PROBLEMS OF ACCELERATING AIRCRAFT PRODUCTION
18 February 1946.

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CAPTAIN WORTHINGTON:

Gentlemen, we have with us this morning First Lieutenant George Lent, of the Army Air Corps, from Wright Field. Lieutenant Lent had business experience with Arthur Anderson & Co., and with Scovell, Wellington & Co., both of New York City. He taught at the Rensselaer Polytechnic Institute, Troy, New York, and at the University of Vermont, Burlington, Vermont. He was with the United States Treasury Department, Division of Tax Research in 1942 and 1943; then served with the War Department, Air Technical Service Command, Wright Field, as statistician, first as an enlisted man, and later as an officer. There he was in the Manpower Office as chief of the Engine and Components Unit, where he reviewed labor requirements for the aircraft industry and developed measures of productivity in the production of airframes and aircraft engines; supervised the publication of reports on indexes of efficiency; conducted in-plant studies of labor utilization; and made studies of labor area supply. As chief of the Program Analysis Branch, Strategic Plans Section, Logistics Planning Division, Plans (T-5), he developed plans for demobilization of the aircraft industry and developed postwar plans of the Army Air Forces.

Gentlemen, I present Lieutenant George Lent, who will speak on "The Acceleration of the Aircraft Program."

LIEUTENANT LENT:

Captain Worthington and gentlemen: As you are well aware, the aircraft production program was second to none in magnitude during World War II. What I plan is to present first the high spots of the magnitude of the expansion that took place as compared with a prewar base period 1939; second, to indicate the general pattern of the expansion that took place with respect to the acceleration of the prewar industry and the conversion of the automotive industry to the production of aircraft engines; third, to give some idea of the time cycles involved in tooling up for production, the construction of new plants, and so on; and, finally, to summarize briefly the major problems encountered in such tooling up and acceleration of the production of aircraft engines. Time permitting, I should like to present some aspects of the postwar program of the Army Air Forces and the Navy.

I have selected the aeronautical engine as the basis for my discussion, since I am most familiar with it. It is perhaps less romantic than the production of airframes, which we immediately think of when airplane production is mentioned. However, it is no less essential. The resources devoted to the production of aeronautical engines alone amounted to about 25 percent of the total resources devoted to aeronautical production during World War II. Whereas employment at the

peak in the aircraft industry was about two million workers, labor involved in the production of aeronautical engines was about half a million workers.

So you can see the magnitude of the problem involved as compared with the production of airframes, where the airframe company makes the shell, so to speak, of the airplane, installs the components and makes the final assembly of the plane. The total employment in the aeronautical engine industry was about 40 percent of that in the airframe industry alone.

Aeronautical engines, like other components, were procured directly by the Air Technical Service Command. That is, they were not purchased by the airplane companies, but by Army Air Forces (and Navy) which scheduled the engines and awarded contracts to meet the requirements for the aircraft production program. Consequently engine production was scheduled to meet the particular requirements of the many types of planes entering into the over-all aircraft production program, and was limited thereby.

The Nucleus -- In 1939, the period from which the expansion took place, there were essentially only two large companies in the field--the Wright Aeronautical Corporation and Pratt & Whitney Division of United Aircraft Corp. At this time Allison was just undertaking the development of its V-1710 engine for fighter planes. But essentially the airplane industry was dependent upon Wright and Pratt & Whitney.

Pratt & Whitney, located at East Hartford, Connecticut, at this time had a total floor area of about 700,000 square feet. Wright Aeronautical, located in Paterson, New Jersey, had a total floor area of some 900,000 square feet. Allison, in Indianapolis, had approximately 100,000 square feet total floor area--altogether an indicated capacity of about two million square feet, in 1939.

Employment in the industry at this time was about ten and a half thousand. Total production was about 5900 units for the year 1939, with a total horsepower of approximately six and a half million.

