

50,000 planes a year? . . . Doubters said it couldn't be done. . . . The President said it had to be done. . . . And it was and more. . . . Franklin Roosevelt's call to arms in preparation for American involvement in World War II stirred vigorous response, and incredible performance, from the small and neglected US aviation industry, which, by the time the war was over, had achieved a war-winning production miracle. Starting out with inexperienced management, "green" personnel, and facilities geared initially to turn out tens—not tens of thousands—of aircraft, the industry guided itself through a complete metamorphosis from one-part-at-a-time "job shops" in 1938 to massive assembly lines that were exceeding government schedules by 1943. In the process, a unique government-industry equal partnership was built that has proved vital to national security in the decades since victory . . .

Industry and World War II—

By Karl G. Harr, Jr. PRESIDENT, AEROSPACE INDUSTRIES ASSOCIATION

I DON'T know how, but I have a *feeling* it can be done." These were the words of a Boeing engineer in connection with a World War II developmental problem. They might well have been the motto for the entire aircraft industry, confronted with a war assignment of building planes in unprecedented numbers under conditions that imposed one roadblock after another. To the leaders of the young industry, which had limped through the mid-thirties with very limited orders, the production demands of the government seemed all but impossible to meet. Nevertheless, the industry approached the task with what might be termed intuitive optimism, a *feeling* that it could be accomplished, even though the evidence pointed to the contrary.

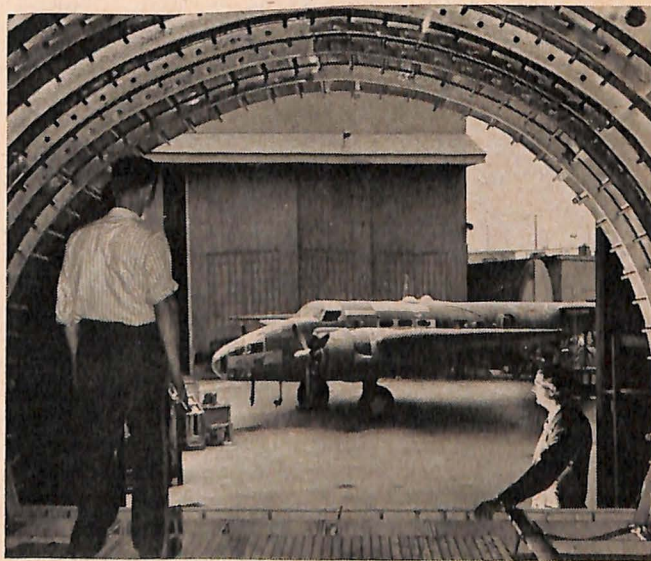
The demands were not only met—they were exceeded. A substantial share of the credit belongs to firms that had little or no experience in building aviation products. They made enormous contributions to the over-all effort; one of them—Ford Willow Run—turned out the greatest airframe weight ever produced by a single plant in a single year. Others had similarly impressive records. In addition, the accessory manufacturers—the firms building a vast variety of products such as instruments, landing gears, and hydraulic and pneumatic systems—moved with great effectiveness in performing their role as a vital part of an unexcelled development-and-production effort.

The war production story is familiar in terms of numbers. The industry turned out more than 300,000 aircraft during the war years, 95,000 in a single year. Airframe weight produced topped the two-billion-pound mark; engine deliveries totaled more than a billion horsepower from 1940 through 1945. In terms of production dollar value, the industry leaped from forty-fourth rank in the national economy to first.

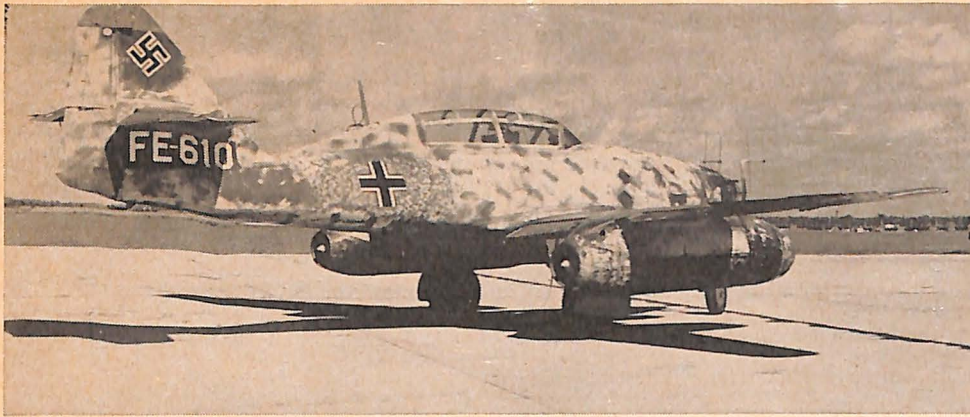
These are truly impressive figures. They tell a statistical story of a production achievement unparalleled

in industrial history. But, as is so often the case with statistics, they only hint at the story: The *how* of the accomplishment, the myriad difficulties that had to be surmounted, the willingness, resourcefulness, and dedicated responsiveness to challenge on the part of the industry's people, which made possible the achievement, make up the rest of the story.

Had it simply been a case of "cranking up" a production machine already in being, accelerating deliveries of tested, proven aircraft by the addition of personnel and tools, the industry's job would still have been a mighty one. But the mass-production machine did not exist; it had to be created. There were too few tested aircraft types available; there were too few skilled people, too few facilities, too few tools.



The 1938 British order for 200 Hudson bombers was a record in the industry for the prewar period, but scarcely any indicator of the production miracles to come during World War II. Above, the last of the Hudsons rolls off the line.



