OK other than comment below
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JET ENGINES FOR WAR

by
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On occasion of the 10th anniversary of Ground Breaking at the Lewis Flight Propulsion Laboratory, Cleveland, Ohio. Luncheon, January 23, 1951, in Cleveland, Ohio, sponsored by the Chamber of Commerce.

Battle says that 10000# thrust [illegible] [illegible] have never been released to U.S. Question advisability of releasing this info.

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JET ENGINES FOR WAR

Ten years ago today, a small group gathered at the edge of the Cleveland airport to watch the first spadeful of earth dug to symbolize the start of a new laboratory to be devoted to research on aircraft powerplants. The world climate was even more bleak and stormy than it is today. Then as now aggression was on the march. France, Belgium, Holland, Denmark and Norway had been overwhelmed. Britain, almost alone, was waging battle in the cause of freedom. Here in the United States, we were almost a year away from Pearl Harbor, but we were taking the first steps necessary to become the "arsenal of democracy." A most important move among these first steps was construction of the Lewis Flight Propulsion Laboratory.

During the mid-thirties, Hitler had begun his preparations for war, and one of his first moves was to improve the quality of German military aircraft. To this end, aeronautical research both in the fields of aerodynamics and propulsion was sharply accelerated. The German effort, compared with American research for this period, was enormous. Not completely unaware of what was going on across the Channel, the British also expanded their aeronautical research programs.

The NACA noted this acceleration of research in Europe, and within the limits of its facilities and appropriations, did what it could to keep up with the aeronautical parade. In its 1938 annual report, it observed that "the history of 1938 bears witness as to how a nation in the space of a few years, by con - centrating much of its scientific research and industrial resources, on the development of air power, could gain, for the time being, a dominating position." Though the language was restrained, there could be no doubt but that the nation in question was Germany.

The following year, the NACA called attention to "a serious lack of engine research facilities in the United States" and urged the taking of "immediate steps to remedy this deficiency." "Foreign leadership in certain important types of military aircraft" was, for the first time, officially conceded.

Actually, in 1939 the Germans were much farther ahead in the field of aircraft power plants than even the most informed American assessment of the situation. And the British were close at their heels.

On August 27, 1939, the Germans made aviation history by flying a Heinkel 178 airplane powered by a jet propulsion engine. On May 14, 1941, the British independently made more history, with the flight of a jet-propelled Gloster airplane. The Russians have not yet disclosed the date when they first took to the skies, jet propelled; though we can be sure that priority will be claimed regardless of the facts.

Those flights marked the beginning of a technical revolution in aeronautics which has not yet run its supersonic course. They marked the birth of a new race of airplane engines which were to make the best of the existing breeds seem puny.

The story of what has happened to the aircraft engine in the United States in the past ten years is too long to tell at this time. Suffice it to say, our manufacturers made tremendous progress in the improvement of their engines at the same time they were producing power plants in quantities which still seem almost incredible. The United States no longer trails in jet propulsion.

Nor is there time or need to recite the story of the part the Lewis Laboratory has played during the past ten years, as a partner of the military-industry-NACA team.

Instead, let us look quickly at the aeronautical picture of today, and then consider briefly the still greater performance which may be demanded from the engines powering tomorrow's airplanes.

Since October 14, 1947, when the Bell X-1 flew faster than the speed of sound, it has become increasingly apparent that the world was entering upon a supersonic era. What made that flight possible, essentially, was the existence of a jet engine which -- at the speed of sound and at the altitude at which the flight was made -- produced the equivalent of about 11,000 horsepower. To be sure, that Reaction Motors engine was a rocket rather than a turbo-jet, and was ravenous in its use of fuel, but without that power in a relatively very small and light-weight engine, the flight would not have been possible.

Today, hardly three years later, the designers of our newest airplanes are not satisfied with engines of this size. Military security prevents me from saying how much more powerful are our new 1951 aircraft engines, but perhaps you will get the idea when I say that even from such a small nation as Sweden come reports of a turbo-jet engine now being tested which is 66% more powerful than the short-range rocket which powers the X-1.

If tomorrow's tactical airplanes -- first the fighters and, soon after, the bombers -- are to fly supersonically, and that no one doubts, it is only because our engine manufacturers can provide them with sufficiently powerful engines. No matter how much we may learn about the best shape of our faster-than-sound airplanes, we will still depend upon power in quantities that only yesterday would have seemed fantastically great.