Within the space of five years the aircraft engine industry had expanded some forty-one times with respect to the total number of units produced. Because of the greatly increased complexity and horsepower per unit, expansion in terms of output as measured by horsepower was some 66 1/2 times or 6600 percent by 1944, the peak of production.

Employment, taking into account the employment of the prime contractors alone, had increased to some 300,000 from 10,000 in 1939, an expansion of approximately 3,000 percent or thirty times. With respect to productive capacity, the floor areas of prime contractors had expanded from 2 million square feet to 53 million square feet, an expansion of roughly 26 1/3-fold.

It is appropriate to examine how this expansion took place. How do we account for this marvel of production which was achieved over the brief span of five years, starting from the relatively small nucleus of approximately two million square feet and ten and a half thousand workers?

The Pattern of Expansion--Obviously, the prewar industry itself expanded and assumed a large burden of aircraft engine production. Pratt & Whitney alone expanded its floor area from approximately 700,000 to roughly eight and a half million square feet over a period of five years. A large part of this expansion was within the area of East Hartford and was largely financed in the early period by the British and French contracts.

It is significant that we would not have had the nucleus that we possessed in 1939 to provide the basis for future expansion if it were not for these foreign orders. In 1940, for example, eighty percent of the total aircraft production was for export to our allies, primarily to Great Britain and France. France in particular financed the early expansion of Pratt & Whitney and Wright, followed shortly thereafter by the British contracts. By the time the United States entered World War II, however, these expansions were taken over and the responsibility assumed, in large part at least, by the United States Government.

There were various expansion schemes, devised to decentralize production and top new labor markets. Pratt & Whitney, for example, built three so-called feeder plants within a radius of thirty miles from East Hartford. These "shadow" plants supplied many parts that were assembled into a complete engine in Hartford. In addition to expanding its own capacity within the environs of East Hartford to some four million square feet, Pratt & Whitney later constructed a branch plant in Kansas City. Financed by the Navy this was one of the largest plants in the country, of about four million square feet.

Now, in respect to the expansion of the prewar companies, there was a very significant clash of policy, you might say, between the Government and the aeronautical engine companies. Pratt & Whitney, very wisely, as it developed, adopted the policy of licensing aircraft production with the automotive industry. As opposed to this, Wright Aeronautical Company pursued the policy of establishing branch plants and increasing subcontracting, so that Wright Aeronautical Company management would be responsible for the final assembly and the production of essentially all the engines developed by that company.

How did this program develop? What direction did it take, and what were the results?

By the middle of 1940 Pratt & Whitney licensed Ford to produce eight hundred engines a month. Shortly thereafter Buick was licensed and started the construction of an enormous new plant, followed by the licensing of Nash Kelvinator and Chevrolet. In addition, several smaller companies were licensed for aircraft engines and components. As a

result of this policy, only thirty percent of the total output of Pratt & Whitney engines were produced by that Company, over the total period 1940-1944. One percent of its production was accounted for by its branch plant in Kansas City, which was started rather late; 29 percent was accounted for by Pratt & Whitney's own production in East Hartford; and approximately 65 percent by Nash, Buick, Ford, Chevrolet, Continental and Jacobs--six licensees. Pratt & Whitney very reluctantly undertook the management of the Kansas City plant when no other company could be induced to operate it.

In contrast, Wright Aeronautical Corporation very early in 1940 was opposed to licensing production of its own engines. The result was that it started off with a vast subcontracting program whereby Studebaker, for example, was brought into the production of parts going into the final assembly of Wright engines. However, under pressure from the Army Air Forces, Studebaker was very shortly converted to production of a complete engine under a prime contract. Continental was also licensed to produce a trainer engine, used most extensively, however, in tanks.

At the same time Wright undertook the expansion of its own plant in Cincinnati, Ohio, up till then the largest industrial plant in the country, and exceeded only by that of Dodge later on. A year or so later Wright constructed another branch plant in Woodridge, New Jersey, for the production of the R-3350 engine for the B-29 airplane.