Because of early indecision on priorities and Hitler's insistence that it carry bombs, the ME-262 jet fighter was not put into serial production early enough to help Germany. Had it come earlier, the jet would have unquestionably exerted a decisive influence on the air war in Europe.

based upon Lt. (later Brigadier General) Kenneth Walker's reasoning that "a well-organized, well-planned, and well-flown air force attack will constitute an attack that cannot be stopped." As early as 1934 the basic principles of radio detection and ranging—or radar—were well understood in scientific circles in the United States, Great Britain, and Germany, but the closely held secret was not generally disseminated within the US military. In a way, this was fortunate since those members of the War Department General Staff opposed to the B-17 probably could have killed strategic bombardment if they had possessed a good understanding of the aircraft-warning systems that would be developed from radar.

Rising to their special requirement, the British expedited the construction of a chain of radar early-warning stations that helped an inferior force of RAF fighters meet and defeat superior numbers of Luftwaffe aircraft in the Battle of Britain. After this, the development and utilization of radar by all combatants permitted offensive fighter control and accurate anti-aircraft artillery direction, thus reducing the ability of bombardment to penetrate.

But at the same time other developments in radar enabled aircraft to perform precision bombing at night or in bad weather, thereby increasing the capabilities of offensive aviation. Electronic countermeasures also reduced the effectiveness of hostile-warning and gun-direction systems. No US bombing attack was ever stopped by hostile opposition short of its target, and, on the average, US strategic bomber combat losses were less than two percent.

Shortly after the war, the Air Force began to test new methods of analysis, and in one war game it played the B-17s and B-24s against the German fighter force and 88-mm. gun defenses of World War II. The war gamers concluded that the B-17s and B-24s could not live in such a hostile environment. "Experience, I think," said General LeMay as he recalled this incident, "is more important than some of the assumptions you make."

One of the strangest aspects of World War II was that Germany had an air weapon technology in her grasp early in the war that might have redressed her growing aerial inferiority, yet her Nazi master failed to push its development. Arrogant after Poland, and sure that he knew how much was enough, Adolf Hitler refused to order full mobilization of Germany's eco-

nomie potential for war until it was too late. In 1940, moreover, Hitler severely curtailed the development of new weapons which could not be quickly made available for combat. In Poland, against little opposition, the old JU-87 Stuka dive bomber was a tremendous weapon, but British fighters easily destroyed them in the Battle of Britain. The Stuka had been built for air exploitation rather than for fighting other aircraft.

Similarly, the admirable little Fieseler Storch plane, which served as an air observation post for German ground armies, was soon shot out of the air by the Allies.

As a result of low development priorities and Allied bombing raids, the Germans did not begin to employ their V-1 and V-2 missiles until June 1944, when the war was entering its final act. And because of early indecision as to priorities and Hitler's obdurate insistence that the ME-262 must carry bombs, that early jet fighter was not put into serial production until November 1944. The operational employment of a jet aircraft—superior by far to any Allied fighter—came too late to exert a decisive influence on the air war. For one thing, the fuel resources that would have been needed to field the ME-262 had already been destroyed by strategic air attack.

In summary, Germany's technological capability was of little consequence to her national defense because the technology was not translated into operational weapon systems.

In Retrospect and Prospect

Looking back at World War II from the vantage point of twenty years, it is easy to find fault with the thoughts and decisions made by political and military leaders who were fighting a war for national survival. Why did they not recognize that wars must be fought for long-term advantages? Why did they not see the close relationship between national policy and military capabilities? Why could they not know that airpower could attain its maximum results only if centralized control enabled it to be wielded as a flexible, unitary force?

However, before we pass judgment on the past, we must ask ourselves one more question: Have we yet learned the lessons of global air warfare, and are we applying them to the future?—END



President Roosevelt called for 50,000 planes a year. The industry, by the time the war was won, exceeded the request. At left, the President confers with (left to right) Douglas Aircraft's Donald Douglas, California Governor Culbert Olson, and Frederick Conant, Douglas manufacturing executive, at Douglas Long Beach, Calif., plant.

Embryo to Vigorous Maturity

"The air industry was called upon," said the late Robert Gross, wartime President of Lockheed Aircraft Corp., "to build thousands of something it had built only dozens of before. It was like a youth who is suddenly expected to go to college before he was graduated from primary school."

To understand the enormity of the accomplishment, the real triumph of the aircraft industry's war record, one must picture the aircraft manufacturing complex as it existed in the years immediately preceding the wartime expansion.

A good departure point is 1938. In that year, government appropriations for all military aviation—research and development, as well as production—amounted to \$122 million, a substantial figure by comparison with earlier years, but hardly one to reflect the urgency of the day. Military aircraft deliveries for the year totaled 900 units. The entire industry employed some 36,000 persons and ranked, in terms of labor force, just behind the knit-hosiery industry. In those days, a contract for fifty planes was considered an enormous order.

In 1938, expansion of the industry's productivity got under way, but it was expansion only in the relative sense. The major customers were not the military services of the United States, but those of England and France. In June 1938, Lockheed received an order from the British Air Ministry for 200 airplanes, the largest order ever received by an American aircraft manufacturer in the years between the wars. The plane was a conversion of the company's Model 14 transport, which became the Royal Air Force's highly effective Hudson Bomber. Lockheed was to build almost 3,000 Hudsons before the end of the war.

An interesting sidelight is the fact that the Japanese had a curious role in the contract award, and unwittingly made a contribution to US productivity. At the time the British Air Ministry was considering the

award, Lockheed was down to rock bottom. Its only business was a Japanese order for Model 14s, and there was "nothing else in sight but the end of the line."

"If we hadn't had this business," said a Lockheed executive, "our factory would have been empty and the British would hardly have dared place contracts with a company that was not in production. So perhaps we owe the Japanese a vote of thanks for having placed us in a position to plunge into large-scale production."

A number of other aircraft and engine plants similarly received foreign orders, and production picked up appreciably in 1939. The delivery rate, however, was certainly not one to prepare the industry for what was to come. Even with foreign orders, only 2,250 military aircraft were produced in 1939.

