AIRCRAFT
IN
WARFARE
THE DAWN OF THE FOURTH ARM

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PREFACE.

The subject of "Aircraft in Warfare," with which Mr. Lanchester deals, is, and for some time will be, highly controversial. In each of its three aspects, the scientific, the military, and the material or manufacturing, it is still in the stage of experiment and speculation. The results obtained cannot always be made available for the information of the general public, and those which are available have usually been set forth in terms so technical, either in a scientific or a military sense, as to be somewhat difficult for the general reader to understand. Very little trustworthy information, therefore, has been disseminated, and the uninstructed public, hungry for information on a novel and alluring subject, of which the national importance is evident, has fallen an easy prey to the imposter. Any plausible rogue, gifted with sufficient assurance, and aided by a ready pen or supple tongue, has been able to pose as an "aeronautical expert," and to find some kind of following. To those who, as a matter of duty, or in search of information, have perused the aeronautical discussions carried on in the Press, or the reports of such discussions elsewhere, the very word "expert" calls up a strange procession of inventors, politicians, motor-trade touts, journalists, trick-fliers, novelists and financial agents, most of them, axe in hand, on the way to the
national grindstone; a few, innocent, following on the same track, on a vague quest for supernatural powers of flight.

As a matter of fact, there are no experts in military aeronautics. There are experts in the various branches: in flying, in scientific research, in the design and construction of aeroplanes and engines, in military organisation and tactics. But, as yet, there is little opportunity for the expert in one branch to gain definite knowledge of the others, except by hard personal experience; in every direction there is progress, in every section of work opinion is fluid, and the views of the workers are not yet sufficiently crystallised to permit of definite instruction to others. Yet there are some students who, by reason of their receptive minds, and their wide and varied experience, have mastered so many of the fundamental problems that they are well qualified to review the general position, and to put forward a reasoned statement of their views. And of those so qualified, none has a wider view than Mr. Lanchester.

Of all the fields in which work for the advancement of military aeronautics has been undertaken, in this country, that of scientific research has, up to the present, produced the results that will probably be the most enduring. It is only by the solution of fundamental problems of science that improvement in the power of flight can be won. Solutions may be obtained, and some few have been, by chance, or by intuition; but to gain the full value of the result, it is necessary that the scientific solution should also be found, as a basis for further deductions. In this work of stating and solving the problems of aeronautics, Mr. Lanchester was one of
the pioneers; he was bold enough to publish the result of his investigations at a time when flying had only just been proved possible; and he has reason now to be well satisfied with the quality of his early work. In this new book he has discussed matters of wide interest and, at the present moment, of vital importance, and has considered in many bearings the relations between aeronautic science and military art. In this effort many difficulties have had to be faced, not the least of which is the lack of definite knowledge of the methods which have been employed and of the results which have been achieved by aircraft in the present war. And, further, there has been the necessity of exercising extreme discretion in the use of information which is within his knowledge. In the first respect I have some advantage over Mr. Lanchester; in the second he, in writing the book, and I in introducing it, suffer under the same disability.

During the past three years Mr. Lanchester and I have had several tussles in private on the questions debated in this book. Each can put up a pretty good defence on his own ground. Mr. Lanchester is well protected by his profound knowledge of physical science and his practical acquaintance with several branches of engineering. I am strongly entrenched behind a barricade of military prejudice, with some dim recollections of early scientific training as reserves for counter-attack. In my incursions into Mr. Lanchester's territory, I have now and then received a buffet which has made me more wary. And occasionally, I think, Mr. Lanchester has found himself hung up in my wire entanglements. I should like nothing better than to fight out, in public and with due formality, these points—not a few—on which he and I disagree; but at the present moment this is impossible,
nor is it advisable that I should do much towards indicating those on which we are in agreement.

There are two theories, however, evolved by Mr. Lanchester to which I may safely draw attention. The first he has called the *N-square* law, and it is, to my mind, a most valuable contribution to the art of war. It is the scientific statement of a truth which, although but dimly perceived, has been skilfully used by many great captains, both Naval and Military, but it is now for the first time stated in figures and logically proved. We can never be governed by the rules of exact science; there are too many conflicting factors, too many fortuitous circumstances; but there are certain rules, whether based on experience or calculation, which no commander may lightly transgress. Concentration of force is one of these rules, and a statement of the inevitable disadvantages of dispersion is valuable. The examples chosen from sea and land warfare illustrate the working of the law with admirable precision.

