DESIGN AND ENGINEERING PROBLEMS OF AIRCRAFT PRODUCTION, 14 May 1946.

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GENERAL ARMSTRONG:

Gentlemen, this morning the Air Forces will be very adequately represented. The developments that Colonel Sessums, the speaker this morning, has been telling me about in the office are astonishing, to say the least. In fact, he says the technology is changing so swiftly that he does not know how planning for industrial mobilization for the aircraft industry can be carried out. However, that is one of the subjects he will talk about this morning, so at least he will make some educated guesses--incidentally, gentlemen, they will be highly educated.

Colonel Sessums has been working on the Wright Field end of the Air Forces for many years and he also served as recorder of the Joint Aircraft Committee and was a regularly attending member of the Munitions Assigned Committee. At present he is the Assistant to the Deputy Commanding General, for Engineering and Maintenance.

Colonel Sessums will speak this morning on "Design and Engineering Problems of Aircraft Production," and I think his talk will be largely directed to the problems to which we are concerned, that is, to the problems of industrial mobilization. Gentlemen, Colonel Sessums.

COLONEL SESSUMS:

Gentlemen: General Armstrong requested in his letter that I discuss engineering and design problems as the Air Forces were affected during World War II, so unfortunately I cannot spellbind you with the "off in the blue" plans of the Air Forces. They are extremely interesting and, as General Armstrong said, I do not know what you are going to plan for in any mobilization for the Air Forces, that is, in industrial mobilization.

I would like to start out by going back to 1939. Before we were in the war, our industry was hardly what you could call an industry. We had a number of manufacturers who were struggling along with very small orders, primarily military orders; it was more or less a subsidy from the Government. They would get orders for five or six airplanes. The Consolidated Company was building the B-24 bomber. That company had just developed the B-24 and it was flying; that was about all. The Flying Fortress had been built and it had been shaken down to the tune of about 35 or 40 airplanes but most of the tools and jigs were made of wood and required a very high degree of skill for the people to build the planes.

They would build the fuselage and then the electrical engineers would go in and they would wire the airplane after it was built--put in the various components--and not very many workers could get in the fuselage so it was very slow, tedious work and it was very unsatisfactory for any high production quantities.

We got a small shot in the arm in our industry, in 1939, as the war in Europe developed. The British came over and gave some contracts to the Lockheed Company, which had an order for a few P-38's from the Army, and they had been building the Lockheed Hudson, a commercial transport; and the British simply put some of their turrets on the Lockheed Hudson and gave Lockheed an order for those; so Lockheed was able to start doing some planning for small production.

The Curtiss Company had an order from the French and the British, for fighters, previously developed by the Army Air Forces and considered old models but the French and British were desperate so they bought a few hundred of these planes. That was the first spurt we had in our aircraft industry.

In June of 1940, President Roosevelt could see the war coming on so he gave us the go-ahead for 50 thousand airplanes; and, you might say, that marked the beginning of our aircraft industry as we knew it in World War II. We got the funds we needed and we immediately began planning production quantities of airplanes. When President Roosevelt gave us this order for 50 thousand planes, we could see that additional orders would be forthcoming in the future, in the way the war was developing, so we planned on airplanes beyond the 50 thousand rate. The Air Forces were fortunate in getting the first jump in to the industry.

The industry was bottlenecked by a magneto manufacturer. There was only one magneto for airplane engines that was considered safe and reliable, and there was only one carburetor. I will not give the names; somebody might disagree with me; but there was only one carburetor that was considered best and the Air Forces insisted on only those. So when we got this go-ahead, we completely tied up the output of that magneto manufacturer and carburetor manufacturer and the manufacturer who built airplane struts. An airplane strut, as you know, is a complicated piston and cylinder--oil and air operated--which takes pretty large forgings, and only one company was building these struts to our specification. I give those three bottleneck industries as examples of how the Air Forces completely tied up their whole outfit. That was fine so far as the Air Forces were concerned but as the program moved along, it did not work out too well for the Allies and the Navy, who were at that time building or starting their program; and they had keels, carriers and crusiers; they had to have airplanes for these; they had to have the same engines that we had and they had to have a proportionate share of these bottleneck items. You know, when they walked in, on the low levels, and asked the Army for a new magneto or carburetor the answer was, "No."

So that was the first thing that developed. When the whole country went all out in industrial mobilization, no one had planned any system of priorities or provided for any organization to deal out these critical items on a strategic basis. In other words, if the first battle was going to be between carriers, why, obviously, the Navy's airplanes had to have the engines and they were going to have to take the carburetors and magnetos that the Army Air Forces ordered the year before, which the Army Air Forces took a very dim view of and which meant we had to wait

probably another year. So in order to meet that situation, they organized a committee in Washington known as the Joint Aircraft Committee.

The committee had as its members General Arnold, Admiral King and a member of the War Production Board who controlled all of the materials and the facilities. They had the actual say as to who could go in what factory and build something. The British were represented by Sir Richard Fairey. These problems were worked out on a strategic basis, but we lost many many months arriving at that organization. Once it was set up, it functioned very well. There were no very severe battles or repercussions; each one on this high level could tell the boys below to stand back, and let the things they ordered a year ago go to somebody else, and wait.

