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THE B-70 PROGRAM - LESSONS LEARNED

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I. MANAGEMENT

A. BACKGROUND

B. CONCLUSIONS

1. REDIRECTION

2. AUSTERITY

3. STUDIES

4. ORGANIZATION

5. PERT

II. PROCUREMENT

A. SPO - AFPR RELATIONS

B. CONTRACTING

1. GENERAL

2. INCREMENTAL FUNDING

3. INCENTIVES

4. COST CONTROL

III. MANUFACTURING

A. AIR VEHICLE ACCEPTANCE

B. REPORTING

C. MATERIALS AND PROCESSES

D. HONEYCOMB PANELS

E. WELDING

F. QUALITY CONTROL

IV. ENGINEERING

V. FLIGHT TEST

VI. CONFIGURATION MANAGEMENT

A. AIR VEHICLE

B. DATA MANAGEMENT

VII. LOGISTICS

I. MANAGEMENT

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A. BACKGROUND

The B-70 R&D program was initiated in 1955 by study contracts to North American Aviation and Boeing Airplane Company for design of the weapon system, and IBM for the B&N system. In 1957, General Electric was awarded a contract for the engine development. In December 1957, NAA was selected to begin Phase I weapon system development. This effort included development engineering and testing, performance specification development; selection of major subcontractors and a mockup inspection in March 1959. The initial program called for first flight by July 1962, and the first operational wing (45 A/V) by December 1965. In January 1958, the Air Force accelerated the program with first flight by January 1962 and first operational wing (65 A/V) by September 1964. In October 1958, the Air Force revised this schedule with a stretch out after first flight and the first operational wing (62 A/V) by September 1965. In October 1959, Air Force again went to an austere program searching for all the short cuts, deletions of high cost simulators, design simplifications, soft tooling, and discontinuance of intensive honeycomb brazing and welding development effort. Under this program, the first operational wing was scheduled for December 1965 with first flight still planned for January 1962.

By December 1959, basic solutions to major technical problems had been demonstrated and engineering drawings were being prepared. Development was well advanced on a broad front and considerable development hardware was in being. In December 1959, the B-70 program was redirected to a single air vehicle and a minimum effort airworthiness test program (first flight in December 1962) reducing the total personnel utilization from approximately 20,000 to 7,000. The IBM B&N System effort was transferred to an Air Force contract and continued at reduced rate, defensive subsystems and M&TC subsystem contracts were terminated and subcontracted airframe work at Boeing, Lockheed and Chance-Vought was withdrawn. On September 19, 1960, the contractor was advised to proceed with the design, development, fabrication and test of one XB-70 prototype and 11 YB-70 aircraft, including development of all the major systems needed for an operational Mach 3 bomber. The problem of recapturing the subsystem contractors at reasonable prices became difficult. The buildup of manpower under this program reached 31,000 people in March 1961, and was scheduled to reach a peak of 45,000.

As a result of the President's budget message on 30 March 1961, the program was again redirected to a prototype development. In April 1961 a three prototype aircraft program was approved (the SPO had recommended only 2 airplanes). The third airplane was to have a B&N system and subsystem development sufficient only for flight test purposes.

Manpower was once more reduced and a new austere look was taken to keep costs as low as possible. This included further simplifications of design, tooling and a model shop approach to fabrication techniques, system developments, etc. In early 1963, the Commander, AFSC, directed a concentrated analysis of the management arrangements and procedures to best meet the specific requirements of the B-70 program. As a result of this analysis, the management of the program became more like that of a specialized project rather than the full management requirements of a weapon system. Other than numerous scheduling and pricing exercises and 5 months of concentrated studies of an RS-70 configuration (Nov 1961 and Feb-June 1962), the 3 aircraft program remained stable until March 1964, at which time the #3 aircraft with military subsystems was terminated.

From the time the B-70 contract was awarded to NAA in December 1957, the program has been subjected to almost continuous exercising and threatened or actual changes. During this period, there have been a minimum of seven major changes distinguished by formal establishment of new schedules and program definitions, 110 other planning and scheduling exercises were carried out by the contractor in the period 1960 through 1965, and 44 program pricing exercises were conducted by the contractor under the one NA-61B program. From January 1961 to April 1961, the contractor submitted 13 program plans for the 3 airplane program which evolved from 38 different schedules and 12 total new plans. In addition to the responsibilities within the Air Force, the accomplishment of such planning efforts involved contractor management and specialist personnel from engineering, manufacturing, financial and material departments plus many supporting people from these and other groups.