In the other case, Mr. Lanchester's calculations are less satisfactory. In considering the proportion of aircraft which is suitable for the requirements of an army in the field, the aircraft are compared with cavalry, and the aeroplane with a single trooper. This is no sound basis for calculation. To begin with, a single aeroplane absorbs, on the average, the services of some twelve officers and men, and its cost, which is not an immaterial factor, would provide more than a score of horses. But even the most accurate display of comparative figures will bring us no nearer to a correct result. The aeronautical arm is a new force in war, performing new functions, extending its activities every day and, at present, recognising but few limitations to its possible development. There is, as
yet, no rule-of-thumb method of arriving at a definite and correct allotment of aircraft to an army of given strength. The only safe line on which to proceed is to consider, first, what are the services which the aircraft are to be required to perform? Second, how much of our available resources are we justified in devoting to these services? The answer to the first question shows a list which increases with each successive month of war. The mere propounding of the second will inevitably raise a controversy of which the only possible settlement will be a compromise. The final decision, however, ought to be based on relative value, not on relative numbers.

On the merits of these and other questions raised by Mr. Lanchester, the reader must be the judge. I hope that there may be many readers, and that they will give consideration to their judgments, for, whether they agree or not with the author, they will find here much that is worthy of study and reflection.

David Henderson.
AUTHOR'S NOTE.

The Military and Naval importance of aeronautics, more especially of mechanical flight, has in the past been slow to receive adequate recognition. Even to-day, in spite of the awakening which has been brought about by the Great War, we are far from a full appreciation of the extent to which, as a nation, our destiny will be determined by aircraft and by military aeronautics.

The early pioneers of mechanical flight were but little concerned with the prospective future of flying; they were rightly occupied in overcoming the difficulties standing in the way of achievement. That ultimately a field of utility would present itself was generally accepted as an article of faith. Many suggestions both as to commercial and military usage were put forward, more frequently than not in ignorance of the limitations by which flight as a mode of locomotion is circumscribed: often claims were made of an altogether extravagant character. If it be true that in some directions, from the point of view of those early engaged in aeronautical development, the outlook has proved a disappointment, it is no less certain that military aeronautics has not only fulfilled, but already transcended, the most sanguine expectation.

Without going so far as to claim having predicted or foreseen in its entirety the many-sided utility of aircraft
xii.  

AUTHOR'S NOTE.

as it is to-day manifesting itself, the author can point to the fact that he has in the past taken every opportunity to insist on the importance of dynamic flight in its Military and Naval application. Thus, so long ago as 1897, in a patent specification* in which all the main features of the present day aeroplane were figured and discussed, the proposal is made for an air-borne torpedo, a device to which the first nine figures specifically relate.

Writing in 1907, in the preface to the first volume of his "Aerial Flight," the author expressed his view in a passage as follows:—

"The importance of this matter [provision for the scientific study of aerial flight] entitles it to rank almost as a National obligation; for the country in which facilities are given for the proper theoretical and experimental study of flight will inevitably find itself in the best position to take the lead in its application and practical development. That this must be considered a vital question from a National point of view is beyond dispute; under the conditions of the near future the command of the air must become at least as essential to the safety of the Empire as will be our continued supremacy on the high seas."

And in 1909, the "Morning Post" (May 11th), reporting the 3rd Cantor Lecture delivered before the Royal Society of Arts, quotes the author as follows:—

"He considered that the immediate future of the flying machine was entirely confined to its military possibilities."

Again in the spring of 1914 (a few months prior to the outbreak of war) the author wrote:—†

"Without looking so far ahead as has been attempted in the preceding paragraph,† it cannot to-day be disputed

* No. 3608 of 1897.
‡ The paragraph in question is that quoted incidentally on p. 158 of the present work.
that the immediate future of the flying-machine is guaranteed by its employment by the Army and Navy. It is already admitted by military and naval authorities that for the purpose of reconnaissance an aeronautical machine of some kind is imperative, and its more active employment as a gun-carrying or bomb- (or torpedo-) bearing machine will without question follow: its utility in this direction has already been experimentally demonstrated. In the author's opinion, there is scarcely an operation of importance hitherto entrusted to cavalry that could not be executed as well or better by a squad or fleet of aeronautical machines. If this should prove true, the number of flying-machines eventually to be utilized by any of the great military Powers will be counted not by hundreds but by thousands, and possibly by tens of thousands, and the issue of any great battle will be definitely determined by the efficiency of the Aeronautical Forces."

In addition to the foregoing, the author gave especial prominence to military aeronautics, as presenting the most promising field of development, in his Presidential address† to the Institution of Automobile Engineers, in October, 1910.