Later on, as the B-29 production became paramount and received highest priority in production in the country, Dodge (or the Chrysler Corporation) was engaged to undertake the production of aeronautical engines in Chicago, involving the construction of the largest plant in the country, with a total area of about six million square feet.

As a result, Wright Aeronautical Corporation had only two major licensees as compared with six of Pratt & Whitney. It operated two vast branch plants in addition to its own home plant in Paterson, New Jersey, which produced about 75 percent of all Wright engines built during the war.

Experimental development--Now, it would considerably underestimate the contribution of the aeronautical engine industry, to our aeronautical program if we overlooked the vast developmental and experimental work assumed by these prewar companies, not only Pratt & Whitney, Wright and Allison, but also Packard.

For example, as many as three thousand workers of a total of thirty-five thousand employed at East Hartford were involved in experimental and developmental work. At the outbreak of the war in 1939 Pratt & Whitney, had only one service-tested aeronautical engine suitable for combat, the R-1830. At that time it was involved in developing a new and large engine, the R-2800. It had also been undertaking the improvements to earlier models which proved to be very important later

on. Over the period of five years Pratt & Whitney developed several new engine types including -- the R-28 0, which went through several developments itself, the A, B and C engines, the last of which was radically different from the first engine.

After the war started Pratt & Whitney developed the R-2000 which was designed for the C-54, as you probably know. And finally, it produced the R-4360 engine, of 3000 horsepower (since stepped up to 3600). While this engine never saw combat, a considerable amount of Pratt & Whitney's resources were devoted to its development, the largest radial engine in the world, and which is only now going into quantity production.

The experience of Wright was similar. Perhaps its major contribution was the R-3350, the largest engine used in combat which powered the B-29 super fortress.

I am passing over the development of jet engines which never saw combat. The responsibility for the initial development of these engines in the United States was undertaken by General Electric. I am concerning myself only with the aircraft engines that actually saw combat.

Requirements for the Allison engine did not necessitate more than Allison's own production effort in its expanded plant in Indianapolis. There were no licensees, no branch plants. However, General Motors companies, heavily involved in the production of parts which Cadillac is one example, were assembled by Allison.

In 1940, as I have indicated, the Allison V-1710 was the only in-line liquid-cooled engine in this country, and the Army and the Navy were switching over to the use of the radial engine for pursuit ships. On the other hand, the British were strongly in favor of the in-line engine. Of several types the Rolls Royce engine was most universally used by the British, being installed on the Mosquito and Lancaster bombers.

In order to meet their rapidly accelerating requirements, in 1940 the Packard Motor Car Company entered into a contract with Great Britain for the production of the Rolls Royce engine. When we entered World War II this expansion was underwritten by the American Government jointly with the British Government.

You might say that Packard was a licensee of a British licensor company for the production of its in-line engine, giving us two in-line engines which we could depend on for our pursuit planes. However, I would rather call Packard a licensor, because of its development in perfecting the Rolls Royce Engine and bringing it up to its high stage of efficiency. Before the end of the war this engine was essentially an American product.

So, to summarize, we had four licensor companies, three of which were prewar--Pratt & Whitney, Wright and Allison--and Packard, which we

may also consider a licensor; approximately eight or nine licensees, most of whom were Pratt & Whitney licensees and only two of which were licensed by Wright.

It is rather interesting to note that, as a result largely of Pratt & Whitney's licensing system, not by reason necessarily of any inherent superiority of the engine itself, the total production of Pratt & Whitney engines over this period of four years was approximately 50 percent greater than the production of the Wright engines. It is known that the Pratt & Whitney engine was substituted in at least one plane where the production facilities for the Wright engine, for which that plane was designed, were not available and could not be made available in time. That was Pratt & Whitney's R-2800 used on the Curtiss Wright transport plane, the C-46 Commando.

