

DEVELOPMENT OF AIRCRAFT ENGINES

By ROBERT SCHLAIFER

Preface

THIS is an examination of relations between government and industry in the development of aircraft engines, particularly in time of peace. Its conclusions are based on the study of history; and to permit the reader to verify the author's conclusions or to substitute his own, the larger part of the historical evidence has been presented in detail. The author's discussion of the evidence and his conclusions will be found in Part I; the evidence itself in Part II.

The history of the relations between government and industry arising from the technical process of engine development had naturally to be based on the technical history of development itself. The author's task would have been far easier had he been able to proceed on the basis of an already written technical history of the development of aircraft engines since the First World War, when a genuine industry was first created. Unfortunately, however, no such history is available; in fact, there does not exist an adequate account of even any single portion thereof.

Thus the author was obliged to begin by establishing for himself the technical history necessary for his primary purpose, which was quite different. In so doing he was forced to choose between two possible alternatives. One was to write an outline or sketch of the general history of aircraft-engine development, mentioning the most important achievements but describing them only briefly, and paying no attention to developments which failed or even to successes of relatively less technical importance. The other alternative was to use a kind of sampling procedure, selecting certain episodes or particular lines of development and writing their history in some detail, while passing over other lines of development completely. Preliminary investigation showed very quickly that the administrative and economic problems involved in the development of any one

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engine can only be understood if its whole history is studied, and accordingly the second alternative was chosen.

It must be emphasized that the episodes or chapters of history selected for study were chosen, not because of their importance in the technical history of aircraft engines, but for the light which they can throw on problems of government-industry relations. As a result — to cite a single example — the history of American liquid-cooled engines in the 1930's is presented in considerable detail, whereas the history of American air-cooled engines in the 1930's is only referred to occasionally, despite the fact that American air-cooled engines were used far more widely than American liquid-cooled engines both in the 1930's and ever since.

The history of the development of aircraft engines cannot be learned from documentary sources. Dates, ratings, and such details can be found therein, but there are almost no written records available which throw any light at all on questions of policy, motives, or incentives; and while success or failure can be established to a certain extent from records of production, the reasons for success or failure cannot be learned from that source.

The really significant facts in the history of aircraft engines are recorded only in the memories of the men who made that history. Fortunately, most of the men who made the aircraft engine of today out of the primitive machine of the First World War are still alive, and almost every one whom the author consulted, in both industry and government, was willing to give generously of his time to supply the author with the essential data for his historical chapters. It was especially pleasing to find British, French, and German engineers and executives as willing to help as their American counterparts.

It would be a pleasure rather than a duty to give the names of these men, and particularly of the two distinguished engineers who have spent weeks rather than hours in reading, correcting, and discussing not one but several drafts of every chapter in Part II. Many of these men have requested, however, that their names be withheld, and the author has concluded with genuine regret that it would be not only unfair but misleading to name some of his sources without naming all. The fact that

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he cannot give published credit does not diminish his very deep gratitude to those without whom this study would have been completely impossible.

An explanation is probably due for the author's use of "the Army" for the organization in charge of land-based aviation in the United States. This has been done purely for the sake of consistency: one organization was involved, whether it was called the Air Service, the Air Corps, or the Air Forces, and it was feared that continual changes from one term to another might confuse the reader. McCook Field and Wright Field have been used to denote the engineering center of this organization before and after 1927 simply because no convenient common name seems to exist.

The author is sincerely grateful for assistance, suggestions, and criticisms offered by many of his colleagues, especially Melvin T. Copeland, George P. Baker, Lynn L. Bollinger, Tom Lilley, Arthur H. Tully, Jr., Pearson Hunt and J. Keith Butters. Miss Ruth Norton and Miss Jananne Morse have helped greatly in preparing the manuscript for publication. Finally, the task could never have been completed within a reasonable time without the invaluable assistance of Miss Ruth Sanborn, Curator of the Aviation Collection at Baker Library.

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Soldiers Field
Boston, Massachusetts
October 1949

PART I

Summary

THE development of high-power aircraft engines in the United States from 1919 to 1939 was almost entirely dependent upon the military services, since the commercial market made use of engines which were only modifications, and usually rather slight modifications, of engines originally developed for military use. Because the government had to pay (directly or indirectly) by far the largest part of the cost of developing these engines, it was frequently proposed that the government should eliminate private profit and develop engines itself, in the same way that it developed military ordnance.

Both the armed services — the Army much more often than the Navy — tried on various occasions to develop an engine themselves, but all these attempts were failures, and the record shows clearly that the services were in general incapable of successfully developing a complex finished product such as an aircraft engine. Even if these government engines had not been failures as developments, difficult problems would have appeared when designs of the prototypes had to be modified for quantity production, and still more serious problems would have arisen when government engineers tried to make the continual improvements necessary in any aircraft engine without the production and service experience which can be gained only by the actual manufacturer.