As I pointed out, the aircraft industry was very small and had very small facilities. In order to meet this terrific expansion that was coming, it was necessary to expand the facilities. Apparently there had been no industrial mobilization planning that envisioned a wholesale spreading out and building of additional plants. There had been no planning, so far as I know, for increasing the engineering talent necessary to man all these expanded facilities. So the Joint Aircraft Committee undertook to allocate these facilities.

There were other organizations in the Government that handled funds; there was RFC, of course, which was in charge of the construction and buying of machine tools; but the Joint Aircraft Committee made the recommendations. For instance, they might recommend that the Pratt and Whitney Company have a new engine plant built in order to meet our future program--our programs were all made up by this Joint Aircraft Committee based on what the known facilities were--so that one branch of the Service or our Allies could not overload any particular industry which would handicap the remainder of our industry.

Now to consider specifically some of the designs and engineering problems: As you all know, we fought the war with the B-17 Flying Fortress, and the B-24, in the heavy group; the B-25 and the B-26, in the medium group; the A-20, in the light group; and the P-47, P-51 and P-38 in the fighter group. Those were the Army Air Forces first line combat airplanes. None were designed after the war started. In fact, I believe, the latest model that got in the war was the B-29. That airplane was designed two years before Pearl Harbor. So the design and engineering problems that the Air Forces encountered in World War II were primarily those of making those airplanes we had, meet the tactical requirements. That involved improving the armament, engineering leakproof tanks in the airplane to prevent fires when bullets go through the wing, improving the radio, improving the bomb-carrying capacity, and improving the power of the engines to carry additional bomb loads. It was an ever-increasing problem. These changes came up as a result of tactical requirements and they had to be made immediately. A commander in the theater would not accept any alibis for delays. The industry had to make these changes immediately.

Normally plans were made for a new turret or a new engine on an airplane before it ever started in the production line at the factory. In the case of making these immediate changes that were essential, we not only had to put them on the plane as it rolled out the door of the factory, but we had to go back and re-equip the planes that had already been delivered; so this resulted in setting up practically another complete aircraft industry. It amounted to another factory right outside the door of each factory we already had. We called these factories Modification Centers, and we had one of them just outside the front door of practically every airplane factory we had. These Modification Centers were a job shop operation. They could not have production line procedures there because the changes were taking place so fast--so many of them--that they had to improvise.

One of the first series of modifications we had to make was the tail guns in the B-24. We had given the British some of these B-24's early in the war. The British had discovered that a power-driven turret was very effective in knocking down fighters and they developed two power-driven turrets, each turret carrying four thirty-calibre machine guns. The turrets were operated hydraulically. There was an electric motor that drove a hydraulic pump and worked with pistons that swung the turret around and made the guns go up and down. Now the gunner that rode in this turret had to work valves to operate it and the operation required that the guns be capable of swinging very rapidly to a target, and then when it got to the target, the control had to become very delicate. It had to be capable of swinging rapidly to the target and then moving very slightly--a very delicate slight movement--exactly as this man moved the controls so that he could stay on the target. Well, this hydraulic system that the British had developed had many deficiencies. We tried it on our test grounds at Eglin Field and the boys could not do so well as they thought they should. They could see improvements for the hydraulic drive. The British asked us to put that turret in their B-24's. We very reluctantly did so. The turret was installed. They had a model which they called the Boulton Paul and another they called the Frasier-Nash; they were very similar, both carrying four 30 calibre guns. We installed those two types of turrets in the tail end of the B-24's going to the British. That had to be done at a Modification Center; there had to be a new tail cone and a new structure around the British turret to hold it. That, of course, changed the balance of the airplane and caused another serious problem, but the British asked us to put that on our planes that we expected to use, saying that their experience had been that we would have to have power-operated turrets to fight in Europe.

We were confident that our 50 calibre gun was much superior to their 30 calibre gun, due to its flatter trajectory and high velocity, and we therefore immediately went into the development of 50 calibre gun turrets. We called in everyone that was in any business associated with anything in which a turret could be built and we had about ten or fifteen manufacturers, each independently going off on their own to build a 50 calibre gun turret. We told them we wanted two 50 calibre guns, a man in the turret, and we want the delicate control that was

required to be able to aim that gun better than the British turret did it. We called in the men and let them study the British designs, and, as a result of that, we came up with about eight different designs--different model turrets manufactured by different manufacturers. Had we done very much advance planning, we probably would have cancelled all but one of the contracts and standardized on one turret, and, as we now know, that would have been a mistake, because the requirements for a turret in a different position on the airplane are quite different. So we wound up by having a turret of a different manufacturer on each part of the airplane.