A jet engine is fundamentally a device for converting fuel into heat and then developing thrust from that heat. At low speeds, the jet engine is not very efficient; the faster the airplane flies, the more efficient becomes its jet engine. The rocket engine of the Bell X-1 is rated at 6,000 pounds of thrust; the engine reported to be under test in Sweden has a thrust rating of 10,000 pounds. At 375 miles an hour, 10,000 pounds of thrust is equivalent to 10,000 horsepower; at 750 miles an hour, the same amount of thrust is equivalent to 20,000 horsepower. At 1125 miles an hour, it is equivalent to 30,000 horsepower!

A turbo-jet engine of 10,000 pounds thrust develops 225,000,000 b.t.u.'s of heat per hour. In the Washington area where I live, this would be enough to heat about 6500 six-room houses. Making allowances for the brisker Cleveland climate, this should be sufficient to keep, say, 4500 six-room houses warm.

To put it another way, let us compare the energy input to this 10,000 pound thrust turbo-jet engine with that of the new railroad locomotive which has been recently announced. That new locomotive can haul a 100-car freight train at 60 miles an hour. I don't know whether it would be possible to tie them all together in a single train, but the energy input to the turbo-jet engine would be sufficient to pull 300 freight cars at the same mile-a-minute clip!

If one infers from what I have said that our aircraft engines today are as powerful as those of anyone else in the world, perhaps the question will also be raised why we should continue to spend more money and more effort at the Lewis Laboratory to improve still further our understanding of the fundamental principles of propulsion.

Such a question requires a two-fold answer. First, we must key our efforts to the rate at which the enemy progresses with its development of aircraft engines. In Korea, Soviet airplanes have gone into combat which are reported to be as fast, or nearly so, as the F-86 North American Sabre, our best fighter in service there. There is no evidence that we may rest on our past accomplishments.

Second, although we have learned how to design and manufacture immensely powerful engines--turbo-jets, ram-jets, prop-jets, and rockets--we have yet to learn how to make them economical in their use of fuel, and how to make them entirely of the materials which are plentiful in the Americas.

Today's jet engines are like a young man who is full grown but hasn't yet gotten out of adolescence. We don't yet realize fully their potential nor how to use it, but like our young man, we must draft him for military service.

How does a radically new device grow to maturity? Every accomplishment of the human race was preceded by a vision of that accomplishment, and even before that, there was a dream of what could be. Man first dreamt of flying on the back of a bird, and then in his dreams sought to equip his own body with wings. Over the centuries men of vision sought to apply the limited scientific and engineering knowledge of their day to accomplish flight. Finally, at the beginning of the 20th Century, enough knowledge about aerodynamics and propulsion had been acquired by the Wright Brothers to enable accomplishment of the goal, and they made the first successful flight of an airplane at Kitty Hawk in 1903.

But man was not content to fly as the birds. Successively higher goals of altitude and speed were set and reached. As a young man just out of college, I was assigned the task of summarizing the knowledge of the physical principles employed in aeronautics. Such a task today would be impossible, so great and complex has become the accumulation of the aerodynamic and propulsion contributions of many men.

Vision today is guided not only by the experience and accomplishments of the past, but by a specialized and somewhat artificial type of experience known as scientific research. Cultivated and controlled types of experience which we call theoretical and experimental research supply the additional elements which make the vision realizable. Realizable, that is, if the problems to be solved are met with ingenuity as well as the bare facts of scientific and technical knowledge.

Once a concept has been established, once the goal has been determined, theoretical and conceptual ideas must be tested by actual trial. Boss Kettering once asked a Diesel engine, instead of a consulting engineer whether the design of a piston was good or not. In other words, he tried his idea. This is applied research, which may be of a very specific nature directed to limited objectives, or of a very general nature, directed to broad objectives. Such applied research determines whether the bits and pieces of a "grand design" will work individually.

To explain this "grand design" let me compare it to the work of a master architect or a great composer. In the case of the architect, the final result would be the mating of steel and stone and a host of other materials into a structure that satisfied most perfectly the given conditions. In the case of the composer it would be the blending of the characteristics and capabilities of all the different instruments of the orchestra to permit most effective interpretation of the musical score.

In earlier days the conception and execution of a "grand design" for an airplane or an airplane engine could be the almost single-handed achievement of one man. Today, even in the matter of conception, group effort is necessary. The problems now faced are individually so difficult, so complex, and so intermingled with other equally difficult and complex problems that new concepts of team activity and functional coordination are required, and such teams must be made up of specialists with knowledge of more and more scientific fields.

