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Lockheed Aircraft Corporation
ADVANCED DEVELOPMENT PROJECTS
BURBANK, CALIFORNIA

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DATE 1 July 1968
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MODEL A-12

TITLE HISTORY OF THE OXCART PROGRAM

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DATE: JUL 2007

REVISIONS

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HISTORY OF THE OXCART PROGRAM

As Recorded by the Builder

This report summarizes briefly the history of the Oxcart program since its inception up through its early operation. It is based on information kept by me on the various aspects of design, contracting, testing and operation. Much of the data presented herein is excerpted from presentations made to CIA Headquarters personnel during numerous briefings as the program progressed.

INTRODUCTION

After the U-2 was in service for several years, it was evident that continued development should be done on the use of aircraft for special reconnaissance missions. In April 1958 I recall having long discussions with Mr. Richard Bissell on the subject of whether or not there should be a follow-on to the U-2 aircraft. We ended our discussions in mutual agreement that there would be at least one more round before the satellites would make aircraft reconnaissaince obsolete for covert reconnaissance.

Lockheed undertook the first study of a Mach 3.0 cruise speed airplane having a 4,000 n. mile range at altitudes over 90,000 feet on 21 April 1958. Concurrently with airframe studies, ADP was engaged in tests to reduce the aircraft radar cross section not only of the U-2, but in all other types of aircraft suitable for the reconnaissance mission. We made an effort to design an all plastic subsonic airplane known as the G2A, but early tests of a model in a radar anechoic chamber showed that this was not feasible, in that equipment items and the fuel itself presented a bigger cross section than an all metal aircraft.

On 23 July 1958, Lockheed made its first presentation to Mr. Richard Bissell, H. M. (Dick) Horner (United Aircraft), Al Donovan, Dr. Ed Purcell and Mr. Eugene P. Kiefer at Cambridge, Massachusetts. Commander Struble of the Navy was present, and he described a Navy

concept of a rubber inflatable airplane which was to be ramjet-powered and carried to altitude by a balloon. I made some rapid notes, and found the balloon would have to be over one mile in diameter and the wing area of that concept would have to be greater than 1/7 of an acre.

I believe at this time the CIA also invited General Dynamics to make certain proposals, which they did. In fact, a very lively competition was held, carrying on over an 18-month period (estimated). By 25 August 1958, ADP was well into studies of various configurations, some based on ramjet engines and several having both ramjets and turbojets. At this time, we were giving our studies the name of "Archangel" 1, 2, 3, etc., which gave the Oxcart finally a designation of A-12. The aircraft was named "Archangel" in that the original name of the U-2 here in the Skunk Works was the "Angel", due to its high altitude operation.

In September 1958, a meeting was held with the following:

> Dick Bissell, Dr. Edwin Land, Dr. Ed Purcell, Guy Steven, Jim Cross (for Gary Norton), Dick Horner (United Aircraft), Gen. Swofford, Col. Norman Appold, Col. Seaberg, Cmdr. Dewey Struble, Al Donovan, Frank Rodgers, Eugene P. Kiefer, Maj. Bob Hippert, Brady (Convair) (for one hour of meeting only).

By this time the inflatable airplane concept had been dropped. Boeing had proposed a hydrogen-powered airplane having a gross weight of 167,000 pounds and a length of over 200 feet. At this time, Lockheed had just concluded work on a hydrogen-powered aircraft and concluded that the range obtainable was quite insufficient. So our CL-400 was dropped.

Convair's proposal at this time was a ramjet-powered Mach 4.0 piloted aircraft to be launched on the B-58. They stayed with this design a considerable period of time.

In the period from December 1958 through July 1959, we studied various aircraft from the series of A-3 to the A-12. The CIA funded Convair at a very high rate compared to what we were given for our studies. Much emphasis was placed on the radar cross section of the aircraft to be chosen. Dr. Frank Rogers worked with both Convair and us on the problem of reducing the radar cross section. As a fundamental concept, I knew it to be a requirement that a Mach 3.0 aircraft had to make many concessions to the aerodynamic and structural problems, as well as merely reducing the radar cross section.