As an example, the B-17 Flying Fortress had a turret built by the Martin Airplane Company on the top of the fuselage. It had a ball turret in the belly of the airplane which was built by Sperry. It had a turret in the nose of the airplane which was built by Emerson Electric Company of St. Louis. It had a turret in the tail which was built by the United Shoe Manufacturing Company. None of them was too satisfactory at first; some of them were not so good on the delicate control as the British turrets, but at the same time, we went on with the development of these turrets. We went to some of our electric laboratories; we told them we wanted to build a turret that would meet our requirements and we told them they could make it hydraulic or electric or a combination of the two. About the time we started getting turrets in quantity, the General Electric laboratories came out with a gadget that they call the amplidyne. I am still not sure what it is, but it was a wonderful thing. It was some sort of an electric motor, as I understand it, double motor, and they had all sorts of wire tapping inside the two motors so that you tapped off the field in one end to the armature in the other and vice versa, and by so doing, they were able to get the power required at very slow speed, which gave the delicate control, and, at the same time, if you wanted to move it fast, this thing would waive around in a hurry. That amplidyne thing we put on every turret we built. It made every turret work and the British threw their hydraulic thing away and took it too.

Another major lesson we learned in World War II in design and engineering problems was our experience with wooden airplanes. Due to the fact that improper planning had been done on our basic materials--and I think I am safe in saying that no one had planned before President Roosevelt, the U. S. being the arsenal for democracy--we simply did not have the stocks of raw material we needed and we found ourselves in the middle of the war running out of aluminum. We were getting requests from our allies to the South, the South American countries, Canada, and all of the Allies in combat for cargo airplanes; so we were forced to build a wooden cargo airplane. It was designed to meet the requirements similar to the airline or DC-3 type airplane, twin engine, carrying the same load and using the same engines as our C-47 standard airline type airplane. After some debate, we elected the Curtiss Company to take the job on, based on their current load, while they were building the C-46 heavy transport and the A-25 dive bomber for the Army and a similar version for the Navy and other Navy

carrier planes in their four or five other plants. We built another plant in Louisville, Kentucky, for the purpose of building this wooden cargo airplane.

We at Wright Field had done some experimenting with wooden structures. We built a fuselage and wing panels out of various processes of laminated plywood and so-called plastics, which was plywood with plastic binding between the layers of plywood. The British had built the Mosquito airplane which was all wood but which was considerably smaller than the plane we envisioned as the cargo airplane. They had been successful in their plane by using balsa wood, about a quarter of an inch thick, and two thin layers of hardwood on the outside forming a sandwich. That plane we must admit was a success; but the Curtiss people, after reviewing our engineering work and our own experimentation and other information available in this country, decided not to use that but to use their own plans and materials in the manufacture of this plane. It was to be built out of mahogany and we laid in great supplies of mahogany for it and the Curtiss Company obtained a group of furniture manufacturers and delegated the various components of the airplane to be built in small parts and assembled in Louisville. Well, each furniture man would have to come then, of course, to find out how to build this structure. He was told by the Curtiss Company and he would go back and maybe he was building the rudder or the horizontal stabilizer. He would build this piece and bring it back to the Curtiss plant where they would test it and it would probably break so they told him to glue more strips here and there and try it again. Well, after a year or so, the various components passed the test and the airplane was assembled but as they rolled it out on the flying line--the usual procedure is to weight the airplane before it takes off so they can see that the balance is correct and so forth--they weighed this thing in, the weight empty, of the airplane, was slightly in excess of what it was supposed to be when it was fully loaded. So it essentially was a pursuit ship--one man pilot.

Well, the first flight was made and the airplane was very heavy. It developed some serious vibrations. In fact, the pilot was awful glad to make a quick circuit to get back on the ground. So they had to add more weight to the airplane to get these vibrations out of it and when they completed that process, two of the Curtiss test pilots took it out on a flight and the Army requested that our project officer on the airplane be allowed to fly along on this trip. The Curtiss Company refused. We were very glad that they refused because on this second flight, it flew apart and the pilots were lost and so was the plane.

About this time the Training Command had been using a primary trainer known as the PT-19, built by Fairchild. It had a tube steel cloth covered fuselage with wooden wings, same type of construction of which the Curtiss Company had tried to build their transport. They were using these primary trainers all over the United States, down in some of the hot climates of Texas, some of the moist places around Florida and our overhaul depots just about decided that a new

pair of wings was necessary about every two or three months to keep the thing going; but at the time we lost this Curtiss transport, we got these complaints from the overhaul depots that the wooden wings were entirely impracticable and they were begging the material men to switch to metal.

Those factors coupled with the fact that by that time we had built some additional aluminum facilities and some aluminum was coming to us, we decided that a wooden airplane was not for the Army Air Forces. And that little venture, due to the fact that we did not have sufficient plans in advance, cost the Government about four hundred million dollars. Curtiss "spruce goose" it was nicknamed.

While it is a little off the subject, I would like to mention to the class the matter of aluminum. I understand that the ore in the United States is of very low grade, requiring quite a plant to process it. It also takes a long time to do it. During the war we were forced to import our bauxite, or aluminum raw material. Most of it, I believe, was brought up from the South, somewhere in British New Guinea, somewhere around there. At one time the shortage of that aluminum ore was so great that the Navy was requested to put additional convoy escort over ships bringing up bauxite, because the loss of one ship would have been that many airplanes out of our aircraft program. I was also told that at the peak rate of our aircraft production during the war, the strategic supply of bauxite in the United States would have lasted about four years. So I think that this class should certainly dig into that phase of industrial planning, availability of the raw material that we are using in aircraft now.