In the field of powerplants, all of the classical branches of science, for example, physics, chemistry, metallurgy, etc., are involved in the work which is being done. For several hundred years, physicists and chemists have studied the combustion processes occuring in gases at rest, and as a result, have derived certain laws regarding those processes.

Well and good. This information certainly is helpful to the modern-day powerplant designer. But the nature of combustion in the sort of high-speed stream of gas which is to be found inside a turbo-jet or ram-jet engine is something else again, and in order to understand more clearly what happens, and to discover the laws which are governing, we must study the subject energetically indeed.

Similarly, the physicist and metallurgist have long studied in detail the properties and characteristics of structural materials for use at room temperature. For some years the characteristics of structural materials for operating at higher temperatures -- say 1000^{o} Fahrenheit -- have been studied. But the jet engine, to be even reasonably efficient, needs to operate at temperatures approaching 1500^{o} Fahrenheit. Knowledge about the characteristics of structural materials for operating at such temperatures is of very recent origin, and is not yet complete. Further, men with vision today are thinking in terms of engines which will operate at temperatures as high as 3000° Fahrenheit. It is obvious that there is still some considerable distance between vision and ultimate achievement in the engine field!

The chemical and physical properties of fuels suitable for use in aircraft engines are being actively studied. One goal is the finding of fuels which will contain more energy per unit of bulk and weight than those presently used. In these studies, in addition to the more obvious possibilities to be derived from petroleum, all manner of combustibles are investigated.

Suitability is not the only factor which must be considered in such work. Availability, too, is important, to say nothing of manufacturing cost. During the last war, American manufacturers turned out 257,000 piston engines for airplanes in a single year. If the present national emergency were to worsen to the point where even 100,000 jet engines had to be built annually, it might be necessary to cut down on the amount of strategic materials used in their manufacture. Columbium, cobalt, tungsten, chromium and nickel are among these strategic materials, and none is now available domestically in sufficient quantities.

There are several ways in which the problem of strategic materials can be eased. The National Production Authority can cut down on the use of such materials in the manufacture of non-defense products. It already has. Cobalt, for example, has been cut back 70% for non-defense use. What will this mean to the civilian economy? For one thing, the cut in cobalt will result in a reduction in the number of bath tubs made, because this mineral is a necessary part of the porcelain that glazes them. The television and radio industries use cobalt. So do the glass makers, to get blue color. So do the paint makers. There will be less of these products, much less. Other strategic materials, diverted to defense purposes, will cause other civilian shortages.

Another possibility is a reduction of the amount of such strategic materials in each engine. If the turbine blades of a jet engine, for example, can be cooled, then they can be manufactured from materials which are more plentiful. Some of the alloys currently being used for turbine blades are more than 90% strategic material in content, so the gains to be achieved could be large.

Turbine blade cooling is the subject of much interest. In addition to learning more about how to cool the blades, using either air or liquid inside the blades, it is important to learn more about how to manufacture the more complicated blade designs which such internal cooling makes necessary. This, incidentally, is one of several aspects of jet engine manufacture in which Cleveland industry would participate actively.

The disk which holds the turbine blades is heavy and contains approximately one-fifth of all the strategic material in a turbo-jet engine. By extensive study of typical turbine wheels, in operation, it has become possible to calculate rather precisely satisfactory strength tolerances which permit substantial weight savings and consequently similar savings in the amount of strategic materials which go into the disk.

Our need is for substantially more power from our engines, with which to propel our airplanes through the skies at still faster speeds. It is inconceivable that we should be frightened by the complexity of the problems faced, and admit defeat. All our thinking in America is toward discovering the ways and means of building turbine engines which will operate successfully at temperatures substantially higher than present-day engines. To this end, new materials are being studied. Combinations of metals and ceramics, called ceramels or ceremets are also the subject of investigation, because they have some promise of standing up under the higher operating temperatures which are desired. Real progress has already been made, but there is much yet to be done.

Let me mention one or two others, among the most urgent propulsion problems. Take the matter of air flow into the engine and out of the exhaust. The Republic P-47 Thunderbolt was one of the top World War II fighters. Its piston engine required 50 cubic feet of air per second. Today, we are thinking in terms of jet engines which will require approximately 2,000 cubic feet of air per second.