Subcontracting--Now, I do not want to ignore the contribution made to this aircraft production program by the subcontracting system that was evolved. Roughly 30 percent of the total aeronautical engine output is attributable to subcontractors. This is exclusive of the production of aircraft engine accessories, such as superchargers, magnetos, ignition harnesses, fuel pumps, and various other accessories that are essential to an aeronautical engine. I do not consider them part of the aeronautical engine production process, but something accessory to it. All these items were produced outside of the aeronautical engine industry itself. General Electric and Allis Chalmers, for example, made a very high percentage of the superchargers used.

Virtually every firm in the program, particularly the prewar licensor companies, was heavily involved with subcontractors. Companies like Buick, Chevrolet and Dodge were considerably more integrated, however, than the prewar aeronautical specialized engine companies. Whereas the subcontracting, for example, of Pratt & Whitney was roughly 50 percent, the subcontracting of a company like Ford and Chevrolet was only 15 to 20 percent.

An excellent example of the subcontracting program is provided by the Wright Aeronautical Corporation. As I indicated before, its early policy of expansion was based largely on subcontracting. The Lockland branch plant had a contract for the production of the R-2600 engine, widely used by both the Army and the Navy. However, the Lockland plant produced approximately only 40 percent of the complete engine. It had magnesium and aluminum foundries to produce the castings necessary. In addition, the Lockland plant machined the cylinder barrel and cylinder head. It made most but not all of the gears. And, of course, it did the final assembling and testing of engines, involving approximately 20 percent of the total man-hours involved in the production of an aeronautical engine.

Supplementing the Wright Aeronautical production at Lockland were the Ohio Crankshaft Company, which made the crankshafts; the Otis Elevator Company, responsible for all the crankcases; Hudson Motor Car Company which manufactured pistons and rocker arms for the engines; the Eton

Manufacturing Company, which made propeller shafts; and the Graham-Paige Automobile Company, which was responsible for manufacturing most of the articulating rods for the engines. These five vendors were an integral part of Wright Aeronautical's engine program. Other items were procured as essential government-furnished equipment by the Air Technical Service Command and shipped directly to the aeronautical engine companies for installation.

There is no clear pattern, however, so far as subcontracting is concerned. Whereas the Wright Aero Company made its castings, had its own aluminum and magnesium foundry, Pratt & Whitney Company, on the contrary, made none of its castings and had no foundries whatsoever. Neither company made its own forgings. So there was really no definite policy as to what processes were undertaken by the licensor plants and which were not.

Construction and Tooling Phases--Passing on, I should like to give some idea of the problems involved in expanding, constructing and tooling up a new plant, such as a licensee plant for the production of such a highly complex item as an aeronautical engine.

Approximately three quarters of the total capacity of the prime contractors involved in the aeronautical engine program was contributed by new expansion and not by conversion of the existing facilities of these companies. Despite the size of the Ford empire, the Chevrolet or Buick plants every one of these companies was forced to expand quite considerably.

Before going into the production of aeronautical engines Buick constructed a new plant in Chicago of some two and a half million square feet; Chevrolet added approximately one million square feet to its own plant; Studebaker approximately two million square feet; and the Dodge plant in Chicago, the largest expansion of all, was approximately six million square feet. Practically none of Chryslers own plant was used to make aeronautical engines, the R-3350. By the time the Chrysler Company entered the program, its plant was pretty absorbed with ordnance production as well as other aircraft items and as a result an entirely new factory had to be built.

Based upon an analysis of twelve or thirteen expansions, involving an increase of floor area from one million to six million square feet each, our wartime experience shows that an average of fifteen months is necessary for the construction of new plants and their tooling up for production of an aeronautical engine. There is considerable variation in the experience of these different companies; but roughly it is safe to say that the gestation period of the tooling-up period for the production of an aeronautical engine took well over one year.

Dividing it into the major phases of this expansion, from the time of project approval to the actual ground breaking for the construction of a new plant, three full months time was taken up in preliminary negotiation. Time was involved in selecting and acquiring a plant site,

in selecting architects, designing the plant, and in granting contracts for construction. Three whole months were involved before the ground was actually broken, on the average, in these expansion programs.