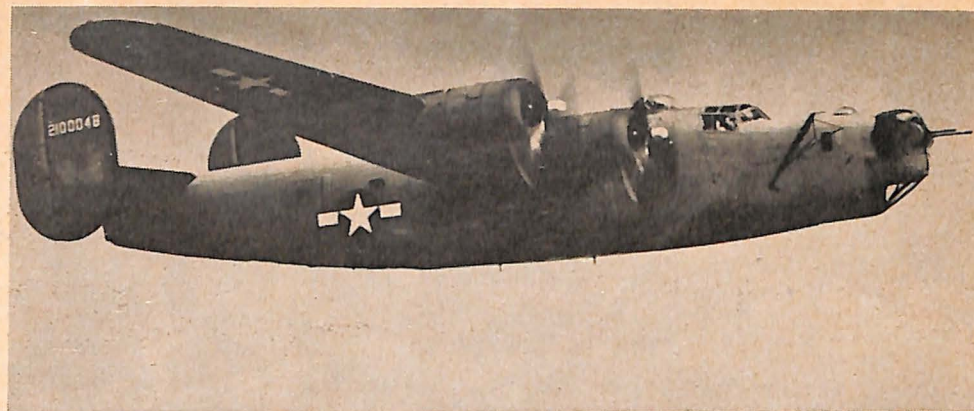
Then in May of 1940, President Roosevelt tossed his memorable bombshell—a demand for 50,000 warplanes. "When the President called for his famous 50,000 airplanes," said H. M. Horner, then General Manager of Pratt & Whitney and now Chairman of United Aircraft Corp., "we didn't know whether he meant an annual rate or a total force of 50,000. Later on, he said he meant 50,000 a year. I think that would really have shaken us up, if we'd believed that at the time." Other members of the industry were shocked even by the 50,000 total figure.

The President immediately set up governmental machinery to start the great expansion, but several months were to pass before the intent was backed by firm contracts.

There were many reasons for the delay. To most Americans, the war in Europe was a distant conflagration, one which could not possibly spread to our shores over 3,000 miles of water. Hence there was no adequate mobilization plan.

There were not many aircraft models in production.
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More of Consolidated-Vultee's B-24 Liberators were built during World War II than any other single type of American aircraft. It was designed and built in a remarkably short time. Design studies began in 1939, and the B-24 was in service by the middle of 1941. B-24s served effectively in all theaters of operations.



Although US forces employed nineteen major models during the war, only four of them were in production status in mid-1940.

Until July 1940, the military services did not have the authority to contract with manufacturers without going through the time-consuming business of obtaining and evaluating competitive bids. In the absence of firm contracts, banks would not undertake financing of the many new facilities the industry needed, and there was as yet no provision for government plant financing. Displaying the sense of urgency that was to characterize the industry's effort throughout the war, some companies put up their own meager funds to start a limited program of plant expansion; others, however much they would have liked to contribute, simply did not have the resources.

There was a delay in establishing a pattern of government/industry relationships on such matters as schedules, contractual arrangements, and profit limitations. There was also a need for a plan to draw other established industries into the aircraft-production program. Incredible as it seems from the infallible view of hindsight, the military services had sponsored no premobilization coordination between aircraft companies and other industries, with the single exception of a plan jointly developed by the Army Air Corps, Wright Aeronautical Co., and Cadillac Division of General Motors Corp.

These and many other difficulties temporarily stalled the war-production effort. As a result, there were only 6,000 planes built in 1940. By mid-1941, government and industry had ironed out some of the major difficulties; the Reconstruction Finance Corporation was providing funds for new facilities, contracts were flowing to manufacturers, and a number of new aircraft types became far enough advanced for mass production. Output climbed to almost 20,000 planes. The industry had moved from first to second gear, but it was still a long way from high.

Then came Pearl Harbor, and with it an influx of new problems and a compounding of some of the earlier ones. Three weeks after the attack on Hawaii, the Production Division of the National Defense Advisory Commission threw away the seemingly unattainable goal of 50,000 planes a year and set a new target: more than 66,000 planes annually by 1944.

Among the new problems was labor. In the pre-Pearl Harbor expansion, the industry had built up a

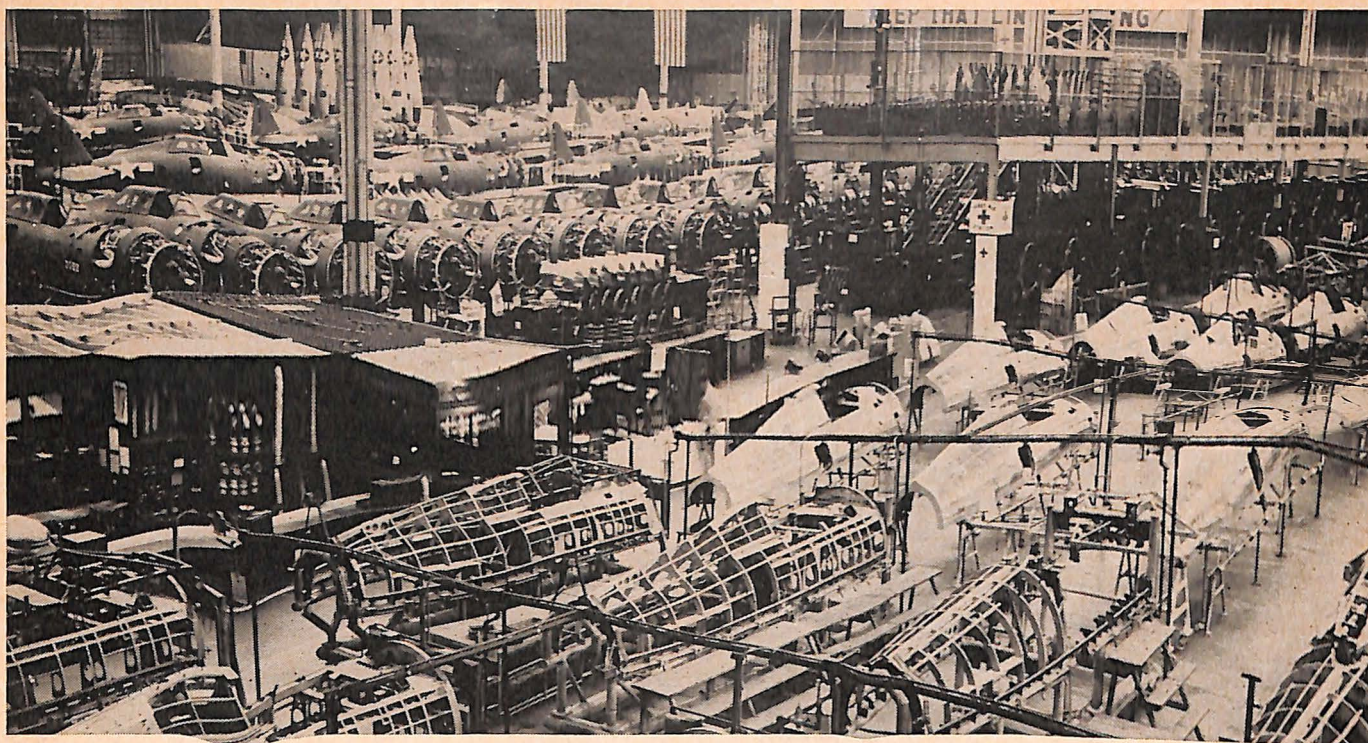
strong and competent personnel force of about 350,000. Despite the draft initiated in 1940, manufacturers had been able to keep most of their skilled workers, thanks to a liberal deferment policy of Selective Service, which recognized that defense production was as vital to the war effort as front-line manpower. But after Pearl Harbor, there came a burst of patriotic fervor, and the young men of the aircraft industry volunteered by the thousands.