In 1961, the contractor's organizational structure, based on a functional concept came under scrutiny of the AF and DOD because of the success of project oriented organizations in the missile program where quick reaction and technical achievement were the major objectives. In October 1961, after many discussions, the contractor established the B-70 Division as an autonomous group.

In July of 1962, it became evident to the SPO that a significant first flight schedule slip could be expected due to the funding ceiling of $171M for FY63 and the total program ceiling of $1.3B. On 20 November 1962, the Secretary of the Air Force was advised that the first flight date would slip due to manufacturing problems and funding limitations. By January 1963, the under-funding had reached the point where it was necessary to curtail efforts on the #2 and #3 A/V's in preference to the #1 A/V, keeping the subcontractors very near their required funding rate, and absorb the under-funding impact within the Los Angeles Division of NAA where it was felt that better control could be maintained. As a result, a number of key NAA personnel were reassigned to other divisions. Included were many engineers, particularly aerodynamicists and structural engineers. On 22 February 1963, $35.8M additional was

NOTE

This reduction of [illegible] is [illegible] price [illegible] Done [illegible]

released against the FY 1963 funding and work was again resumed on the #2 and #3 A/Vs on a schedule that would provide the greatest overall program economy; however, the recapture of the released engineers was very small. Experience with manufacturing personnel was not as bad because most of them had been retained on other efforts.

As the magnitude of the schedule slippage increased, the results of the austere program became more evident. Combined with the short cut assembly methods hopefully employed to minimize shop flow time, the results of the curtailment of concentrated honeycomb structural system development and fuel and nitrogen sealing became overpowering and the procedures became one of cut-and-try due to the lack of resources. In early May 1963, General Holtzapple chaired an Air Staff, on site review of the XB-70 program which was presented to Mr. Zuckert on 17 May. Again, it was recognized that problems still existed in fabrication, solutions were somewhat hampered due to lack of resources resulting from the previous program instability, but that it was still considered feasible and desirable to continue with the program, recognizing the schedule slip and increased cost. At this time, the air vehicle contract was converted from CPFF to CPIF in keeping with direction from Hq USAF. This could be considered a re-financing of the program and resulted in continual reassessment of the program progress and cost.

The first air vehicle was rolled out for public view on 11 May 1964. For a period of about 5 weeks during the preflight checkout, the airplane became, for all intents and purposes, a hydraulic system mock up and simulator to solve the problems that developed with the hydraulic system. Most of these problems could have been resolved on the hydraulic simulator but because of program austerity one had not been provided. What had been previously forecast as 30 days for preflight operations stretched into about 4½ months. Most of this time was consumed in correcting problems in the hydraulic system, fuel tank sealing, and a myriad of minor repairs to the air vehicle.

First flight occurred on 21 September and by 24 October 1964, four flights totaling 5 hours and 2 minutes had been accomplished and Mach 1.42 had been reached. On 9 October 1964 the first airplane was returned to Palmdale to complete proof load testing to assure structural integrity for Mach 3.0 flight. The first air vehicle returned to flight status in February 1965 and has accumulated more than 20 hours of flight test time. The second XB-70 rolled out on 29 May 1965 and flew on 17 July reaching Mach 1.4 and 40,000 feet.

B. CONCLUSIONS

1. PROGRAM REDIRECTIONS. There have been three major B-70 redirections; weapon system to one prototype in 1959, one prototype to limited weapon system in 1960, and back to prototype development in 1960. A redirection from a weapon system program to a prototype development aside from the economic impact on the contractors involved, results in substantial costs to the Air Force. These costs can be determined to a degree where the terminated effort involved subcontracts for work related solely to a weapon system; however, in the case of the basic Air Vehicle; it forces some redesign, changes in tooling, reallocation of manpower, etc, all of which costs money; the exact amount is not capable of calculation since there is continuous contractor activity in these areas regardless of the kind of program. Another undesirable byproduct of redirection is the effort required by SPO personnel in reprogramming, contract changes and so forth. This effort is over and above the normal work of the SPO and means that time usually spent in performing the prescribed management actions must instead be devoted to getting the reoriented program functioning satisfactorily.