The intention to write specifically on the subject of Aircraft in Warfare had been in the author's mind for some years, it was only after the outbreak of hostilities however that this intention came to be realised. The present work may be said to date from its contribution as a series of articles to "Engineering," covering a period from September to December, 1914. The text and order of the original articles have been preserved in the present volume, and thus the matter appears under the dates of its original publication. Revision

* Perhaps an overstatement of the case. Compare § 18.
has, in the main, been confined to ordinary legitimate corrections, the articles having been regarded and treated to all intents and purposes as a first proof. The last two chapters, however, include new matter; they are for this reason undated.

That it is at least desirable to give the dates of first publication is determined by the fact that the ever ready plagiarist commonly has one's writing over his own name almost before the ink of the original has had time to dry. Beyond this the author has no wish to present as a new edition, matter which is more justly entitled to rank as a reprint; he has the satisfaction of knowing that articles in a technical journal, whatever its standing may be, can never appeal to so wide a circle as publication in book form.

*A coincidence such as the following scarcely requires comment.

From an article contributed by a certain writer to the "Westminster Gazette," February 26th, 1900:—

"... that Lilienthal invented a gliding apparatus, which was improved in its structural features and in its method of control successively by Chanute and the Wright brothers, until the latter, by installing a comparatively light-weight motor and screw propeller, achieved, for the first time in history, a man-carrying machine propelled by its own motive power."

From a paper read by the author December 8th, 1908, before the Aeronautilcal Society of Great Britain; as reported in "The Engineer," December 15th, 1908, and as subsequently published in the proceedings of the Society, January, 1909:—

"The gliding machine originated by Lilienthal, was improved especially as to its structural features and its method of control, successively by Chanute and the Brothers Wright, until the latter, by the addition of a light-weight petrol motor, and screw propellers, achieved, for the first time in history, free flight in a man-bearing machine propelled by its own motive power."

Unfortunately, even though one may be morally certain as to the fact, it is not usually possible when broad opinions or the general results of an investigation are taken without acknowledgment, to "pillory" the offender; it is only when concerned with a quite trivial matter of words, as in the foregoing, that an accusation can be brought home. If such cases were clearly deliberate they would morally constitute a theft, since Editors commonly pay according to the space filled, but it is fair to assume that plagiarism of this kind is quite unconscious, what is read or heard one day, masquerades in the writer's mind as inspiration the next.

Occasionally one is fortunate, as the author when his theoretical method of treating the problem of the screw propeller was attributed to Drewiecki in a report in which the author's specially invented terminology was used throughout. Those who misappropriate another man's gold should take the ordinary precaution of throwing away the purse.
AUTHOR'S NOTE.

Looking back to the time at which the original articles were penned, it must be admitted that very great progress has been made, progress not only in the number and quality of the belligerent aeroplanes, but also more generally in the understanding of the potential capabilities of the Aeronautical Arm; the author finds, however, that his own ideas also have developed and expanded; the experience gained has, in a sense, cleared our vision, and enabled us to look still further into the future. Thus, in spite of the great advance, the pressing needs of the future seem in no wise diminished.

The author in conclusion desires to acknowledge his debt of gratitude to Maj.-Gen. Sir David Henderson, K.C.B., to whom the preface of the present volume is due. He counts himself singularly fortunate in having been accorded the support of so great an authority on Military Aeronautics, and feels confident that his gratitude will be shared by those into whose hands this book may fall.

Birmingham,
November, 1915.
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ERRATUM.

P. 179, line 2 from top, *for* "our" *read* "an."
AIRCRAFT IN WARFARE

THE DAWN OF THE FOURTH ARM

CHAPTER I.

(September 4th, 1914).

AIRCRAFT AS CONSTITUTING A NEW OR FOURTH "ARM." THE PRIMARY AND THE SECONDARY FUNCTIONS OF THE AERONAUTICAL ARM.

§ 1 Introductory. All authorities may to-day be said to agree on the broad fact of the utility and importance of the flying-machine or aeroplane—or, more broadly, aircraft—in warfare; but at present the air service as a fourth Arm of the military organisation, either of this country or of any of the other great military Powers, can only be regarded as of a tentative and experimental character.