The industry launched an intensive recruiting drive to fill its plants. Men of every age and all walks of life, exempted from service by reason of disability, age, or family considerations, were mustered into manufacturing service. Bookkeepers, farmers, salesmen, and bootblacks became riveters and welders. Women were hired by the tens of thousands, not only to take the place of those who had gone to war, but to meet the new demands of increased production. Housewives, grandmothers, and beauty-parlor operators became inspectors, expeditors, turret lathe operators, and tractor drivers. Even youths still in high school joined the effort; manufacturers and school boards worked out plans whereby the youngsters could go to school for four hours and work four hours daily.

Round-the-clock production, in being to some extent before Pearl Harbor, became standard practice. To take advantage of labor sources outside the traditional centers of aircraft manufacture, plants were built in other areas, notably the Midwest. Small "feeder" plants, making parts of an airplane or engine, were set up to make use of workers who were beyond the commuting range of the main plants.

These measures provided a sufficiency of bodies, but a plant full of people does not constitute an efficient work force. The new labor had to be trained, and this job fell, for the most part, to the shop supervisor or foreman. He was charged with "getting out the work" in the face of ever-heavier schedules, while at the same time contending with the massive problems of welding inexperienced help into an effective production team.

Executives also faced new responsibilities far removed from the technical considerations of turning out airplanes. Gasoline and tire rationing made it necessary to set up company-operated bus services. One company ran as many as 117 vehicles covering 12,000 miles a day to keep employees on the job. Manufacturers also organized car pools and in some



Design work on Republic's P-47 Thunderbolt started in 1940, and in short space of ten months an embryonic production line was operating. Production continued while bugs were ironed out, and six models were built by the time World War II ended.

instances created company stores for the purchase of bicycles. Because of the large influx of female workers, firms established women's clinics, where counselors provided answers to domestic problems and arranged for child care. The industry went into the restaurant business in a big way; it was necessary to create commissaries capable of serving 50,000 or 60,000 meals a day.

One of the major headaches of war production was design change. Development of an airplane never really stops until the craft is retired from service. The basic design is constantly changed. In peacetime, such changes are usually a normal part of the production cycle. In wartime, with the plant exerting every effort to get maximum production, design change was an extremely disruptive influence.

There were many reasons for the changes: "Bugs," which escaped detection during service testing, would be discovered; someone in the using service or the company's own design staff would come up with an idea to improve performance; or the changing tactical situation in a war zone would dictate new requirements. As more and more planes entered service and more and more pilots gained combat experience, there came a constant flow of complaints and suggestions from operational commanders, many of them resulting in change orders.

Some changes were easily handled, but others involved major redesign. This necessitated work stoppage on one model and redesigning and retooling for a new one. As soon as the line was running efficiently again, there would inevitably come a new change. And the changes had to be made immediately. In many cases, companies bypassed the red tape and instituted changes backed only by a phone call from one of their

military customers. It was possible for a plane which had undergone a major redesign to roll out the door before the formal change order reached the plant.

Eastern Aircraft Division of General Motors Corp., Grumman's licensee building the Navy F4F Wildcat, was given a change order to increase the number of guns on the fighter. That sounds like a relatively simple change, but it involved more than 4,000 engineering orders.

The Republic P-47 Thunderbolt, one of the outstanding planes of the war, serves as a good example of the wartime developmental and change pattern. Design work started in July 1940, and in the short space of ten months Republic had an experimental model flying and an embryonic production line. Then, in the initial flight-test program, a number of bugs were discovered. They were ironed out by design changes. The first planes started to roll off the line before the test program was completed, and advanced testing uncovered further deficiencies, necessitating restriction of the first lot of aircraft to noncombat use. On the line, the deficiencies were again corrected, and Republic started turning out the solid, high-perform-

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Honor graduate of Princeton, former Rhodes Scholar, holder of an Oxford University doctorate, graduate of the Yale Law School, World War II Army intelligence officer, Karl G. Harr, Jr., became President of the AIA in 1963. He had previously served in high posts in the Department of State and Defense and as a special assistant to the President.





This is how the production line at Pratt & Whitney's East Hartford, Conn., plant looked during the war, when P&W was building the R-1830 engine. "Impossible" deadlines and frequent design changes made job difficult, but it was done.

ance aircraft. But despite the extremely rapid start of the program, the P-47 did not get into combat service until 1943. When it did, there came more change orders as combat employment of the plane turned up new requirements.