Program redirection from time to time is apparently inevitable; whatever measures that are available should be taken to lessen the impact both on the Air Force and the contractor. The SPO should be provided more complete direction and should be given a new approved program as soon after reorientation as possible. For example, the three XB program did not receive approval until 4½ months after the weapon system effort was ended (from March 1961 to mid-August 1961 when the PSPP was approved) and the program directive itself was not published until October 1961. The two air vehicle experimental program was directed in March 1964, the directive reflecting this decision was not received in the SPO until May 1964.

In effect, program redirections require the expenditure of funds for which there is no matching return except for accomplishing the redirection itself and results in a period of inefficient operation by the Air Force and the contractor

2. AUSTERITY. The program redirections which had funding limitations dictated the use of the most economic practices possible in achieving program objectives. Some of the things done were elimination of expensive simulators, the use of soft tooling, the discontinuance of most manufacturing development, and a minimal structural test program. The impact of these actions were felt at different times and to varying degrees. The extended period for fabrication of air vehicle #1 was due in great part to austerity measures; the soft tooling generated many problems such as wing-to-fuselage mismatch and the requirement to jack panels into position causing some panel voids which in turn required repairs. It took nearly two years to seal fuselage tank #3 in air vehicle #1. This was the result of using the aircraft itself to develop fabrication and tank sealing techniques, an extremely expensive method which could have been avoided to a large extent had there been adequate manufacturing development earlier in the program.

Hydraulic simulators were eliminated. The effect was manifested from air vehicle #1 roll-out until well into the flight test program. It was one of the primary reasons for the very long preflight period and caused difficulty on the first flight. The gear would not retract and remained down for the entire flight. If the reverse had happened, i.e., the gear retracted but would not extend, the result very likely would have been loss of the aircraft. The lesson from these examples is clear; the money saved by eliminating essential development is lost many times over later on through the necessity to solve the same problems the basic development was intended to solve. It is interesting to note that the engine development was not subjected to the same degree of short cutting as the air vehicles and the engines have proved to be very reliable and have demonstrated excellent performance. In summary, austere measures, unless very carefully applied, will not save time or money, on the contrary, if the objectives remain the same, the net results on advanced programs such as the XB-70 are increased costs and program stretch-out.

3. STUDIES/STATUS REPORTING. The B-70 program has been the object of continuous attention from many levels within the DOD as well as the Congress. This attention resulted in requests for voluminous studies as well as program status reporting on a more frequent and detailed basis than normally required. Each of the studies was conducted in conjunction with the Los Angeles Division of NAA and in some cases directly by the Corporate management. To obtain the information necessary for decisions, a deep penetration into the contractor's personnel was required. Many of these exercises were conducted under tight schedules involving extensive weekend and night efforts on the part of salaried personnel, Both government and contractor. Although much of this was without direct charge to the program, it exacted a toll upon the organizations. It is impossible to place a price tag on the total costs, but it is certain that this cost can be measured in hundreds of thousands of dollars. Calculable costs incurred as a result of 2 major redirections, (the one XB program and the three XB program) indicate a cost of approximately $100M. The estimated cost incurred in the RS-70 planning exercise alone was $578,903.00. This does not represent the true magnitude of the effort since a large amount of uncompensated overtime hours were expended by supervisory personnel on the part of both the Air Force and the contractor.

Program progress reporting on the directed basis forced the SPO to place personnel on continuous TDY to the contractor's facility to personally observe manufacturing status and make daily progress reports to the SPO. This information was evaluated and sent to higher headquarters on a weekly basis, sometimes more frequently. It should be emphasized that these procedures were instituted with no increase in SPO resources. If these people had been performing their normal functions it may be conjectured that more substantive manufacturing analyses could have been conducted which might have reduced production time and costs. Program management requires some given number of people and some finite amount of time for accomplishment. If additional requirements are imposed, these should be recognized as such and sufficient additional manpower authorized.