The private firm was the only agency which between 1919 and 1939 showed itself capable of developing aircraft engines rapidly enough to reach production before they reached obsolescence. Because the government was the main market for all types of high-power aircraft engines, and particularly for new types and models, the government had the power to control

even the work done by private firms in all its details, but development was fully successful only when the services gave the firms all possible freedom in deciding on details of design and development. Government intervention in technical details always led to very considerable delay, and often to a poorer product in the end.

The services were obliged, however, to supervise the general technical course of engine development, and on occasion to require the engine builders to follow lines which they would never have followed of their own initiative. As the principal customer of the industry, the government necessarily exercised a large degree of general control simply by the preferences it indicated. When a simple indication of the government's desires did not suffice, and no private firm was willing to carry out at private expense a development which one of the services deemed necessary, that service actively promoted it by development contracts. Since the available funds did not permit the services to support every project for which government support was requested, the very awarding of development contracts obliged the services to decide which of several alternative technical choices was preferable before all the possible choices had actually been tested in practice. The services went even further, however, and sought out firms to develop projects which they themselves had conceived. That this was justified is amply proved by the record. If the services had limited themselves to choosing between projects recommended by private industry, some of the most important steps forward in the history of engines would have been seriously delayed.

Although the attempts of the services to develop their own engines were all failures, the services, and particularly the Army, did make very valuable contributions to technical progress by their research on problems which were being neglected by private firms or for which private firms had not the necessary facilities. The share of the National Advisory Committee for Aeronautics in the research on aircraft engines done by government will undoubtedly be larger in the future than it was before 1939, when by far the larger part of the NACA's work was related to airframes. Nevertheless, the great success of certain

pieces of applied research done by the military services before 1939 certainly justifies the assignment of applied research as one of their regular functions.

The major and the only really important incentive leading private industry to carry out the development of aircraft engines effectively was the prospect of profits on quantity production. As soon as the services had a fairly regular program of procurement of aircraft engines, beginning about 1926, potential profits on production were not only a necessary but a sufficient incentive for a very large part of American development. Disliking the technical interference and the delays commonly involved in development contracts which paid any large part of the total cost of development, the major engine builders preferred to pay most of their engineering expenses themselves. The services made this economically possible by permitting the firms to count development of new models as current overhead and to include it in the cost and price of current models sold to the government. This did not mean, however, that the company's risk was eliminated, since failure of the projects undertaken would have quickly led to cessation of quantity sales and thus to failure of the firm.

The British followed a contrary policy, which amounted in essence to the assumption of all risk by the government. British firms, like their American counterparts, undertook only those projects which they themselves believed most likely to lead to production and profits, but before doing any extensive development they submitted the project to the government and continued with it only if the government awarded a development contract. This contract meant that the government approved the project, and that its eventual failure to prove useful would not be grounds for cessation of government support of the firm.

The American system of development at private risk produced a series of engines which at the outbreak of war in 1939 were roughly equal in military utility to the engines resulting from the British system of development at the government's risk and direct expense. The system of development at private risk and expense seems likely to have been somewhat the less costly

to the government, although definite evidence on this point is impossible to obtain.

Although private risk was effective in the United States in producing development of the most commonly used type of aircraft engine, it did not suffice for certain essential military projects where applications seemed likely to be limited in extent, or where the technical obstacles to be overcome were such that the risk involved was too great for private firms, or where the major engine builders did not believe in the soundness of the project and the only firms willing to attempt it did not have the necessary resources. In such cases development contracts by which the government assumed a large part or even all of the direct cost of the development were absolutely essential if the work was to be done. Even when development contracts were given, however, they were never sufficient in themselves to arouse a real interest on the part of any firm: a belief in the possibility of profits on quantity production was still necessary. Consequently results were far better when the military services made it clear that a worth-while market for a given type of product existed than when uncertainty and instability in procurement plans, largely due to constantly changing personnel, made the size or the very existence of a quantity market dubious. Obviously not even the best prospective market offered any incentive at all if the firm developing an engine had no proprietary rights in the design. The Army on a few occasions tried to have an engine developed by a private firm for a fee while the Army itself retained the rights to the design, but in each case the result was failure.

Even under contracts which gave all possible incentives to the firm, development largely paid for by the government never proceeded so efficiently in the United States as in Britain. The two principal reasons for the difference were the lack of stability in American development programs, again largely due to frequent changes in government personnel, and the excessively restrictive American legal framework, which prevented informal but effective agreements from being quickly and easily reached.