In April 1959 I proposed a concept of a single base operation with air-to-air refueling, operating out [redacted] The A-11 aircraft was one which made no compromises for the anti-radar design, and the A-12 which was finally built made substantial design changes to reduce its cross section. During meetings in this period, the Air Force was represented by Gen. Marvin Demler, Gen. J. R. Holzapple, Col. Norman Appold and sometimes Col. Leo P. Geary.

By July 1959, Convair had come to the conclusion that they were unable to accelerate the B-58, carrying the ramjet-powered Super Hustler, through Mach 1.0. It was also evident that a single ramjet flying a manned aircraft over Russia for covert reconnaissance was unfeasible from a reliability point of view. From this period, our studies regarding radar cross section showed that any flyable aircraft to be operational in the period after 1963 could not avoid radar detection. This did not mean that we had not gone all out on the reduction of radar cross section, as we made many very important contributions, including those of basic shape, to the whole problem on the A-12. At this time, Mr. Bissell and Gene Kiefer stated that Convair also had not made any important breakthroughs in the anti-radar field which would guarantee an invisible aircraft. In fact, much of the work we did on the A-11 was transferred directly to the Super Hustler. Toward the end of July 1959, Convair was given another contract to design an air-breathing twin-engine airplane known as the Kingfisher. This airplane had two side-by-side engines mounted in the fuselage and actually used rectangular plastic afterburners which could not conceivably work. Its radar cross section was not better than our A-12. By this time we were working with P&W on a J58 engine. To overcome the afterburner problem of a large radar cross section return from the aft quadrant, we proposed the use of cesium additive to the fuel. This was first brought up by Mr. Ed Lovick of ADP, and its final development was passed over to P&W. It was eventually a basic part of our cross section reduction methods.

We had been working with titanium alloys for several years as a structural material for the aircraft because of the high temperatures involved, and felt we had a good research background to use the most advanced alloys which could be obtained from our titanium industry. There were numerous meetings between the contractors and the CIA, with Air Force participation and strong support. The Air Force representatives solidly supported our design concepts throughout this period over those of Convair.

On 28 August 1959, Mr. Bissell told me to come east for the 19th time in this competition. He told me that we had won the competition, subject to our proof of low radar cross section between that period and 1 January 1960. We were told that the degree of security and method of operation used by ADP on the U-2 were to be followed on the new project, but for the next three months we could make no large material commitments until a full scale model was evaluated on a new test range [redacted] On 29 August 1959, I had written up a proposed work statement of 20 items and had given a go-ahead of 4.5 million dollars to cover the period to 1 January 1960. Our basic quotation, not including the service contract or development of the inertial guidance system, was 96.6 million dollars for 10 aircraft.

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On 31 March 1959 we started to build a full scale mockup and elevation device to raise the mockup 50 feet in the air for radar tests, and I started to gather personnel to implement the project. Up to this point,

I had no more than 50 people on the project. On 10 September 1959, Col. Leo Geary and [redacted] visited Lockheed. At this time we convinced [redacted] and others that the place to put the radar test facilities was [redacted] and not to continue testing at a very poor facility they had at Indian Springs. By 15 September 1959 we were well on our way toward implementing our contract, particularly in the anti-radar field. We had located the project in Bldg. 82A of the Lockheed facility at Burbank.

DEVELOPMENT OF THE A-12

The development of the Oxcart airplane, which I refer to as the A-12, was faced with many substantial problems not solved previously in the industry. We learned rapidly that the technology which we expected to be developed for the B-70 and the F-108 was non-existent, and we shortly passed the B-70 in all phases of the hardware development. At the peak of the basic design effort on the A-12, I had 135 engineers on the project, including myself. We decided to go the route of a titanium aircraft rather than the stainless steel honeycomb concept of the B-70, becuase of the better strength/weight ratio possible and the more straightforward type of construction that could be used.

I did not feel that the Skunk Works had the capability to build a stainless steel honeycomb aircraft with the incredible amount of precise tooling required; nor did I foresee, either, the incredible amount of tooling that it would take to make it out of B-120 titanium. This material was not in use by any other project. It was as strong as stainless steel, but weighed only slightly more than half as much. We knew it would require very precise control of forming and heat treating to get a decent structure. In fact, of the first 6,000 sheet metal parts we made, 95% were scrapped because of extreme brittleness.

