4 a.m. it arrived above Heligoland, from whence it made for Potsdam, where it was hailed 9.20 a.m. At 5.15 p.m. it landed at Johannisthal.

That journey certainly showed the long-range powers of the latest Zeppelins. If, as will be seen, it is comparatively easy for a few well-directed aëroplanes to wreck them in mid-air, still they have ceased to be military or naval playthings.

(ii.) *Schutte-Lanz* (German). — The Schutte-Lanz rigid airship is an attempt to secure the advantages of the rigid type without the fragili-

ties of the Zeppelin. The framework, which contains the separate gas compartments, is made of fir wood. The gas-bags are claimed to be very strong. These are filled, excepting two, which remain empty when there is only sea-level pressure; when, however, the gas expands, it flows into the latter. These become full when an altitude of some 2,000 metres is reached. A centrifugal pump is employed for distributing the gas.

The volume of this airship is 26,000 cubic metres (918,000 cubic feet). It will be seen, therefore, that this mammoth airship in size surpasses even the largest Zeppelins.

II. SEMI-RIGID.

(i.) *Lebaudy* (French).—This airship is a cross-breed between the rigid and non-rigid systems. By this method of construction a considerable amount of support can be imparted to the gas-bag, though it does not dispense with the services of the ballonnet, as does the entirely rigid type. To the genius of M. Julliot, Messrs. Lebaudy Brothers' engineer, we are indebted for the

Types of Modern Airships 25

introduction of this excellent type. It no doubt forms an exceedingly serviceable military airship. In the Lebaudy original airship the underside of the balloon consisted of a flat, rigid, oval floor made of steel tubes; to these the stability planes were attached, and the car with its engine and propellers was suspended. This secured a more even distribution of weight over the balloon. The gas-bag was dissymmetrical in form. Though not exactly resembling that excellent pattern, "La France," it partook of the important quality of having the master diameter near the front. The car was a steel frame, covered with canvas, and in the form of a boat. The screw propellers were placed on either side of the car.

In 1909, as the British Government at that time possessed only very small airships, the nation raised a sum of money by subscription to present the Government with one of efficient size. The military authorities compiled a list of somewhat severe tests which, in their opinion, they thought an airship should be able to perform before acceptance. At the request of the

Advisory Committee, of which Lord Roberts was chairman, the writer went to France in an honorary capacity to select the type of airship to be adopted. There was at that time only one firm of airship makers in France who were willing to undertake the formidable task of making an airship that would come up to the requirements of the British Government—the brothers Lebaudy, whose engineer and airship designer was M. Julliot.

The semi-rigid airship which M. Julliot designed and executed was without doubt a *chef d'œuvre* of its kind. The rigid tests it had to undergo necessitated a modification of some of the details that were conspicuous in the airships the constructor had previously built.

In this airship the girder-built underframe was not directly attached to the balloon, but suspended a little way beneath it.

The gas envelope had a cubic capacity of 353,165.8 cubic feet; the length was $337\frac{3}{4}$ feet. There were two Panhard-Levasseur motors of 135 h.p. each.

On October 26th, 1910, this airship made an

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historic and record flight over the Channel from Moisson to Aldershot in five hours twenty-eight minutes, at a speed of some thirty-eight miles an hour, sometimes against a wind of twenty-five miles an hour. Unfortunately, owing to a miscalculation by those responsible, the shed which had to receive the new airship on its arrival was made too small to house it safely. While the airship was being brought into the shed its envelope was torn and placed *hors de combat*.

Since this airship was made the Lebaudy brothers have ventured to still further increase the size of their semi-rigid airships.

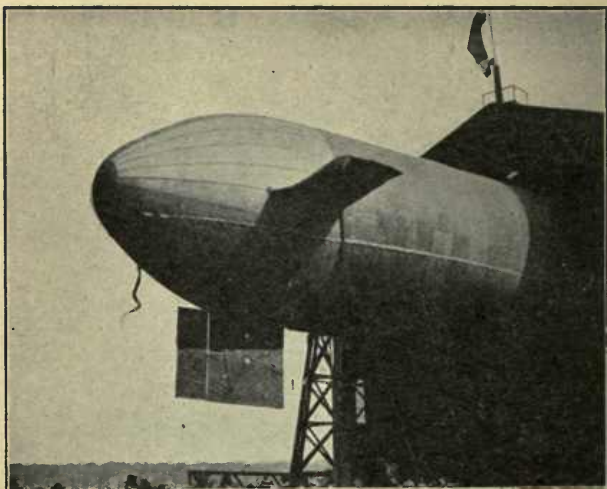
(ii.) *Gross* (German).—This airship may be described as being more or less a German reproduction of the Lebaudy type. It forms part of the German airfleet. A considerable number have been made of various sizes (for dimensions, etc., see table, German Airships, Chapter IV., page 38).

III. NON-RIGID.

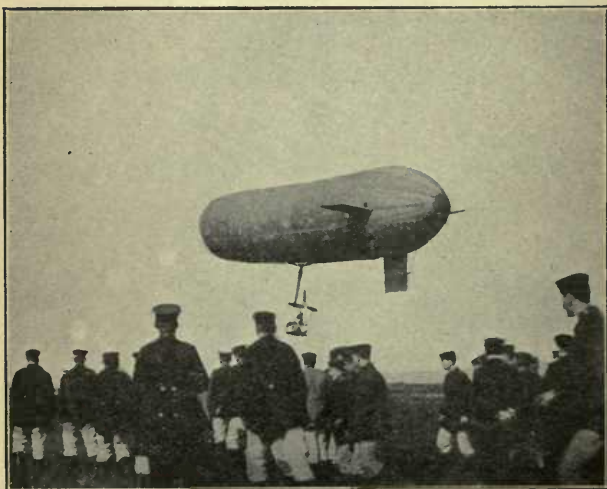
This type is dependent for its maintenance of form on the pressure of the gas inside the

envelope. It is all-important that the envelope of a navigable balloon should not lose its shape—that it should be kept distended with sufficient tautness, so that it may be driven through the air with considerable velocity. On this account the non-rigid type depends entirely on the ballonet system, which consists of having one or more small balloons inside the outer envelope, into which air can be pumped by means of a mechanically driven fan or ventilator to compensate for the loss of gas from any cause. The ballonets occupy about a quarter of the whole volume of the envelope. Such a type is exceedingly well suited for the smaller-sized airships, destined rather for field use than long-range offensive service. Such airships are quickly inflated and deflated. They are also easily transported. Even the Lebaudy or Gross semi-rigid types, though not so clumsy or difficult of transport as the Zeppelins, require more wagon service than the absolutely non-rigid.

The British Government have evolved several non-rigid airships of moderate dimensions which have been exceedingly useful as *ballons d'in-*



PARSIFAL AIRSHIP LEAVING ITS HANGAR.



Digital PARSIFAL AIRSHIP, *Microsoft*®
showing one of the fixed horizontal planes, steering rudder, and car.

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struction. For obvious reasons it is not desirable that particulars concerning them should be published at the present crisis.

(i.) *Parsifal* (German). — Very numerous examples of non-rigid airships could be cited, but it will suffice now to mention two, the German *Parsifal* and the French *Clement-Bayard*. The *Parsifal* is the only type that the German nation has allowed to be supplied to foreign countries. For instance, our Navy possesses one. It has also been supplied to Austria, Italy, Russia, and Japan. On account of its portability it is perhaps the most generally useful type of airship that has been designed, if we exclude long-range service. It has been exceptionally free from accidents on account of its subtleness. The originator of the *Parsifal* seems to have thoroughly grasped the sound idea that to attain success in navigating a subtle medium like air the machine should be correspondingly subtle—as, indeed, are the animal exponents of flight.

In the *Parsifal* the exclusion of the element of rigidity has been carefully studied. All that

is rigid about it is the car and motor, and this can be conveyed in one cart.

The size of the Parsifals has been advisedly limited. The majority of them are not more than a third of the cubic capacity of the Zeppelins. A distinctive feature is the distance of the car from the gas-bag. This in the first types constructed was nine metres, though in more modern forms the figure is less. Owing to the distance of the car from the main body the attaching cords are distributed with equal tension over the whole length of the envelope. In the Parsifal airships there are two balloonets, one at the front and one at the back of the gas-bag. They are not only used for keeping the envelope rigidly expanded, but also to facilitate rising and falling, air being admitted into the one and expelled from the other, as the case may be. Another distinctive feature is the four-bladed propellers. These have fabric surfaces, and are weighted with lead. When at rest the blades are limp, but in revolving, owing to centrifugal force, they become endowed with the necessary rigidity. The dimensions of the Parsifals vary

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considerably, the smallest made had a capacity of 3,200 cubic metres (1908), the largest more recent ones have a capacity of 11,000 cubic metres. A very useful size is the P L 8 (1913), station Cologne, of which the dimensions are :—

Length	77 metres
Diameter	15.50 metres
Volume	8,250 cubic metres
Total lift	5½ tons
Motors	300 h.p. (Daimler 150 h.p. each)
Speed	41 miles per hour

(ii.) *Clement-Bayard*.—It is a question whether it is advisable to extend the non-rigid system to the amount that has been latterly done in the case of such a construction as the Clement-Bayard. This type of French airship is familiar to many in this country, as it was the first airship to cross the Channel from France to England.

The cubic capacity of this airship was 6,300 cubic metres. A feature was the comparatively large size of the ballonnet used. To realise how the Clement-Bayards have grown since this

type of airship came to this country, see table, French Military Airships, page 34.

Astra-Torres Type.—The Astra-Torres airships may be said to form a rather special subdivision of the non-rigid class, for, though there is no rigid metal in its construction, an unbendableness of keel is assured by panels of cloth so placed horizontally as to be kept rigid by the pressure of the air in a ballonnet. Thus the virtue of rigidity is attained without the extra weight generally appertaining thereto, and a greater speed with economy of weight and size. The British naval authorities possess one of these airships. For dimensions, etc., of the latest Astra-Torres airships, see table, French Military Airships, page 34.

It will have been seen from the above short descriptions of distinctive types of airships Germany is the only nation which makes a very marked feature of retaining the rigid form. It is true France has evolved one form of rigid, the Spiess, in which the framework is made of wood, but she undoubtedly has a preference for the semi-rigid and non-rigid types. The rigid

type has not found much favour in Great Britain.

Reckoning from the year 1911, France appears to have nineteen military dirigibles, and she may have one or two older ones in repair. Some of these are building; and as in France there are many eminent aëronautical factories, there are always also a number of private airships built, or in building, of various sizes and various types. These firms have enormous private airship hangars, and every convenience for making, filling, and storing. The number of military hangars in France is seven, at the following towns: Epinal, Maubeuge, Belfort, Rheims, Toul, and Verdun, where there are two.

In the spring of 1913 the Italian military dirigible fleet consisted of two units of Series M—M1 and M2—dirigibles of 12,000 cubic metres, and three units building of Series M—M3, M4, and M5.

These dirigibles of the M series were found in practice to be the most successful; they attained a speed of 70 kilometres per hour, and a height of 2,000 metres; they are all semi-rigid. The Italian Government is ambitious of

AIRSHIPS.

	Name.	Maker.	Type.	Capacity Cub. Metres.	H.P.	Speed m.p.h.
1911	Adjutant Reau	Astra	Non-rigid	8,950	220	32
	Lieut. Chaure	Astra	Non-rigid	8,850	220	32
	Le Temps	Zodiac 9	Non-rigid	2,300	50	29
	Capt. Ferber	Zodiac 10	Non-rigid	6,000	180	33
	Capt. Maréchal	Lebaudy	Semi-rigid	7,500	160	28
1912	Adjutant Vincennot ..	C. Bayard	Non-rigid	—	—	—
	Dupuy de Lôme.. ..	C. Bayard	Non-rigid	—	—	—
	Selle de Beauchamp ..	Lebaudy	Semi-rigid	8,000	160	28
	Éclaireur Conté	Astra	Non-rigid	9,100	—	28
	E. Montgolfier	C. Bayard	Non-rigid	6,500	150	36
1913	Comot Coutelle	Zodiac	Non-rigid	9,500	360	37
	Fleurus	Military Factory	Non-rigid	6,500	160	40
	Spieß	Zodiac	Rigid	16,400	400	43½
	*Clement-Bayard VIII.	C. Bayard	Non-rigid	23,000	1,000	47
	*Clement-Bayard IX. .	C. Bayard	Non-rigid	23,000	1,000	47
1914	Astra-Torres XV. . . .	Astra	Non-rigid	23,000	800	43
	Astra-Torres XVI. . .	Astra	Non-rigid	23,000	800	43
	Zodiac XII.	Zodiac	—	23,000	1,000	50
	Zodiac XIII.	Zodiac	—	23,000	1,000	50

* These two carry each one gun.

rivalling in its aëronautical fleet that of Germany, and decided in that year, 1913, on a new series—Series G. These were to be of 24,000 cubic metres, and to travel at a speed of 100 kilometres the hour.

At the present moment Italy is building some very large airships, some even bigger than the Zeppelin, and she practises ascents diligently with those she has. One of the new airships building for the Italian navy is a Parsifal of 18,000 cubic metres.

Great attention is paid in Russia to aëronautics. The Russians have no national types of dirigibles or aëroplanes yet developed; but they manufacture in their own country.

They have thirteen dirigibles (one is rumoured to be destroyed), semi-rigid and non-rigid, amongst them a Lebaudy made in 1910, Parsifals of 1911 and 1913, an Astra of 1913. The Parsifal of 1913 has a speed of 43-68 m.p.h. (km.).

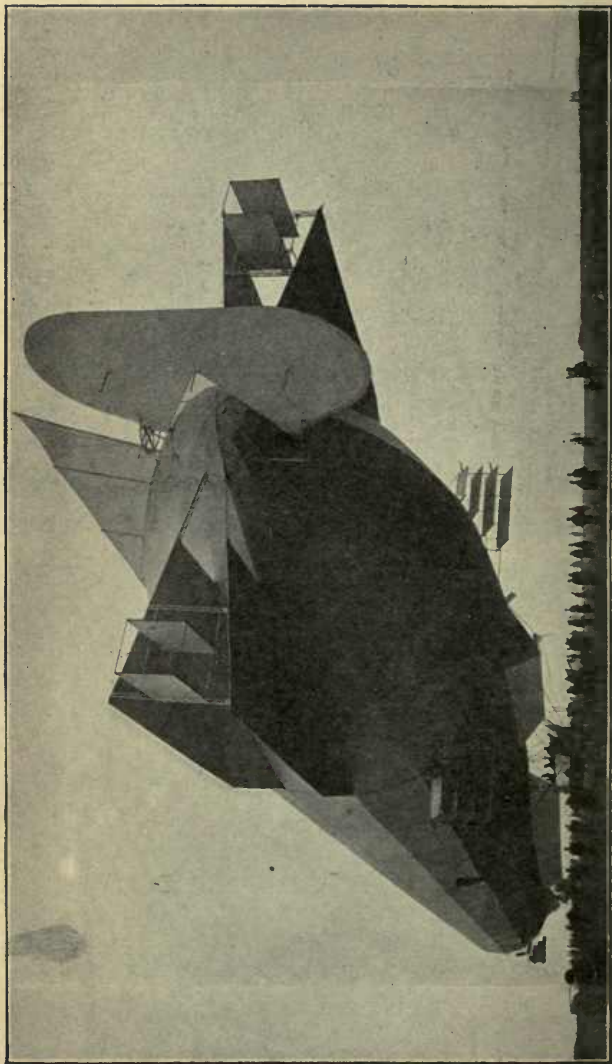
Formerly Austria-Hungary led the way in aëronautics amongst the nations of the Triple Alliance. Germany particularly looked to her

for flying machines, and the first Etrichs were hers; but military aëronautics in Austria-Hungary are now at a low ebb.

The decline is ascribed to monopoly and centralisation. At the present moment Austria has one dirigible, in a feeble condition, and about ten aëroplanes of foreign make. Two German houses, the Albatross and D.F.W., have quite lately opened branches in Austria.

The dual monarchy began well; in 1909 she had a small Parsifal, in 1910 a Lebaudy, in 1911 the Körting. These three perished in accidents. Her own system, the Boemches, presented to her by a national subscription, failed in speed; but though she has no dirigibles to inhabit them she has three good hangars!

Belgium has three airships, all non-rigid—two Godards and one Astra. Although not of very late construction, all three have innovations and interesting features. The Astra is private property.



ZEPPELIN AIRSHIP AT COLOGNE,

showing at the rear large vertical rudder, and two pairs of vertical rudders for horizontal steering, the horizontal planes at the sides for vertical steering, two of the four propellers at side of airship, car beneath airship.

[*Topical Press.*

CHAPTER IV

THE GERMAN AIRSHIP FLEET

MANY reports have been current concerning the exact dimensions of the airship fleet that Germany can put into action. It has been said that she has been extremely active since the beginning of the present war in adding fresh units to the forces she had available when the war broke out. It has also been rumoured that she is making a new type of Zeppelin—one much smaller, and which will have greater speed than the larger type.

We must accept with some reserve the reports that are current in this respect, and it may be pointed out that in accounts of the doings of Zeppelin airships in the papers it can be reasonably doubted whether all the Zeppelins men-

GERMAN AIRSHIPS IN THE SPRING OF 1913.