If you will bear with me, I would like to read a chronological history of the B-29 airplane. This was prepared by some of our engineers and I regret that there may be a few technical terms in here that you who are not associated with the aircraft industry will not get, but I will be glad to explain them later if you so indicate.

"As the Pacific war progressed, it became increasingly apparent that the range of our heavy bombardment aircraft must be increased if we were to eliminate the jumping from island to island with a corresponding loss of personnel, equipment and time. The B-29 Superfortress was the tool of the Army Air Forces designed to accomplish these missions at extremely high altitudes. The size of this airplane, the rate at which they were produced, the large number of prime contractors and subcontractors fabricating complete articles and parts therefor, the retarded status of development of the experimental airplane, and the advanced experimental equipment installed thereon at the time production was undertaken resulted in extensive design, engineering and production problems which had not been encountered previously in the production of aircraft.

"When the Air Material Command first considered the B-29 project in 1940, it was generally believed that the first experimental airplane would fly some time in 1941 but as the actual work of fabricating the XB-29 progressed, a continual torrent of problems delayed the project

so that the first airplane flight did not take place until September of 1942. The initial engineering work included the selection and wind tunnel testing of a revolutionary wing section of low drag characteristics which carried unprecedented weight for its area. The initial design gross weight of the airplane was 100 thousand pounds but an overload weight of 120 thousand pounds was anticipated with a view of utilizing new combat equipment which was in a development stage at that time. Eventually, a gross weight of 137 thousand pounds was carried by the aircraft with a resulting wing loading of approximately 80 pounds per square foot."

To give you a yardstick on that, the old Jenny flew at about twenty pounds per square foot.

"In order to realize a design range of approximately 5,500 miles, it was essential that the design incorporate a maximum of aerodynamic refinement. In order to achieve this goal, it was decided to maintain a streamline fuselage nose, incorporating curved glass panels. In so doing, it was found that the pilot's forward vision was badly distorted and it became necessary to substitute flat glass panels in lieu of the previously conceived curved glass design. Wherever possible, plans called for the use of existing equipment already proven in combat use. The landing gear assembly offers a specific illustration of this point. The enormous weight of the B-29 airplane threatened to impose shock loads far beyond the capacity of the tires, and the design as well as production of a new tire promised to bring delays and difficulties. The problem was solved by designing a dual wheel landing gear, utilizing twin wheels and tires identical to those installed singly on the B-17 airplane," that is, the Flying Fortress. "This design further allowed the landing gear to be retracted in a more compactly faired space, aft of the inboard nacelle, thereby maintaining the important aerodynamic cleanliness of the airplane.

"One of the most unique features of the B-29 design was the pressurization of those portions of the fuselage which housed the crew, giving 8 thousand foot conditions in the interior of the airplane while flying at 25 thousand feet and higher. The development and original investigation of pressurized cabins was pioneered in 1937 when an Army Air Force designed airplane built by Lockheed was used for exhaustive tests at high altitudes. The application of these and subsequent investigations were combined in the subject airplane. The Boeing Company built a test airplane cabin on which numerous structural tests were conducted to eliminate air leakage under load. A series of gunfire tests were also conducted during which the cabin was repeatedly riddled by gunfire to determine the action of the structure and the reaction of the crew during these conditions. After completion of the airplane, and during subsequent flight tests at high altitude, a sighting blister"--that is a frog-eye type of window on the side of the fuselage--"which houses a gun aimer in the waist of the fuselage blew out a 25 thousand feet. The B-29 instantly became a pneumatic cannon and compressed air rushed through the fuselage at 140 miles per hour. The gunner was blown through the hole left

by the failed blister and parachuted to safety, meanwhile the remainder of the crew were experiencing 'explosive decompression' and, in effect, they were raised in a split second from 8 thousand feet to 25 thousand feet. Condensed moisture filled the fuselage with a white haze and the crew were forced to resort to oxygen masks, located in the airplane for such emergencies. This experience had two results:

"(1) It forced extensive experimentation regarding the structural details of the design and mounting of the blisters.

"(2) It presented additional problems for the Aero Medical personnel at Wright Field.

"The original material used in the construction of the blisters was molded glass. However, it was found that the required additional strength could be obtained by use of laminated plastics formed to shape under heat and air pressure. The mounting of these blisters was also revised to absorb the vibration in the fuselage and prevent its transmission to the blister itself."

Obviously if the man is sighting through the blister, it cannot be vibrating; it must be still.