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We chose to build the nose section of the airplane, which involved the most complex structure, using the thinnest material gauges. But this included the cockpit and canopy, so that we could use the first titanium

structures we built for practice in construction as a part of the mockup for testing airplane systems in our research "lab", which we fondly called "The Fort". Because of security, we could not make use of the ample Lockheed facilities existing at Burbank and Rye Canyon, so we made do with an old P-38 revetment that had walls 8 feet thick and 20 feet high, where we could test our hot systems and structures, including a full-size mockup of the fuel system, without subjecting the local populace to danger from explosions or failure of mass systems.

On 2 and 3 November 1959, we had our first suppliers' meeting, similar to those Mr. Bissell had held on the U-2. Those present were:

P&W	George Armbruster Richard Coar Deane McCarthy C. T. Roelke
Perkin-Elmer	Milt Roseneau Rod Scott
Phillips Petroleum	Emil Malick
Narmco	Carl Fredericks
Eastman Kodak	Joseph Boone Edward Green
Headquarters	D. Bissell James Cunningham Br. Gen. Don Flickinger Col. Leo Geary Gene Kiefer John Parangosky

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Headquarters - (Cont'd)

Scott AFB, Illinois

Lt. Col. Adolph Gaertner
Maj. James R. Smith

By 9 November, our full scale radar test model was complete. It was shipped by special truck and installed on the new post by 18 November. We were able to prove by 1 January 1960 that our concept of shape, additive, and loaded plastic parts had enough promise to warrant going forward with the project.

On 16 December 1959, the second suppliers' meeting was held in the P&W offices at West Palm Beach, Florida. At that time, we reviewed the status of the J58 engine, the use of fuel additive, the requirements that we had for a very low vapor pressure fuel, and had a good deal of discussion on the use of the Hamilton Standard inlet control. We did contract with them for a hydraulic pneumatic control based on their experience (we thought) in working on the B-70, and facilities provided under the B-70 program and their reputation for having made excellent propeller controls for many years.

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On 26 January 1960, Dick Bissell informed me that we had the full go-ahead on either 10 airplanes plus a static test unit or 12 airplanes plus a static test unit, but that we should now go all out and place material orders, etc.

Gen. Howell Estes asked me to come in on 16 and 17 March 1960 to talk about the A-12 as an air defense fighter. Mr. Bissell gladly gave his consent and this was actually the start of the YF-12A. By this time we were well into the design and fighting such problems as hydraulic fluids, lubricants, control cables, inlet controls, and everything about the airplane. I offered $50 reward to anyone who could find anything easy that we do on the airplane. To this date, no one has.

The actual airplane parts began to come out on 5 April 1960. They were extremely costly and machined or formed with the greatest difficulty. We had to institute the most careful quality control, starting at the mill of Titanium Metals Corporation and carrying right through to installation of the part in the airplane. We made test coupons at the rate of tens of thousands per month, and in the end it was possible for us to trace the material and processing of any part of any airplane all the way back to the sheet from which it had been cut, and then back to the mill from there. We ran wind tunnel tests on all facets of the design. Before we had a usable inlet, we had to collect two million data points in the wind tunnel, and later we had to do at least that many in flight.

By that time I was having 7 o'clock meetings every day with our shop people, to solve the problems of the day. I had set up a special machining group under Mr. Bob Vaughn, with an aim to double within three months the rate of metal removal current in the industry for titanium, and to obtain a rate of ten times the industry average within 18 months.

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We had a difficult weight problem on the airplane. On 11 October 1960, I made independent contracts with each of the engineers, as shown in attachment 1.

On 30 November 1960, Lockheed sold Headquarters the prototype 1649 transport for $305,000 including $37,000 to put it in condition to use as a shuttle transport [redacted]

At the time of our suppliers' meeting at Burbank on 19 December 1960, our cost situation was very bad, in that we were 24% over our projections -- 80% of this being due to added material costs. Also, a new Russian radar, known as "Tall King", showed up, which greatly affected the range at which an aircraft could be detected. This put greater pressure than ever on our anti-radar work.

In February 1961 we were having terrific problems in getting the wing built. This was due to lack of material, a high scrap rate, and the necessity of training personnel.

At that time we were in the midst of testing systems. Each one had to be invented, including such things as new hydraulic oils, plumbing fittings, control cables, windshields, ejection seats and pyrotechnics, as well as ground starters and similar items.