A number of the changes involved major redesign. For instance, when it was discovered that the Army's daylight bombers could not operate effectively without fighter escort, the P-47 was one of the types selected for conversion to escort duty. Extension of both the range and the speed of the airplane required major changes, such as installation of a new engine and belly tanks, each of which in turn called for other changes in the airframe structure. By the end of the war, Republic had produced in quantity six major models of the P-47 and within each model—B, C, D, G, etc.—there were separate production "blocks," the planes within one block differing considerably from the others.

Similarly, the R-1830 engine built by Pratt & Whitney and its licensees was categorized as a single engine type. Actually, there were six major types under that one designation and variations within types—"dash numbers"—which brought the total to twenty-four models, none completely interchangeable with the others. It was a wearing experience for the production engineering staffs, faced with continual changes and forced to make them under the pressure of terrific deadlines.

Even in 1942, a large part of the industry was still employing the "job-shop" approach to production. The job shop was made up of a number of general-purpose tools, with similar types of equipment grouped together in one area. Parts were made in lots, then sent off to an assembly area.

This type of work was adequate and even desirable for the low-volume production of the prewar era, but completely unsuitable for high-volume turnout, since

it was geared to intermittent rather than continual production. It became apparent that the industry could never hope to meet the government's demands through the job-shop approach. A switch to line production was necessary.

Line production, or the assembly-line technique, in which the basic product and its various parts are fed into work areas in a controlled, progressive flow, had been employed for some time by the automobile companies and other American industries. It was, however, new to aircraft manufacturers, who in the lean years had never had an order requiring such methods.

The conversion required a great deal more than rearrangement of the plant and its tools. Channels were established for the flow of parts and there was an incredible amount of detail involved in getting the right part to the right place at the right time. New tools, processes, and techniques had to be devised to meet the demands of line production. It would have been a difficult task at any time, but it came in a period when the industry was still breaking in inexperienced help, amid frequent government-ordered schedule and design changes. The design changes constituted a particular problem in the conversion process. The automobile industry was successful in utilizing line-production methods primarily because a company could freeze the design of an auto before sending it into mass production. The exigencies of war made it impossible to freeze aircraft designs. The production teams not only had to convert to an entirely new manufacturing technique, but also adapt it to the necessity for continuing on-line changes.

A postwar report on aircraft production, prepared by the Division of Research of Harvard University's Graduate School of Business Administration, had this to say on the problem of conversion: "The fact that the aircraft industry was ultimately able to introduce a high degree of flexibility into production procedures, and, thereby, to make effective use of line-production techniques in spite of change, constituted an outstanding contribution to production management.

"While techniques were borrowed from other industries," the report continued, "the special characteristics of airframes and engines made it impossible to adapt the established techniques of any other industry without revisions. To meet wartime production goals, the manufacturers of airframes and engines were not only forced to do, on a vastly greater scale, a job that they had already been doing in peacetime. They had to do an essentially different job which neither they nor others had ever done before."

Nonaviation firms had to dismantle their plants and rebuild them for a vastly different type of work, they had to learn about tolerances undreamed of in their peacetime production, they had to retrain even their most skilled people, they had to find subcontractors where they were almost nonexistent since every established aviation supplier was already producing at full capacity for aircraft industry firms. They asked from their licensors process sheets, time studies, routing sheets, and other essentials of their peacetime line-

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Boeing's design group foresaw the need for a follow-on to the B-17 that would be capable of spanning the Pacific Ocean for "super-bomber" missions in the Far East. Out of their forecast, and after many design changes and performance enhancements, came the B-29. It devastated Japan, hastened the end of the war.

production operations, only to find that such things did not exist in an industry barely under way on the massive task of converting from job-shop to assembly-line methods.

The aviation firms, on the other hand, had to divert valuable management and engineering talent to the task of putting the licensees in business at a time when they could not spare a single worker from their own programs. They had to build the initial parts, components, and assemblies to provide the licensee with a "shakedown" assembly line. Pratt & Whitney, for instance, had to contribute 100 man-years of production and engineering talent to educate its licensees—Ford, Buick, Chevrolet, and Nash-Kelvinator—in the art of aircraft-engine production.

The pressures were certainly not conducive to harmonious relations, yet the introduction of these new companies to aviation production was carried out with a minimum of friction.

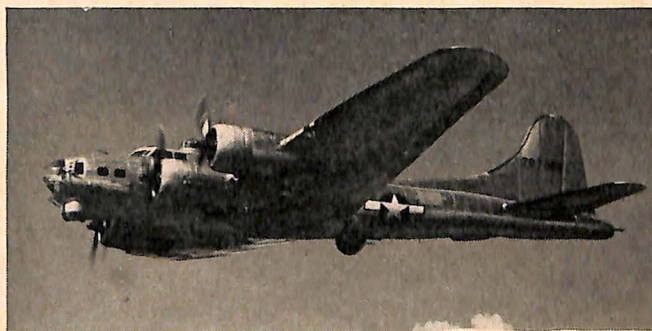
In addition to the licensees, other industries felt the impact of expanding aircraft production. The aircraft industry was a technological "feed-bed" for these other industries, forcing them into enormous expansions parallel to the growth the airplane builders were experiencing. The most notable example was the aluminum industry. Born in the latter years of the nineteenth century, the aluminum industry grew with the nation at a normal rate until the early thirties. In that period the aluminum industry expanded considerably as its high-strength, lightweight metal gradually found its way into aircraft production use, first as a structural material, later as wing and fuselage skin. When the big aircraft production buildup started in 1939, the aluminum industry similarly expanded to a multifold increase in production during the war years.