Type.	Volume m.	Motive Power.			
		No.	Type.	h.p. per Motor.	Max. Speed. m/s
Zeppelin	17,700	3	Maybach	150	21
Zeppelin	18,700	3	—	150	21·1
Zeppelin	18,700	3	—	150	22
Zeppelin	18,700	3	—	150	22
Zeppelin	22,000	3	—	150	—
Zeppelin	20,000	3	—	170	—
Zeppelin	18,700	3	—	170	—
Zeppelin	—	—	—	—	—
Parsifal	4,000	1	Daimler	85	14
Parsifal	7,500	2	N.A.G.	110	15
Parsifal	8,000	2	Maybach	180	18·8
Parsifal	10,000	2	Koerting	200	18·5
Parsifal	8,000	2	N.A.G.	110	16
Parsifal	10,000	4	Maybach	180	—
Siemens-Schückert ..	15,000	4	Daimler	125	19·8
Schütte-Lanz	19,500	2	Daimler	270	20
(1) Gross-Basenach ..	5,200	2	Koerting	75	12·5
(2) —	5,200	—	—	75	12·5

(1) and (2) as in 1911; since then they have been renovated, and no doubt their speed and volume are much greater.

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tioned are in reality Zeppelins. Probably some are the smaller types, such as the Gross or Parsifal. The word Zeppelin seems to have become synonymous with a German airship, and the wounded soldiers or prisoners who are responsible for many of the stories told would not be likely to have complete knowledge of the distinctions between classes of airships.

Though what Germany is exactly doing in way of new manufacture must remain in much fog, still we can form some opinion as to her preparedness with aircraft on the lighter-than-air principle from our knowledge of what she possessed last year.

The table on the opposite page will show that her fleet of airships, including those under construction, was then by no means negligible.

A nation possessing such a fleet of large airships as Germany does must be provided with sheds (hangars) for their reception in all parts of the country, and by the table that is appended it will be seen that in this way last year Germany was very amply provided.

I am indebted to the *Aérophile* for the follow-

ing list of German hangars for dirigibles, with dates of construction and names of owners :—

Place and Date of Construction.	Proprietors.	Observations.
Aix-la-Chapelle	—	Designed for 1914
Allenstein	—	Designed for 1914
Baden—Baden-Dos (1910)	—	—
Berlin—Biesdorf (1909)	Siemens and Schücker	—
Berlin—Reiniekendorf	—	—
Berlin — Johannisthal (1910)	Aeronautical Sport Society	—
Berlin — Johannisthal (1911)	—	—
Berlin—Tegel (1905) ..	Prussian Army	—
Berlin—Tegel (1907) ..	Prussian Army	—
Berlin—Tegel (1908-10)	Prussian Army	—
Bitterfeld (1908) ..	Luffahrtzeug Society	—
Bitterfeld (1909) ..	Luffahrtzeug Society	—
Braunschweig	Airship Harbour Society of Brun- swick	Designed for 1914
Cologne	—	—
Cologne — Leichlingen	Rheinverke Motorluftschiff Society	—
Cologne—Nippes ..	Clouth	—
Cuxhaven	German Navy	Designed for 1914
Dresden	City of Dresden	Will only hold one balloon
Düsseldorf (1910) ..	City of Düsseldorf	—
Cologne-Bickendorf (1909)	Prussian Army	—

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Place and Date of Construction.	Proprietors.	Observations.
Frankfurt am Main (1911)	Delay	—
Friedrichshafen (1908)	Zeppelin Society	—
Friedrichshafen—Mannzell (1900)	Workshops of the Zeppelin Society	—
Gotha (1910)	Town of Gotha	—
Graudenz	—	Designed for 1914
Hannover	—	Designed for 1914
Hamburg-Fuhlsbuthel (1911)	Hamburg Airship Harbour Society	—
Hamburg-Hansa	—	—
Kiel (1910)	Union for Motor-Airship Travel	—
Königsberg-im-Preussen (1911)	Prussian Army	—
Lehr	—	Designed for 1914
Leipzig	Leipziger Luftschiffbau Flugsplatz Gesellschaft	—
Liegnitz (1913)	Prussian Army	In construction
Mannheim — Schwetzingen	—	—
Mannheim-Rheinau (1909)	Luftschiffbau Schütte ü. Lanz	—
Metz (1909)	Prussian Army	—
Potsdam, near Berlin (1911)	Zeppelin Society	—
Posen	—	Constructing
Schneidemühl	—	Building
Strasbourg	Prussian Army	—
Thorn (1912)	—	—
Trèves	—	Building
Waune (1912)	Rhenish-Westphalien Flying and Sports Club	—

Such monster airships as the Zeppelin call for a large proportion of pure hydrogen. This is, indeed, manufactured on a large scale in Germany. It is produced in quantities by the electro-chemical works at Bitterfeld, Griesheim, and at Friedrichshafen, specially for the needs of the Zeppelins at the latter place. There are also works for the production of very pure hydrogen by electrolysis at Bitterfeld, Griesheim, Gersthofen, and Dresden.

In the particular way Germany means to use her lighter-than-air fleet in the present war time will show. If, however, there have not yet been attempts at any combination of action, individual Zeppelins have already played the rôle of dreadnoughts of the air. Though their powers have been no doubt exaggerated, they have been the terror of some Belgian cities.

Early in the morning of August 25th a Zeppelin airship visited Antwerp, and drifting silently with the wind steered over the temporary Royal palace. There it discharged six highly explosive bombs. Not one found its intended mark, though all fell near the palace. One appears

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to have been very near hitting the tower of the cathedral. Though the bombs failed to attain the object sought, no less than six or seven persons were victims to the outrage. One struck a private house, killed a woman, and injured two girls, killed two civic guards, and wounded another. One bomb fell in the courtyard of the hospital of St. Elizabeth, tore a hole in the ground, smashed the windows, and riddled the walls.

The Zeppelin repeated its visit early in the morning of September 2nd, but this time with less deadly result. The bombs only wounded the victims. The experiences of the first visit had given effective warning against a repetition of aërial invasion. The city had been darkened, and the airship was attacked from the forts and the high points of the city as soon as it made its appearance. The crew of the airship seem to have been struck with panic when it failed to find its bearings over the darkened city.

It appears they suddenly dropped all their bombs as ballast and rose quickly out of harm's

way. The bombs used on this occasion were not of the same type as those used on the previous attempt on the city. The latter were of high explosive power designed to destroy buildings. The former were covered by thin envelopes, and held together by mushroom-shaped rivets. They were filled with iron bolts and nuts, and were evidently designed for the destruction of human life. It is stated that this is a type of bomb which has never been used by artillery, being made on the same model as that used by the notorious French robber, Bonnet.

In reference to airship raids over cities, it has been suggested in America that the air in their immediate neighbourhood should be mined. This could be done by having a number of captive balloons or kites, the mines on which could be discharged electrically from the ground. For future wars there will no doubt be devised some form of travelling aërial torpedoes for destroying the intruding airships. Such torpedoes would, however, have to be capable of guidance. As has been pointed out by Mr. W. F. Reid, in 1884, at the siege of Venice, the

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Austrians used free balloons for the purpose of dropping bombs upon the town. The bombs were attached to the balloons in such a way that after the burning of a certain length of safety fuse, the connection was severed, and the bomb fell. The length of fuse was calculated according to the speed of the wind; but, unfortunately, when the balloons rose, they entered an upper air-current travelling in a different direction from that below, and many of the bombs burst in the Austrian lines, whence they had started. Thus it would not be expedient to let loose ordinary unmanned balloons loaded with timed explosives, even if the direction of the wind seemed favourable, for their meeting an approaching airship fleet, as an upper current might bring them back over the city, where they might do mischief.

It is, however, quite conceivable that in the future aërial torpedoes may be devised in the shape of unmanned balloons or aëroplanes controlled by wireless waves of electricity. Those who saw the striking experiment of steering a small navigable balloon in a large hall entirely

by wireless electric waves must have realised the possibilities which may thus be opened out in the future.

While writing, the news has come that another Zeppelin has dropped three bombs on Ostend, the casualty list being one dog. Two unexploded projectiles were found on a field near Waeragheim. These were probably thrown from the same airship. They show how constantly missile throwing from a moving airship may fail to come near the mark. There is no doubt that to hit particular objects aimed at from airships is by no means an easy matter. Success would seem to require considerable training in this particular method of warfare. The late Colonel Moedebeck, in his well-known pocket-book of aëronautics, makes the following remarks on the throwing of balloon missiles :—

We may assume that, if handled skilfully, the object aimed at will be hit very exactly. We must distinguish between the throw when the airship is at rest and that when it is in motion. In throwing out while at rest, which is only possible when the

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airship can travel against the wind, the following points must be considered :—

(a) *The height of the object.*—This may be accurately determined from the contour lines on the map, or from a determination of its normal barometric height. Both must be done before starting.

(b) *The height of the airship above the object.*—The barometric height is read and reduced to normal conditions. The difference in heights as found from (b) and (a) gives the height above the object.

(c) *The velocity of the wind.*—May be read on an anemometer in the airship, or determined beforehand by captive balloons.

(d) *The time of fall.*—Given by the law of gravitation from the determination under (b).

$$\text{The height of fall} = h = g \frac{t^2}{2}.$$

$$\text{Whence the time of fall } t = \sqrt{\frac{2h}{g}}.$$

$$(e) \text{ The resistance of the air. } R = \frac{\gamma}{g} Fv^2.$$

(f) *The leeway.*—The longer the fall, and the lighter and larger the falling body, the stronger is the drift. For known missiles, the drift for different heights and wind velocities may be determined practically.

(g) *Unsteadiness of the airship*.—The irregularity of the pressure of the wind, and its constant variation in direction, renders it impossible for the airship to remain perfectly steady.

The elements stated under (b) and (f) must be rapidly determined, and suitable tables have been prepared for this purpose. The irregularity of the wind and the peculiarities of the airship mentioned under (g) render a preliminary trial necessary. The drift also is determined by this method, before the large air-torpedo is cast out.

The air-torpedo must be brought by sight vertically over the object by steering the airship, the value of the mean drift previously determined being allowed for.

In throwing out a missile while actually travelling, the velocity of the airship must be taken into account, as well as the elements (a) to (g) given above, since this velocity is also possessed by the body thrown out.

The determination of the proper point is now greatly increased in difficulty. Its position is a function of the relative height of the airship above the object, of the velocity, and of the drift, and allowance must be made for all these factors. For this purpose, motion, either with or against the wind, is the simplest. On account of the point on the earth over which the missile must be thrown out not being

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in general well marked, it is necessary to use also angles of sight.

The problem before the aëronaut is, then, as follows:—For a given height, velocity, and drift to find the necessary angle of depression at which the missile must be thrown out in order that it may fall on to the object.

The casting out of the missile against the object while travelling is governed, therefore, by the same rules as those governing the discharge of a torpedo from a torpedo-boat.

CHAPTER V

ADVANTAGES AND DISADVANTAGES OF AIRSHIPS

THE chief advantages of aircraft that are lighter than air over those that are heavier than air in warfare are :—

1. Their speed can be variable.
2. They can hover over a particular point.
3. They can be noiseless by cutting off motive power and drifting for a while with the wind.
4. They can from their possible size have long range of action.
5. They can carry considerable weights.
6. They are endowed with sustaining power and stability.

1. *Their speed can be variable.*

This advantage becomes apparent in cases where they are used both for scouting and offensive purposes.

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In a later chapter it will be pointed out that though the aëroplane scout has often to make dashes over the enemy, and it would be thought that from his swift movements his impressions might be vague, still, in practice, most satisfactory work has been undoubtedly accomplished. Many, however, will maintain that there are circumstances when it may be advisable for observers to proceed at variable speeds. When at a safe height it may be an advantage for the observers to take their time and leisurely survey the country, observe, and take photographs. The airship can stealthily travel over camp and fortress and steal secret after secret of the enemy.

2. They can hover over a particular point.

The fact that the maintenance of the airship in the air does not depend upon a certain speed being maintained, as is the case with the heavier-than-air machine, endows it with the property of being able to hover in fairly calm weather. The hovering power is certainly an advantage for such offensive operations as dropping bombs.

3. *They can be noiseless.*

At night it may often be possible to approach over a fortress, camp or city quite noiselessly at a low altitude by shutting off the motive power and navigating by means of the natural forces alone.

4. *They can from their possible size have long range of action.*

From their size and the amount of fuel they can carry it is possible for them to travel for long distances.

This quality renders them specially fitted for naval purposes, though possibly in the not very distant future more highly developed hydroplanes will run them very close.

5. *They can carry considerable weights.*

The weights large airships can carry is an advantage in offensive operations. It enables larger stores of bombs to be carried than is at present possible with aëroplanes. Then several persons can be carried long distances in the larger airships.

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6. *They are endowed with sustaining power and stability.*

As the envelopes of airships are filled with a gas which lifts and sustains, the great disadvantage of instability which is the bugbear of aëroplanists is absent. If engines break down or stop, it does not necessarily mean that the airship must immediately descend. It can often remain in the air while the machinery is being repaired.

But in spite of these advantages airships have very numerous counterbalancing disadvantages, so marked, indeed, that it seems a question whether, if the world decided to entirely use aëroplanes in their place, it would be much the loser.

The principal disadvantages would seem to be :

1. The resistance of the gas-bag.
2. Danger of fire from close combination of petroleum motor and gas-containing envelope.
3. Danger of fire from self-electrification of surface.
4. Difficulties in the way of applying the propulsive screws in the most effective position.

5. Difficulties of making gas envelope gas-proof.

6. Great cost of airships.

7. The great amount of personnel needed for the manipulation of large airships.

8. Great liability of being destroyed by aëroplanes in war.

9. Insufficient power of quickly rising.

1. *The resistance of the gas-bag.*

From a mechanical point of view it is in opposition to science to attempt aërial navigation by pushing such a large resisting surface as the envelope of an airship against the air. In navigating an airship against the wind, as the latter increases speed is diminished, until a limit is reached when the motive power will be unavailing. Thus there are weather limitations to the airship. Not that the aëroplane is unaffected by the weather. That also has its limits ; but recent practice has shown that the proportion of days when aëroplanes can fly is considerably larger than those on which airships can venture forth from their sheds.

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This disadvantage of the resistance of surface was very manifest in the earlier experiments with navigable balloons, when only feeble motive power was available. For instance, in Count Zeppelin's experiments in 1900, his two motors of 16 h.p. could not combat a greater wind-force than about three metres a second. Then airships could indeed only be called toys. It has only been possible to make them partially successful concerns by enormously increasing motive power. At the h.p. figures with which the latest made large airships have been endowed, the wind limit is much lower than in the case of the heavier-than-air constructions. Though now airships can encounter moderate winds, they are still fair-weather instruments. For the great records of distance established by Count Zeppelin favourable meteorological conditions have been wisely selected. It was M. Santos Dumont who first led the way in making airships something beyond toys. He, in his picturesque and world-alluring experiments, first dared to encounter winds which in force exceeded what would be called calm weather. It is

exceedingly difficult to ascertain what are the exact wind forces overcome by a body moving in air. The measurements have to be taken from a point independent of the moving body. We generally find this one important figure omitted in accounts of airship voyages. M. Santos Dumont's experiments gave especially favourable opportunity for ascertaining correct records of the wind forces overcome. Since M. Santos Dumont so frequently rounded the Eiffel Tower close to the storey where the meteorological instruments were placed, the writer obtained from the authorities of the Eiffel Tower a record of the wind forces registered on all the days of his experiments. A comparison of those records with those of M. Santos Dumont's journeys made it possible to approximately ascertain the highest wind forces he combated on his journeys round the tower; these were about five metres a second. M. Santos Dumont, however, appears to have claimed six metres a second for his highest wind record.

The brothers Lébaudy in their earlier experiments about doubled the record of Santos Dumont

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in this respect. As time has gone on greater advance has been made, though the limit is still represented by moderate wind.

There is, perhaps, some consolation in this thought for those who fear raids of an inimical airship fleet. The proverbial windy nature of our favoured islands is perhaps even more protection than darkened cities and artillery shot, though it is well indeed not to neglect the two latter precautions.

Meteorologically speaking, to make a raid with bulky airships from a distance over these islands would be a very risky undertaking, fraught with the greatest danger to the occupants of the airships. It must be remembered that, chiefly owing to the weather, the history of the Zeppelin may well be called the history of disaster. For the very reason of its fragility over and over again it has been the victim of tempest and flame.

The use of aluminium for the framework of the Zeppelins has been largely responsible for Count Zeppelin's repeated weather misfortunes. There has been a fascination about this brittle

metal, aluminium for aëronautical work on account of its lightness. Its employment for aircraft construction, except for trivial purposes, is, however, a fallacy. That most practical aëronautical engineer, M. Julliot, in working out his semi-rigid constructions, has never fallen into the snare of aluminium allurements, wisely using steel instead. Considering the aluminium framework of the first Zeppelin constructed was fairly wrecked by the trifling accident of its falling down from the ceiling of the shed to the floor, it is a wonder that this species of metal has been retained, to be crumpled up almost like paper in the many accidents that have occurred.

2. Danger of fire from close combination of petroleum motor and gas-containing envelope.

In airships of all three types—rigid, semi-rigid, and non-rigid—this danger is constantly present. There have been examples of airship conflagrations in mid-air, but the greatest danger of conflagrations is in descending when the airships have been overtaken by strong and gusty

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winds. As has before been stated, fire has been the great destroyer of the Zeppelins.

The nearer the car containing the motors is placed to the gas envelope, the greater the fire risk becomes. The Parsifal airship, in which the car is suspended a considerable distance from the gas-bag, should in this respect be the safest of all the types of airships yet constructed.