It is difficult to visualize how much 2,000 cubic feet of air is, but perhaps this comparison will help. In today's conception of housing design, a bedroom 10 by 12 feet is considered of reasonable size. The jet engines we are thinking about would use up all the air in such a bedroom in less than one-half second. Air in such quantities must be moved efficiently into the engine and then out again. Internal air flow problems today are at least equal to those of the external flow around the outside of the airplane, and both continue to be difficult.

One of the first discoveries about jet engines in flight was that when the airplane reached a high altitude, the "fire" in the engine often went out, as the pilot would say. This forced him to come down to a very much lower altitude to restart his engine. Sometimes he had to make a forced landing if the engine wouldn't start again. This problem was only poorly understood, and threatened to limit seriously the altitude at which jet airplanes could be flown. Fortunately, at about the same time this problem was faced, the Lewis Laboratory had completed new research facilities which permitted duplicating the altitude operating conditions, on the ground. The NACA part in the solution of the problem, in collaboration with industry and the military services, was to determine what caused the flame inside the jet engine to burn unsteadily at altitude, and finally to go out. Next, of course, came steps to improve the burning process at altitude. The progress made has been good; today's jet engines can be operated dependably at altitudes more than twice as high as before this research program began.

In the conduct of its research the Lewis Laboratory has need for all manner of complicated equipment. Most fortunately, many of the original facilities which were begun ten years ago, and which were designed for use in research on the problems of reciprocating, piston engines, could be adapted for use on the problems of the new jet engines. Since then, as the stream of progress has continued to open up new vistas, new and sharper research tools have been acquired.

To name but a few, these include: A laboratory devoted to icing experiments on aircraft and parts; a rocket laboratory; several supersonic tunnels, including the 8- by 6-Foot Supersonic Wind Tunnel, the world's largest supersonic wind tunnel; a high-energy fuels laboratory; a fractionating tower for making special fuels; and a new propulsion sciences laboratory, now under construction. Scheduled for construction soon is a new supersonic wind tunnel which will be more powerful, and larger, than the 8- by 6-foot tunnel.

One aspect about the work of the Lewis Laboratory which makes it unique and of such importance to the nation at this time, I am sure, is that it represents a coordinated, comprehensive, continuing exploration of the aircraft propulsion problem. Other scientists in other places are studying aircraft fuels, and doing good work. Elsewhere other scientists are seeking to solve the strategic materials problem, and making progress. Elsewhere scientists are working on other propulsion problems, and profitably. But here at the Lewis Laboratory all the problems are being considered as parts of a single, over-all problem, and attacked as such.

In fact, the Lewis Laboratory has quite a number of such research tools which themselves are in the "only one in the world" category. As examples, let me cite the 8- by 6-Foot Supersonic Wind Tunnel already mentioned and the Altitude Wind Tunnel in which full-size jet engines can be actually operated under conditions which simulate those at 50,000 feet altitude.

In the conduct of research, as in any of the other steps between dream and accomplishment, group effort today is increasingly important. The solutions for one problem must be such as to mesh smoothly with the other parts of the encompassing propulsion equation.

So, in an even larger sense, the complexity of today's problem calls for group effort, group thinking, group cooperation by the nation's aircraft engine team. The solutions to problems made possible by the better understanding provided by research effort must be sufficiently practicable to be used by the industry member of the team who designs and manufactures the engines. They must be answers which will enable the production of engines which will satisfy the requirements of the military services. The military services, in turn, must make clear to the manufacturers and the researchers what they expect from the engines they want. Must speed alone be the deciding factor? Or must range, which can be obtained only through use of more economical fuel consumption, be all important? Then, finally, there must be sufficient money and brainpower, all along the line if the job is to be done as well as it must be done. We are learning, all of us, how to do our share as members of the team.

In his State of the Union message earlier this month, the President said that the threat of world conquest endangers our liberty and endangers the kind of world in which the free spirit of man can survive. Our men, he said, are fighting in Korea to protect our "right to govern ourselves as a free nation." In discussing the state of perpetual mobilization in Soviet Russia and its satellite nations, President Truman observed that the enemy has both a large air force and a strong submarine force.

That, most briefly, is why today's airplanes and today's airplane engines will never be quite good enough for the United States.

Let me close by reading you the concluding sentences from the President's message:

"Peace is precious to us. It is the way of life we strive for with all the strength and wisdom we possess. But more precious than peace are freedom and justice. We will fight, if fight we must, to keep our freedom and to prevent justice from being destroyed.

"These are the things that give meaning to our lives, and which are acknowledged to be greater than ourselves."

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January 18, 1951