It is, unfortunately, not yet possible to draw conclusions of a lasting nature from the actual usage of aircraft in the present war, mainly for two reasons. Firstly, the machines at present available (with possibly a few exceptions) are entirely without armour or defence of any kind, and, dirigibles apart, are, generally speaking, without guns or other offensive armament of an effective character. Secondly, the machines are numerically so weak that, as an Arm of the Service, the aeronautical forces are a negligible factor. The question of sufficiency in numbers is evidently dependent upon the point of view
§ 1 AIRCRAFT IN WARFARE.

taken. On the one hand, if we regard the flying corps as merely the successor to the pre-existing balloon corps, the numbers, as they at present stand, may be regarded as sufficient; indeed, perhaps, even liberal. On the other hand, if we would recognise in the advent of the aeroplane the dawn of a fourth Arm (this being the point of view adopted by the author), the present strength, which in no case represents numerically one-twentieth part of 1 per cent. of the number of bayonets, is a truly negligible quantity. In order to get a fair perspective of the position, it is sufficient to institute a comparison with the cavalry, to which Arm, from its function, the aeronautical Arm is most closely akin; here the accepted numerical proportion in a modern army is about 6 per cent. Now there are many otherwise competent authorities who would deny to the aeroplane (or to aircraft generally) the potential importance which the author hopes satisfactorily to demonstrate is its due; let us put the matter to the test. We hear frequent reports of the work done by German aircraft, and particularly the effective tactical reconnaissance of the German aeroplanes, which appear to be continuously employed during the course of every engagement for locating our gun positions, directing gun-fire, following up bodies of troops in retreat, etc. We also hear reports of their wider field of operations, presumably reconnoitring the strategic distribution of the forces of the Allies at points remote from the enemy's lines. We may presume that the Belgian, French, and British aircraft are employed with equal success; but here, in the nature of things, the information which appears in our Press is meagre. As already pointed out, the total number of machines engaged is microscopic; the Germans are reputed to have possessed at the outbreak of hostilities some 500 machines in all. If the German cavalry had been limited to 500 mounted
A NEW MILITARY "ARM." § 1

men, would it have proved of any real utility? Answer is unnecessary. It may be reasonably argued that the capital value of an aeroplane, with pilot and observer, being so much greater than that of a cavalryman, the above comparison is unfair; granting this objection, the position is not seriously altered, the equivalent force would be quite unperceived and be of no tangible service to the German army of to-day.

If, then, instead of the present moment being that of the introduction of the aeroplane (and dirigible), it had chanced to be the moment when mounted men were put on trial for the first time as a fighting force, and presuming the initial trial to have been made on a similarly modest scale, the mounted men would, relatively speaking, have proved a failure, and no one, not possessed of exceptional intuition or foresight, would have had the least conception of the possibilities of cavalry when numerically sufficient, boldly handled in masses and with appropriate supports.

The foregoing does not constitute a demonstration that the air service is in the future destined to become as important an auxiliary to an army in the field as the cavalry of to-day, although this is in effect the belief of the present author. Clearly, if we may judge from the scale of preparation which obtains, it is far from being the accepted view, in this country at least. The difficulty in connection with the present subject is that in order to get the future into true perspective, it is necessary to be able to look forward along two parallel lines of development—i.e., to visualise the improvement of aircraft possible in the near future as a matter of engineering development, and simultaneously to form a live conception of what this improvement and evolution will open up in the potentialities of the machine as an instrument of war. The author does not wish it to be supposed that he is
§ 1 AIRCRAFT IN WARFARE.

endeavouring to lay down complete axioms as to the military future of aircraft of a positive character, or that he pretends to be in a position to formulate a cut-and-dried constructive programme; his intention is rather to give something in the nature of a lead in the direction in which it appears development may be logically anticipated.

§ 2. The Primary and Secondary Functions of the Aeronautical Arm. It is generally recognised that in its employment in connection with military operations a most valuable property of the flying-machine or aeroplane is its mobility; it is mobile to a degree which can scarcely have been dreamt of in the warfare of the past. When, therefore, we look for uses in co-operation with an army in the field in which the aeroplane may show to advantage, we naturally turn to examine the duties at present fulfilled by the cavalry, hitherto the Arm to be employed wherever mobility is of importance. Thus it is well recognised that one of the main duties for which the cavalry have hitherto been responsible—namely, reconnaissance—is a duty to which aircraft are pre-eminent suited. It is at the outset important to realise that cavalry, in face of the improvements in small arms and artillery,* with the advent of the armoured motor-car, and with the greater mobility of the main bodies of troops in modern warfare, have been finding the difficulties of effective reconnaissance continually on the increase. It is stated by one of the greatest authorities on the subject that of the reports sent in by cavalry patrols not more than 1 per cent. are of any use to the commanding officer, usually owing to events having anticipated the receipt of the information; in other words, the whole process of tactical recon-

* Not to mention entanglements of barbed wire.
R.A.F. TYPE B.E.2. As flown at the International Competition in August, 1912. The forerunner of the later B.F.2 Types. Speed: Max. 70 m/h.; not inherently stable.
naissance by cavalry has become far too slow to keep pace with the conditions of modern war.