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By September 1961 it was perfectly evident that the J58 engine would not be available for the initial flights of the aircraft. I then proposed that we try to install the J75 engine, having much less power. But it was finally agreed that we would do this, and that was how we first flew.

On 28 February 1962, Dick Bissell resigned from the project. Dr. Herbert (Pete) Scoville, Jr. took over in his place.

Early in March 1962 we placed the first A-12 on a specially designed truck, enclosed it in a removable housing and drove it to [redacted]. When we first poured fuel in the aircraft, it developed 68 leaks. This was a bad blow, after all the research we had done with this Viton sealant, which was the only thing we knew which would take the temperature. We had to strip the sealant from the aircraft and reseal it with another, which we knew was not as good at high temperature.

We worked around the clock to get the bird ready for flight, and on 25 April 1962, Lou Schalk first got the aircraft into the air. He flew it about a mile and a half at altitudes of about 20 feet. The aircraft got off the ground with almost full right rudder on, and then required an immediate correction in the other direction. This set up lateral oscillations which were horrible to see. The trouble was determined to be an improper hookup between the rudder pedals and nose wheel steering, as the rudder and nose wheel turned in opposite directions from those desired.

On 26 April 1962, we made the official first flight. Lou made a beautiful takeoff, but, by the time he got to about 300 feet, we started to shed lower fillets. Bill Park was chasing him in the F-104. A beautiful landing was made and we had an opportunity to investigate all the usual first flight incidents. In four days we fixed the fillet problem

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by proper venting and attachment, although these fillets had been designed very light to save 600 pounds of weight. We flew again on 30 April for 59 minutes, with no difficulty.

Throughout the summer of 1962, we continued our flying, completed the static tests on the static test article in Burbank, and concentrated on redesigns of the plastic fin, which gave us a great deal of trouble.

By the end of July 1962 we had made 28 flights, and aircraft number 2 was being mounted on the pole for AR tests. = ANTI RADAR It was quite an experience to see such an expensive piece of machinery that far up in the air. But it worked very well.

At that time, we were faced with increasing vendor overruns on cost, and our own experience with hot forming titanium was requiring us to rework the hot sizing blocks as many as three times to get the parts required for the airplane. This is the area in which ADP overran its costs.

Hamilton Standard had overrun by much more than 100% at that time, and we had great difficulty with the air inlet control.

In mid-June 1962 the first J58 engine was delivered to us. Very substantial rework was required in removing the J75 engines. The thrust was down about 1500 pounds per engine and the specific fuel consumption was up, but our main problem was trying to get the inlet control to work properly.

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On 19 December 1962 we delivered the fifth airplane [redacted] meeting our schedule requirements for the year. However, it was delivered minus engines, as they were not available.

In April 1963 we were directed to rebuild the aircraft chines to change the optimum radar cross section at S-band to favor better performance against the "Tall King". This was an expensive and (as it finally turned out to be) undesirable change.

We had increasing difficulty in this period with engine damage due to foreign objects. Most of these were built into the nacelles in Burbank and were sucked through the engine in early runups. We instituted an extremely difficult FOD program, including xrays, shaking of the nacelles, putting screens on the various air entrances, and finally getting the problem in hand.

On 24 May 1963 we lost airplane number 3. The pilot was Ken Collins. The airplane landed south of Wendover, Utah. The cause of the accident was probably the freezing up of water in the pitot tube. When the pitot heat was turned on, however, the air speed read correctly, but the pilot didn't believe it. The airplane stalled at 123 knots, as it should have, and spun in. Ken ejected successfully, and our escape mechanism worked well.

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On 10 September 1963, Mr. McCone became considerably agitated by lack of progress in getting to our design goals. He instituted an "in-house" study comparing our development rate with that of the B-58. The result of that report showed that we had developed four times

faster than the B-58, had come closer to our objectives in a given time, and had done it at substantially less cost. It was, nevertheless, a very difficult and trying period.

Shortly after that time, five follow-on A-12 airplanes were added to the program., Brig. Gen. Leo Geary was very instrumental in having this done. His contributions to the Oxcart program were very large. Throughout his whole tenure in the Pentagon, we had the most excellent support from the Air Force in providing whatever they had which we needed.