Approximately two months additional were involved up to the time of the erection of the first steel; and before the first machine tool could be installed in that plant approximately eight months had elapsed. Again, these are all average figures. There was considerable variation in the experience of the different companies.

After the installation of the machine tools the plant was not yet ready to begin production. Since tools must be installed, the plant laid out, and machine tools set up by skilled mechanics for the initial production of parts of engines, an additional one and a half months are involved after the installation of the machine tools before production was actually started. By "production" I mean when the first direct man-hours were applied and the first chips began to fly.

From the time of the start of production approximately five months were required for the machining of parts, their assembly, testing, teardown and final assembly of the first engine produced.

General Knudsen used to remark: "Whether in peace or war it still takes nine months to produce a baby." It takes well over a year to produce an aeronautical engine involving the construction of a new plant. However, it should be noted that, once the plant was established and ready to go, a licensee, or a licensor company for that matter, could greatly expedite the tooling up phase of a new engine once they had that experience.

To give a very pointed example of that, the Chevrolet Motor Car Company, one of the most efficient producers in the automobile industry, took approximately twelve months for the tooling up and production phase of its first engine, the R-1830. However, when it undertook production of the R-2800 in 1944 Chevrolet had gained enough experience to tool up and produce the first engine in six and a half months, setting a record for all companies, licensee or licensor, in the production of an aeronautical engine.

This period of fifteen months involved only the production of the first engine. An additional sixteen or seventeen months were involved in accelerating production to capacity and building up the "float" or work in process essential to achieve that level of production.

That seems like a long time too. However, in that respect delays are not attributable so much to the aeronautical engine companies themselves as they are to Government, or the Army Air Forces in particular. During this period the Armed Forces were expanding their requirements and constantly raising the sights of the aircraft program. Consequently, the prime contractors were continually forced to revise their goals and, delays were involved in successive reorganizations of production involving new expansions.

Tooling -- Now, I would like to pass over to the problems involved in tooling. It is obvious, of course, that the tooling program was parallel with the program for construction of the plant itself. The two could proceed hand in hand. While the plant was being constructed by the contractor, the automobile company or the licensor could proceed with its own tooling. It was necessary to design and fabricate tools from blueprints, have special machine tools constructed, lay out the plant for line production, install the machine tools, and set them up with proper tooling before the company could proceed with aircraft engine production.

Very frequently, although not always, the actual fabrication of the tooling, jigs, dies and fixtures was farmed out by the prime contractor, with specialized tooling companies. Most of Studebaker's tools, for example, were fabricated by outside vendors; and practically all of Dodge's tooling was designed and fabricated by others.

Major Factors of delay -- Now, just the high spots of the problems involved, running down the list. I see the time is short.

One of the crucial problems involved in the expansion or construction of licensee companies was the process of transferring engineering information itself. This entailed blueprints and process cards by which the licensee company was enabled to proceed with the design of tools, the ordering of machine tools, and the purchase of materials and supplies.

Transfer of engineering information between engine companies however, was not nearly so serious a problem as the transfer of engineering information in the airframe industry. The aeronautical engine companies, it should be noted, had some prior experience in this transfer of information in the sale of its designs to foreign countries--not only our allies, but our enemies as well. They had thus been able to perfect a comprehensible blueprint containing the necessary specifications, dimensions, processes and so on involved in the construction of the engine so that the transfer of this engineering information did not present too much of a problem.

However, the engineering drawings were inadequate for the job shop methods of the automobile industry. In other words, while the drawings could be read, they were not adaptable to the particular type of line production or high-quantity mass production to which the automobile companies were accustomed. So the automobile companies, such as the Chevrolet Company and others, had to practically rewrite the drawings, with the result that, for example, only two percent of the Pratt & Whitney drawings were used by Buick. Not that the drawings were illegible or could not be read, but they just were not adaptable to the shop practices of the automobile companies. So considerable time was consumed in redrawing, and it is known that such redrawing did delay production to some extent.