"The original conception of the B-29 airplane was necessarily predicated on the use of the largest engine which it was anticipated would be ready" at the time the airplane was completed. "The Wright" 18-cylinder 3350 cubic inch engine was selected. "This engine had successfully completed a 50-hour endurance test in 1937 but it subsequently developed a series of difficulties which had not been satisfactorily solved when production contracts were let in May 1941 to provide engines for the B-29 and other four-engine aircraft. All possible pressure and assistance was placed on the development of this engine, but regardless, the first airplane had to be flown with experimental power plants and was later lost due to the failure" of one of these engines. "Further difficulties were encountered with the propeller reduction gearing." We had never attempted to use that quantity of power. The engine has to run at approximately twice as fast as the propeller and the reduction gearing has to be light and it is a very complicated gearing problem, and it was attempted, in this case, in a revolutionary manner to save weight. It was very unsatisfactory. "As soon as the airplane began to receive actual combat service, it became apparent that the engine cooling was unsatisfactory. Extensive ground nacelle tests and wind tunnel nacelle tests were conducted resulting in the installation of ducted engine baffles." That is simply a screening process in that they put tin baffles on to direct the air in certain directions over the engine; certain portions of the engine run hotter than others and those hot portions were causing failures so they had to design and develop some new air ducts to put the air where it was needed on the engine. That may sound insignificant but the thing that held the B-29 back in the early part of the combat was this baffling of the engine plus a very simple change which is known as the crossover tubes

on the rocker arms that actuate the valves of the engine. The Wright Company that had been engineering and building engines for 25 or more years did not have those in and it was up to a buck sergeant in our Oklahoma City Air Depot to develop those two changes that made the airplane work. They were standardized and our losses from fire just went straight off as soon as these two changes were made.

"The internal changes in the R-3350 engines played havoc with the production line and as late as October 1941, there was but a single R-3350 engine available and a year later there were 30. Not until the end of 1943 did engine production begin in earnest but even at that late date, there were only some 800 engines available to both the Army and Navy." The Navy was using them on a big flying boat; they had them on a twin engine boat. "The engine situation placed a tremendous burden on the operating units in that a perpetual series of changes were required to be incorporated in the field, with only crude facilities available and in weather conditions which were anything but helpful." Most of those changes were made out in Kansas during the winter and the wind was up to 50 miles an hour, and there was just no shelter; the men had to stand on these little ladders and work on those engines; it was pretty rugged. "The power plant problems were solved, however, and by the time bases had been established on Guam, Tinian, and so forth, the engine cooling and most engine operation difficulties had been drastically reduced.

"A radically new armament system was envisioned for this airplane to give remote control of strategically located gun turrets from a centrally located gunner's position." The airplane had these power operated turrets on top, underneath, front and rear, and one man had a little dome in the top of the plane where he sat at his controls, directed all the guns on the airplane on any target on which he chose to sight. In addition to that, these side windows--these frog-eye blisters on the side--each carried a sighting station with a gunner sitting there. If an attack developed on one flank of the plane, the side gunner, if he pressed his gun trigger, took control of the gun away from the master gunner who was on top, so that it was a very flexible arrangement but very complicated. Each gun had a Sperry sighting gadget on it, which I am sure some of you have seen in the Artillery Corps, this big box that looks like a wardrobe trunk that has dials all around the four sides and cranks and four men stand there and crank these corners and cables run off over to the gun and they crank in the lead and the deflection and so forth for aiming the gun. Well, each turret on the B-29 had all that stuff in a little box about that big (indicating). All that was developed during the time the war started and obviously we had very few people who could lift the cover off and look inside and accomplish anything; but we stayed with it; we made that central fire control system on the B-29 work and the reports from the using people were very satisfactory.

"This system was initially flight tested in the B-17 type airplane and there were such discouraging results that equipment and design had to be discontinued. A parallel development which was being

carried on at the same time, however, proved more fruitful and was used in the production B-29 airplanes. The system utilized five separate gunners, three of which were stationed in plastic blisters in the waist of the airplane and one each in the tail and nose of the fuselage. Each blister employed direct sighting rather than periscope scanning. Bitter arguments ensued during the early tactical use of the 4-gun forward turrets because many of the operating personnel felt that only two guns per turret were necessary and that the additional weight and corresponding decrease in fuel and bomb loads did not warrant their use. It was later proven that the 4-gun turret was highly desirable during sweeps over Tokyo and surrounding areas where heavy enemy fighter attacks were encountered.

"Coincident with the engineering and design difficulties were paralleling production problems. As stated before, the extreme urgency of the B-29 requirements and the fact that the airplanes were committed to an early appearance in combat theaters, not only shortened service test period, but telescoped every successive phase as well. The airplanes went directly from the factory to staging points where modifications and training in addition to the staging were performed simultaneously. Further, the combat theater commitments made production line changes impractical, thereby making large scale maintenance modifications mandatory. In order to satisfy the production needs for this airplane, additional factories and contractors were introduced into the program, among which was the Fisher Body Corporation. The methods of preparing aircraft drawings unfamiliar to these former automotive manufacturers required extensive liaison between the prime contractor who was receiving assemblies from this company."

There again we had no industrial mobilization planning, and we had no plans in industry to throw the Ford automobile company into business; but we wound up by paying Ford--on our contract termination which was settled last week--approximately one billion four hundred million dollars. That was for the unfinished business that he was caught with at the end of the war. I might say, in explaining that figure, that the Ford Company built the engine that was put on the Thunderbolt fighter, the engine that went in the twin engine C-46 cargo plane that flew the "Hump" over CBI. They built turbo supercharges for all our engines. They built several other products. The contract termination involved about five or six major items that Ford was turning out, in addition to the B-24 bomber which he built at Willow Run.