A case history is that of Aluminum Company of America, pioneer of its industry and by far the major supplier during World War II. In 1938, Alcoa produced 287,000,000 pounds of aluminum; then, as the aircraft manufacturing companies started to expand, so did Alcoa. For aircraft structures, skins, engines, propellers, and many other applications, Alcoa produced forgings, rivets, extrusions, wire, rods, bars, tubing, and a variety of sheet. The company also developed allied applications, such as aluminum landing mats for speedy construction of landing fields, and aluminum

gasoline drums for saving weight in the air transport of fuel. By V-J Day, Alcoa had produced 11,400,000,000 pounds of alumina—the oxide of aluminum used in preparation of metal; smelted 5,500,000,000 pounds of aluminum; and fabricated 2,700,000,000 pounds of sheet, 450,000,000 pounds of extruded shapes, 500,000,000 pounds of forgings, and 400,000,000 pounds of castings. Although much of this production went into nonaviation uses, aircraft requirements accounted for the major part of the expansion.

Production, of course, was not the industry's only assignment in the hectic war years; there was also research and development, which was carried out on a scale never before attempted. A good portion of the effort went into development and the improvement of aircraft, engines, and other equipment in existence at the time of Pearl Harbor or shortly thereafter. But the industry was also heavily engaged in a broad program of research on new plane designs; guided bombs and missiles; and a wide range of auxiliary products, from navigation systems to survival equipment.

Industry made a major contribution in this area, by developing in its own "think-shop" ideas that were later translated into increases in US combat effectiveness. A notable example was Boeing's Design 341, started early in 1939. At that time, Boeing's B-17 Flying Fortress was in early-production status, and its range of 3,000 miles constituted the maximum distance for which there was an official requirement. But, long before anyone was thinking in terms of bombardment
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Boeing's B-17 was used against Germany and gave the Nazis a bitter taste of the airpower they had used against Europe in their drive to enslave the Continent. Based in England, the B-17s became a familiar sight en route to targets.



General Motors production expert, Lt. Gen. William S. Knudsen, "drafted" by FDR, headed logistics. Above, he meets with Boeing's J. E. Schaefer, AAF's Brig. Gen. K. B. Wolfe.

missions spanning the vast overwater routes of the Pacific, Boeing's design group foresaw a need for a "superbomber," one with a range at least a third greater than that of the B-17. The group had a year head start before the requirement became official, a year that hastened the entry into service of what was to become the B-29.

Development of the B-29 also illustrates the flexibility of the industry design teams—their ability to adapt to constantly changing requirements. Design 341 started life as a 48,000-pound airplane with a range of 4,500 miles and a speed of 390 miles per hour. The Air Corps requirement demanded 5,333 miles' range, greater speed and altitude, and the weight went up to 85,000 pounds. And in other areas the Air Corps

wanted more: more armament, powered gun turrets, leakproof fuel tanks, armor plate, higher cabin supercharging, and a short-range bomb capacity of eight tons. And it wanted these things with no sacrifice in performance.

Boeing went back to the drawing board and came up with Design 345, a larger airplane in every respect, weighing in at 112,000 pounds and offering performance comparable with the original design. Further additions sent the design gross weight up to 120,000 pounds and by the end of the war crews were flying the airplane at 140,000 pounds.

Throughout the industry, design teams maintained this type of flexibility. They watched closely the developments of the accessory manufacturers and were quick to incorporate, wherever possible, advances in equipment, such as new superchargers, safer fuel tanks, better deicing equipment, new armament, and many other advances in minor, yet important, components.

Nor did the responsibility of the manufacturer end when a plane was accepted by the military. Some companies sent large staffs overseas to set up repair and modification centers. Lockheed, for instance, operated a huge base in Belfast, Northern Ireland, which at its peak employed about 6,000. In two and a half years, this base modified more than 3,000 planes, serviced 11,000 more, and overhauled some 450,000 components. In addition to this type of service, all manufacturers sent into the combat areas teams of technical representatives, who reported to the home office on how the company's aircraft were performing and what could be done to make them better.

An Honor Roll of Industry . . . Who Built

Fourteen companies engaged in production of combat-type and large transport aircraft produced the bulk of all airplanes manufactured during the wartime expansion period 1940-44.

Because of the differences in weight of the various types, total weight of airframes produced, rather than number of units, was the primary criterion of a company's production record. On a company basis, Douglas Aircraft Co., operating six major plants, ranked first. According to postwar statistics compiled by the Air Technical Service Command, Douglas produced 306,573,000 airframe pounds, or 15.3 percent of the total in the combat/large-transport category. In second place was Consolidated-Vultee Aircraft Corp., predecessor of the Convair Division of General Dynamics Corp. Consolidated turned out 291,073,000 pounds, or 14.6 percent of the total in that category. Boeing Airplane Co., now The Boeing Co., was third with 226,477,000 pounds, 11.3 percent of those in the same category.

Next, in order of rank, came North American Aviation, Lockheed Aircraft Corp., Curtiss-Wright Corp., Glenn L. Martin Co. (now The Martin Co.), Ford Motor Co., Republic Aviation Corp., Grumman Aircraft Engineering Corp., Bell Aircraft Corp. (now Bell Aerospace Corp.), Eastern Aircraft Division of General Motors Corp., Chance Vought Division of United Aircraft Corp. (now an element of Ling-Temco-Vought, Inc.), and Goodyear Aircraft Corp.

From the standpoint of production in an individual plant, Consolidated-Vultee's San Diego plant ranked first

with 180,702,000 airframe pounds. Other leaders on this basis were Boeing Seattle, Douglas Long Beach, Ford Willow Run, and Martin Baltimore.