The Packard Motor Car Company experienced the most trouble in this respect, since it was faced with the problem of reading foreign drawings. Even though they were British drawings, they were entirely foreign to American patterns. The drawings were not only illegible, not only did not conform to American shop practices, but they were simply incomplete

and inadequate. Packard had to completely redraw the designs, convert them from the metric to the American scale, and adapt the parts to American production techniques. So it was virtually a new and redesigned engine by the time Packard was through with it.

Secondly, there were problems involved in facilities, plants and machine tools. However serious it may have been at the time, it is difficult to attribute any significant delay in the program to failure to receive machine tools.

The most serious problem with machine tools was in the procurement of special machine tools which had to be built to specifications. However, companies were able to improvise and to substitute general-purpose machine tools pending receipt of the special machine tools. But a considerable amount of expediting had to be done. Thanks to high priorities given the Army Air Corps procurement of machine tools and construction of plant did not significantly delay production.

Materials were not a serious problem after 1943. By 1943, with the introduction of the Controlled Materials Plan, the materials distribution allocation program was pretty well worked out; so that very few difficulties were presented. There were difficulties however, in the securing of castings and special materials among other things, but nothing very critical.

Finally, manpower did not become a problem until the latter part of 1943. However, it was not so much a problem of acquiring the necessary warm bodies, you might say, as it was a matter of engineers, and other necessary skills such as die sinkers, machine setup, men, foremen and specialists, that are necessary for this highly technical work. The machines themselves were so designed that they were practically push-button affairs, and untrained, unskilled workers could use them, with the result that as high as 50 percent of the labor employed in the plants was unskilled female workers. The need was for a nucleus of skilled mechanics to set up the machines, die sinkers, pattern makers, and so on.

Finally, the over-all management limitations, you might say, generally set a ceiling or limit on aircraft production. That was brought forcibly to our attention in one situation after another. The wisdom of the Pratt & Whitney policy with respect to licensing companies was exemplified in this respect: that it exploited a highly developed organization of managerial skills in companies like General Motors, Ford, Dodge and Studebaker and others and to apply those skills to a product of which manufacture was essentially similar in kind, if not in degree.

The specialized companies themselves did not do so badly. Although Wright Aeronautical, as you know, bogged down quite considerably at one period, it was able to pull itself out after a shift of management. But there is no question that the aircraft program was limited by the availability of management. Had we had more highly skilled men of the required broad scope and ability, the aircraft program might have exceeded even its most miraculous accomplishments.

Obviously, I have already run over the time and I will have to cut this short, but there may be a few minutes left for questions, if you would like to raise any.

A STUDENT:

I understood you to say that you were able to simultaneously do plant construction and tooling. Then again I understood you to say that in the machine tools in some cases you had to use general-purpose tools where you had expected special-purpose tools. Did you throw that tool away?

LIEUTENANT LENT:

These special-purpose tools were constructed by the machine tool companies and fabricated by the machine tool companies rather than by the licensee or the aircraft engine company itself. Companies such as Buick and Ford were able to fabricate their own tooling which replaced that special tooling and to apply it to its own general purpose, nonspecial machine tool use. When no longer needed, of course, this tooling was abandoned.

A STUDENT:

Maybe it was because of too high priorities, but we found that we could not depend on getting these special type machine tools at the same time that the plant was being built.

LIEUTENANT LENT:

In other words, it was not possible to acquire machine tools parallel with the construction of the plant itself?

A STUDENT:

No, sir. Not to install in the plant.

LIEUTENANT LENT:

I should say generally that the Air Forces were able to accomplish that, but not without considerable improvisation and substitution of one machine tool for another. But it was difficult to attribute any delay except in one or two isolated cases to failure to receive machine tools. Dodge apologized, you might say, for the long time required to get into production by claiming that it did not receive the machine tools believed necessary to go ahead and produce--in spite of the fact that the Army Air Forces called attention to the possibility of improvising and using other machine tools on hand to fill the gap while waiting for those thought necessary. Of course, it took time to get the specials, but this did not delay production necessarily.