So far as the author is aware, there has, up to the present, been no serious attempt to work out in complete detail the duties which can be undertaken by aircraft, or to define in specification form by any process of logic the types of machine which will be necessary at the outset to deal with the various duties so postulated. It is necessary to say at the outset, in view of the fact that if to-day we had a perfect organisation based on existing conditions, the first great Power to be similarly equipped would require to be answered in the form of a further equipment especially directed to his destruction, and so (as in the evolution of the Navy) we may in due time have aerial destroyers and "super" destroyers, and again still faster and more heavily-armed machines for the destruction of these.

The primary function of, and basic justification for, any Arm is the execution of its duties in relation to other than its own kind; thus, although it is admittedly one of the first and most important duties of cavalry to drive the enemy's cavalry out of the field, and establish ascendancy, this is actually the secondary function of the cavalry Arm; its primary function is the observation and harrying of the other Arms of the Service. Again, the primary function of a fleet is neither to hold nor defeat a hostile fleet, although this, its secondary function, is universally admitted to be its first and most important objective. Ultimately, in every case, there must be some primary purpose which gives rise to the need for any kind of fighting machine, apart from its power of offence or defence against its own kind; it is this primary purpose that imparts the initial impulse and direction to its development.

It is proposed forthwith to define the primary
§ 2 AIRCRAFT IN WARFARE.

function of the aeronautical Arm as comprised by its duties and actions relating to the three pre-existing Arms of the Service—viz., the infantry, cavalry, and artillery.* Its secondary function is defined as comprised by its duties in the attack on and defence from its like Arm—i.e., the destruction or countering of hostile aircraft.

It is necessary to be perfectly clear as to the above definitions. In considering, in the first instance, the comparative merits of the aeronautical and the older Arms of the Service for any particular duty, as it is needful to do in order to justify, or otherwise, any particular type or usage, it is futile to import into the initial discussion the action or possible counter-manœuvres of the enemy's aircraft; this latter may, or may not, eventually prove an important factor, but its influence, when taken into account, must be studied not only as touching the air service in contemplation, but also at the same time as affecting the other Arms of the Service (more particularly the cavalry) in its corresponding usage. In brief, as a matter of logic, in discussing the functions and duties of the aeronautical Arm, and the type-specifications of machines by which its objects are to be secured, the primary function alone has to be considered. Subsequently, when a provisional scheme and specifications have been formulated, it is time to take count of the secondary function, and to endeavour by careful prevision to forestall the enemy.

* Also the Navy and merchant marine where naval warfare is in question.
CHAPTER II.
(September 4th, 1914).

AEROPLANE versus AIRSHIP OR DIRIGIBLE.

§ 3. Aeroplane and Dirigible: Speed Limitations. Two questions are involved in the consideration of the relative merits of the aeroplane and dirigible. We are firstly concerned with their respective advantages and disadvantages in relation to their primary function—namely, as instruments of reconnaissance, attack, and defence; secondly, we have to take into account their secondary function—i.e., their relative power of mutual destruction; the question whether, for example, either can drive the other from the field, or whether each may have its own rôle to play in securing and holding the command of the air.

Before going into either of these questions in detail it is convenient to review a few of the facts by which limitations are imposed on the ultimate performance of either type of aircraft. We must avoid falling into error by judging each too closely by its performance of to-day.

The all-important question of speed is a matter depending primarily on the lightness (i.e., horse-power per given weight) of the prime mover, and the law of resistance. The horse-power per unit weight of motor is roughly the same whichever type of aircraft is in question, and any future advance in the art of motor construction tending to diminish weight will, we may presume, be equally available for either type. The laws of resistance of the aeroplane and dirigible are
§ 3 AIRCRAFT IN WARFARE.

well understood; in the case of the former the resistance is approximated by a curve $a$ $a$, Fig. 1, representing the sum of a resistance following the $V$-square law and a constant; the latter (the dirigible) may be taken as following the $V$-square law implicitly, Fig. 1, $b$ $b$.