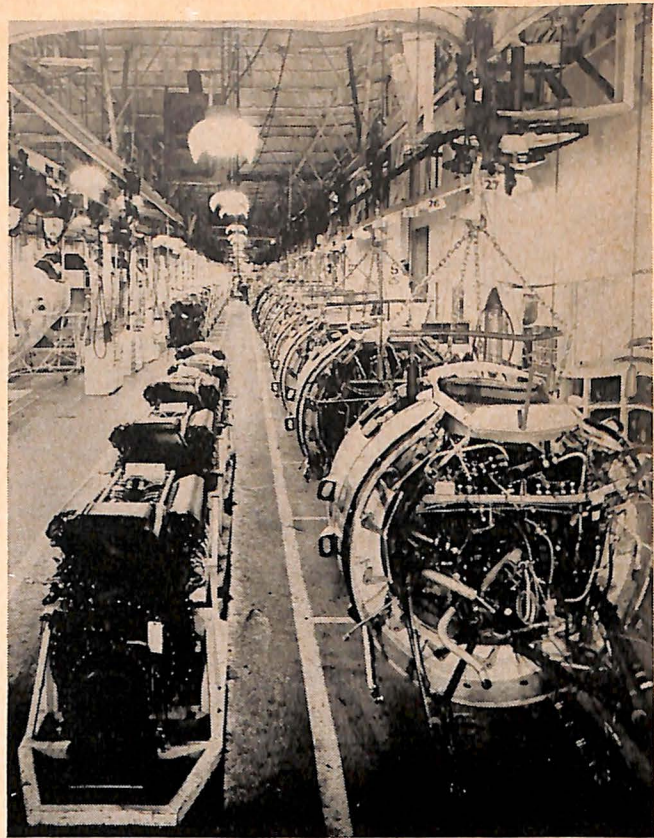
Additional contributors to aircraft production, either building models of their own design or working as subcontractors on major programs, included Brewster Aeronautical Corp., McDonnell Aircraft Corp., Northrop Aircraft, Inc. (now Northrop Corp.), and Ryan Aeronautical Co. Major producers of trainers, light cargo, and utility aircraft were Aeronca Aircraft Corp., Beech Aircraft Corp., Bellanca Aircraft Corp., Cessna Aircraft Corp., Columbia Aircraft Corp., Fairchild Engine & Airplane Corp. (now Fairchild Hiller Corp.), Fleetwings Division of Kaiser Cargo, Inc., Globe Aircraft Corp., Howard Aircraft Corp., Piper Aircraft Corp., Sikorsky Aircraft Division of United Aircraft Corp., St. Louis Aircraft Co., and Taylorcraft Aviation Corp.

Horsepower delivered was the guideline for engine production. Wright Aeronautical Co., with three major plants, led in production of engines for combat/large-transport aircraft. Of a 1940-44 total of slightly less than one billion horsepower, Wright produced 24.6 percent. Pratt & Whitney Aircraft, operating two main plants, contributed 17.2 percent of the total horsepower and Allison Division of General Motors, one plant, 10.8 percent. Collectively, Pratt & Whitney's licensees—Ford, Chevrolet, Buick, and Nash-Kelvinator—accounted for 30.4 percent of the total. Studebaker Corp., Wright's licensee, produced 9.9 percent

The industry group which fell heir to the heaviest burden was management. Many of the larger technical problems filtered up to the executive level, but management was also faced with an administrative job of enormous proportions. First there was the task of building an administrative machine from scratch, a machine that could direct the output of as many as 100,000 persons in a single company which had had only three or four thousand at the start of the expansion. Management was confronted with hundreds of decisions daily, and the decisions had to be communicated throughout the organization to ensure that each activity of the company was coordinated with the many other activities. There were never enough qualified managerial personnel available throughout the war.

As government production demands mounted, new problems were thrust upon company managements by the necessity for opening branch plants. This diluted the already scarce supply of managers and complicated the task of intracompany coordination of operations. Even the addition of one branch plant placed considerable strain on management, but some of the larger firms were assigned responsibility for several plants. Douglas, for instance, had six major plants in addition to its "feeders," spread through California, Oklahoma, and Illinois. Consolidated-Vultee had four large plants in four different states. Curtiss-Wright's Airplane Division operated five plants while its Engine Division had three more. These and other manufacturers' multiple responsibilities spread very thin the pool of production and administrative executives.

(Continued on following page)



Three conveyor lines at the North American plant at Inglewood, Calif. At far left, elevated, the assembly line for B-25 aft sections. Center, engines for P-51 Mustang fighters. Right, Wright engines being readied for the B-25s.

and Helped Build What in World War II

and Packard Motor Car Co., a licensee of Rolls-Royce, Ltd., 7.1 percent.

The major builders of smaller engines were Air-Cooled Motors Corp., Continental Motors Corp., Jacobs Aircraft Engine Co., Kinner Motors, Lycoming Division of The Aviation Corp. (now Avco Corp.), Menasco Manufacturing Co., Ranger Division of Fairchild, and Rohr Aircraft Corp. (now Rohr Corp.).

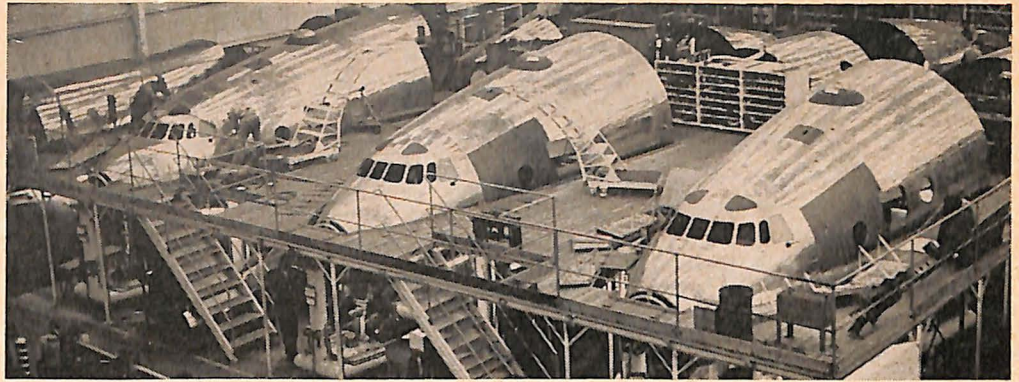
In a special category was General Electric Co., which developed the I-16 and I-18 turbojet engines during the war years and built in limited quantities the I-40 (later J-33) which never saw combat service.