A STUDENT:

I have one other question. You also made the statement, at least I understood you to say, that you had difficulty in getting companies to transfer engineering information.

LIEUTENANT LENT:

Yes.

A STUDENT:

Did you at any time during the war period attempt to use industrial integrating companies? If you did not, did you have access to specific machine tool groups in one plant where another plant was running short?

LIEUTENANT LENT:

Not to any extent, to my knowledge.

With respect to transferring engineering information, in the B-17 program we had the so-called BVD committee, which was a more or less control committee for the exchange of information. It acted as a focal point for the interchange of that information. It was composed of a representative of Boeing, Douglas and Vega (or Lockheed). That was used as a medium for transferring engineering information.

Now, in the aeronautical engine industry Wright set up a teletype system for the transmission of engineering information. In the case of the Pratt & Whitney licensees, Chevrolet, for example, sent a team of men to Pratt & Whitney, who remained there for practically the duration of the war and simply acted as intermediaries or liaison for the transfer of such engineering information.

A STUDENT:

What did you call those committees?

LIEUTENANT LENT:

BVD.

A STUDENT:

What does "BVD" stand for?

LIEUTENANT LENT:

Boeing, Vega, and Douglas. That was also used in the case of the B-29 program. All those companies involved, such as Chrysler, Bell, Boeing, Martin, Fisher Body, etc. were associated in a committee.

A STUDENT:

Captain Worthington, it appears to me that a part of this outline has not been covered. It contains a lot of interesting information for us. Is there any chance that we may have Lieutenant Lent say something about that?

CAPTAIN WORTHINGTON:

Could you go ahead with it?

A STUDENT:

Not that I look forward to a prolongation of the hour, but I do think there is some important information there that we would like to hear.

LIEUTENANT LENT:

Shall I proceed?

CAPTAIN WORTHINGTON:

Yes.

LIEUTENANT LENT:

The point is that the Army Air Forces for that matter finds itself in the same position that it found itself in before, when England, France and other countries came to our rescue and were largely responsible for building up the industry to at least a reasonable size nucleus from which we could expand more rapidly.

Now, the Army Air Forces' aircraft program will be approximately what is indicated in this table. I do not know whether you all have copies of the table or not--"The estimated postwar level of the industry." I should not limit myself to the Army Air Forces, because it contains the program of the Navy as well as estimates for commercial aircraft production. Here it is estimated that if the Air Forces, Bureau of aeronautics and commercial production continue as we project them, the estimated postwar level of the aircraft engine industry will be approximately as represented or estimated on this sheet of paper. In other words, the number of units, so far as the level of production is concerned, will be approximately as high as it was in 1939. In 1939 the production, you may recall, may be attributed 75 or 80 percent to foreign export orders.

I have ignored the export orders in my estimate of the postwar production. The output is measured by horsepower. Obviously the aeronautical horsepower was accelerated very rapidly in every unit. It was raised some eight times the level that it was in 1939 to an output of 49 million horsepower a year.

Now, that is attributable not only to improvements in the conventional engine, the largest horsepower which we have now being 3500 horsepower, but

also to the jet gas turbine engine, although it is difficult to translate them into terms of horsepower. Assuming that one pound of thrust equals one horsepower at 275 miles per hour, we now have an engine with a horsepower of approximately 5 thousand horsepower per unit. Engines are now being made by General Electric and General Motors with ratings in the neighborhood of 4 or 5 thousand compared with 1200 horsepower for the engine that went into the B-17. So the horsepower output is being stepped up quite appreciably.

With respect to the nucleus of know-how or management which will provide that base for expansion, if another emergency arises--and by "emergency" I mean war, of course--we could expect to have a base of some 36,000 workers in the aeronautical engine industry, exclusive of subcontractors. It should not be overlooked that, although Wright and Allison, General Electric and Pratt & Whitney anticipate some subcontracting, the same as they have in the past, these figures are limited to prime contracting. With General Electric, Westinghouse, Allison, Wright and Pratt & Whitney and others we can expect to have some 36,000 employees or three times the level of 1939.