3. Danger of fire from self-electrification of surface.

This appears to be a great danger in the case of airships whose gas-bags are made with india-rubber surfaces. No less than two Zeppelins have been destroyed from this cause. In the case of the explosion of the gas in a Zeppelin of 1908, when it burst from its anchorage at Echterdingen, the destruction of the airship appears to have been caused by electric sparks produced by the friction of the material of which the gas-bag compartments were made. Colonel Moedebeck, in the *Aëronautical Journal* of October, 1908, gave an expert opinion as to the cause of this accident:—

The balloon material, which is india-rubber coated,

has the peculiar property of becoming electrified in dry air. When rolled up or creased in any way it rustles, and gives out electric sparks, the latter being (as shown by the experiments undertaken by Professor Bonsteim and Captain Dele for the Berlin Aëronautical Society) clearly visible in the dark.

Now, the lower parts of the material of which the gas-cells are composed would, owing to the height to which the airship had ascended (1,100 m.) and the release of gas from the valves, become creased or folded upon each other, and the rubbing thus produced would be quite sufficient to generate the electric sparks above referred to. Under ordinary circumstances, when the space between the gas-cells and the outer envelope of the airship is full of atmospheric air, continually renewed, as when it is in full flight, these sparks would be harmless enough, but when the ship is at anchor, as at Echterdingen, this is not necessarily the case.

We know that the carefully made tissue of the Continental Caoutchouc Company resists the penetration of hydrogen very strongly, but some may have leaked through into the space between the cells and the outer envelope, while it seems very probable that when the mechanics opened the valves, and the long axis of the balloon became inclined, more hydrogen entered this space and an explosive mixture was formed.

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According to the description given by eye-witnesses, the explosion took place after the forepart of the vessel (dragging its anchor) struck the ground. The shock thus caused would have been transmitted to the creased and wrinkled gas-cells, and the tearing of the material, already in an electrified condition, might easily have generated sufficient sparks to detonate the explosive mixture.

Again, in 1912, there was a repetition of this kind of disaster in the case of the destruction of another Zeppelin, the "Schwaben." In this case the framework of the airship had got broken, being battered about in landing in an adverse wind. The india-rubber-coated bags were rubbed against each other, with the production of electric sparks. These either set fire to the gas issuing from one of the gas-bags or exploded the mixture of air and gas contained in the space between the gas-bags and outer covering of the airship. Perhaps it was on account of this accident that gold-beaters' skin has sometimes been used for the gas containers of the Zeppelin airships.

4. *Difficulties in the way of applying the propulsive screws in the most effective position.*

Most airships are exceedingly defective in

this respect, the screws being applied to the propulsion of the car and not to the whole system. The result is that the cumbersome gas-bag lags behind. Certainly, one of the best points in a Zeppelin was the attachment of the screws to the airship framework above the cars, thus securing more advantageous position. This, however, only amounted to something like half measures. In the case of the ill-fated airship "La Paix," the Brazilian aëronaut Severo undoubtedly aimed at the ideal, though the experiment cost him his life. He devised the ingenious system of combining balloon and car in one symmetrical melon-shaped body, through the centre of which passed longitudinally the shaft which revolved the propelling screws at either end. The screws were therefore in the position in which to propel the whole system and not the car only. This, however, necessitated the introduction of a very small space between the car and balloon proper. By reason of this very small space the presence of the petroleum motor in the car could not fail to be dangerous, and was the cause of the fiery end of Severo's balloon

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and the death of the inventor and engineer. On the morning of the ill-fated May 11th, 1902, Severo and Sachet ascended in "La Paix." A few moments after the ascent the balloon exploded, in the words of an eye-witness, like a crash of thunder, and the occupants were precipitated to the ground.

In spite of the engineering advantages of Severo's system no one has dared to revive the plan.

It has, however, been pointed out by the writer—and the suggestion elicited the keen interest of the late Professor Langley—that if electricity could be used as the motive power in an airship the Severo system could be reasonably revived. Then the electric motors could be inside the gas-bag. There, electric sparks and electric heating could do no harm. For it is only the borderland that is the place of danger, where there are oxygen atoms to combine with the hydrogen atoms. In the case of a balloon filled with gas it is surprising to what short distance the danger zone extends. In the case of the writer's electric signalling balloons, on one

occasion the ladder framework which supported the incandescent lamps was being hauled up into the balloon. Through some fault in the connections there was sparking at the framework just as it had passed over the dangerous borderland. The sparks went on with safety. An inch or two lower and there would have been an explosion!

But on account of the weight of the battery the practical application of electricity for propelling navigable balloons seems to be as far off as it was in the days of "La France," and in airships we have to continue placing the screws in the wrong place.

5. *Difficulties of making gas envelope gas-proof.*

The absence of the knowledge how to obtain a really gas-proof envelope is, no doubt, one of the greatest difficulties of airship construction. As has already been pointed out, the gas-holding quality of gold-beaters' skin is remarkable. Its cost, however, is fairly prohibitive in the case of large airships. A material which is a combination of india-rubber and cotton surfaces

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is now generally used for large airships, but this has undoubted disadvantages. India-rubber is a substance which time, low temperature, and certain climatic conditions deteriorate. All those who have worked with india-rubber experimental *ballon-sondes* (sounding balloons) can testify to its perishing qualities. Very much can be accomplished with a brand-new airship. Turned out of a factory it will retain its gas-holding qualities for a short time excellently. The lapse of time reveals deterioration and leakiness.

Considering the extreme importance of a varnish that will retain pure hydrogen for a reasonable time, it is a matter of surprise that chemists should have almost entirely neglected its production. Mr. W. F. Reid alone of British chemists seems to have given any serious thought to the question. In a paper which Mr. Reid read before the Aëronautical Society of Great Britain, he made some exceedingly important suggestions in the way of obtaining balloon and airship varnishes. In case this little volume should fall into the hands of any chemists who may like to devote their powers of original

research to the production of one missing link in airship construction, the following quotation from Mr. Reid's remarks are appended below.

Varnishes may be divided into two classes—those in which the film solidifies or “dries” by absorption of oxygen from the air, and those in which the varnish “sets” by the evaporation of a volatile solvent in which the solid ingredients have been dissolved. To the first class belong the drying oils, chiefly linseed oil, for, although there are a number of “drying” oils, but two or three of them are used commercially in the manufacture of varnishes. When exposed to the air, especially in warm weather, linseed oil absorbs oxygen and forms an elastic translucent mass termed by Mulder “linoxyn.” This linoxyn has completely lost its oily nature, does not soil the fingers, and is, next to india-rubber, one of the most elastic substances known. It possesses but little tensile strength, however, and can be crumbled between the fingers. It forms the basis of all linseed oil paint films, and is largely used in the manufacture of linoleum. Linoxyn, however, is not, as Mulder supposed, the final product of the oxidation of linseed oil. When exposed to the air it is still further oxidised, and then forms a sticky, viscid mass, of the consistency of treacle and of an acid reaction. This latter property is

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of importance because it is due to it that fabrics impregnated with linseed oil so soon become rotten. In order to hasten the oxidation of linseed oil it is usually heated with a small quantity of a lead or manganese compound, and is then ready for use. No method of preparation can prevent the super-oxidation of linseed oil, but experience has indicated two ways of diminishing the evil effects so far as paints and varnishes are concerned. The first is to mix the oil with substances of a basic character or with which the acid product of oxidation can combine. In the case of paints, white lead or zinc oxide are chiefly used for this purpose. The other method consists in mixing with the oil a gum resin which renders the film harder and prevents liquefaction. Such a mixture of linseed oil and Kauri gum forms an elastic, tough mass, which is much more durable than the linoxyn alone, and also possesses greater tensile strength. During oxidation the linseed oil absorbs about 12 per cent. of its weight of oxygen, and when the area exposed is very large in proportion to the weight of the oil the temperature may rise until the mass catches fire. At a high temperature the super-oxidation of the oil takes place more rapidly than in the winter, and I have seen fabrics that had only been impregnated with an oil varnish for a month cemented together in one sticky mass, and, of course, completely ruined.

When the linseed oil is thickened by the addition of a gum resin, it is too thick for direct application, and is thinned down with a solvent, usually turpentine or a mixture of this with light petroleum. Many resins and gum resins are used in the manufacture of varnishes in conjunction with linseed oil, but none of them can deprive the oil of the defect referred to, and if used in too large a proportion they become too brittle for balloon purposes. Both scientific investigation and practical experience show that any varnish containing linseed oil must be looked upon with suspicion by the aëronaut, in spite of the glowing testimonials some manufacturers are always ready to give their own goods.

When we consider those varnishes which are solutions and which do not depend upon oxidation for their drying properties we enter upon a very wide field.

Practically any substance that is soluble in a neutral solvent and leaves an impermeable film on drying is included in this class. One of the simplest examples is gelatine in its various forms, with water as a solvent. Until recently glue or gelatine would have been useless for our purpose on account of its ready solubility in water, but now that we are able to render it insoluble by means of chromic acid or formaldehyde it comes within the limits of practical applicability. A fabric may be rendered almost impermeable to

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gas when coated on the inside with insoluble gelatine, and on the outside with a waterproof varnish. Animal membranes are far less permeable to gases than fabrics coated with varnishes of the usual kinds. A balloon of gold-beaters' skin, if carefully constructed, will retain hydrogen gas for a long time, and if treated with gelatine that is afterwards rendered insoluble it becomes practically impermeable. Fabrics treated with linseed oil varnish, on the other hand, allow gas to pass with comparative ease. This is not a question of porosity or "pinholes," as is sometimes imagined, but a property inherent to the material. Hydrogen or coal gas is absorbed on the one side of the film and given off on the other in the same way as carbonic oxide will pass through cast iron. An inert gas, such as nitrogen, does not appear to diffuse in this way, even when there is a considerable difference in pressure between the two sides of the film. Such a varnished fabric transmits hydrogen readily, but retains nitrogen, and is perfectly watertight. In filling up the interstices of a fabric composed of cellulose the most obvious substance to use would be cellulose itself, but until recently solutions of this kind were difficult to obtain. Toy balloons have long been made of collodion, and are fairly satisfactory, but a cotton fabric impregnated with pure collodion becomes hard and even brittle. Celluloid solution, which is collodion with camphor and a small

quantity of castor oil, is more flexible, but, probably on account of the camphor, is more permeable to hydrogen than collodion. A variety of collodion known as flexile collodion is a solution of collodion cotton with a slight addition of castor oil, and is much to be preferred to any of the preceding forms. In using it great care must be taken to exclude moisture, as the presence of this renders the film opaque, in which case it is always more or less porous. A substance allied to collodion is velvрил material, composed of collodion cotton and nitrated castor oil. It is tough and flexible, even in thick films, and gives a good coating to paper or cotton fabric. Unless very carefully prepared, however, acid products may be generated from the decomposition of the nitro-compounds present, in which case the strength of the fabric would suffer. Another form of cellulose in solution is viscous, which forms a good coating when applied in a very thin layer, but makes the fabric harsh and brittle if used in excess. The solutions of this substance do not keep well and are liable to spontaneous decomposition.

The difference in flexibility between thin and thick films of the same materials is very considerable.

Given an elastic, supple cement, such as is afforded by concentrated solutions of some of the above-mentioned substances, it is quite possible to cement a tough, close-grained paper to a cotton fabric of

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open mesh, and the compound material thus produced is much more easily rendered impermeable than the fine cotton fabric now used. An extremely tough paper made from silk, a recent invention of T. Oishi, a Japanese manufacturer, would be specially useful for such a purpose. . . .

It will be noticed that the texture is very compact and free from pores, as might, indeed, be expected on account of the fineness of the silk fibres of which it is composed. It must not be forgotten that cotton fibres are tubes, and gas may pass through them even when they are embedded in an impermeable film. Silk fibres, on the other hand, are solid, as well as stronger than cotton.

Another way in which a tough, flexible cement may be utilised is to cement a metal foil to a textile fabric. Aluminium foil, for instance, cemented to cotton by means of flexile collodion, gives a completely impermeable fabric of much greater suppleness than the sheet aluminium hitherto used for balloons.

Fine aluminium flakes dusted upon the freshly varnished surface adds greatly to the impermeability of the fabric, and the same may be said of coarsely powdered mica.

It may be noted in this connection that an impermeable varnish does not only apply to

balloon and airship construction, but will also have its use for impregnating the planes of the heavier-than-air machines.

6. *Great cost of airships.*

The cost of airships compared with that of aëroplanes certainly favours the extended use of the latter in war. It is easy to spend £50,000 on a very large airship. Supposing the cost of an aëroplane seating two persons is £1,000, it is a question from an economic point of view whether the possession of fifty aëroplanes is not far better military value for the money expended on the solitary airship. But in the case of the latter it is not only initial expense that has to be considered, but cost of housing, maintenance, and hydrogen gas. These items are very considerable. The upkeep of one large airship very much exceeds that incurred with fifty aëroplanes.

7. *The great amount of personnel needed for the manipulation of large airships.*

It is no exaggeration to say that the ground manipulation of large airships necessitates the

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attendance of quite an army. In the case of a Zeppelin the exigencies of wind may call for the assistance of 300 trained sappers on landing. This is the reason why it is so advisable to have the resting-places of large airships on water. In the case of rigid airships a slight bump on the earth may do considerable damage. Colonel Moedebeck has laid especial stress on the advisability of water landing.

In practice it is never possible, even by working the motor against the wind, to avoid a certain amount of bumping, since the aërostatical equilibrium is not easily judged and allowed for, especially in strong winds. On this account the safer water landing is always preferable.

An airship can be anchored more easily with the point against the wind on water. It is quite impossible to anchor on land when assistance is not forthcoming to hold down the airship. On water, also, the airship will give a little to side winds and to alterations in the direction of the wind, without overturning. On land this danger is not excluded, even with rigid airships. Of course, a watertight and seaworthy car is a necessary condition for landing on water.

The landing requires great attention, and rapid,

decisive handling and management on the part of the aëronaut.

In the opinion of the same expert airship travelling on a large scale would not be possible without the publication of special charts, which would furnish information concerning natural airship harbours, and their relation to various winds, and also of the various airship sheds which may be erected. He states it would be highly dangerous to undertake airship voyages without the existence of suitable stations against storms, and where gas supplies, driving material, and ballast could be renewed.

8. Great liability of being destroyed by aëroplanes in war.

This is no doubt one of the greatest dangers the airship has to face in war. The aëroplane is the airship's deadliest enemy. So terrible to the airship is this hornet of the air that the former has no chance of making an attack. It must ever remain on the defensive. The speed and quickly rising power of modern aëroplanes settles this question. When the aëroplane is

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advancing the airship cannot escape. Nor can it now any longer rise to safe altitude, for the nimbler heavier-than-air machines can easily outdo it.

The only salvation of the attacked airship is its mitrailleuse gun fixed on the platform at its topmost part, but the chance of hitting the swiftly advancing aëroplane is fairly remote.

There are more ways than one in which the fatal attack of aëroplane *v.* airship can be made. The airman can, indeed, ram the gas-bags by hurling himself and machine against it. Then destruction would be swift and sure, with the probable loss of the airman's own life. Better tactics would be to fly above, and drop suitable weapons on the fragile gas-bag; a few sharp and jagged stones would probably suffice. Sharp darts of steel would be all-effective. So easy, indeed, would it be for one aëroplane skilfully handled to end the existence of the largest airship that one cannot refrain from asking the question whether on this account alone it can survive as the instrument of war?

9. Insufficient power of quickly rising.

This is a point which wants the attention of the aëronautical engineer. The old-fashioned spherical balloons were made to rise and fall by the alternate sacrifice of gas and ballast. Thus the very life-blood of the balloon became quickly exhausted. It was obvious that when airships supplanted balloons the former must be supplied with a less exhausting process of vertical movement.

As has already been mentioned, when treating of the Zeppelin airship, for the purpose of rising horizontal planes are now fitted to airships. Some engineers have thought these should be supplemented by a mechanical device, so that the speed of rising might be augmented. The late Baron de Bradsky provided his airship with a horizontal screw placed beneath the car. But one horizontal screw beneath an airship tends to twist it round—to convert it into an aërial top. To avoid this effect it would be necessary to have two horizontal screws rotating in opposite directions. This precaution was absent in De Bradsky's construction, and it kept on twisting round,

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with the disastrous effect that the steel wires which held the car to the balloon snapped, with tragic results. But the idea of the horizontal screw is worth reviving. It has been a cherished plan of M. Julliot to include the principle in his designs, but on account of extra weight he has, I believe, hitherto not tried the interesting experiment.

The colour of most of the airships is a disadvantage, though this is a matter so easy of alteration that it has not been included in the list of disadvantages.

In military airships, and, it may be added, aëroplanes also, the colour should be a neutral tint that is as invisible as possible against the sky. Most of the airships have been made a glaring yellow, so that the india-rubber in the envelopes may be better preserved from the action of light. This protection may have to be sacrificed to the overpowering advantages of invisibility in the case of naval and military airships.

CHAPTER VI

THE ADVENT OF THE AÉROPLANE

THE year of 1908 will be memorable in aëronautical science for its demonstration of the possibility of mechanical flight. Day after day in France and America was then seen the spectacle of men flying in the air, with a grace equal to that of the soaring bird. This was done with a machine not raised by the buoyancy of a gas, but with one that was heavier than the medium in which it travels, and whose sustentation and direction was accomplished by dexterity and skill. The experiments of the brothers Wright were new triumphs of man, new examples of the old truths that a difficulty is a thing to be overcome, and that the impossibility of to-day may be the achievement of to-morrow. This progress in human flight was not the result of any new discovery ; it was the sequence of a long series

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of experiments ; nor was it one nation only that forged the links that connected past researches to the successful issues of the present century.