"The XB-29 tests were still far from completion when it was decided to jump into production on the airplane, thereby making the production tooling of the component parts a terrific gamble. This situation was further aggravated by the acute machine tool shortage in the spring of 1942. Myriads of small production difficulties arose during the period that the design, as engineered by the Boeing Company, was being made suitable for production by other prime contractors who utilized entirely different production methods and facilities. By 1945, more than a thousand engineering changes had been initiated on the B-29 airplanes and of these approximately 75 percent actually became effective."

We had any number of manufacturers building parts for these airplanes and one manufacturer may have had a thirty thousand ton hydraulic press; he could press out a piece of metal so big (indicating) with that big press, but we also had some other fellow making those things who had only a ten thousand ton press, so you can see what the engineering problems were in trying to farm this stuff out to various manufacturers without sufficient tools to do it.

"As is normal in aircraft design, the weight empty of the airplane gradually increases as the tactical utility changes and new equipment becomes available. It became apparent by August of 1944 that a determined campaign was necessary to eliminate all the unnecessary equipment and gadgetry in an effort to reduce weight and improve the tactical operating radius of this airplane. Superfluous instruments, extra cameras, auxiliary crew bunks, cabin soundproof lining, and many other small pieces of equipment were eliminated and armor plate was replaced by flak curtain." Instead of having a half inch thick piece of steel behind every man in the airplane, they simply used this material of armor suit cloth with little squares of tin helmet material sewed all into cloth; they simply hung these curtains around in the airplane which were very much lighter than the steel armor plate. "An immediate saving of approximately 4 thousand pounds resulted, thereby allowing the range to be increased 500 miles."

Well, I apologize for boring you with that detail, but there were a number of engineering and design problems pointed out in that B-29 story.

Going back to the problems that we had in industry, as soon as we were on a major expansion program, the draft hit the aircraft industry. It was a young industry and most of our experienced, highly trained engineers were young men. They were first to get caught in the draft. There had been no plan of any kind, so far as I know, for keeping a man who was much more valuable in building airplanes than he was in marching around with a gun. So we thought we had received a mortal blow when they took our young engineers out of our plants. And, as they went out, of course, the labor force was drafted too; we were told that we had to build airplanes with women. Well, the number of women used in the aircraft industry, during the war, reached somewhere around 60 percent.

A typical example of how we utilized these women and how we made out when we lost our engineers was evidenced by the Curtiss C-46 cargo airplane. That was a big two-engine airplane that carried the supplies over the "Hump," CBI. They built the fuselages of that airplane in one big steel frame. There were several locater points in that airplane--the place where the wings were to be attached and the place where the tail had to be held in proper relation to each other so that this big steel frame carried the entire fuselage. They had to put in all the radio equipment because they built this shell in this frame. They had people crawling all over one another. One fellow was trying to run wire from one end of the plane to another; one man was trying to

install the oxygen lines; another was working with radio equipment; another was trying to put in the hydraulic systems with pipes and tubes running all over the airplane. They were putting in bomb rack controls and these shackles with which they drop the paratrooper and equipment. The result was confusion and Curtiss was struggling along with that until the Army Air Forces moved in to break the bottleneck. Their excuse was that they had all women employees; they did not know their jobs, and so forth. So that fuselage main frame, or jig, was broken down into seven slices just like you slice a banana; the fuselage was built in seven different little steel frames so that each frame amounted to just a cylinder and they assigned maybe six or eight women to one of those cylinders. They would tell a women that her job was to take this little box--that may have been a radio control box or it could have been any kind of a gadget--and it had red paint on it and there was a red dot on the fuselage. Her job was to put the box on the red dot, put in two screws and that was it. They could teach a woman to do that in 20 minutes.

Instead of the intricate wiring system which they had, with people crawling over one another--at the beginning of the war--they had these wires all in metal tubes to prevent fire. Well, the first thing we did was stop the tubing and just run the loose wire around the plane. They laid it out on a board, a painted diagram which looked very much like a tree and each line had a different color and the wire spools were different colors and the girl would go over and pull off a blue wire and tack it on the blue line and take a red wire and tack it on the red line and when they were all cut, she would run tape around the bunch of them and thereby turn out a wire harness. As soon as these were put together, another woman took the harness; the woman painted a little blue line--she didn't know why, but she painted a blue line. Another woman placed the blue wire along the blue line and the women did that very delicate wiring job that we had paid highly skilled engineers to do before the war. And that same type of tooling had to be done in the whole industry in order to absorb the woman labor.

General Armstrong has asked me to give you a little something of our future plans. I know it is extremely dull and uninteresting to talk about what is past, but the only way we can judge the future is by the past.

In trying to look ahead, in making plans for industrial mobilization, it takes some good crystal ball gazing. We do not know of what these guided missiles are going to be made. We do know, however, that the temperatures encountered in flight have been very intense. We know that the German V-2 burned up as it entered the atmosphere; as it got up to a speed of 3600 miles per hour, while it was in the rarefied space and came down and entered the thick atmosphere, the friction of the air on the body of the thing burned up about 50 percent of them before they got down to the ground. Apparently the fuel would explode due to the friction heat.