4. ORGANIZATION

a. NORTH AMERICAN AVIATION. In the early phases of the program, the NAA approach to weapon system management was to create a B-70 "program manager" with responsibility for overall direction of the technical development. His group acted essentially as a staff organization to the operating elements of the Los Angeles Division. This was in contradiction to at least two of the recognized functions of a manager, ie, to control and to direct. The situation was one of responsibility without authority with a predictable outcome; there was not sufficient emphasis placed on the B-70 within the Los Angeles Division. Although accepting the importance of the B-70 program, NAA executives were still loath to make organizational changes and it required Air Force intervention in an area traditionally a company prerogative; internal organization. At the behest of the Air Force, the Los Angeles Division was reorganized to give the B-70 manager the necessary status and authority. He was named an Los Angeles Division vice president, an autonomous B-70 Division was created, and the program was able to proceed on a sounder management basis. System developments are becoming more and more costly and it has become evident that the only acceptable method of organizing for the effort is to establish a group for the purpose and to endow it with the power and resources commensurate with the task.

b. THE B-70 SPO. During the first few years the SPO (WSPO) was in reality three separate organizations. There were the ARDC "managers", with their chief who was nominally the SPO director, there were the ARDC engineers with their chief, and there were the AMC people with their chief. In 1961, when AFLC and AFSC were formed, one of the three "heads" was absorbed, there remained however the engineers, who operated as an independent group for all intents and purposes and their chief was to be "responsive" to the needs of the AFSC Program Director. This is the situation today, there are AFSC program managers supported by RTD engineers who do not report to the program director. This type of organization does not always lend itself to efficient operations, differences of opinion sometimes have to be resolved at levels which should not be concerned with such details. Research people, if that is what they really are should not be a part of a SPO, but engineers who perform analyses and studies directly related to the program and on a recurring basis should be an integral part of the Program Directors team, not merely "responsive". A final observation is that the organization of each SPO should be tailored to the requirements of the program at hand, not be required to organize in accordance with a "standard" which is established by regulation.

5. PERT. This management control system was started on the B-70 Program in late 1960. Prior to this time, the status of milestones or "events" was tracked through a system whereby information on each milestone was recorded on punch cards, updated monthly and the printout of these data supplied to the SPO as a milestone report. There were upwards of 1000 of these milestones, and shown for each one were the scheduled date, a reschedule date if applicable, and the responsible contractor department. Also provided, as a supplement to the milestone report, was a "Variance Report" which contained analyses of the critical areas of effort as well as reasons for milestone slips, rescheduling actions, etc. These reports coupled with frequent trips to the contractor's plant enabled the SPO to maintain adequate surveillance of the program.

The introduction of PERT in 1960 was expected to improve the Air Force's ability to detect incipient trouble areas and to give a more comprehensive picture of the overall situation. As applied to the B-70 program, however, PERT did little to increase SPO knowledge of contractor activities or to provide timelier status information. There were several reasons for this: (1) PERT reporting was on a monthly basis, therefore no improvement over the old system in this respect, (2) scheduled completion dates for events were forecast using single time estimates instead of the three normally used with PERT, in effect then, these "events" were no different than the milestones previously used, (3) because of austerity the contractor was unable to furnish all the resources necessary to support a classic PERT program, (4) the SPO was likewise not able to provide the manpower for adequate network design, analysis, etc., which is a must if the potential of a PERT system is to be realized, and (5) during the latter stages of fabrication of Air Vehicle #1, SPO personnel were on continuous TDY at the contractor's plant and were able to report the status of critical areas as much as 30 days in advance of the publication of the PERT report containing the same information. Largely because of these factors, the decision was made in mid 1964 to terminate further PERT reporting.

Following some three years of the use of PERT as a management control system, the following conclusions were reached:

a. PERT should be used from the start; later applications do not realize the full benefits of the system and may in fact produce reporting not significantly better than before at a much higher cost.

b. The contractor should train personnel in how to properly use PERT before it is put into operation; the results derived are only as good as the information inputs.

c. A full scale PERT system should be used. Lesser versions are little or no better than conventional methods of progress reporting.

d. PERT should not be required on austere programs since one of the features of the system is the detection of critical areas needing additional resources. If these are not available, then the use of PERT was not economical to start with.