Fig. 1 represents approximately actual values of the resistance coefficients, in tractive effort per cent., in machines of average size as they exist to-day, for the speeds given in miles per hour.*

One salient fact is at once evident; the greater the horse-power available for a given engine weight the greater the advantage in the matter of speed in favour of the aeroplane; the highest speed of flight of an aeroplane attained to-day (through, i.e., relatively to, the air) is already more than twice that of which

* The maximum speed attained by an airship is approximately 50 miles per hour; the maximum in the case of an aeroplane is considerably over 100 miles per hour; thus (Fig. 1) the tractive coefficient in the case of the aeroplane is actually greater than in the case of the airship. The reason for this is that the dead-load in the airship—represented by the envelope and its appurtenances—is disproportionately great, and the proportion of the weight that can be devoted to the motive-power installation is relatively smaller than in the aeroplane. Were it not for this fact the airship would have held the advantage until speeds about 60 miles per hour had been reached and the aeroplane after.
the fastest dirigible is capable. There is every prospect that its advantage in this respect will increase rather than diminish with the march of progress.

Beyond the above, it is well understood that an increase in size is conducive to a reduction in the resistance coefficient; this applies to both aeroplane and dirigible. This fact has been one of the controlling considerations in dirigible design; no dirigible, other than of comparatively large size, has been found to be of real service. It is, moreover, evident that, in the case of some of the large Zeppelins, it will not be found practicable to go very much further in the direction of increase. Here again the aeroplane is at an advantage; we can in nowise regard the aeroplane of to-day as defining the limit.

It is abundantly manifest therefore that the dirigible is at a permanent disadvantage of not less than two to one in the matter of speed.

§ 4. Aerooplane and Dirigible: other points of comparison. The question of range and duration of flight is largely determined by petrol-carrying capacity. In the aeroplane both range and duration depend definitely upon the petrol supply holding out; in the case of the dirigible the same applies to a limited extent; but here the duration and, to a less extent, the distance can be greatly prolonged by reducing the speed to the minimum possible without jeopardising the control. In the dirigible the gradual loss of buoyancy, due to the leakage and escape of hydrogen, is an independent determining factor. Taking everything into account there is not much to choose between the two types of aircraft in the matter of range or radius of action; on the other hand, under favourable conditions, the dirigible has undoubtedly the advantage on the score of duration of flight. The maximum is about 24 hours in
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the case of the aeroplane, against 48 hours in the case of the dirigible. This may be taken as a fair indication of their relative capacity, though of no quantitative value as a guide to what is to be expected under service conditions. The possibilities of the future are here rather in favour of the airship; there is an absolute limit both of range and duration where the aeroplane is concerned.

On the question of storage or housing the advantage of the aeroplane is overwhelming; the aeroplane, especially if furnished with folding wings, can be stowed away in any ordinary shed or barn, or may be anchored in the open without serious risk, whereas the "balloon hall" necessary for the safety of an airship is not only costly, but is an unmistakable landmark for hostile aircraft at 20 miles distance. Again, bad weather affects the storage of an aeroplane but little, whereas the housing or getting out of an airship in a strong wind is a difficult and risky business, even under the best of conditions. A large Zeppelin may sometimes call for the services of 300 men.

The foregoing by no means exhausts the grounds of comparison, but is sufficient for the present purpose. It is scarcely necessary to point out the very great disparity of weight, and, incidental thereto, carrying capacity, between the two classes of machine; the large German Zeppelins have a gross weight, taken from their displacement, of 22 tons (military) up to 35 tons (naval); of the aeroplanes in service, practically all the military machines are less than 1 ton "tare," and most types do not exceed 1 ton gross—i.e., with full complement, petrol, oil, etc.

If we were concerned with the primary function of the aeronautical arm alone, there appears to be no reason to doubt that both kinds of aircraft would have their place; the large air-ship has unquestionable
advantages under suitable conditions: cruising at high altitudes over the battlefield, or over or in the rear of the enemy's lines, and reporting to headquarters by wireless every movement of strategic or tactical importance, it might render the most vital service. It is able to carry a complement of officers trained to observation, capable of giving an accurate interpretation of what they observe, and acting under most favourable conditions, such as are not possible in any existing aeroplane; it can move at some fifty miles per hour, if required, or remain to all intents and purposes stationary; it can follow continuously the course of events from sunrise to sunset, and remain the whole time in touch with headquarters, either for sending or receiving. On the other hand, for bearing despatches, for flying at low altitude within range of shot and shell, as may be necessary for detail reconnaissance or in cloudy or misty weather, for bringing machine-gun fire to bear at some important point or at a critical moment, etc., all these are duties for which the aeroplane is pre-eminently suited, as also for rapidly locating and signalling gun positions, directing fire, and duties of such-like character.