It is, however, not without honour to the British nation that one of the fundamental principles of the biplane was proposed and elucidated by a Briton in 1866. I refer to the important principle of superposed surfaces advanced in that year by the late F. H. Wenham. He pointed out that the lifting power of such a surface can be most economically obtained by placing a number of small surfaces above each other. Wenham built flying machines on this principle with appliances for the use of his own muscular power. He obtained valuable results as to the driving power of his superposed surfaces, but he did not accomplish flight.

In 1872, H. von Helmholtz emphasised the improbability that man would ever be able to drive a flying machine by his own muscular exertion. After his statements there came a period of stagnation in the attempts to navigate the air by bodies heavier than air.

It is difficult to say how much aëronautical

science owes to two illustrious names—Sir Hiram Maxim and the late Professor Langley. The two eminent men took up the subject of flight about the same time in the last decade of the last century, and applied to it all the scientific knowledge of the time. The flying machine had come to be associated in the public mind with foolhardiness and failure. In the discussion following Sir Hiram Maxim's paper, "Experiments in Aëronautics," read before the Society of Arts on November 28th, 1894, he said, "At the time I took up this subject it was almost considered a disgrace for anyone to think of it; it was quite out of the question practically." But these two scientific men stepped into the breach, rescued aëronautics from a fallen position, and fired in its cause the enthusiasm of men of light and leading.

Sir Hiram Maxim built the largest flying machine that had been constructed. It spread 4,000 square feet of supporting surface, and weighed 8,000 lb. The screw propellers were no less than 17 feet 11 inches in diameter, the width of the blade at the tip being 5 feet. The

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boiler was of 363 h.p. The machine ran on wheels on a railway line, and was restrained from premature flight by two wooden rails placed on each side above the wheels. On one occasion, however, the machine burst through the wooden rails and flew for 300 feet.

In 1896 Langley's tandem-surfaced model aërodrome had luck with the aërial currents, and flew for more than three-quarters of a mile over the Potomac River. This machine had 70 square feet supporting surface, weighed 72 lb., and had an engine of 1 h.p., weighing 7 lb. It is well known how, in later years, Langley exaggerated his model into a machine which carried a man, and how twice, when it was put to the test over water, at the very moment of being launched, it caught in the launching ways and was pulled into the water. It is interesting to note that the American aviator, Mr. Curtiss, has lately unearthed the Langley flying machine, and flown on it. Thus to Langley has come a posthumous aëronautical honour.

Lilienthal, in Germany, in considering equilibrium, experimented with what are called gliding

machines—aëroplanes which are launched from some hillside against the wind, and depend upon gravity for their motive power. In this way the art of balancing could be practised on motorless gliders. With Lilienthal commenced the age of systematic experimental flight; he made the discovery of the driving forward of arched surfaces against the wind; he made some 2,000 glides, and sometimes from a height of 30 metres he glided 300 metres. The underlying principle of maintaining equilibrium in the air has been recognised to be that the centre of pressure should at all times be on the same vertical line as the centre of gravity due to the weight of the apparatus. Lilienthal sought to keep his balance by altering the position of his centre of gravity by movements of his body. One day he was upset by a side gust and was killed. Pilcher, in England, took up his work. With his soaring machines he made some hundred glides, but he also made one too many. One day, in 1899, in attempting to soar from level ground by being towed by horses, his machine broke, and he fell to the ground. He died

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shortly afterwards, a British martyr of the air.

Mr. Octave Chanute's experiments in 1896-1902 formed important links in flight development. He first introduced the vital principle of making the surfaces movable instead of the aviator, and he made use of superposed surfaces. Though his work was a stage in the development of the flying machine, it was reserved to two other geniuses, the brothers Wright, to bring flight to a point of progress where prejudiced critics would be for ever silenced.

The brothers Wright first carried out laboratory experiments; they then, in 1900, first began to experiment with gliding machines at Kitty Hawk, North Carolina. With the comparatively small surfaces (15.3 square metres) they used in that year, they endeavoured to raise the machine by the wind like a kite; but finding that it often blew too strongly for such a system to be practical, in 1901 they abandoned the idea and resorted to gliding flight.

These machines of 1901 had two superposed surfaces, 1.73 metres apart, each being 6.7 metres from tip to tip, 2.13 metres wide, and arched

1-19th. The total supporting surface was 27 square metres. They dispensed with the tail which previous experimenters had considered necessary. Instead, they introduced into their machine two vital principles, upon which not only the success of their preliminary gliding experiments depended, but also their later ones with their motor-driven aëroplanes—(1) the hinged horizontal rudder in front for controlling the vertical movements of the machine; (2) the warping or flexing of one wing or the other for steering to right or left.

Later, a vertical rudder was also added for horizontal steering. The combined movements of these devices maintained equilibrium. The importance of the system of torsion of the main carrying surfaces cannot be overestimated. We have only to look to nature for its *raison d'être*, and observe a flight of seagulls over the sea: how varied are the flexings of nature's aëroplanès in their wondrous manœuvrings to maintain and recover equilibrium! Since the appearance of the Wright motor-driven aëroplane, the principle of moving either the main

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surface or attachments to the main surface has been very generally adopted in other types of flying machines. A feature of these early experiments was the placing of the operator prone upon the gliding machine, instead of in an upright position, to secure greater safety in alighting, and to diminish the resistance. This, however, was only a temporary expedient while the Wrights were feeling their way. In the motor-driven aëroplanes the navigator and his companion were comfortably seated. After the experiments of 1901, the Wrights carried on laboratory researches to determine the amount and direction of the pressures produced by the wind upon planes and arched surfaces exposed at various angles of incidence. They discovered that the tables of the air pressures which had been in use were incorrect. Upon the results of these experiments they produced, in 1902, a new and larger machine. This had 28.44 square metres of sustaining surfaces—about twice the area that previous experimenters had dared to handle. The machine was first flown as a kite, so that it might be ascertained whether

it would soar in a wind having an upward trend of a trifle over seven degrees ; and this trend was found on the slope of a hill over which the current was flowing. Experiment showed that the machine soared under these circumstances whenever the wind was of sufficient force to keep the angle of incidence between four and eight degrees. Hundreds of successful glides were made along the full length of this slope, the longest being $22\frac{1}{2}$ feet, and the time 26 seconds. A motor and screw propellers were then applied in place of gravity, in 1903, and four flights made, the first lasting 12 seconds, and the last 59 seconds, when 260 metres were covered at a height of two metres.

In 1904, several hundred flights were made, some being circular. All this work was carried on in a secluded spot and unpublished. In December, 1905, the world was startled by the news that the brothers Wright had flown for $24\frac{1}{4}$ miles in half an hour, at a speed of 38 miles an hour. More than this at the time the brothers would not say, and for three years the world thirsted for the fuller knowledge only revealed

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in 1908. In the interval some went so far as to distrust the statements of the brothers Wright ; but those who, like myself, had had the privilege of correspondence with them from their first experiments felt the fullest confidence that every statement they had made was fact.

I have somewhat dwelt on the preliminary experiments of the brothers Wright with their gliding structures as indicating the rapidity of progress attained when sound scientific method is combined with practical experiment. Too often in the past there has been a tendency amongst the workers in science to keep theory and practice apart. They are, however, interdependent. Each has a corrective influence on the other.

To the labours of the Wright brothers we certainly owe the advent of the mobile and truly efficient military air scout. It is their efforts that have revolutionised warfare. In the present war we see only the beginnings of what will one day be ; but they are none the less truly prophetic.

It was the enthusiastic Captain Ferber, who

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They were separated by a distance of 1.80 metres. At a distance of 3 metres from the main supporting surfaces was the horizontal rudder for controlling the vertical motions; this was composed of two oval superposed planes. At 2.50 metres in front of the main supporting surfaces was the vertical rudder, composed of two vertical planes.

The 25 h.p. motor was placed on the lower aëro-surface; this weighed ninety kilogrammes. At the left of the motor were the two seats, side by side, for the aëronaut and his companion. The two wooden propellers at the back of the machine were 2.50 metres in diameter. They revolved at the rate of 450 revolutions per minute.

The area of the sustaining surfaces was fifty square metres. The weight of the whole machine (with aviator) was about 450 kilogrammes. Levers under the control of the aviator regulated the various functions of the machine, the flexing of the carrying surfaces, the movements of the horizontal rudders, the vertical rudder, etc.

Soon after the experiments at Le Mans had commenced there came the news of the accident to Mr. Orville Wright's machine in America, in which the latter's leg was broken and Lieutenant Selfridge was killed. This was a critical moment for aëronautical science. I can myself bear witness to its depressing effect on an illustrious aëronautical assemblage, for I was myself present at Wilbur Wright's aëroplane shed when the telegram came bearing the sad news. The sacrifice of one life at that moment seemed to counterbalance the advantages gained by the triumph of the brothers Wright. Even Wilbur Wright himself seemed to half repent he had conquered the air! He exclaimed, "It seems all my fault." It was, indeed, then little thought what the future toll of the air would have to be.

Fortunately for aëronautical progress, two days afterwards Wilbur Wright recovered his nerve, and made the convincing flight of 1 hour 31 minutes 25 4-5th seconds.

From that day onwards there has been an increasing flow of progress in the mastery of the air.

CHAPTER VII

TYPES OF AËROPLANES

FRANCE has indeed been the breeding-place for types of aëroplanes. From France have the nations of late been largely gathering them—save Germany. She has preferred to evolve her own distinctive types. Even before Wilbur Wright appeared with his machine at Le Mans and the details were known, hearsay of his doings had fired the French imagination to do what he had done. In ignorance of the vital principle of movable surfaces that the Wrights had evolved, there came into existence the unbending, rigid type that was not destined to survive.

The first of these was the bird of prey of M. Santos Dumont. Rudely simple was it in its

construction. Two box kites formed the supporting surface. In the centre was the motor, with the screw behind. To attain flight the machine was run upon wheels along the ground until a certain speed was reached, when the machine rose into the air. With this the inventor did not do much more than make aërial jumps ; but rude as it was it contained one feature which has since been retained in all aëroplanes. In this one respect it was an advance—and a very necessary one—upon the Wright machine. That feature was the attachment of wheels to the machine that has been mentioned above. This was, indeed, an important step in the evolution of the aërial scout. Had it been necessary to continue using the external starting catapults that were a feature of the early experiments of the Wrights, the application of the aëroplane to warfare would have been somewhat limited.

The well-known Voisin machine was another outcome of this period, but, imperfect as it was, it brought Mr. Henry Farman into fame, for on it he was the first man in Europe to fly any distance worthy of mention.

THE FARMAN BIPLANE.

Discontented with the Voisin machine, Mr. Henry Farman constructed one of his own design. Though it appeared at an early stage of aëroplane development, it still remains one of the most efficient types of biplanes. It has been used enormously in France, and armoured Farmans play an important part in the great war that is proceeding.

Mr. Farman quickly realised that for maintaining lateral stability the vertical planes fitted between the main planes of the Voisin type were a very poor substitute for the wing-warping method of the brothers Wright. He, however, produced the movement of the main surfaces in an original manner. He hinged small flaps to the rear extremities of the main planes. These he called "ailerons." They produce much the same effect as the wing-warping method of the brothers Wright. When the biplane tilted sideways, the flaps were drawn down on the side that was depressed. The pressure of the air on the flaps forced the aëroplane back on an even keel. In the normal condition the

flaps flew out straight in the wind on a level with the main planes. Another noticeable feature of Mr. Farman's machine was the production of the first light and efficient landing chassis. This was a combination of wooden skids and bicycle wheels. Below the biplane, on wooden uprights, he fitted two long wooden skids. On either side of each skid he placed two little pneumatic tyred bicycle wheels, connected by a short axle. These were held in position on the skid by stout rubber bands passing over the axle.

In a general way the wheels raised the skids from the ground, but if the ascent was abrupt the wheels were forced against the rubber bands and the skids came in contact with the ground. With the abatement of the force of the shock the wheels came again into play.

Simplification of the chassis is becoming evident in the latest forms of all military aëroplanes, the reduction of weight in this portion of the apparatus being important.

To Mr. Farman belongs the credit of having first applied to his aëroplane the now famous

Gnome motor, in which seven or more cylinders revolve. It can truly be said that the influence of this motor on facilitating flight generally, and very particularly military aviation, has been nothing short of prodigious. The aëroplane, like the airship, had to wait for the light petroleum motor. Its advent made flight possible, but achievement in flight would have been comparatively small had it not been for the welcome appearance of a motor specially adapted to the purpose.

The early forms of aëroplane engines in which the cylinders were fixed had proved to be quite unreliable owing to the high speeds at which the engines had to work. Overheating, loss of power, and stopping were frequent occurrences. The water-cooling and air-cooling systems introduced were equally inefficient. The very fact that the cylinders of the Gnome motor revolved effected the desideratum of automatic cooling, and also gave a smooth, even thrust to the propeller.

If the aëroplanes in the present war were flying over the enemy's lines with old-fashioned

engines, they would be dropping down into hostile hands as quickly as dying flies from the ceiling on the first winter days.

After the introduction of the Gnome motor, it was quickly realised that the speeds secured by its use gave the aëroplane a stability that was absent in the more slowly moving machines. Winds that were the bugbear of the aëroplanists could then be combated, and the aëroplane ceased to be the fine-weather machine. Heights could then be climbed that a little while before were undreamt of. It is said that there are some disadvantages in the case of revolving cylinders—that they have been known to produce a gyroscopic effect that has upset the machine. This, however, is a somewhat doubtful point. It may be urged that the greater silence of motors with fixed cylinders is an advantage in war. This may sometimes be so, and it is quite possible that for offensive aëroplanes a special type of motor may be in the future evolved.

To return to the other features of the Farman machine. The plan he adopted in his racing

machines of making the upper plane larger than the lower one was a valuable step in speed-producing machines.

The records won by Mr. Farman with his machines alone testify to its efficiency. Often he has held the world's records of distance, duration, and height, wrestling, indeed, for these with the Blériot monoplane.

In 1911 Mr. Farman began to make types of biplanes specially designed for military use, and in which he studied how he could best give the observing officer an unobstructed view of the ground beneath him. He placed both pilot and observer in seats projecting in front of the main planes. He also made a new departure in placing his upper plane in advance of the lower one. He claimed that this facilitates climbing and descent. He has, however, quite lately evolved a newer type of scouting machine.

In this the lower plane is only one-third the span of the upper one. The nacelle is not mounted on the lower plane, as in the ordinary types of his machine, but, instead, strung from

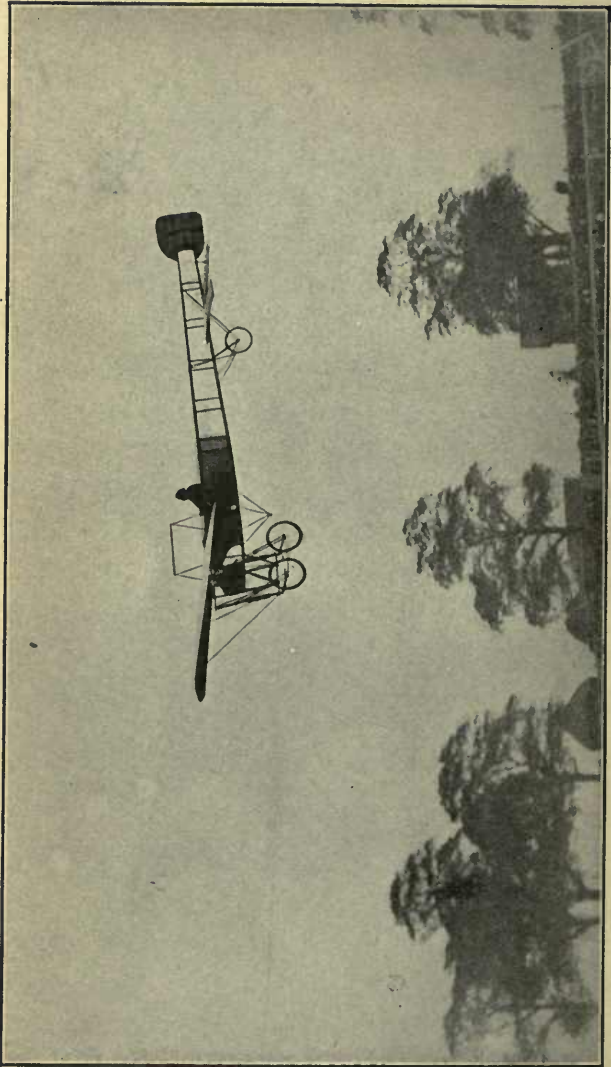
the main spars of the top one. The usual chassis is absent. There is a single running wheel mounted at each end of the lower plane, which is brought very close to the ground. The upper and lower planes are separated by four pairs of struts. The tail is similar to that used on the ordinary type.