By the end of September 1963 we had obtained a level flight speed of Mach 3.0, but we were having substantial difficulties with the inlet control, as well as the engine control. Our transonic thrust and/or drag left a great deal to be desired. We finally overcame this problem by improving the engine, increasing the penetration speed for Mach 1.0 by 50 knots, and making a whole host of structural beefups in the nacelle tail flaps, which we had to do over three times to take the terrific loads and temperatures.

In January 1964 Dr. Albert (Bud) D. Wheelon took over Pete Scoville's job. He visited the Area for indoctrination. A few days later, our pilot Jim Eastham took the test airplane #121 to a Mach number of 3.3, with 15 minutes above Mach 3.2.

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On 1 March 1964, President Lyndon Johnson announced the YF-12A. Twenty minutes after he did this, we flew the two birds

to Edwards AFB. They were fast flights, and the aircraft were so hot that when they were moved into the new hangar the fire extinguishing nozzles came on and gave us a free wash job.

On 6 May 1964 we were visited by Roger Lewis, Bob Widmer, and other General Dynamics' people, who came to learn of our experience with ejectors, power plants, and high speed flights. We had a great deal of trouble, but not nearly as much as they seemed to be heading for.

On 9 July 1964 we lost airplane #133. ADP pilot Bill Park was flying it. He ejected laterally at 200 feet altitude on approach. The cause of accident was temperature gradients in the outboard elevon serve valve. It seemed that, while we tested for high temperatures and low temperatures and normal temperatures, we didn't test for cold hydraulic oil with a hot servo valve, or vice versa. We did from then on.

In September 1964 we had a great many important visitors, resulting, I think, mainly from the President's announcement of the type. We were called upon to help the B-70 in a number of its problems, which we did willingly.

On 23 October 1964 we flew aircraft #128 4,500 n. miles with two refuelings, at Mach 3.0 and altitudes as high as 80,000 feet.

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On 26 October 1964 we were visited by a large number of airplane manufacturers and directed to discuss what was known as UNLOCK data, the purpose of which was to pass on information which would be of value to the supersonic transport.

In March 1965 we were still having nothing but trouble with the Hamilton Standard inlet control. We had run well over 10,000 wind tunnel tests and had taken 1,250,000 data points, but we couldn't make the inlet control work. After a $17,000,000 program with Hamilton Standard, we went forward to design our own inlet control. AiResearch built the electronic components and we designed and built the hydraulic and mechanical ones.

In September 1965 we had been having consistent electrical problems, due to high temperatures in the nacelle and our inability to get high temperature wiring and plugs. I spent six weeks [redacted]. We rewired much of the aircraft, and designed some fundamental improvements in terminal plugs, etc., in an effort to prepare for Project Blackshield.

On 28 December 1965 airplane #126 crashed on takeoff. It was flown by Mel Vojvodich, Jr., who ejected safely. It was perfectly evident from movies taken of the takeoff, and from the pilot's description, that there were some miswired gyros in the aircraft. This turned out to be exactly what happened. In spite of color coding and every other normal precaution, the pitch and yaw gyro connections were interchanged in rigging.

In July 1966 Gen. Leo Geary left the Oxcart program.

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Upon returning from a vacation on 2 September 1966, I was met by a committee made up of Carl Duckett of the CIA, Mr. Fischer of the Bureau of the Budget, Mr. Bennington of the Office of the Secretary of Defense, and John Parangosky. This group were investigating the over-all program, as well as the interaction of the SR-71, as completely as they could. It ended up with what was known as the Fischer-Bennington report, recommending that the Oxcart airplanes be stored and the Area closed. By the end of calendar 1967, the SR-71's, under the Strategic Air Command, were to be assigned the basic mission of manned aircraft reconnaissance for the U.S. This was a horrible blow.

On 5 January 1967 we lost pilot Walter Ray and A-12 #125 on a training mission. This was the first failure of an ejection seat or, rather, of the seat belt, which was a standard Air Force type, and which did not release as required. The aircraft ran out of fuel, due to a combination of circumstances.

During the month of January 1967, in a desperate effort to save the Oxcart program, I proposed that half the SR-71's be converted to bombers. This would then result in our not having a surplus of reconnaissance aircraft, as claimed by Fischer and Bennington.