Although it is difficult to estimate floor area, these figures are based on requirements assuming one shift operation of 250 square feet per worker. I think that the floor area or plant capacity, that is, the plant area or estimated plant production, would be expected to be in the neighborhood of ten million as compared with two million prewar.

Obviously, if such an Air Force program develops, and the Naval aircraft program and the commercial expansion assume the level of what is now shaping up, we shall obviously be immeasurably better prepared for some future emergency if these estimates are anywhere near correct, as I think they are. They were based upon consultations with the companies themselves.

Now, the great bugaboo of industrial planning is the rapid obsolescence of aircraft. This (indicating) shows the trend of the Air Forces so far as production is concerned. That is what makes it so difficult and almost impossible to undertake any future planning at all, because there are such rapid technological changes taking place within the industry. We can never really know just how things are shaping up five or ten years from now, and certainly we would like to plan that far ahead.

We have developed jet engines. Nobody can be sure whether they will be universally used in five, ten or fifteen years for commercial transportation. Lockheed says fifteen years, somebody else says ten, and others say five. It depends largely upon how fast the funds flow into research and development; whether that research and experimentation is telescoped into a period of two years or whether it is spread out over a longer period of time.

However, it is rather certain that the conventional engine, as we know it, is rapidly becoming obsolete. It is extremely likely that within two or three years fighter planes will be powered exclusively by jet engines.

With respect to the gas turbine engine, the progress is just as rapid, of course. The gas turbine is nothing more than the application of a propeller to a jet engine. It is very likely that the gas turbine propeller driven engine will replace the conventional engine in commercial transportation within ten years--for long-distance flights. That is almost certain if the present trend continues since it is the most economical at those ranges and the most economical at the altitudes that we propose to fly--45,000 feet. It is or will be just as economical so far as fuel consumption is concerned.

Despite the rapid progress in new technological developments in this field, and despite an Air Forces military personnel of 400,000, it is still necessary to go a step further with respect to preparing ourselves for mobilization of, say, the automobile and refrigerator industries in the event of another emergency. Not only must we have an adequate aeronautical engine industry, but we must be prepared to mobilize American industry as well. And we must have up-to-date at all times, complete, accurate and legible, standardized engineering drawings which will enable most any company to take those drawings and to design tools and fabricate tools at its plant and go into substantial production at very short notice.

These mobilization plans involve not only blueprints, of course, but they involve tool design, having up-to-date tools designed for quantity production, and, not necessarily although desirable, by peacetime tooling designed and fabricated on a quantity basis. Obviously we are not going to have the same kind of tooling for a rated production of 30 a month that we would have for 300 a month. If the companies produce only two or three different engines in the postwar period at a rated production of 300 a month or something of that order, they would have developed tooling and the tools necessary for duplication of that tooling which will facilitate expansion of output in the quantities required.

In addition to that, we need bills of materials to enable us to estimate our material requirements and the capacity essential in the raw materials industry. Also the labor required, the machine tools, the floor area and so on. It is purposed to develop these plans, keep them up-to-date and on the shelf, ready to be put into effect very rapidly as the sign of emergency.

In addition to these production plans the Army Air Forces and the Navy have a program of stand-by plants for the production of aeronautical engines. They are now proposing to acquire some of these plants, which will enable the Government to commandeer or to requisition them from whatever private company is operating them within a period of thirty to sixty days for the production of aircraft.

In addition to that it is proposed by the Army and the Navy and approved by the War Department, and, I believe, the Navy Department, to retain in stand-by, some 65,000 general-purpose machine tools, which will enable us to relieve the load at least on the machine tool industry in the event of rapid tooling up and expansion if the war clouds come again. However, I believe there is a program which will take up a more thorough discussion of these mobilization plans at a future date, so I will close.

CAPTAIN WORTHINGTON:

I wish to thank you, Lieutenant Lent, for a most interesting and instructive presentation.

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(6 June 1946--200.)S