Finally, there were the accessory manufacturers who supplied thousands of individual items vital to the operation of the aircraft and engines. The more important, with a sampling of their product lines, included:

Aeroproducts Division of General Motors Corp. (propellers); Aerojet Engineering Corp., now Aerojet-General Corp. (jet-assist takeoff rockets); AiResearch Manufacturing Co., now AiResearch Division of The Garrett Corp. (cooling and pressure control systems); American Brake Shoe Co. (forgings); American Propeller Corp., a subsidiary of The Aviation Corp. (propellers); Aluminum Company of America (a wide variety of aluminum products); The B. G. Corp. (spark plugs, ignition harnesses); Bendix Aviation Corp., now The Bendix Corp. (literally hundreds of separate products among the company's many divisions); Chandler-Evans Corp. (carburetors, pumps);

Cleveland Pneumatic Tool Co., now Pneumo Dynamics (landing gear units and pneumatic tools); Curtiss-Wright Propeller Division (propellers); Firestone Tire & Rubber Co. (tires and rubber products); General Electric Co. (armament systems, superchargers, ignition systems, generators, electrically heated flying suits, etc.); B. F. Goodrich Co. (tires, deicers, hose, fuel cells, exposure suits, etc.); Hamilton Standard Propellers Division of United Aircraft Corp. (propellers); Hercules Powder Co. (explosives); Hughes Aircraft Co. (aircraft radar and electronics); Jack & Heintz, Inc. (instruments); International Business Machines (fire-control instruments); International Telephone & Telegraph Corp. (electronic systems); Kollsman Instrument Division of Square D Co., now Kollsman Instrument Corp. (instruments); Link Aviation Devices, now a division of General Precision, Inc. (training devices); Minneapolis-Honeywell Regulator Corp., now Honeywell Inc. (autopilots); Pacific Airmotive Corp. (test stands); Radio Corp. of America (radio equipment); Reynolds Metals Co. (aircraft aluminum); Rohr Aircraft Corp. (superchargers, fuel tanks); SKF Industries (ball and roller bearings); Solar Aircraft Co., now Solar Division of International Harvester Co. (exhaust systems, cowlings, heat exchangers); Sundstrand Corp. (tooling); Thompson Products, Inc., forerunner of TRW Inc. (valves, pumps, hydraulic couplings, oil filters, superchargers); and Westinghouse Electric Corp. (generators, voltage regulators, switches, radio equipment, starters).—END

Looking like the front end of fish, Constellation nose sections are lined up in assembly docks at Lockheed's Burbank, Calif., plant during early phase of production process. The fuselage of Constellation was built in eight separate sections, all finally joined in a huge mating rig.



Another factor adding to the management burden was the number of models some companies were asked to build. Each model, of course, had its own facilities, tools, and supplies, so administering it was almost like administering a separate company. Some of the larger manufacturers had ten or more production lines. Lockheed, for instance, built twelve types of aircraft, Douglas eleven, and Pratt & Whitney ten engine models.

Subcontracting posed still another administrative problem. Unlike the licensee, who built entire airframes or engines, the subcontractor produced only small parts or assemblies. It was the complex task of the prime contractor's management group to control the flow of subcontracted items from thousands of suppliers and ensure that they reached the assembly line at the right time and in acceptable condition.

Management had one more major load—maintaining contact with a great many government agencies. In the preexpansion era, a manufacturer with a single low-volume production contract had one government manager, who usually was familiar with the company's operation. In the war years, company management teams might have to confer, within a single week, with a number of different departments of the Army Air Forces and the Navy Bureau of Aeronautics, the War Production Board, the National Labor Relations Board, the War Labor Board, and a variety of other government agencies. Top management, therefore, had to spend much of its time on governmental coordination, forcing delegation of decision-making authority to lower levels and compounding the problems of second-echelon management.

The management load was lightened somewhat by the addition of top men from other industries, but, as production expansion moved into high gear, companies used this remedy less and less; and it was felt that the addition of green management personnel at that stage of the effort would only impair the efficient teamwork of the existing management. Throughout the war years, the industry's management groups operated under great strains.

These were the major problem areas; there were many others. In light of them, the production record becomes incredible instead of remarkable. By the end of 1942, the industry was in high gear; it produced 47,675 planes that year. In the following year the monthly production rates began to exceed government schedules and the yearly total amounted to 85,433. Finally, in 1944, the peak year, more than 2,000,000

industry employees sent 95,272 planes off to the war.

The models and the records of US planes in World War II are beyond the scope of this article.

Among some of the major airframes were North American's B-25 and P-51; the Glenn L. Martin Company's B-26 and PB4Y flying boat; Bell Aircraft's P-39 with Allison engines played an important role on the Russian front; Northrop created the first US night fighter, the P-61; and Chance Vought's F4U and the Grumman F6F were widely used by the Navy.

Utility aircraft producers, such as Piper, Beech, Cessna, and others, not only turned out training aircraft. They also built major aircraft sections such as wings and fuselages for bombers, fighters, and transports as subcontractors.

The transport aircraft came of age. Supply by air was carried out in every theater. The memorable Douglas C-47 was joined by the C-54, the Curtiss C-46, and the Lockheed C-121.

Much of the experience acquired by the industry in the war years went for naught, because the technological revolution of the fifties completely changed the character of the industry. Mass production became a thing of the past. In its place came low-volume production of weapon systems of vastly greater destructive capability than the planes of World War II. But some of the experience was invaluable. The government/industry relationship which was established, with industry evolving into a hardware-producing full partner, established a framework for a partnership that has grown continually stronger in the postwar years. And the great wartime emphasis on research and development produced a foundation for what was to become the primary role of the aerospace industry.

Certainly the managerial techniques developed in the handling of large volume orders served the industry well in the postwar technological revolution, when management of contracts running into the hundreds of millions of dollars became as important a function of the aerospace firm as fabrication of equipment.

Perhaps the most important effect was the industry's demonstration of its ability to rise to a challenge, a demonstration that founded national confidence in the industry and led to its later assignment of new responsibilities in the field of missilery and space exploration. To borrow a couplet from Tennyson: "Men, my brothers, men the workers, ever reaping something new: that which they have done but earnest of the things that they shall do."—END