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On 31 May 1967, three Oxcart aircraft were deployed to Kadena, flying nonstop across the Pacific. They refueled twice and got to their destination in slightly under six hours. Ken Collins, however, landed

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at Midway with some radio difficulties. The results of the Blackshield deployment appear to have been very successful. Flying over North Viet Nam, they took excellent pictures and contributed significantly to our knowledge of the enemy deployment.

On 14 February 1968, a successful mission was launched over North Korea, after the seizure of the Pueblo. It was an extremely important mission. The aircraft is working very well to date. The same goes for the complete complement of crews, made up of both Agency and contractor personnel.

As of 9 May 1968, the future disposition of the Oxcart aircraft has not been decided. We have made studies of converting them to air defense fighters, handing them over to the Strategic Air Command, and even stacking them three-deep in a hangar at Palmdale and letting them be stripped for parts! In looking back at the ten years of effort in this program, I believe that Mr. Bissell and I were right in our early discussions. There is a place for the Oxcart program, along with satellites, in the foreseeable future. While the aircraft is not invisible to radar, the combination of tactics and ECM gear can live in a hostile environment, and the flexibility of operation due to long range is certainly of great importance to our country.

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In the appendices attached, I will comment on some over-all cost factors and present several significant charts on the program which were used in suppliers' meetings and which are useful to an understanding of the Oxcart history.

SOME IMPORTANT DATES

21 April 1958	Undertook first studies of Mach 3.0 cruise airplane having a 4,000 n. mile range at altitudes over 90,000 feet.
23 July 1958	Made first presentation of study to Dick Bissell.
31 March 1959	Started to build full scale mockup for radar testing.
28 August 1959	Informed by Dick Bissell that we had won competition, subject to proof of low radar cross section by 1 January 1960.
2 November 1959	First suppliers' meeting.
9 November 1959	Full scale radar test model completed.
26 January 1960	Received full go-ahead on either 10 or 12 airplanes plus a static test article.
5 April 1960	First parts beginning to come out.
26 April 1962	Official first flight (J75 engines).
30 April 1962	First flight for VIP's.
4 May 1962	First supersonic flight.
5 October 1962	Flew first time with one J58 engine.
9 March 1963	Flew first time with two J58 engines (#121)
20 July 1963	Flew first time to Mach 3.0 (#121)
26 February 1962	First airplane delivered at Burbank
25 March 1964	Last airplane delivered at Burbank
30 November 1965	Airplanes declared operational for Project Blackshield.
23 May 1967	First flight across Pacific (#131).
31 May 1967	First Operational Mission.
26 June 1968	Close out ceremonies for the Oxcart Program [redacted]
1 July 1968	Storage of Oxcart aircraft at Palmdale, essentially completed.

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LIST OF REPORTS

SP-119	The Probability of Radar Detection of Airborne Targets, 30 April 1959
SP-151	A-12 Model Specification (15 January 1960)
SP-447	Penetration Study (revised 27 November 1962)
SP-639	Progress Report for 1963
SP-708	P&W/LAC Progress Report (23 July 1964)
SP-762	Charts Used in Suppliers' Meeting [redacted] 5 January 1965
SP-806	Blackshield Charts Used in Meeting at [redacted] May 1965
SP-816	Blackshield Charts Used in Meeting at [redacted] June 1965
SP-874	Blackshield Charts Used in Meeting at [redacted] July 1965
SP-880	Blackshield Charts Used in Meeting at [redacted] August 1965
SP-903	Blackshield Charts Used in Meeting at [redacted] September 1965
SP-912	Blackshield Charts Used in Meeting at [redacted] October 1965
SP-920	Charts Used in Meeting at Burbank, 18 November 1965
SP-948	Engine Air Inlet System - Reviewed (20 January 1966)
SP-1123	A-12 Current Status (1 October 1966)
SP-1207	A-12 is Ready (1 June 1967)

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SUMMARY OF CONSTELLATION OPERATION

The three Constellations (1049G, 1049H and 1649) provided basic transportation between Burbank [redacted] in the time period between January 1961 and 12 May 1968. A summary of their performance is indicated below:

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Flights: (A flight consists of one landing and one takeoff.)	11,495
Flight Hours: (Takeoff to touchdown)	12,897
Passengers Carried:	492,205
Cargo Carried	4,328,073 Lbs.
Mileage Flown (approx.)	3,669,900
Delays:	
Passenger/Cargo	77
ATC	27
Weather	62
Maintenance	55
Security	5