The British have encountered already on their jet fighters trouble with the plastic bubble canopy that houses the pilot--transparent canopy of the pilot--the material loses strength rapidly with increased temperature and they have encountered a 65 degree rise in temperature while flying around 600 miles an hour. This plastic gets soft and they have had trouble losing the canopies on their jet fighter planes. We at Wright Field are now thinking about a small refrigerator in the cockpit to cool the pilot. The airplane gets hot, you know, at as fast a speed as we are getting into now. Some of this information is classified so I would like to remind you of that fact.

Our whole military program, practically a hundred percent across the board, is centered around jet planes. We have a jet bomber now that is being manufactured. It is not flying yet, but it weighs more than the B-29 and it has six 4-thousand pound jet engines on it. It is faster than the P-80 Shooting Star and it will carry all known types of bombs. We have a number of models that would probably be classed as medium bombers, although they are in the weight class with the B-17 and B-24. They are all jet; everything is jet; and I might say that the efficiency of these jet engines now is comparable with that of our conventional engines at the altitude and speed that they are supposed to operate. Actually the range is not up to the range of the other conventional airplanes because we lose too much efficiency in getting up to where we have to operate. But, the conventional engine, having been some 50 years developing, it is interesting to note that the jet engine is already up with it from the standpoint of efficiency.

Now if there are any questions, I would like to try to answer them.

GENERAL ARMSTRONG:

Colonel Sessums, you spoke about the difficulty--and I think it is one that we should bear in mind--in getting aluminum as a material for airplane production. Last week some of us were at Midland, Michigan, and saw the production there of sheets of magnesium. Can you tell us if the magnesium sheets can become a substitute? Of course, you realize, as we do, the importance of an unlimited supply of magnesium, that is, magnesium is produced in Texas and some other places from sea water.

COLONEL SESSUMS:

General Armstrong--your question is, have we progressed in the development of magnesium sheet to where it is satisfactory for aircraft production purposes? I believe the answer is no. Now we have had a small inadequately financed program at Wright Field for many years trying to do just that. We have succeeded in developing magnesium to where it can be cast. In fact, we had standardized on magnesium cast wheels before the war. All of the Army airplanes used the magnesium cast wheel which was 30 percent lighter than aluminum and satisfactorily strong. There again no planning had been undertaken and no one could foresee the fact that the Thermite Bomb would be

replaced with a magnesium bomb and that we were going to furnish the Russians and British with all the magnesium in the world, practically, which made us, right in the middle of the war, stop building magnesium wheels and go back to casting aluminum wheels which is quite different, and we lost considerable time in retraining the casting people in casting aluminum. But the magnesium sheet we have not developed to the extent where it is as satisfactory as aluminum. In fact, the aluminum developments seem to be outstripping the rate of development of magnesium.

There is a new aluminum sheet called 75-ST which is much stronger than anything which we have ever had in the past.

GENERAL ARMSTRONG:

Is the difficulty then in the strength of the sheet?

COLONEL SESSUMS:

The difficulty is in the metallurgical problems. They have satisfactorily been able to weld it by using a reducing atmosphere, that is, they weld it surrounded by an atmosphere that will not burn and the magnesium does not have a chance to catch fire, while welding. That process has been perfected. They can satisfactorily weld magnesium sheet now but it is the characteristics of the metal that they have not been able to alloy properly to get the results we need.

GENERAL ARMSTRONG:

How about the man-hours on the making of an airplane nowadays as compared with the former technology; do you still use riveted construction or do you do welding to a great extent?

COLONEL SESSUMS:

We use riveting still very similar to the prewar type construction and there I think is one of the largest fields that the class could investigate. The only outstanding example that I know of where some actual progress has been made, has been on the little private airplane known as the "Sea Bee." I am sure some of you have seen it. It is a little amphibian, 215 H.P., all metal, all aluminum with thick gage material used. It will not get dented; and the Republic Company built that airplane with only 140 man-hours of labor; using the conventional manufacturing methods, it would take a minimum of 3,500 man-hours to build an airplane like it. They have built the wing with not a rib in it. You can go to one end and look right through the wing; it is just a tube. He used a heavy gaged sheet skin on the outside with some little crimps that kept it from oilcanning, so to speak, and has run three longitudinal spars lengthwise in the wing. And his structural people said, "We cannot tell you whether or not it is any good." "The only thing to do is build it." They built it and tested it and it proved out 70 percent as strong as a Thunderbolt wing and it is a

four place amphibian. Incidentally, if any of you are interested in private airplanes, it is a pretty nice plane. I have flown it.

GENERAL ARMSTRONG:

What are they going to charge for it?

COLONEL SESSUMS:

It sells for $3995.

QUESTION:

Colonel Sessums, General Eaker has gone on record here at the College as forecasting that within 10 to 25 years the airplane as a combat vehicle will be obsolete. It will be replaced, according to him, by guided missiles, to be launched from a distance of as much as 5,000 miles. In the light of your view of investigations up to now, what are your sentiments on that, specifically?