II. PROCUREMENT

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A. SYSTEM PROGRAM OFFICE/AFPRO PLANT REPRESENTATIVE RELATIONS

1. BACKGROUND

Throughout the XB-70 Program, the relationships between the XB-70 SPO and the Los Angeles AFPRO have not been significantly different than the relationships between other SPO's and associated AFPRO's. The SPO's mission is primarily to establish program requirements in conjunction with engineering and support personnel and implement these requirements by means of a contract. The AFPR is responsible for implementation and monitoring the accomplishment of each contract. There has always been an attitude that once the contract has been established, the AFPR was responsible for its implementation and essentially the SPO should not be concerned with the details of how it is done. This is probably a carry over from the days when programs were on a CPFF basis and the function of the ACO was that of determining overhead rates, preparing shortage reports, conducting price analyses, monitoring facilities, and coordinating the supplying of Government Furnished Property. This is practiced on routine lo-value contracts, however, not on programs of the magnitude of the XB-70 which encompasses a potential $1.5B expenditure. Detailed surveillance of contractor activities by the ACO and other elements of the AFPR's organization is absolutely essential. The AFPR has always maintained that he is not adequately staffed to perform the depth of surveillance which the Program Director feels he requires and this is undoubtedly true in view of the fact that most ACO's have multiple contracts to administer. On the other hand, when the Program Director, due to the lack of on-site surveillance, established his engineering and manufacturing review teams, there was a tendency to deal directly with the contractor which resulted in the AFPR's being still less informed of the direction and status of the program. This cycle of events tends to perpetuate itself to the point that the ACO can become completely ineffective. This lack of coordination and unified control of the contractor's efforts was recognized first in the development and engineering area and a team was established by AFSC in September 1962 to provide an on-site development engineering office to support and work with the SPO development engineers in carrying out the engineering effort. A comparable effort was attempted by the AFPR Production personnel; however, this was not completely successful, again due to the assigned manpower limitations and the rapid reaction time required by the SPO. Therefore, manufacturing monitoring was essentially accomplished directly between the SPO Manufacturing Division and the contractor. In the contract area, contractual operations between the ACO and the PCO were handled strictly by the prescribed regulation procedures.

2. CONCLUSIONS

It is absolutely essential that the AFPRO be provided sufficient personnel at the onset of any program of the magnitude of

the E-70 so that the AFPR can properly support mission objectives on a continuous basis at every level of the organization. Written agreement should be reached defining the responsibilities and procedures to be exercised between the Program Director and the AFPR and a similar agreement made between the corresponding organizations of each should also be established. Daily or at least weekly discussions be held between SPO and AFPR personnel to discuss current plans and problems. Otherwise, the Air Force may find itself in the position of the contractor playing one organization against the other, or either organization may take unilateral action with the contractor without the knowledge of the other. There has been considerable searching over a period of years for a solution to this problem, an example being a proposal to establish the Program Director's organization on-site at the contractor's facility jointly with the AFPRO.

If an AFPRO is properly staffed and adequate coordination efforts are accomplished, no new organizational realignments are required to carry out a program objective.

B. CONTRACTING

1. GENERAL

In the carrying out of the contract function of the procurement organization from the design phase through the manufacturing and test of XB-70 air vehicles, a basic change in concept of procurement occurred. The initial Contracts AF33(600)-38669 and follow-on letter contract AF33(600)42058, contemplated a design which would form the basis for the development of a complete operational weapons system. This in turn would be converted to firm procurement specifications for the acquisition of the required operational weapons system. Therefore, although the initial contract was on a CPFF basis due to the design and development of the initial effort, it was contemplated that the resulting procurement specifications would be firm, demonstrative requirements and that the associated flight test program would require specific demonstrative performance criteria. Subsequent to the initiation of letter Contract AF33(600)42058, re-direction was received to limit the development to a prototype effort. As a result, a firm contract, AF33(600)42058 was negotiated for the design and fabrication of three (3) XB-70 air vehicles. At this time, the concept was changed from a requirement for the delivery of air vehicles in strict compliance with firm specifications to a best efforts approach under the philosophy of a research and development effort only. The performance specifications were changed from requirements to objectives. Notwithstanding the further amendment of the CPFF contract to a CPIF cost incentive sharing arrangement, the contractor was only required to attempt to build three (3) air vehicles on a best efforts basis. In anticipation of a follow-on flight test program, a decision had to be made whether to amend the basic development Contract AF33(600)-42058 to include the flight test effort or to negotiate a separate flight test contract. Based upon the factors and conditions existing at the time the decision was made to negotiate a separate flight test contract on a CPIF basis, containing not only cost, but also air vehicle performance incentives. The basic philosophy of the contract was that the contractor in an R&D environment, would attempt on a best efforts basis to meet the general flight performance parameters. As a result, several contract administrative problems arose:

a. The change procedures implemented under Contract AF33-(600)42058 were materially different (due to the nature of the contract) than that implemented under the flight test contract. For example, a change common to all three (3) aircraft was handled differently between the aircraft in the flight test inventory and those still in the process of manufacture under the development contract and were of necessity handled by two separate contract instruments. In addition, some cases were of necessity negotiated at a different rate of fee.