The system under which the American armed forces admin-

istered aeronautical development entrusted the posts where key decisions were made to military officers, and left these officers in these posts for only a few years before assigning them to different tasks. Consequently these executives were often lacking in the personal capacity and preliminary training desirable for these particular assignments, and even when they possessed these prerequisites it was nearly impossible for them to acquire the necessary experience and carry out a consistent long-range program based upon it. In Britain all the key positions in the organization administering aeronautical development were held by permanent civil servants, except for one or two military officers at the very top, and this system seems to have been definitely superior to the one used in the United States. To make a system like the British work in the United States would, it is true, have required both considerable revision of salary scales, particularly to provide higher salaries at the top, and a considerable relaxation of formal regulations on employment and promotion. But if military officers were to be put in charge, those showing real ability should at least have been allowed to make a full career in engineering, and the rewards of that career should have been such as to make it as attractive as any other career in the services.

The American system of administering development did, however, have one feature greatly superior to both the British and the German systems. This was the sponsorship of development by two separate agencies, the Army and the Navy. The first and most obvious result of a separate organization for naval aviation was, of course, that development specially directed at the needs of naval aviation was not slighted in the United States as it was abroad. In addition, however, the existence of two independent agencies meant that the mistakes or omissions of one were corrected in a surprisingly large number of instances by the actions of the other. Whatever may be the merits of the case for unification of the military services in other respects, there can be no doubt that the sponsorship and direction of development by two separate agencies brought results worth very much more than the cost.

Many so-called accessories which are in fact absolutely essential parts of an aircraft engine have often been developed by independent specialist suppliers rather than by the engine builders themselves, and this arrangement has probably been advantageous on final balance. The independent could profit by the combined experience and advice of all engine builders. In the presence of competition the specialist probably had a stronger incentive to improve his particular accessory than an engine builder would have had who was producing the accessory himself, since the specialist's profits depended on the sales of that accessory alone, whereas for the engine builder it was only one of many important parts of the engine. In the absence of competition, however, the development of accessories by specialists sometimes lagged seriously, and in some cases real progress was made only when an engine builder did take over the development of the accessory in question. In any case, no supplier could develop any important engine accessory without the active participation of the engine builder.

By the beginning of the 1940's the services were leaning toward a policy of making the engine builder responsible for the accessories he used in the same way that he was responsible for the integral components of his engine. Such a policy would imply that all technical and financial arrangements with specialists would be made directly by the engine builders; this would have the great merit of eliminating the delays and disputes which arose not infrequently in the 1920's and 1930's, when the services dealt directly with the specialists and often set up specifications which pleased neither the specialist nor the engine builder.

During the period between the two World Wars almost all development of aircraft engines, both that done at private risk and that directly financed by the government, consisted in refinement of well-known basic types of engine rather than genuine innovation in design. The only radical innovation of this period, the turbojet, was backed in its early stages neither by government nor by the engine industry, but by such sources as airframe builders (in Germany) or even venture

capital entirely unconnected with the aviation industry (in Britain). This seems to have been no accident. The successful engine manufacturers properly gave their primary attention to the progressive improvement of their regular product, and the engineers of the armed services were almost equally obliged to concentrate on problems pressing for immediate solution. For this reason the services' policy of giving a hearing to inventors and proponents of radical ideas, even when these men were not connected with established firms, was more than justified.

Since successful producers of aircraft engines believed that their engineering facilities and manpower could be most profitably used in the improvement of their standard products, they were usually unwilling to develop other types of engine even when the government was willing to pay the cost. As a result, liquid-cooled engines were developed in the United States in the 1930's primarily by small firms with inadequate resources and little background of experience, and the earliest development of turbojets was done by such firms in both Britain and Germany, where this type of engine originated. But in almost every case where a development was carried out by a new and inexperienced firm without the resources of the established producers, the development was carried out so slowly that the product either failed to be ready for use before the design was obsolete or barely succeeded in escaping that fate.

Since, however, various essential developments would not have been undertaken at all if they had not been undertaken by these newcomers to the field of aircraft engines, the services were certainly right in not excluding such firms. The services also realized in general that a project was better entrusted to an established producer when one could be genuinely interested. Their only serious error was their failure to realize that if a new firm was to succeed, the first prerequisite was to permit it to put an engine in production and set itself up as a full-scale manufacturer as quickly as possible. The cost of quickly creating a new source of engines in this way would have been very high, but such a policy was the only one which could bring satisfactory results.

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The development of aircraft engines is a highly specialized art. Its complexity and the rapidity with which it advances makes only highly efficient and highly experienced private firms able to compete in carrying it out, and the primary objectives of all policy must be to maintain a sufficient number of such firms in existence, set proper goals for them, and then give them the resources and leave them the freedom required for their work.