COLONEL SESSUMS:

I think General Eaker is quite right. I am not sure what the point of your question is; if it is a matter of range, primarily, I do not think we know too much about the possible ranges except that we know they will be very great.

QUESTION:

I was thinking of both range and control.

COLONEL SESSUMS:

There are some tremendous problems that are involved but we have solved all of the basic problems. The control during the flight through space where there is no atmosphere in which we can use guide vanes to guide the weapon--we must use a deflective rocket jet; that is the only force we can get in space.

In other words, once this guided missile gets out of the atmosphere into space, wings or anything else will not guide it. It has to have a positive force and the only force we can work with is jet. So they will have to deflect the jet in order to blow the thing around in any direction they want it to go. But you will all remember that in the last war, when the Germans were experimenting with that long-range gun, they fired it a couple of times and they had calculated where the shell would land and they had spotters over there and they were unable to locate any of the projectiles. They figured the range was something like 40 miles, I believe, and after they fired a number of additional rounds and the spotters still could not find them, they began to get some complaints from a place 75 miles away. What had happened was that this projectile had gone up and while it was in space, it violated the laws of artillery trajectories and came down way beyond that.

How we will handle guided missiles when they get out of the atmosphere into space, no one knows, but I would think very little force would take the thing quite a distance without any resistance at all. We have a book that thick (indicating) full of projects of every kind, size and description of guided missiles, with every kind, size and description of guiding means to control those guided missiles. They have radar "gimmicks" in the nose; they could tune the thing to select any target they wanted to seek, and, of course, they use proximity fuses; if the thing gets within a certain distance of something else, it explodes. I believe you probably saw in the paper recently where the Army Ground Forces are going to fire 2 V-2's and attempt to use some of our equipment in the nose of one of them to shoot the other one down. They are going to fire one and try to knock down the second one by using this radar homing and proximity fuse equipment.

QUESTION:

Colonel, we have been seeing pictures of that flying wing, could you tell us if it has ever flown, is it expected to fly and will it revolutionize the design of planes if it is successful?

COLONEL SESSUMS:

I would probably be court-martialed if anyone heard me say this in authority, but the cemeteries are full of flying-wing pilots. Actually, we think the bigger a flying wing gets, the greater the chances are of its success. The main problem has always been using a flap on the wing for landing. When they pull a flap down on the wing, slow it down for landing, they have a terrible time controlling the longitudinal stability of it. The B-35, which is the plane you referred to, was built as our answer to the War Department General Staff request for a ten thousand mile and ten thousand pound-bomb-load bomber. It is the closest thing to it. It will carry ten thousand pounds about 9,800 miles, I believe--something like that, just barely falls short theoretically of doing it. Actually the plane has not been flown; it is getting its ground tests at this time; it has all four engines installed and the engines cool and operate satisfactorily on the ground, but they are now running the landing gear shimmy test and it is expected to fly in a very short time.

QUESTION:

Colonel, if it is not too highly classified, can you tell us what critical raw materials problems you are meeting with the jet planes and the guided missiles; what new critical raw material problems?

COLONEL SESSUMS:

Colonel, that is a very difficult question to answer because we have not gotten into the program far enough to know what those problems are going to be. We do not know, at this time, whether our guided missiles will eventually be built of plastic, magnesium or some other light material. We do know that it must be some material lighter than that we are now using because they have a term they call "the mass ratio;"

the initial start of one of these tremendous rockets--the thrust that this jet can develop--is awfully close to the gross weight of the whole thing. You have probably noticed the V-2 or some of these big rockets in the movies; they come out like a fish, going very slow, a few miles per hour, when they first come out of the track; they have stabilizing equipment that will cause them to swim like a fish until they unload some of that terrific fuel they have; it is unloaded very rapidly at that point when it is first taken off; as the fuel burns and it gets lighter, it picks up speed and finally is really moving at the end of its travel.

But to answer your question, we are not even far enough into the program to know what material is to be used. That is the point I was making when I said the crystal ball will have to be used in industrial planning for mobilization because no one can tell us of what we are going to build those things. The rockets that the Germans developed all used carbohydrate fuel--carbon base--that is the family of fuels of coal, fuel oil, gasoline, alcohol and kerosene. Those fuels all have an energy content of about 22 thousand B.T.U.'s per pound, any one of them, they are all practically the same. Now if we get fuel that has three or four times that much energy, we are going to have less trouble getting these guided missiles started. They are thinking of liquid hydrogen as the next step. We will be using liquid hydrogen that has around 50 thousand B.T.U.'s per pound. It has to be contained in a container that will stand three or four thousand pound pressure to keep it in a liquid state. But by using liquid hydrogen, we can get some good results in our guided missiles.

QUESTION:

Colonel, do you utilize the services of the Forrest Products Laboratories, Madison, Wisconsin?

COLONEL SESSUMS:

We used them all through the war. Whether or not we have a contract currently with them, I am unable to say.

GENERAL ARMSTRONG:

I want to thank you for your patience as well as for a magnificent presentation here to the College this morning. It has certainly given us a new light on the future of the airplane industry and also a new light on the past. We are very grateful to you for your contribution.

(8 July 1946--200.)S

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