b. The air vehicles were produced under a development contract and became government property upon acceptance by the Air Force. They were then bailed to the contractor to support the flight test program, which left the Air Force responsible for possible contractor

non-accomplishment of flight test objectives, due to use of unsatisfactory government property developed (by the contractor) on a best efforts basis. If repair or re-design of the government property is required, it would be new work chargeable to flight test contract and would necessitate a corresponding adjustment in target cost and fee.

2. CONCLUSIONS

a. From the above, several significant problems resulted from a configuration standpoint. It was necessary under the best efforts development concept to provide the contractor with the flexibility in configuration control. Any non-concurrence with the contractor's design approach resulted in the requirement for re-negotiation of the target price and schedule which in turn presented some difficulty in controlling program cost. Also, there was no assurance that the aircraft delivered by the contractor for acceptance by the Air Force would, in fact, be capable of meeting the objectives of the flight test program which relieved the contractor of responsibility for flight capability and transferred it to the Air Force upon acceptance of the air vehicle. Since the program schedule dictated the necessity for accepting air vehicles with items incomplete, it was necessary that recovery schedules for the incomplete effort be negotiated in conjunction with the projected flight test contract. This further complicated the contract negotiation of delays which occurred during the flight test program as to the responsibility for program delay being chargeable to the contractor under Contract AF33(600)42058, as being due to the uncompleted work, or being chargeable to the Air Force under flight test Contract AF33(657)-12395 as new work resulting from the flight test effort.

b. It would appear that for a Research and Development effort such as the XB-70, the design development and flight test program should be procured by a single contract with specific cost and performance incentive negotiated for the total design development and flight test effort. The resultant developed air vehicles would then not be an end in themselves but would be the means utilized by the contractor to demonstrate his flight test criteria, and provide the contract data to substantiate the feasibility of his development called for under the contract. This would have several specific benefits:

(1) The contractor would have the responsibility and flexibility necessary to carry out the program without continuous contract amendments.

(2) He would have the responsibility to provide an aircraft to meet the flight test objectives and if aircraft were not

capable of doing so, the responsibility for redesign or modification of the air vehicles to meet the program objectives procured without further charge to the government.

(3) The Air Force would not take title to the air vehicles until satisfactory completion of the flight test contract or close out of the contract due to unsatisfactory performance.

2. INCREMENTAL FUNDING

a. BACKGROUND

The availability of funds has always been a basic problem as reflected by the various program redirections. The B-70 Program was confronted initially with the problem of procuring a program within the limitation of funds incrementally allocated on a fiscal year basis and subsequently as approved for the three (3) air vehicle $1.3B program. Program decisions for continuing or extending the program have always been based upon factors which outweigh the question regarding the method by which the effort should be funded. Incrementally funding of the B-70 Program has, therefore, been accepted by B-70 SPO Directors and the contractor, not by choice, but as a matter of necessity.

b. CONCLUSIONS

As a management tool, the B-70 SPO incrementally funded the contract on a monthly and quarterly basis. The basic reasoning for funding the contract on a monthly basis was to encourage the contractor to maintain his expenditures within reasonable limits. This approach is not considered to be realistic for several reasons. If the basic contract requirements for effort and schedule to be accomplished are not amended accordingly as the contractor has a high degree of development and manufacturing difficulties such as NAA had during the period of 1963-1966, the contractor will not stop incurring costs and it will only tend to aggravate and add to the contractor's management problems. Assuming he has taken the normal management actions of reducing personnel to the minimum in cutting down in his overhead costs, he must either extend his program schedule or delay some of his development efforts. This results in extending his continuing operational costs over a longer period of time and incurring a more rapid buildup in cost expenditures at a later date—The ultimate result being greater program costs in the end for the same or less effort. It is, therefore, the opinion that if incrementally funding is applied to a program, it should be on no less than a quarterly basis which would allow the contractor a firmer base on which to plan his outlay of expenditures and provide him the program flexibility necessary to a Research and Development type contract. This does not relieve a Program Manager of any of his management responsibilities but requires him to maintain closer surveillance of the contract and funds management in respect to the contractor's progress in meeting delivery schedules, provisioning and engineering changes which effect the overall objectives of the contract.