The following are the dimensions of one of the latest 1914 types of one-seated Farman machines :—

Length	3.75 metres
Span	11.50 metres
Area	26 sq. metres
Weight (total).....	290 kgs.
,, (useful)	175 kgs.
Motor	80 h.p. Gnome
Speed	110 km. per hour

The following are the details of one of his high-power hydroplanes (1914) :—

Length	8.80 metres
Span	18.08 metres
Area	50 sq. metres
Weight (total)	605 kgs.
,, (useful)	275 kgs.
Maximum speed	105 km. per hour



A BLÉRIOT MONOPLANE IN FLIGHT,
showing one of the two wings attached to the tubular body of machine, chassis, stabilising plane, and rudder at rear. [Topical Press.]

THE BLÉRIOT MONOPLANE.

At the same time that Mr. Henry Farman was making his first flights on his biplanes, M. Blériot was experimenting with monoplanes. His first attempts were disastrous. Time after time he was dashed to the ground. But he persevered, and produced a machine which by its performance staggered the aëronautical world.

When he was first experimenting most people thought that it was in superposed surfaces that success alone lay. They forgot the researches of Langley. These had showed that support depended on two factors—speed and surface; that when speed is increased a less supporting surface will suffice. The success of Blériot took the world by surprise. If I were asked to name the men who have done most to further practical aëronautical development, I should unhesitatingly say: 1, the brothers Wright; 2, Blériot; 3, Pégoud.

The first have been already dealt with. I will speak of the two latter together.

Of the work of both there has been one under-

lying characteristic—simplicity. The former has produced a machine stripped indeed of encumbering complexities, in which the restriction of accessories to what is absolutely necessary is carried to a fine art ; the latter with that very machine has performed experiments in the air that the most sanguine enthusiast of a few years back would have deemed far beyond the region of the possible. In his graceful air diving, looping the loop, and flying upside down, he gave the world a great object-lesson of the materiality of air. He showed the air can give the aviator as much support as the water can to a fancy swimmer. He showed that if the aëroplane is an unstable thing, the human brain can supply the stability ; that in human flight, like the bird and its wings, the machine and individual can be in closest touch. No one has stripped the air of its terrors as has M. Pégoud. In the yielding air there is indeed safety ! It is the ground the aviator has to fear !

I have spoken of the simplicity of the Blériot monoplane. In the machine with which M.

Blériot flew over the Channel in 1909, stretched like the wings of a bird on either side of a tubular wooden frame partly covered with canvas and tapering to the rear, are placed the two supporting planes, rounded at the ends. At the front end is placed the motor (in the original type a three-cylindered engine, now replaced by the Gnome motor), geared direct to a 6 feet 6 inches wooden propeller, and on a level with the rear end of the planes. Immediately behind the engine is the petrol tank, and behind that the aviator's seat. Near the rear end of the frame and underneath it is the fixed tail, with two movable elevating tips. How simple is the working of this monoplane! Moving a lever backwards and forwards actuates the tips of the fixed tail at the back of the machine, and causes it to rise or fall. Moving the same lever from side to side warps the rear surfaces of the supporting planes. The act of pushing from side to side a bar on which the aviator's feet rest puts the rudder into action and steers the machine.

The triumphs of the Blériot monoplane would

fill many pages. It was the first machine to fly over an expanse of water—the Channel. Later, it carried M. Prior from London to Paris without a stop, traversing 250 miles in three hours 56 minutes, beating the performances of the fleetest express trains by three hours. If it no longer for the moment holds the record of height, which it has so often done, it carried M. Garros up to a height of 5,000 metres. When his engine broke down at that prodigious height, by its superb gliding powers it brought him safely to earth!

It has flown over the Alpine peaks! It carried the first aëroplane post—1,750 letters and cards—from Hendon to Windsor in seventeen minutes!

In 1911 Blériot No. XI. flew with ten persons on board.

Its past records have indeed fitted it to be a military machine. It is doubtlessly destined to play an important rôle in the present war in the hands of the French aviators. Especially suitable is this type for the one-seated military machine. Often it may be desirable to employ a two-seated machine to carry pilot and observer ;

but there is often, too, a use for the single-seated type of machine flying at a rate of some eighty miles an hour. The work of these observers is to make swift dashes over the enemy's lines, make a speedy reconnaissance of the enemy's position, and return at once to headquarters with what information has been obtained.

The following are the dimensions, etc., of the 1914 type of armoured Blériot monoplanes :—

Length	6.15 metres
Span	10.10 metres
Area	19 sq. metres
Motor	80 h.p. Gnome
Speed	100 km. per hour

THE ANTOINETTE MONOPLANE.

There is another monoplane that will figure in the history of aëronautics—the Antoinette monoplane. This was the first flying machine to fly in a wind. Up to the time that Mr. Latham went to the flying meeting at Blackpool, which took place almost immediately after the famous Rheims meeting, aviators had only dared to fly in calm weather. On the flying grounds there

used to be tiny flags on posts. When the flags hung down limply that was the time for flying. When they moved about, even languidly, that was the time to put the aëroplane to rest in its shed. Aviators then underestimated the capabilities of their own machines.

When the aviators came to England the island breezes kept the little flags vigorously moving about. The aviators were consternated. The public was disappointed. It began to regard flight as a calm-weather business. Aëroplanes could not face one breath of wind! Of what practical use would they ever be!

Latham at that time had his Antoinette monoplane at Blackpool. It consisted of large and strongly built wings, giving a surface of about 575 square feet, set at a dihedral angle. The motor was some 60 h.p. At the back of the body of the machine were fixed horizontal and vertical fins. There were hinged horizontal planes at the end of the tail for elevating or lowering the machine. "Ailerons" were used on the main surface for controlling lateral stability. One day, at Blackpool, Latham went up in a very

high wind, and remained in the air for a considerable time. How much of the stability of his machine was due to his dexterity, or how much to the machine, it is difficult to say. Probably the fact that the wings were set at a dihedral angle had much to do with it. He also had a much larger horse power than his contemporaries, which no doubt contributed to his success. Anyhow, by the Antoinette monoplane flight was redeemed from the reproach that it was merely a pastime for ideal weather conditions. From that time aviators have sought the winds as well as the calms. Now aircraft can fly in winds of forty-eight or even fifty miles an hour! This step of Latham gave a great impetus towards the military adoption of the aëroplane. The military and naval mind tends to despise what is only of use in the most favourable conditions. It had put aside the airship till it could combat moderate winds. It did the same with the aëroplane.

The Wright, Farman, and Blériot machines may be described as the parent types from which have sprung the large variety which at the

present time are at the disposal of the aviator. Amongst the various types which have sprung from the parent forms we search in vain for any underlying new principles, if we except the Dunne machine. There is, however, in the various types plenty of variety of constructional detail. Perhaps the two most important features of modern aëroplane work are (1), the gradual substitution of steel in place of wood, and the general strengthening of aëroplane construction; (2), the armouring of vital parts of aëroplanes for the exigencies of warfare. Of this latter innovation mention will be made later. Regarding the various types of machines now available, it must suffice in this chapter to especially mention a few which have features of special interest for the purpose of warlike operations.

The success of the operations of the British aëroplanists in the war is evidence of the efficiency of the apparatus being used. The British military aëronautical authorities have evolved a very useful form of aëroplane. In present circumstances, however, detailed description of this must be omitted.

WEIGHT-LIFTING MACHINES.

i. *The Cody Biplane*.—The Cody type was quite an experimental machine. It should not, however, be without notice, as it was an early effort towards the production of weight-lifting machines. These, in the future, will have to be evolved if the aëroplane is to take a large part in offensive operations. Scouting and offensive work call for different types of machines. The Cody biplane had the largest supporting surface that has been made, excepting that of Sir Hiram Maxim's flying machine. The two main surfaces were 52 feet in length, 7 feet 6 inches wide. They had a supporting surface of 775 square feet. But this was small compared with the Maxim giant, which spread 4,000 square feet of surface. In the Cody machine the front elevators, which bore some of the load, alone represented 150 square feet. The two vertical rudders were at equal distances fore and aft of the main supporting surfaces. A distinctive feature was the elevator. This was in two separate parts, each of which could be moved independently of the other. Cody adopted the

method of the brothers Wright for attaining lateral stability and steering—warping the main surfaces.

There were vertical and horizontal rudders operated by a single steering wheel. Cody used generally an 80 h.p. engine, but in some of his experiments he went up to 130 h.p. A peculiarity of the screws was their greater width at the base than at the tips. The weight of the machine was about one ton. Though it was such a large machine some attempts were made to give it portability. The two ends of the main decks, each 16 feet long, were removable. The girder supporting the elevator could also be detached, as the rear rudder frame was made to fold back against the body. With this machine Cody flew at excellent speeds, averaging fifty miles an hour. On one occasion he was credited with seventy miles an hour.

It was the Cody machine which won the first prizes which were open to the world at the military trials in 1912. Of all the earlier practical fliers in this country no one perhaps did so much to popularise flight as Cody. His pluck

and perseverance, despite the constant disasters that were his lot, gained British appreciation, and all recognised that if he was not a man of letters he was one of intuition. His well-known man-lifting kite, unequalled indeed for the purpose for which it was designed, was an example of the illuminating flashes that were wont to cross his brain. It was not the product of calculation, but the happy thought.

ii. *Maurice Farman Biplane*.—A type of weight-carrying machine that has survived is that designed by Mr. Henry Farman's brother, Mr. Maurice Farman. This machine has extensions to its main surfaces, which enable it to carry a considerable weight. It has been found capable of remaining in the air a very long time, which is an important consideration for war use, especially when the aëroplane is on the offensive. It is capable of flying at a very low speed. A disadvantage is that it requires very skilful piloting, especially when used in high winds.

THE BREGUET BIPLANE.

Very conspicuous in the Paris Salon exhibitions

has been the Breguet biplane. This is one of very advanced type ; it is a military machine *par excellence*. Simplicity and portability throughout are its distinguishing features, and these are the essence of a machine designed for war. One might almost call it a combination of monoplane and biplane construction. There is the familiar tapering of the framework, with controlling planes at the end, such as in the Blériot, but two superposed planes, instead of the bird-like projecting wings of the Blériot, are above and below the body of the machine. Steel enters largely into the design. There is a maximum of supporting struts between the main surfaces. These are constructed with thin metal ribs, and are therefore flexible, an exceedingly important feature, rendering the machine exceptionally stable in high and gusty winds. For portability the main surfaces can be taken out of position in a few minutes. By the excellent method of hinging the planes to the body of the machine the former may be turned back and folded up beside the body of the machine. The aëroplane can therefore be described as a folding-

up one. It can therefore travel on the road like a motor-car, instead of having to be packed up and conveyed in a wagon. This method of road conveyance would be impracticable with a machine with its wings outspread.

THE SHORT DOUBLE-ENGINED AËROPLANE.

How many times have engines failed during flight on both monoplanes and biplanes! How many tragedies have thus been enacted! Time and experience indeed have mitigated this type of aërial disaster. The improvement in engines has been one cause of salvation in this respect, the practice of vol-planing the other. But even now from the seat of war comes the news of engines that fail and machines that drop into the realm of the enemy. The old proverb of having two strings to one's bow should apply to aëronautics.

The desideratum, indeed, is the duplication of such a vital part as the motor. Considerations of weight have been the hindrance to engine duplication. Mr. Short has given very special attention to this matter, and has designed what appears to be an excellent machine, undoubtedly

of military value. The biplane is supplied with two Gnome motors. One drives the screws in the front of the machine, and placed a considerable distance apart. The other drives a single screw behind the planes. In the ordinary way both engines run at moderate speed, but if one fails the acceleration of the speed of the other will keep the machine flying.

THE VENDÔME MONOPLANE.

A monoplane which has repute in France for strength, general aptitude, and convenience is the Vendôme type. It has been especially commended by experts on account of the quickness with which it can be put together and dismantled. The only criticism to which it has been exposed is, perhaps, that it is a little too strong for requisite lightness, and that a modification of the metallic portions might reduce weight without sacrifice of efficiency. This machine throughout is made of hickory wood.

BREGUET-BRISTOL BIPLANE.

This is one of the newest machines France has at her disposal. It is a happy combination of

British and French make, due to the collaboration of two firms, the Bristol Company and La Société Breguet.

The result of the combination is said to be eminently satisfactory. A distinguishing feature of this machine is rapid dismantlement. There are two pairs of wings. These are identical, interchangeable, and connected in each case by a flexible partition, which permits of the wings being laterally straightened up. The area of this interesting machine is 39 square metres; length, 8.90 metres; span, 11.50 metres.

THE DESTROYER NIEUPOORT MONOPLANE.

During this year, even before the outbreak of war, the aëroplane had been well armoured and armed. A striking example of an armoured air-scouting machine is the Nieuport monoplane. This type has obtained brilliant result. Equipped with pilot, bombs, and armament it has flown at the rate of 145 kilometres an hour, risen at the rate of 500 metres in 3 minutes 45 seconds, made its departure and landed within an enclosure of 150 square metres.

This monoplane has 24 square metres of surface, and weighs more than 1,000 kgs. The armoury is carried out by a cuirass of steel or nickel plates, which cover the vital front parts and the place where the pilot sits.

ARMOURED CLEMENT-BAYARD MONOPLANE.

This new type is exceedingly well armoured, the protective caps covering the motor and the middle of the machine.

The following are the dimensions, etc. :—

Length	5.60 metres
Span	9.50 metres
Area	18 sq. metres
Motor	100 h.p. Gnome
Weight	415 kgs.
Speed	150 km. per hour

On June 6th last the French military aviators with their armoured and armed aëroplanes were reviewed at Villacoublay by General Joffre and General Bernard, the director of military aëronautics. Amongst the types of aëroplanes present was the Dorand biplane, having two Gnome motors driving separate screws, armoured in its vital parts, and armed with a Hotchkiss mitrail-

leuse. This was mounted on a pivot, and could be fired in almost every direction. There were, too, the Morane-Saulnier, Blériot-Gouin, Nieuport, and Breguet-Bristol types.

M. Raymond, in his speech before the Senate in February last, said that Germany was in possession of armoured aëroplanes, but that France had none. The June review at Villacoublay showed what vast strides in military aëroplane construction the French had made in a few months.

The French military aëroplanes consist of Farman types, and many other leading French forms. In 1913 there were about 500 French military aëroplanes and a few naval hydroplanes.

France manufactures a great number of aëroplanes, of late years about 1,000 per year. These include Government machines, those of private owners and export machines. There are at least twenty-nine French flying grounds, many of them flying schools and trial grounds of the leading French airship and aëroplane makers.

In 1913 Italy appears to have had about a hundred military aëroplanes, including those on

order, Blériots, Bristol (monoplanes), Farmans, Nieuports, and others. She had six or eight naval aëroplanes. She is well provided with military flying schools and other flying grounds, nearly all fitted with hangars.

There are military airship hangars at Rome, Milan, Verona, Venice, and Bracciano.

Belgium has a military school of aviation near Antwerp, and in 1913 she had as many as twenty-four military aëroplanes—H. Farman, 80 h.p. Gnome. There are in Belgium about half a dozen flying grounds, and as many aërial societies or clubs.

As already stated, Germany, in the first instance, looked to Austria-Hungary for her aëroplanes, and the Etrich was an Austrian machine. In late years, however, Austria's aëroplanes were mainly Lohners; the Government favoured this make and discouraged others, consequently enterprise and invention languished. After the accident to the Aspern the Lohner was condemned as of too feeble a resistance, and meanwhile discouragement had effaced all the other systems.

Aëroplanes are used both in the Russian army and navy. Those of the navy are hydro-aëroplanes, or capable of being so arranged. In number, the Russian navy has about a dozen. Of military aëroplanes Russia has probably from 250 to about 300, many of them of modern type, and built in Russia, the principal types being Rumpler, Albatross, Aviatik, Nieuport, Farman, Bristol and Duperdussin.

Bulgaria has a number of aëroplanes, mainly Blériots and Bristols.

SYKORSKY'S GIANT AËROPLANE.

A very remarkable type of aëroplane is the giant biplane invented by the Russian aviator Sykorsky. It doubtless marks the beginning of a new era in the construction of machines on the heavier-than-air principle. Most aviators have shirked the use of a machine that could carry a large number of persons. It would seem that Russia is destined to take the lead in this class of machine, which may before long put the lighter-than-air Zeppelins entirely out of date. The machine of Sykorsky is not, indeed, a

mere project, but a reality, for at Petrograd on February 25th, it flew for eighteen minutes with sixteen passengers on board. They represented a weight of 1,300 kilogrammes. The height attained in this flight was 300 metres. On February 27th the machine flew from Petrograd to Tsarskoe Selo and back again, taking nine persons, in two hours six minutes, at a height of 1,000 metres. The performance constituted a triple record of distance, height, and duration of flight with nine persons on board.

The following are the dimensions, etc. :—

Length	20 metres
Span	37 metres
Surface	182 sq. metres
Distance between planes ..	2.80 metres
Motive power	4 Argus motors (100 h.p. each)
Weight of motors	220 kgs.
Weight of machine without passengers	3,500 kgs.
Weight with 16 passengers	4,800 kgs.

The motors are placed in groups of two on each side of the body of the machine. Each pair works a screw and each individual motor can be

put into action and stopped separately. The body of the machine contains a chamber for the pilots three square metres in size, a passenger salon of five square metres, and two other chambers of three and two square metres respectively. The whole are lit by four windows on each side. The rooms can be artificially lighted by electricity and warmed by motor gas. There are, indeed, future possibilities for such a machine in war!

I have mentioned that the type of aëroplane devised by Lieutenant Dunne is characterised by a distinctive principle of its own. The claim is made that it is automatically stable. It has, however, rather a claim to "inherent stability" than "automatic stability," if we accept the terms as Professor Bryan has defined them.