It is more than questionable whether actual fighting is any part of the primary function of a dirigible at all; it is at least becoming apparent that bomb-dropping is an entire misuse of the large airship; the results are incomparably small in view of the means employed, and can never affect decisively the course of any battle or campaign.

It is important to note that though it is possible effectively to armour an aeroplane, at least to be proof against small-arms fire, and that in any case the vulnerable target is small, the dirigible, presenting a mark larger than the proverbial haystack, cannot be effectively
protected. In spite of the fact that injury to the envelope is not necessarily dangerous, it has been reported that such injury has already necessitated a hurried descent into a hostile country, with the effective loss of both vessel and crew. These are the considerations which place the dirigible at a formidable disadvantage when within reach of the enemy's guns.

§ 5. Aeroplane and Dirigible, analogy between Air and Naval Forces not tenable. We may now pass to the discussion of the secondary function of the aeronautical Arm in its present relation—that is to say, we shall consider the question of aeroplane versus dirigible in armed conflict.

At the outset it is desirable to dispose of the much-worried analogy that crops up again and again when the present subject is discussed. Some of the most strenuous supporters of the airship as an auxiliary to the aeronautical service are fond of drawing a parallel between the air service and the Navy, the airship being put forward as analogous or comparable to the battleship or battle-cruiser, and the aeroplane to the torpedo boat or destroyer. In the author's opinion any such analogy is totally fallacious. The effective area of the target presented by an aeroplane is but a few square feet. The effective target area of a torpedo boat or destroyer is more than one hundred times as great. The time during which an aeroplane is visible and under fire, owing to its small size and high speed, is short compared to that of torpedo craft at sea. The armament which a Zeppelin can bring to bear on an attacking aeroplane is confined to that which she can carry on a platform arranged on top of the structure, since the hostile aeroplane making its attack from above

* Added to this, in order to detect the approach of a hostile aeroplane, the sky has to be scanned in the three dimensions of space.
FIELD TENT FOR AEROPLANE: BACK VIEW. Supported by two poles only: Roof ridge formed by stretched wire rope. Designed R.A.F. 1913.
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can manoeuvre to remain in billiard phraseology, “snookered” so far as the gondolas and their armament are concerned. Beyond the above, the speed of the aeroplane is approximately double that of the airship, whereas the speed of a fast destroyer is not more than 25 or 30 per cent. superior to that of a fast and heavily-armoured cruiser or battleship of modern type, and even this advantage is lost in heavy weather.

It will be realised in considering the above facts that the whole analogy breaks down—the continued existence of the battleship or cruiser in the face of torpedo-craft does not in the least degree imply or involve the continuance of the airship as a logical probability.

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§ 6. Aeroplane and Dirigible in Armed Conflict. Having in the preceding sections devoted some attention to contrasting the respective merits and limitations of the aeroplane and airship or dirigible, and to disposing of the false analogy so frequently drawn between the air forces and the Fleet, we pass to the consideration in greater detail of their mutual relationship in matters of attack and defence. Firstly, it is evident that the attack will essentially be on the side of the aeroplane; the dirigible can do no more than act on the defensive. The great disparity of speed alone, whatever armament the airship may carry, settles this definitely; it is within the power of the aeroplane to choose precisely when, how, and where it will engage in conflict. The dirigible, like the submarine, is too slow to run the enemy to earth or to bring him to bay, and, to its disadvantage, cannot, like the submarine, make itself invisible and attack by stealth. Beyond this, its quarry (the aeroplane) is of small size, often scarcely visible at a mile or two distance, and when not actually in the air can be either concealed
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or efficiently protected. Any attempt at aggressive action on the part of the dirigible is totally and completely out of the question; it is, in fact, beyond the conceivable range of possibility.

On the other hand, if the airship is to continue as a factor in warfare at all, it must be able to defend itself against hostile aircraft, and in particular be capable of repelling the attack of the enemy's aeroplanes. Now the only power of defence possessed by a dirigible when attacked by an aeroplane is counter-attack by gun-fire; hence the extent, character, and distribution of its gun armament is one of the most important factors in its design.

In the earlier days of the development of the aeroplane when its horse-power was but little in excess of the minimum required for the bare necessities of flight, its rate of ascent was so extremely slow (if it could be said to have any real rate of ascent at all) that it was commonly assumed that a dirigible, or airship, could seek safety in altitude. To-day, however, many aeroplanes will make altitude at a speed of 700 ft. or 800 ft. per minute, thus being more than able to hold their own with the lighter-than-air machine, and can ascend to over 10,000 ft. altitude (even twice this height has been reached); again having the dirigible at a disadvantage.