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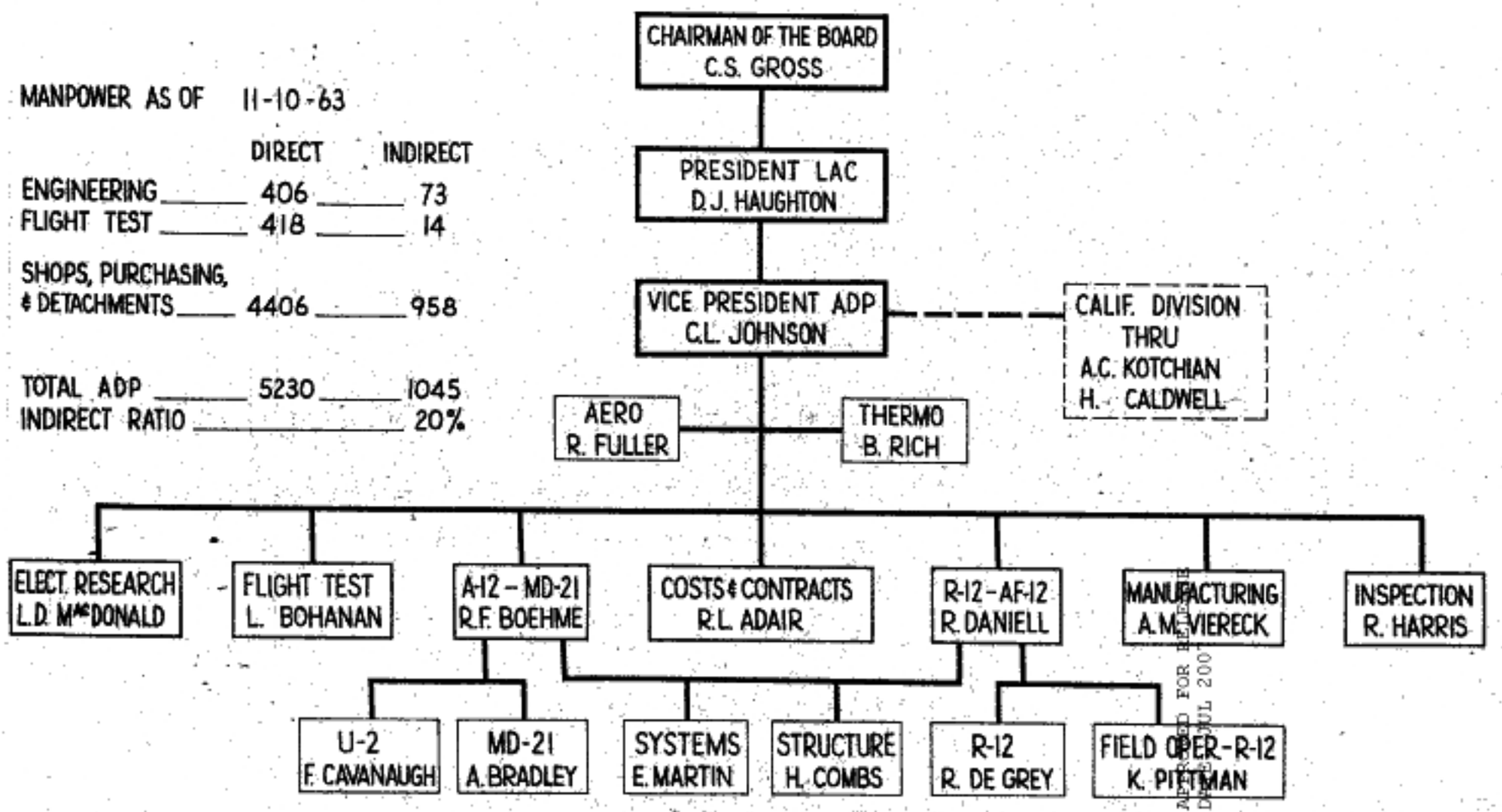
ADP ORGANIZATION

MANPOWER AS OF 11-10-63

	DIRECT	INDIRECT
ENGINEERING	406	73
FLIGHT TEST	418	14
SHOPS, PURCHASING, & DETACHMENTS	4406	958
TOTAL ADP	5230	1045
INDIRECT RATIO		20%



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