The following details appeared in the "Aëronautical Journal" :—

The salient features of the machine are the backward slope of the planes, which, in plan view, form an angle with the apex in the direction of flight, and the absence of a tail or supplementary planes of any description. The following are its chief

dimensions :—Span, 46 feet ; length (fore and aft), from apex to rear wing tip, 20 feet $4\frac{1}{2}$ inches ; length of body, 19 feet ; surface, 500 square feet ; weight (including pilot and six gallons of petrol), 1,700 lb. ; engine, four-cylinder 50-60 h.p. Green, 1,100 r.p.m., driving twin propellers placed one on either side of the body in the rear.

The weight in flight being 1,700 lb., the aëroplane carries a load of about 3 lb. per square foot. The speed in flight averages about 40 m.p.h.

The chord of the surfaces is even throughout—6 feet ; the vertical distance between the surfaces is also constant at 6 feet ; at either extremity a vertical curtain is placed between the surfaces to prevent leakage of air sideways. The surfaces slope back from the apex at an angle of 58° on either side, the rear wing tips, therefore, actually being in the rear of the aft end of the body, and the entire outer extremities of the wings lying back well behind the centre of gravity.

The curve or camber of the planes is not uniform, and, briefly, it may be said that each wing may be viewed as a portion of the surface of a cone with the apex to the rear. A consequence of this is that the angle of incidence of each wing gradually decreases from the root to the tip ; so much so, that while the angle at the root is positive, that at the tip is distinctly negative, the difference in the respective

angles being 45° . Apart from this, an interesting feature is the extreme downward bend of the *trailing* edges over a short distance where the two surfaces meet in the centre ; this arrangement has been adopted chiefly to enable the aëroplane to right itself naturally in the event of its having assumed a vertical position in the air. A further interesting consideration is that this machine is the only one that could safely be forced backwards. It may be added, briefly, that the loss in efficiency arising from the negative angle of the wing-tips is compensated by the backward slope and angle of the surfaces, which naturally causes the flow of air to be depleted outwardly beneath the planes, and even induces a certain amount of compression beneath the outer ends. The body is entirely covered in ; the pilot's seat is in the prow ; the motor further to the rear. The centre of gravity is well forward, and about six inches above the lower plane. The propellers are carried on a transverse girder, and are chain-driven in the same direction—contra-clockwise viewed from the rear. The centre of the boss is situated 1 foot 2 inches above the lower plane, and 4 feet from the central axis of the machine. The propellers, designed by Capt. Carden, are of solid wood, 7 feet in diameter, 7 feet 6 inches pitch, each weighing 21 lb. The chassis comprises two main wheels, with a small wheel-and-skid fore and aft. The system of controls is extremely simple.

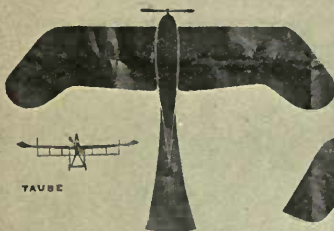
The trailing edge of each extremity of the upper plane forms a hinged flap, measuring 7 feet 2 inches by 1 foot 9 inches. These are independently controlled by two levers, one on either hand of the pilot a couple of mirrors allow the pilot to ascertain the working of the steering-flaps when in flight. The throttle control is fixed to the right-hand lever.

On several occasions, while flying on this machine, the pilot used both hands for writing and making notes, leaving the machine uncontrolled, and came down with his hands raised above his head.

Germany has many forms of aëroplanes, and these will be treated of in the next chapter.

AVIONS ALLEMANDS

MONOPLAN TAUBE



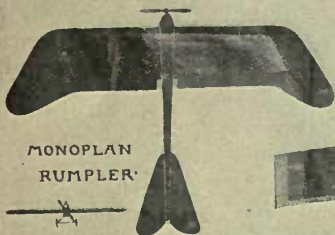
TAUBE

TIREZ
sur ces Appareils

MONOPLAN GOTHA



GOTHA



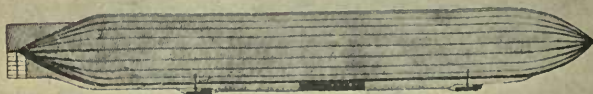
MONOPLAN
RUMPLER

RUMPLER



BIPLAN
ALBATROS

ALBATROS



ZEPPELIN

A DIAGRAM ISSUED BY THE FRENCH WAR OFFICE FOR THE
GUIDANCE OF THE MEN IN THE TRENCHES.

It gives a silhouette of some Aéroplanes and an Airship in the German service,
and bears the injunction—"German Aéroplanes—fire on these machines."

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CHAPTER VIII

GERMANY'S AËROPLANE EQUIPMENT

THE history of Germany's developments in aërial navigation on the heavier-than-air principle during the last few years is the history of preparation for war. France was, indeed, the first nation to realise that though there was a war use for the aircraft on the lighter-than-air principle there would, in time, be no comparison between the advantages of aëroplanes over airships.

Directly aërodrome performances were replaced by cross-country flights that gave opportunities for the attainment of those records in distance, height, and speed which have made the aëroplane the marvel of the twentieth century, France vigorously attacked the problem of turning out machines specially adapted for military purposes. In 1910, France held the position

of being the only nation who possessed military aëroplanes to any great extent, having no less than thirty-five. It may be noted that in that year the British Government only possessed seven. It was in October, 1911, that the magnificent tests carried out at Rheims taught the world the importance of the aëroplane as an arm of war. It was those tests which woke up this country to the fact that it was ignoring the greatest military arm of the future. It was those tests that made Germany, ever on the alert to increase and intensify her war weapons, determined to leave nothing undone to set herself in the van of progress! Germany, therefore, set to study the aëroplane especially from the military point of view, and determined to build aëroplanes which should embody simplicity, strength, high speed, and weight-carrying capacity. Early in 1911 Germany could boast of the possession of nearly fifty military aëroplanes, and from that time forth she has been rapidly increasing the number. The number of aëroplanes in Germany now available is variously estimated; it is stated she has 500 quite modern military aëroplanes,

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a number of older ones, and about 100 privately owned ; others assert, however, that Germany now has as many as 1,500 in the country.

In Sir John French's report, mentioned in the introductory chapter, he tells us that our own Flying Corps in the present war were exposed to the shot of friend as well as of foe. As the German aëroplanes have a more or less distinctive appearance, it seems probable that these peculiar shapes were not well known to our troops at the beginning of the war. Such a knowledge would protect the aëroplanes of the Allies from being mistaken for those of the enemy. The shape of a bird has been very generally adopted for the German flying machines. The monoplanes are specially given the form of a bird flying with wings stretched out and tail distended, the ends of the back portion of the wings projecting beyond the central part.

The biplane frequently presents in front an arrow-like appearance, and the upper plane is bird-shaped. It will certainly be incumbent upon us to ascertain, for the future development of flying machines, how far the adoption of this

natural bird-shape influences speed, etc. The tables on the opposite page will give some idea of the aëroplane equipment the Germans possessed at the beginning of the war.

Regarding the various types of German aëroplanes, it must suffice to enumerate a selection.

THE ETRICH MONOPLANE.

This was the forerunner of the German monoplanes, and very representative of German type. These machines were first made in Austria, and are excellent examples of strong, simple, efficient military aircraft. The wing-shaped supporting planes have upturned wing tips at the back, which are flexed up and down for the purpose of lateral stability; the back portion of the tail plane is movable, and can be flexed for elevating.

Regarding the other types of German machines, Germany appears to have gone through three stages of construction: 1. The stage in which the types evolved were chiefly copies of various well-known French machines. 2. That in which a characteristic German type was produced, the

SOME GERMAN BIPLANES.

Make and Type.	Span.	Length in metres.	Area in metres ² .	Engine and h.p.	Speed by the hour in kilometres.
L.V.G., 1913	14.9 m.	9 m.	44 m.	Argus or Mercedes 100 h.p.	100 km.
Otto	14.9 m.	10.8 m.	—	100 h.p.	100 km.
Albatross	14.4 m.	9.2 m.	—	Argus or Mercedes 100 h.p.	110 km.
Rumpler Taube	13 m.	8.5 m.	38 m.	Mercedes 100 h.p.	—
Aviatik	16 m.	10.8 m.	43 m.	Argus or Mercedes 100 h.p.	100 km.

SOME GERMAN MONOPLANES.

Make and Type.	Span.	Length in metres.	Area in metres ² .	Engine and h.p.	Speed by the hour in kilometres.
Rumpler Taube, 1913-14	14 m.	10.2 m.	35 m.	Mercedes 100 h.p.	120 km.
Kondor	14 m.	9.8 m.	—	Mercedes 100 h.p.	120 km.
Albatross (Hirth Type)	14.6 m.	10 m.	35 m.	Mercedes 100 h.p.	105 km.
Etrich Taube	14.3 m.	9.85 m.	38 m.	Argus or Mercedes 100 h.p.	105 km.
Gotha Taube	14.4 m.	10.2 m.	—	Argus or Mercedes 100 h.p.	100 km.

Taube (dove), a type which possessed many excellent qualities, but also several defects.

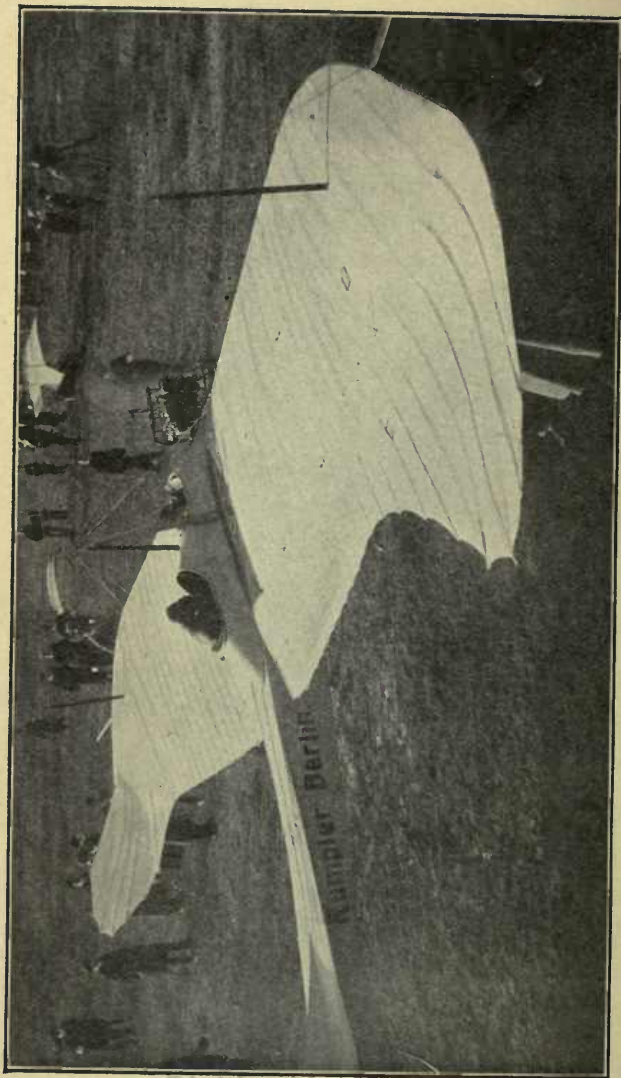
3. That in which the indifferent qualities of the characteristic type were removed.

Of the first type may be mentioned the Euler, which is a modification of the Voisin; the Otto, which embodies the H. Farman principles; the D.F.W. (Deutsche Flüggen Werk); some of these are practically H. and M. Farman biplanes. They also include a rapid type, called Mars biplanes, in which the main surfaces are shaped like those of the famous Nieuport machine.

Amongst the more distinctive machines are

THE AVIATIK BIPLANE.

This is one of the most noticeable of German machines. A special feature is the space provided in the front part of the fuselage, which gives the observer every opportunity of free movement for scouting, writing, photographing, and throwing bombs. The vital parts and front are well fortified with a metallic "capot," and the rest of the fuselage is also armoured. The rapid erection and dis-



A RUMPLER MONOPLANE (A TAUBE),
showing the distinctive bird shape so affected by the German monoplane makers.

[*Topical Press.*]

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mantling of this machine has been especially well planned. The supporting surface consists of two planes of unequal dimensions, the upper one being the larger. Each is divided into two sections fixed independently on the fuselage. The planes are coated with a liquid to render them incombustible. The longitudinal stability is assured by a fixed plane prolonged by a rudder for controlling the vertical movements. Two large "ailerons" at the back of the upper planes are provided for lateral stability.

Steering is effected by a vertical rudder placed between the two portions of the horizontal plane rudder. The dimensions of one type of the Aviatik can be seen in the table of types of German aëroplanes.

THE RUMPLER MONOPLANE.

In this, as in all the Taube flying machines, the wings are in the shape of a dove or pigeon. The end of the wings are flexible. The stability of the apparatus is assured both by the shape of the wings and their flexibility. It is at once a combination of the inherent stability type

and that depending on the warping of surfaces ; the advisability of blending the principles is one practice alone can decide. In some of the Rumpler monoplanes, instead of the ends of the wings being flexible, there are " ailerons " attached.

THE RUMPLER BIPLANE.

This biplane with the Aviatik is remarkable for the amount of space provided for pilot and observer. The fuselage is protected in front with aluminium. The upper plane is not made to join in the centre, as in most German machines ; instead, there is a short immovable central plane, which is permanently attached to the fuselage by four tubes ; to the ends of this central plane, on either side, the other planes are fixed.

THE ALBATROSS.

This is a successful and much used German type, made at Johannisthal, near Berlin ; about two hundred of these machines were made in 1913. The German Government have a great number of Albatross biplanes and monoplanes (Taube), and also several Albatross waterplanes.

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There appear to be four improved Albatross types for this year, two of them biplanes, one waterplane, and one monoplane (Taube), all with Mercèdes 100 h.p. motors, capable of attaining a maximum speed of 65 to 68 m.p.h. The biplane types are just over 26 feet in length, while the waterplane and monoplane average $29\frac{1}{4}$ feet.

The Germans have not favoured rotary engines and have almost exclusively adopted those with stationary cylinders, but an exception has been made in the case of the Sommer arrow-shaped biplane.

Another feature of German machines is that they are all, with one exception, double seated, the extra swiftly dashing scouting monoplane does not seem to appeal to the German. We find, however, one exception to the rule: the Argo type of monoplane is a one-seated machine. It has a span of 9 metres, surface of 15 square metres, and speed of 130 kilometres per hour.

A feature of aviation in Germany during the last few years of peace has been the night flights. For these, they have made special provision in the

shape of aërial lighthouses, scattered all over the country. Some of these are electrically lighted, others by acetylene ; some are " Morse " fires ; some are fixed, others revolve, and the nature of the light has a distinct meaning, such as " near is a high tower to be avoided," and so on. Germany is alone amongst the nations in her appreciation of the necessity of aërial lighthouses.

Round Berlin there are six such stations at, respectively : Nauen, Döberitz, Tegel, Reinickendorf, Linderberg, and Johannisthal ; and there are also aërial lighthouses at the following places :—Königsberg, Posen, Liegnitz, Dresden, Belgern, Eilvese, Gotha, Weimar, Schleissheim, Strasbourg, Grosser-Feldberg, Berncastel-Cues, Metz, and Bonn.

Besides building aircraft on the lighter-than-air principle, Germany has not been idle in their use during the last few years of peace. She has German military flying schools, seventeen in number. They are as follows, arranged alphabetically :—Darmstadt, Döberitz, Freiburg, Germersheim, Graudenz, Hannover, Güterbog, Köln (Cologne), Königsberg, Metz, München-

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Oberschleissheim, München - Oberwiesefeld, Posen, Saarbrücken, Schneidemühl, Strasbourg, and Zeithain.

There are three naval flying schools, at Kiel, Danzig, and Wilhelmshaven, and about three dozen seaplanes, mainly biplanes—Rumpler, Albatross, Curtiss, etc.

There are also in Germany no less than eighty-eight civilian aëronautical bodies, many of whom possess flying grounds, and there must be at least between thirty and forty of these private flying grounds, in addition to those of the military schools.

M. Raoul Volens, in his lucid articles, has pointed out how Germany, who was in 1911 so much behind France, has been able to produce by 1914 an equipment that rivals hers. He points out that in the Imperial manœuvres of 1911 it was with difficulty that Germany could produce eight aëroplanes; in 1912 she produced eight squadrons; at the end of that year 230 certificates had been granted to pilots by the German Aëro Club; in 1913 the number was 600; in 1912 the number of flying machine

manufacturing firms was twenty; there were fifty in 1913. The number of flights made in Germany in 1911 was 7,489; in 1912, 17,651; in 1913 it was 36,817.

In 1911, the total duration of flights was 821 hours 41 minutes; in 1912, 1,966 hours 3 minutes; in 1913, 4,096 hours 48 minutes.

The progress made appears to have been largely due to the efforts of the German National Aërial League, which collected 7,234,506 marks, to be spent on aëronautical development in a few months' time. The Council of the League made a very practical plan for acquiring a large number of pilots, and at the same time developing the most efficient class of machine possible. They left the training of the pilots to the manufacturers, giving them grants for each qualified pilot they had trained.

They also adopted the plan of giving premiums to pilots who accomplished certain practical flights of the nature of what would be required in war. For instance, if a pilot flew for an hour without a drop, he received 1,000 marks; if he made the flight outside an aëro-

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drome, and was accompanied by a passenger, he received an additional prize of 500 marks ; for a flight of over six hours, a monthly sum of 2,000 marks was given to a pilot who flew the longest distance without descending for as long as he held the record.