§ 7. AEROPLANE versus DIRIGIBLE, means of Attack and Defence. The method by which an aeroplane may most effectively attack a dirigible is a matter that remains for future experience to settle. If the aeroplane pilot is prepared to sacrifice himself, and has at his disposal a powerful machine of modern design, no dirigible can stand against him. Thus, if, as a matter of experience in actual service, men are found of sufficient grit and grim determination to adopt ramming tactics, and to hurl themselves and their craft bodily at the
gas-bag of the dirigible, its destruction is immediate and complete. There is no defence possible against this mode of attack. The crew of the dirigible may not have even the most slender chance of stopping the aeroplane by machine-gun fire; the attack can be made from above by a steep *vol plané* or a vertical dive. In the case of a large airship of the Zeppelin type, even with machine guns mounted "on the roof," the chances of defeating such an attack are remote; the speed of a machine descending vertically, or steeply, is approximately that of its limiting velocity—commonly about 150 miles per hour—leaving a very brief period in which to score a hit. Beyond this, no ordinarily fatal hit is effective under the conditions in question; no injury to the motive-power installation is of the least effect as a stopper, and the pilot is in almost perfect security in his position behind the engine. If by an exceptional chance he should be wounded, he is still able to effect his purpose, unless totally disabled.

The steep or vertical descent is admittedly a dangerous feat of airmanship, but it is not intrinsically dangerous; the risk involved is due to the structural stresses to which the machine is subjected when "flattening out." These, it is well known, may become excessive; any objection on the score of danger has obviously no weight whatever under the conditions contemplated.

It is an open question whether airmen will be found ready to step forward at the critical moment to go to certain death, and so the general feasibility of ramming tactics must for the time being remain in doubt. However, there are many other modes of attack open to the aeroplane pilot, all more or less untried at present; unquestionably also there are still other methods that will in due course be devised. In the case of the non-rigid dirigible, as in the ordinary spherical balloon, it is almost
certain that a hundred or so yards of barbed wire trailed beneath an aeroplane would be a quite sufficient weapon; equally effective would be an incendiary shell, or a rocket, presuming any part of the envelope to be hit. Ordinary small-arm or machine-gun fire is comparatively ineffective, since the bullet holes are, in any case, small, and in some of the modern machines repairs can be effected without coming to earth. However, even rifle fire has proved sufficient to bring a balloon down. It is evident that the weak point of any dirigible or airship is its liability to attack from above; in the non-rigid type, without going to the length of any elaborate apparatus, and without endangering the attacking aeroplane, almost any angular and weighty object dropped from a height cannot fail to be of conclusive effect if it fairly hits the envelope, and likewise in the case of the rigid type—such as the Zeppelin—the structure would not stand up under a blow from, say, a steel bar of any ordinary stock section of 70 lb. or 80 lb. weight dropped from a height of 200 ft. or 300 ft. Without saying that the above are suitable methods of attack, it may be claimed that they fairly indicate the inherent weakness of the dirigible in face of attack by an aeroplane of sufficient power to master it in the matter of altitude. There are methods not mentioned here which are actually in use or in contemplation, but which, for obvious reasons, require to be treated as confidential. It is, however, in the author's opinion, quite unnecessary to carry the matter further; the weaknesses of the dirigible on the defensive are so great and of such a character as to render it quite unfit to remain an active participant in aerial warfare. It may escape for a time, and may render a certain amount of useful service, but only thanks to the circumstance the number of high-powered, fast-climbing aeroplanes is comparatively limited, and to the fact that scientific methods of attack have not
yet been fully worked out or put into practice. However, even to-day, the finest of Germany’s fleet of Zeppelins would be absolutely at the mercy of a modern aeroplane in the hands of a man prepared to make his one and last sacrifice. So fragile and combustible a contrivance as a dirigible, whether rigid, or non-rigid, can never, in the author’s opinion, survive in the face of the rapid development of the aeroplane and the engines of offence with which before long it will be furnished.

Before proceeding to the broader considerations, it has been thought desirable to dispose of the airship as a factor in the aeronautical service—its dismissal being an initial simplification. It is not altogether important whether or not this conclusion turns out to be literally true. It may be that, in spite of all that has been put forward, the large airship may retain some degree of utility; even if this be so, the main conclusions will be unaffected. It is the aeroplane, and the aeroplane only, either as a reconnaissance or a fighting machine, acting independently or in flights or squadrons, which will in effect constitute the aeronautical Arm; and whether the considerations we discuss are strategic or tactical, it is the potential capabilities and limitations of the aeroplane that we require to keep constantly in mind.