Regarding the development of aëronautics in Germany, it is interesting to note that just before the present war broke out two world records, those of height and duration of flight, were won by Germans ; up to this year they had been held by France. These were the last victories of peace ! On July 14th last Herr Oelerich rose from Leipzig-Lindenthal at 3.45 in the morning on a D.F.W. biplane, military type, furnished with a Mercèdes motor of 100 h.p., and attained an altitude of 8,150 metres.

On July 10th last, Rheinold Boehm rose from the Johannisthal Aërodrome at 5.54 a.m. on an Albatross biplane of military type, furnished with a Mercèdes motor of 75 h.p. He flew round about Berlin. During the night-time the aërial lighthouses indicated to him his whereabouts. He did not touch the earth till 6.12 p.m.,

having been in the air for twenty-four hours and twelve minutes. It is curious to note in what regular progress the records of duration had been won this year. On February 4th the German Langer flew continuously for 14 hours 7 minutes. On February 7th the German Langer had flown for 16 hours 20 minutes. On April 8th the Frenchman Poulet had flown for 16 hours 28 minutes. On June 22nd and 23rd the German Basser wrested the record away from Poulet, and accomplished 18 hours 12 minutes. Then the German Landmann on June 27th and 28th beat his countryman with the record of 21 hours 50 minutes. Then came the final exploit of Boehm, which has been recorded above.

CHAPTER IX

THE FIRST USE OF THE AËROPLANE IN WAR—TRIPOLI—THE BALKANS

MANŒUVRES in peace were the first practical test of the value of aëroplanes in war. The French proved their efficiency in their manœuvres in Picardy as long ago as 1910. The result of their use was a surprise for the military authorities themselves. Before the test it had been considered that an observer in an airship which could hover over the lines of the enemy or over a fortification would have a good chance of being able to bring back to headquarters useful details of what they had seen; but it had been thought by many military experts that the aëroplanist from his forced, rapid movement would not be able to form a mental picture of what actually passed his eyes, that if the

retina had recorded the fleeting image on the brain, there would be confusion. The success of the aviator was an example of the truism that experience often does not coincide with preconceived opinion, for the reason that some unknown factor exists, and is only brought to light by the special circumstances of the case. Of all people, the aviator is one who constantly practises sharpness and concentration of sense ; his eye and brain have a perpetual habit of harmonious and close-bound working ; time to him has an enhanced value ; none, like he, has ever learnt the exigencies of the minutes. His whole system becomes acclimatised to the constant maintenance of the equilibrium of his powers, for he has realised that for any negligence he will pay the death penalty. Is it wonder then that the glance of the practised aviator over the far-stretching regions beneath him becomes super-sight ? So is it that the best aërial observer is often one who combines in himself the varied occupation of engineer, pilot, and scout, and who in his swift machine, arrow-like, darts above the enemy.

First Use of the Aëroplane in War 139

In the case of the military machines at the French manœuvres above mentioned, the work of pilot and observer was often divided ; and it was found that the observer generally required some familiarity with flight before acquiring the requisite sharpness of vision.

Generally speaking, in the manœuvres, the information brought back was clear, defined, decisive. The intelligence brought back by cavalry scouts has sometimes been a puzzle to the generals in command—hints suggesting to them probabilities, perhaps, rather than accumulated certainties. But the air scouts brought such definite statements as these : “ Have seen infantry hidden in a wood,” “ A squadron with machine guns are marching towards ——,” “ Seen a company digging trenches at ——,” “ The enemy are in full retreat,” etc.

The value of the new arm was manifest in this country in the very first manœuvres in which aëroplanes were used ; by its use the plans made were all rapidly discovered and rendered useless ! Plans made on the old principle of fighting in the dark, each side ignorant

of the operations of the other, fell through once and for all ; and it became recognised that the coming of the aëroplane meant the revolution of the methods of conducting war.

But if from the experience of manœuvres the value of aëroplane reconnaissance was patent to expert military authority, the public generally did not realise the value of the new arm until it had been tried in something beyond mimic warfare. This occurred in the Italian war operations in Tripoli. In this war the need of reconnaissance was great ; operations had to be carried on in a difficult country, and with an enemy that adopted "tricky" forms of warfare. To Italy belongs the credit of being the first nation to put aëroplanes to the test in war, both for reconnaissance and offensive purposes. The types of aëroplanes used in this war were chiefly Blériot and Nieuport monoplanes ; one Etrich monoplane was also included.

Very valuable information was acquired on several occasions by the air scouts, who flew over wide tracts of desert, marking the position of Turks and Arabs, and ascertaining their

First Use of the Aëroplane in War 141

movements preparatory to making attacks on Italian positions. The aëroplanes were fired upon by the enemy, and sometimes the wings of an aëroplane were riddled by shot without resulting accident, proving that the riddling of the wings, so long as sufficient supporting surface remains, is not the greatest evil to be feared. On one occasion Lieutenant Rossi, while making a reconnaissance, nearly fell into the hands of the Arabs. The motor suddenly stopped, and his machine was rapidly falling; the motor, however, recovered just in time for the aviator to remain in the air, and he was able to return to Tripoli.

Regarding the offensive use of aëroplanes in this war, it was related that Lieutenant Gavotti threw from his machine upon an Arab camp a bomb made of picrate of potash; he was at the time 700 feet above the oasis of Aïn-zara, when he discovered beneath two masses of Arabs, numbering each about 1,500 men. He took out the bomb from a bag at his side with one hand, while with the other he manœuvred the machine, and as he passed over a group of

Arabs he dropped the bomb. He could follow its course for a moment or two while he was passing over the bright green verdure of the oasis, but it was speedily lost to sight, while the noise of the motor prevented his hearing the explosion below. He saw, however, a cloud of smoke and the Arabs flying in all directions. This was the first instance on record of bomb throwing from aircraft. Gavotti was himself of opinion that in bomb throwing the operation should be carried out with the aid of two aëroplanes; the one in advance should throw the bomb, the one following observe the result. The one in advance would have to fly at a lower level so as to drop the bomb; the observer following would fly much higher. The dropping of the bomb in this case produced excellent moral effects. When, on a later occasion, the aviators revisited the same spot, there was no trace of Arab encampments. On another occasion Captain Moizo threw two bombs into the Turkish camp near Aïn-zara, which also had the effect of putting the Turks to flight.

A troublesome feature of flight over sandy

First Use of the Aëroplane in War 143

deserts is found to be the intrusion of sand into the valves and bearings of the engines ; but if aëroplanes can be armoured against shot, doubtless a sufficiently light and effective means of protecting the engines against sand can be devised.

Use of aëroplanes was also made in the Balkan war ; and it may be noted that before that war broke out Germans went to instruct the Turks in bomb throwing from aircraft. Bulgaria had a hastily formed aviation corps, and it showed itself useful.

It is, however, in the present European war that the large-scale use of aëroplanes is being daily more and more manifested.

CHAPTER X

THE NEW ARM IN ARMAGEDDON

THE question has been often asked why we were so long in this country in grasping the necessity of keeping pace with other countries by having a national flying corps? In an introductory chapter I have stated that a want of public interest was the cause of British dilatoriness in aëronautical matters; but there was also another very potent reason—a meteorological one. From the weather point of view, the conditions for practising flight in this country cannot be compared with those obtaining on the Continent. Our insular position affords an uncertainty of wind force that in the earlier days of the aëroplane would have been fatal to progress had the pioneers chosen this isle for their experiments. Even while the aëroplanes

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were only calm-weather machines, and even when they first essayed flight in moderate winds, there was an undoubted instinct in the minds of an eminently practical nation that the loss of life consequent upon a systematic military use would be hardly justifiable. So the nation waited for a certain stage of progress in flying machines before launching them into the winds and gusts for serious military work. When they were first used in this country, the nature of our climate proved exceedingly disastrous and swelled the casualty lists of peace. Those who have survived have had a hard and exceptionally strenuous training in the ways of the air, ever having had to be on the alert against the ever-present threatening blasts which tend to upset the stability of flying machines. But is it not the exceptionally hard training that the military aviators in this country have had to undergo that has produced the exceedingly able and successful Flying Corps that is struggling for King and country in the present campaign? It has been seen how they have been commended in the first report of Sir John French. Their

efforts have also met with the greatest appreciation of the French. General Joffre in his report specially dwelt on the regular and valuable reconnaissance of the British Royal Flying Corps. In Sir John French's report, dated September 11th, the following passage appears :—

Quite one of the features of the campaign, on our side, has been the success attained by the Royal Flying Corps. In regard to the collection of information it is impossible either to award too much praise to our aviators for the way they have carried out their duties or to overestimate the value of the intelligence collected, more especially during the recent advance.

In due course certain examples of what has been effected may be specified, and the far-reaching nature of the results fully explained, but that time has not yet arrived. That the services of our Flying Corps, which has really been on trial, are fully appreciated by our Allies is shown by the following message from the Commander-in-Chief of the French armies, received on the night of September 9th by Field-Marshal Sir John French :—

“ Please express most particularly to Marshal French my thanks for services rendered on every day by the English Flying Corps. The precision, exactitude, and regularity of the news brought in by its

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members are evidence of their perfect organisation, and also of the perfect training of pilots and observers."

To give a rough idea of the amount of work carried out, it is sufficient to mention that, during a period of twenty days up to September 10th, a daily average of more than nine reconnaissance flights of over 100 miles each has been maintained.

The constant object of our aviators has been to effect the accurate location of the enemy's forces, and incidentally—since the operations cover so large an area—of our own units. Nevertheless, the tactics adopted for dealing with hostile aircraft are to attack them instantly with one or more British machines. This has been so far successful that in five cases German pilots or observers have been shot in the air and their machines brought to the ground.

As a consequence, the British Flying Corps has succeeded in establishing an individual ascendancy which is as serviceable to us as it is damaging to the enemy. How far it is due to this cause it is not possible at present to ascertain definitely, but the fact remains that the enemy have recently become much less enterprising in their flights. Something in the direction of the mastery of the air has already been gained.

The Royal Flying Corps has already won the distinction of the Legion d'Honneur. ®

The principal uses of the new arm in war may be said to be :—

1. Reconnaissance.
2. Directing and correcting artillery fire.
3. Offensive operations.
4. Rapid despatch carrying to a distance.
5. Distributing handbills to cities.
6. Photography.
7. Locating submarines, mines, etc.

1. *Reconnaissance.*

As a particular example of the value of reconnaissance in the present war one may well refer to that mentioned in Sir John French's first report. He says, "When the news of the retirement of the French and the heavy German threatening on my front reached me, I endeavoured to confirm it by aëroplane reconnaissance, and as a result of this I determined to effect a retirement to the Maubeuge position at day-break on the 24th."

It is undoubtedly expedient to train aërial observers to make reconnaissance at high altitudes. This has been the method employed by Great Britain and France. During the pre-

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sent war we hear of the British and French machines flying at 6,000 feet, where they are fairly safe from gun-fire. The Germans often appear to fly considerably lower. This probably accounts for the loss of so many German machines from gun-fire. It has been stated that at the time of writing British aviators have already brought down seventeen machines. But there have been instances of the aëroplanes of the Allies also making reconnaissance at lower levels. One very remarkable case of an aviator persisting in his reconnoitring task in spite of the fire of the enemy has been reported in the daily papers. The French aviator, M. Poiret, who is in the Russian service, said that

during the recent Russian-German fighting he reconnoitered over the enemy's positions, with a captain of the General Staff as observer, at a height of 1,200 metres. He was for twenty minutes under rifle and shell fire. Ten bullets and two fragments of shell hit his aëroplane. Nevertheless, he retained his control of the machine. The captain was shot through the heel, the bullet coming out of his calf, notwithstanding which he continued taking notes. The aëroplane returned safely.

In making reconnaissance over the enemy's lines it is well for the aviator to be practised in the art of making vol-planés. On more than one occasion in the present war the engine has failed while the aviator has been flying over the enemy. A well-directed vol-plané has brought him down within friendly soil. This gliding by means of gravity without the motor working in times of peace may have been thought to be a foolhardy practice, merely done for the sake of sensation. But the sensation of a few years back is the necessity of to-day! The vol-plané has become one of the most useful features of aëroplaning. A machine that is fitted with wireless telegraphy equipment undoubtedly possesses a great advantage for reconnoitring. It is especially useful when a heavy attack on an enemy is in progress. By its means a continuous stream of intelligence can be supplied to headquarters. The French have been particularly active in the development of wireless messages from aëroplanes, and have devised extremely portable forms of apparatus. It will be of great interest to hear accurate information

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in regard to their practical use in the present war.

Aëroplane reconnaissance in naval operations is almost equally as important as its use on land. This will be one of the principal uses of the hydroplane, which can either travel on the surface of water or rise in the air. In the present war two seaplanes were recorded as scouting near Antivari on September 8th, 1914. It is also said that the Germans gave information to the Heligoland forts by biplanes concerning the fight in Heligoland Bight.

2. Directing and correcting artillery fire.

Very many reports of the use of the aëroplane in this respect have come to hand during the present war. The Germans appear to be very keen on this particular use. Stories told by wounded soldiers graphically describe how with the appearance of the enemy's aëroplane there comes accurate and deadly fire. The Germans appear to have several simple and ingenious means of indicating the instructions of the aërial observer in this respect. An

interesting contribution to our knowledge has been supplied by Bombardier Smith, who was wounded by a bomb dropped from a German aëroplane. Writing to the *Times* he describes how the Germans have special bombs for range-finding.

Those bombs have proved a great success in the war, as they find the enemy's ranges very accurately. The bomb when dropped leaves a thick, black, smoky line to enable their gunners to take the exact range. We were in a good position but suffered loss. The enemy could not find us until the aëroplane came on the scene. Then we had it rather hot. The gunners had to leave the guns, but later saved them all after being reinforced by other guns.

Another method the Germans adopt is to drop a silver ball. Almost as the ball drops from the range-finding aëroplane, the shrapnel shell bursts over the lines of the opponent.

They also sometimes pull up and down a little disc suspended beneath the aëroplane. A still further variety of signalling is accomplished by the use of lamps that are visible in daylight.

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Almost every method of signalling can be used for the purpose, such as flag signalling; wireless signals are no doubt especially effective.

I will quote from a recent article by Mr. F. W. Lanchester in "Engineering" as to the German use of the aëroplane in this respect:—

The value of aëroplane work will be relatively greater the longer the range; in fact, it may in future be found possible to employ heavy artillery of long range under conditions in which without the help of the aëroplane it would be comparatively useless. As an illustration, there is nothing to-day to prevent a long-range battery, well served by its aëroplanes, from effectively shelling an enemy without knowing in the least the character of its objective—*i.e.*, whether an infantry force or position, a body of cavalry, or the enemy's guns. In the present war the aëroplane appears to have been utilised by the German army, as a matter of regular routine, as an auxiliary to the artillery in the manner indicated. It has been reported again and again that the appearance of an aëroplane overhead has been the immediate prelude to the bursting of shrapnel, frequently the very first shell being so accurately placed as to indicate that the method of signalling, and, in fact, the whole performance, must have been well thought out and equally well rehearsed.

3. *Offensive operations.*

This use might be well subdivided into legitimate and illegitimate offensive operations. There has been, unfortunately, ample example of the use of both airships and aëroplanes for purposes that are illegitimate and barbaric in the present war. To use the advantage of travelling in the air at altitudes for the purpose of the wanton destruction of harmless citizens, and, further, to destroy in cities the amassed wealth of art that only centuries, not years, produce, is an unrighteous use of the science of aërial navigation. Before the war it was condemned by the Hague Convention. Since, it has met with the denouncement of all civilised nations—save the one that has perpetrated the outrages. In the case of the aëroplane raid made into Germany by our own British naval airmen, one party of aviators went to Cologne to try to attack the airship halls there. The city was enveloped with an opaque fog, and it was hopeless to try to locate the position of the airship sheds. Though the British aviators circled over the town for an hour and a half they refrained from discharging

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any bombs, rather than run the risk of destroying civilian life or property. An example, indeed, of the legitimate offensive use of the aëroplane was the attempt to destroy or put out of action the very kind of aircraft which had been so wantonly used over Paris, Antwerp, Ostend, and other cities.

Perhaps the most important offensive use of the aëroplane is for fighting airship and aëroplane. Mention has already been made about the deadly character of the aëroplane when it encounters an airship. When it meets an aëroplane the chances are more evenly balanced. Success will depend chiefly upon the speed of the respective aëroplanes, their climbing power, their armouring, and the guns with which they are armed. Speed and climbing power are perhaps the greatest protective factors. Several stories have already been told of the pursuit of German aëroplanes by those of the Allies. The climbing power of the machines of the latter has often been the cause of victory. It is the well-directed shot from above to which the airman is exposed that has ended the career of airman and machine.

At the beginning of the present chapter it was pointed out that the British and French aëroplanes generally fly at about 6,000 feet, which is a height fairly safe from gun-fire. While speaking of the offensive work of aëroplanes, a few more words about the attack on them by gun-fire may not be out of place. As Mr. Lanchester has pointed out, an aëroplane is liable to attack by rifle, machine-gun, and shell fire. Ordinary field artillery fire can be put out of the question in the use of so rapidly moving a target as an aëroplane in flight. He has estimated that an aëroplane is absolutely safe from rifle or small-bore machine-gun fire at 7,000 feet, and it would be difficult to hit it a thousand feet lower.

Not only would the velocity become so reduced as to render a "hit" capable of but little mischief, but the time of flight of the bullet, rising vertically to this altitude, would be about eight or nine seconds, and the distance moved by the aëroplane 1,000 feet, more or less. Therefore, it would be necessary to fire into quite a different part of the heavens from that in which the aëroplane was seen.

The vertical range of aircraft artillery is much

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higher. In the case of a one-pounder having the same velocity the range would be over 12,000 feet ; but it is a question of luck whether the aëroplane would be hit. The great difficulty is the angle of "lead" which must be given to allow for the velocity of flight.

This angle is only constant so long as the velocity of the projectile is constant, assuming (as fairly represents the conditions) the flight speed not to vary ; at extreme heights the velocity of the projectile has fallen so low that a very slight error in range-finding will be fatal to accuracy.

In regard to aëroplane artillery, Mr. W. F. Reid has collected some interesting details of the guns that Krupp has devised for the purpose of hitting aëroplanes.

The 7.5 cm. gun of this firm has seats for five men and storage for sixty-two shells. It is mounted on a car which weighs 4,300 kilos., the weight of the gun alone being 1,065 kilos. Each projectile weighs 5.5 kilos. (12 lb. 2 oz.), and the horizontal range is given as 9 km. The vertical range is 6,300 metres.

A lighter gun of 6.5 cm. gauge weighs, with car, 875 kilos., the gun weighing 352 kilos. Each projectile weighs 4 kilos. (8 lb. 13 oz.), and the extreme horizontal range is stated to be 8,650 metres (9,450

yards). The height of fire obtainable is 5,700 metres (18,700 feet). The initial velocity of the projectile is 620 metres (2,034 feet) per second. A coiled spring balances the weight of the gun when pointed above the horizontal.

For naval purposes Krupp has constructed a 10.5 cm. gun weighing 3,000 kilos. with carriage. The projectile weighs 18 kilos. (40 lb.). The muzzle velocity is 2,100 feet per second, and the shells discharge a train of smoke to facilitate aiming.

Ehrhardt, in Düsseldorf, has also built a special gun for use against aerial craft. Its bore is 5 cm., and its barrel is 30 calibres long, while the length of the Krupp barrels is 35 calibres. The weight of the Ehrhardt gun alone is 400 kilos.; with car, ammunition, and five men the weight is 3,200 kilos.

With regard to the difficult subject of armouring aeroplanes, I should like again to quote from Mr. Lanchester :—

It is manifestly not possible for an aeroplane to perform all the duties required of it in connection with tactical operations at high altitude*, and whenever it descends below 5,000 feet or thereabouts, it is liable to attack from beneath; in fact, at such

* For military purposes we may take the term "high altitude" as defined by the effective vertical range of small-arm fire, in other words, as denoting an altitude of 5,000 feet or 6,000 feet or more.

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moderate altitudes it must be considered as being under fire—mainly from machine-gun and rifle—the whole time it is over or within range of the enemy's lines. Protection from the rifle bullet may be obtained in either of two ways : the most vital portions of the machine, including the motor, the pilot, and gunner, can only be effectively protected by armour-plate ; the remainder of the machine, including the wing members, the tail members, and portions of the fuselage not protected by armour, also the controls, struts, and the propeller, can be so constructed as to be *transparent* to rifle fire—that is to say, all these parts should be so designed that bullets will pass through without doing more than local injury and without serious effect on the strength or flying power of the machine as a whole ; in certain cases components will require to be duplicated in order to realise this intention. It is important to understand clearly that any intermediate course is fatal. Either the bullet must be definitely resisted and stopped, or it must be let through with the least possible resistance ; it is for the designer to decide in respect of each component which policy he will adopt. The thickness of the armour required will depend very much upon the minimum altitude at which, in the presence of the enemy, it is desired to fly ; also upon the particular type of rifle and ammunition brought to bear. There is a great deal

of difference in penetrative power, for example, between the round-nosed and pointed bullets used in an otherwise identical cartridge.

If it were not for the consideration of the weight of armour, there is no doubt that an altitude of about 1,000 feet would be found very well suited for most of the ordinary tactical duties of the aëroplane. At such an altitude, however, the thickness of steel plate necessary becomes too serious an item for the present-day machine, even allowing for the very excellent and highly efficient bullet-proof-treated steel that is now available ; at the altitude in question, the minimum thickness that will stop a 0.303 Mark VI. round-nosed bullet is 3 mm. ($\frac{1}{8}$ in.), but, if attacked by the modern pointed-nose Mauser, nothing short of 5 mm. or 6 mm. is of avail. If we compromise somewhat in the matter of altitude and prescribe 2,000 feet as the minimum height for which protection is to be given, the figures become 2 mm. (about 145 W. gauge) for the 0.303 round-nosed bullet, and for the pointed Mauser 3 mm. or slightly over ; at present it is not expected that it will pay to armour a machine for the duties in question more heavily ; thus we may take 2,000 feet as representing the lower altitude limit of ordinary military flying. . . On this question of armour it cannot be too strongly insisted upon that anything less than the necessary thickness definitely to stop the projectile is worse than useless ;

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a "mushroomed" bullet, possibly accompanied by a few detached fragments of steel, is infinitely more disagreeable and dangerous than a bullet that has not been upset.

An aëroplane armoured in all its vitals with 3 mm. steel, and otherwise designed on the lines indicated, flying at not less than 2,000 feet altitude, will be extremely difficult to bring down; so much so, that unless its exposed structural members be literally riddled and shattered by rifle and machine-gun, or unless a gun of larger calibre be brought to bear, it will be virtually impossible to effect its capture by gun-fire alone.

4. *Rapid despatch carrying to a distance.*

Considering the advantages of the swift monoplane for carrying despatches from one commander to another, it would seem that in time it must oust the despatch rider.

There is no obstacle to the despatch rider. The difficulties and delays of hills, woods, and rivers melt away before his ever onward course. The despatch rider on horseback may have to face the sudden appearance of the enemy, but if the aëroplane despatch carrier does, he has only to rise up out of his range of fire, and, still undisturbed, he can make his way towards his

destination. There must surely already be many instances of the use of the new arm in this way in the present war. It has been reported that the Germans used aëroplanes to send messages to recall German troops stationed in the village of Coutrai to reinforce those at Charleroi.

5. *Distributing handbills to cities.*

This is a use which has not been much taken into account until the present war. It appears, however, one that is destined to become very general in war. It has been already used either to excite terror or encouragement amongst the population of a city either already besieged or threatened with speedy investment. It has been stated that when Liège was besieged the French aviators distributed circulars over the city to the effect that the citizens should keep up their courage, as help would soon be forthcoming. When the Germans were approaching Paris the German aviators distributed pamphlets urging the surrender of the Parisian capital. Reports also came to hand that French aviators flew over Alsace and Lorraine with pamphlets

to describe the violation by Germany of the neutrality of Belgium and Luxemburg!

6. *Photography.*

The value of aëroplanes for this work in war is self-evident, and various means for securing good photographs from flying machines have been devised. Some years ago the public was made familiar with photographs at great altitudes in the air by the beautiful specimens taken by the late Rev. J. Bacon and the late Mr. Percival Spencer from the cars of their balloons. Since then Mr. G. Brewer has become an adept in the art of aërial photography. The clearness of detail in these photographs gives sufficient evidence as to the value of aërial photography in war.

Satisfactory photographs from balloons have been taken from as great a height as 10,000 feet. The success of aërial photography, however, depends upon the amount of haze upon the earth, which veils the plate from the actinic power of the reflected light. In taking aërial photographs from aëroplanes, owing to meteor-

logical conditions it may often be necessary in war to take the photographs from lower and more perilous positions. The value of the photographs will, however, often be worth the risk, as very complete aërial surveys of war regions can be made from a series of photographs.

For taking photographs from aëroplanes special and in some cases automatic cameras have been designed.

The Germans use a camera fitted with a special Telephoto lens.

In an apparatus of British make, designed by Mr. Baker, the camera is suspended beneath the aëroplane. The airman presses one button to make an exposure, another when he wishes to change the plate.

7. Locating submarines, mines, etc.

In the present war ample evidence has been given of the deadly work that submarines, torpedoes, and mines can perform. Some years ago the late Rev. J. Bacon carried out experiments from balloons to show that when the

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surface of the sea is viewed from an altitude the observer has a vision which penetrates to some depth below the surface. At the time the great advantage of such surveys in naval war-time was pointed out.

Such aërial surveys form an important use for both the smaller types of airships, aëroplanes, and hydroplanes. When more records come to hand than it is now possible to obtain in regard to naval doings in the present war it will be interesting to observe the amount of actual work that has been done in detecting submarines and the other hidden dangers in the sea.

CHAPTER XI

PRESENT DEFICIENCIES AND FUTURE POSSIBILITIES OF THE MILITARY AËROPLANE

IN the portion of this handbook which especially dealt with airships, certain advantages possessed by them over aëroplanes were noted; several of their disadvantages were also a matter of comment. It was hinted that in the future it might be possible to impart to aëroplanes also those very advantages of which the airship can still certainly make boast. Should this be done by engineering skill—and it is well within the limits of reasonable possibility—then it would seem that the lighter-than-air machine must entirely yield its claim as an adjunct of war to the heavier-than-air principle. The free balloon

“mounting heavenwards,” as Carlyle said, “so

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beautifully, so unguidably," is now merely a past reminiscence, and even so, too, will be the mammoth motor-impelled gas envelopes. When the din of war ceases, the still greater perfection of the aëroplane should be the object of the attention of British engineering skill. The endowment of the aëroplane with certain qualities in which it is still deficient appears to be merely a matter of engineering detail based on principles that have been already elucidated.

Since the brothers Wright made their epoch motor flights which gave to man the attribute of the bird, so long his envy, progress in flight records has been largely made in the attempt to win a money prize. In one sense the pilot has progressed at a faster rate than has the evolution of the machine. He has accomplished heights, durations, and distances on machines in which the margin of safety is indeed small. It might be well if the next series of prizes should be devoted to the further development of the machine itself—prizes which would, in their turn, stimulate the genius of the aëronautical engineer.

Four essential points in the future development of flying machines are :—

1. Variable speed.
2. Immediate rising into the air.
3. Hovering in the air.
4. Stability.

1. *Variable speed.*

The aërial machine that cannot vary its speed, so as to be able to go fast, at moderate pace, or quite slow, must from one point of view be in a crude state of development. Yet aëroplanes are as yet in this stage of growth.

More than one plan has been suggested for endowing the aëroplane with the power of variable speed, which would make its use in war still greater. One of these plans is the extension and reducing at will of the sustaining surfaces, so that for high speeds the practical minimum of surface may be utilised, for low speeds the practical maximum. A machine to produce this result has been already planned by Mr. C. F. Webb. It

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was described at a meeting of the Aëronautical Society of Great Britain in 1906. At the time of the reading of the paper the world was hardly ready to realise the importance of considering this problem ; at the present moment all military aëronautical experts agree as to the advisability of the production of a variable speed flying machine, though they shirk the complexity of structure the variable speed machine would seem to necessitate. In Mr. Webb's design is a form of aëro-surface which, by special adaptation, can vary its area in accordance with the requirements of, and in proportion to, the constants, speed, and weight, and thus automatically adapt itself to the requirements of the varying speed of the wind. In this machine the two wings are situated on each side of the car in such a way that the centre of support of each is some distance above the centre of the mass of the machine. Each wing is fan-curved from front to rear, with the outermost segment longer than the innermost. The fan wings are opened or contracted by a hand-lever

arrangement, and besides the hand levers there is an automatic pendulum mechanism which regulates their area to the requirements of the wind. Whether or no the inventor's exact arrangements may prove on trial to be successful is a matter on which decisive opinion cannot be given; but the principle of expanding and diminishing surface is thoroughly sound, and is worthy of lavish expenditure and experiment. Other ways of attaining variable speed machines have been suggested, though the method of a variable surface would seem likely to carry the regulation of speed to a greater nicety than do the other plans. One of these projects is to alter the angle of the incidence of the planes while the machine is in flight; the angle would have to be steep for slow speed, and gradually flatten for increase of speed.

2. *Immediate rising into the air.*

It is undoubtedly a disadvantage of the aëroplane that it has to run on the ground on wheels to get the initial velocity necessary for flight.

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In some of the earlier military experiments with aëroplanes the machines were made to run over ploughed fields, for it was recognised that machines which could only rise when running on smooth ground would be useless for military work. But one can imagine that it may often be expedient in military operations for machines to rise from land so unequal that with the present method flight would be impossible.

The perfect military aëroplane should be able to rise in the air at any time and from any place. The application of horizontal lifting screws beneath the flying machine would make this a possibility, though it would be necessary to have two of such screws revolving in opposite directions. It is indeed curious that so little has been done in the way of such experiments. It will be said that each added screw means engine multiplication and complication; but these difficulties are details of engineering that are not unsolvable.

In the case of such large aëroplanes as the Russian type that has been described, it would

seem specially feasible to attach the lifting screws.

3. *Hovering in the air.*

One great advantage of the lifting screws would be that by their use the machines could hover in the air. Now, when the vertical screw is stopped, the aëroplane must fall to earth unless the aviator makes the "vol-plané." This necessity brings into strong relief the present imperfection of the flying machine. When horizontal screws are attached to a flying machine we really have the essential feature of sustentation, and the existence of the ordinary supporting surface becomes superfluous. The flying machine has, in fact, become of the "Hélicoptère" type, though doubtless for some time the supporting surface will be retained as a means of additional security; in time it may vanish altogether, and support as well as progression depend upon revolving screws.

4. *Stability.*

It has been stated that the properly con-

structed airship is stable when in the air; it has not got to fear the more treacherous side gust which over and over again has brought the aëroplane to earth, and coupled its name with tragedy. The vexed problem of the stability and equilibrium of aëroplanes is the most important that has yet to be solved; until this is done it is not likely the airship will completely disappear as an instrument of war. In speaking of the remarkable exploits of Pégoud, it was said that they were an object-lesson on the materiality of the air, and we have yet to learn how to use this materiality to the best advantage, so as to afford us continual stability. Until the problem is solved, man cannot be said to have brought himself to the level of the soaring bird; the latter, indeed, makes good use of the very attributes of the wind which at present tend to upset the aëroplanist—the vertical component of the wind, its internal work, *i.e.*, its gustiness; its non-uniformity, *i.e.*, its different velocities at different levels. Every light, therefore, that can be thrown experi-

mentally or mathematically on the difficult subject of equilibrium and stability should be eagerly sought.

Professor G. H. Bryan's mathematical researches are indeed epoch-making, and their study by the aëronautical engineer should be prolific of practical result. He does much to elucidate points of the problem of stability that before had been imperfectly grasped. For instance, take the case of his remarks as to distinction between equilibrium and stability.

We say that the motion of a flying machine is steady when the resultant velocity is constant in direction and magnitude, and when the angle of the machine to the horizontal is constant. If this motion is slightly disturbed the machine may either return after a time to the original motion, or it may take up a new and altogether different mode of motion. In the first case, the steady motion is said to be stable, and in the second unstable.

It is evidently necessary for steady motion of any kind that there should be equilibrium—*i.e.*, that there should be no forces acting on the machine (apart from accidental disturbances) which tend to vary the motion, and hence it follows that the number

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of modes of steady motion of which a machine is capable is, in general, limited, and that when an unstable, steady motion is disturbed, the new mode of motion taken up is entirely different from the old.

It is necessary to distinguish carefully between equilibrium and stability, as the two are very often confused together. Equilibrium is necessary to secure the existence of a mode of steady motion, but is not sufficient to ensure the stability of the motion. The question of the stability of a rigid body moving under the action of any forces has been solved by Routh. In order to apply his results to the stability of flying machines, it is necessary to know the moment of inertia of the machine about its centre of gravity, the resistance of the air on the supporting surfaces as a function of the velocity and angle of incidence, and also the point of application of this force—*i.e.*, the centre of pressure for different angles of incidence. If these are known for the surfaces constituting any machine, then the problem of its stability for small oscillations can be completely solved. Unfortunately, our knowledge of these points is very unsatisfactory. Several valuable series of experiments have been made to determine the resistance on planes, but there is still some doubt as to the position of the centre of pressure at small angles of incidence, especially for oblong

planes, and very little indeed is known as to the movement of the centre of pressure on concave surfaces. Until experiments are made on this point it will be impossible to solve the problem of stability for machines supported on concave surfaces.

The subject of the stability of aëroplanes falls under two heads :—

1. Automatic stability.
2. Inherent stability.

Attempts have been made to produce the first by the aid of moving gyroscopes and pendulums without much success, and Professor Bryan has pointed out, apart from the fact that movable parts are likely to get out of order, they also increase the degree of the friction of the machine, thus further adding to the number of conditions that have to be satisfied for stability.

It would seem, therefore, that the desideratum is inherent stability. Professor Bryan considers that there is hope of attaining longitudinal and lateral stability by the use of exhaustive mathematical researches; these will result in the fixing of independent auxiliary surfaces in aëro-

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planes in such happy positions as will secure stability in all conditions of atmosphere. Or it may well be that through some unlooked-for observation or simple experiment the answer will come. In the shape of the aëroplane surfaces alone may be the solution of the problem. But if the aëroplane be still an imperfect instrument, it is sufficiently developed to be already one of the greatest factors of modern warfare.

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