Incremental funding has no specific advantage in the provisioning of Spare Parts and FTGSE since they were procured as separate items under the contract and have been purchased by individually priced exhibits with only lo-value or interim release hi-value items below $1,000 per unit for a total of $10,000 aggregate being released for procurement prior to D-70 SPO authorization. Each priced production list is contractually authorized and funded on an individual basis. It is considered that, in negotiating a contract which provides for incremental funding, the clause for POOBing (Provisioning Order Obligation Document), Spare Parts and FTGSE should be included in the contract terms and conditions to become effective at such time as the contract enters into an overrun condition. This is particularly important when the contract provides for interim release provisioning procedures covering the lo-value Spare Parts and FTGSE as indicated above. Although the MD-70 Contract, AF33(600)42058, now contains such a POOBing clause, essentially most elements of the clause were accomplished in programming contract funds requirements thereby a minimum amount of funds were set aside to cover any substantial contractor interim release of lo-value items or unanticipated permissive specification changes which could result in an increase to the contract target price prior to final contractual coverage.

3. ENCLOSURE 1

a. BACKGROUND

Based on the Research and Development nature of the B-70 program, first during the conceptual stage under Contract AF33(600)38669 and the later realigned XB-70 program for eleven XB-70 air vehicles, one XB-70 and one static test air vehicle, as well as the subsequent three air vehicle program under Contract AF33(600)42058, the program was negotiated on a CPFF basis. This approach provided the contractor with maximum management flexibility necessary in a best efforts program with the associated risk involved.

As the program progressed, the contractor began to encounter manufacturing problems in attempting to meet basic design criteria, particularly in metal to metal fuel tank sealing. The result was an increased cost over-run position.

Since the contractor had stated positively that the three air vehicle program could be accomplished within a [illegible] billion dollar ceiling, the Air Force felt that the contractor should assume more of the financial risk in carrying out the program. Consequently in April 1963, the Air Force entered into a negotiation with the contractor to establish under the AF33(600)42058, a Cost Plus Incentive Fee (CPIF) arrangement. This was accomplished by means of a Supplemental Agreement, a negotiated adjustment was made for the then current overrun condition and a new target price established with a [illegible]/[illegible] incentive sharing arrangement for cost exceeding the adjusted target price.

At the time of the third air vehicle termination in March 1964, the contract was again adjusted by negotiation to a new target for the remaining two air vehicles with an [illegible]/[illegible] sharing arrangement, which is the current contractual arrangement with North American under Contract AF33(600)42058.

The flight test contract, although basically a research and development effort, was not considered as great a contractor risk due to his prior experience. Therefore the cost incentive was established on an 80/20 share arrangement and performance incentives for Mach No. and flight hours were added.

b. [illegible]

The result of injecting [illegible] into the XB-70 manufacturing and flight test contracts, instead of improving the contractor's cost control procedures and over-all [illegible] caused other problems: (1) Any Air Force decision which [illegible] the contractor's design or delivery schedule resulted in a r[illegible] for negotiating an adjustment to the contract target price and [illegible] incentives. (2) The contractor was obviously reluctant [illegible] any development design changes as being within the scope of the [illegible] and not subject to fee adjustment, which in fact reduced the [illegible] for timely design changes. This situation requires extensive negotiation by the contractor to determine actual responsibility for the change [illegible] specification which consists of design and performance objectives rather than firm requirements. In an apparent contradiction, due to the nature of the program and with no immediate follow-on contract in view, the contractor earlier in the program evidenced a willingness to accept an over-run penalty in order to keep the program in existence. As Air Vehicle #2 delivery approached, this tendency did not continue.

Under the flight test contract, the contractor has taken every opportunity provided by the contract to exercise his right to renegotiate the target price of the contract due to damage claims or engineering changes which would put him in an over-run position. While this may be desirable from a financial and program management position, it has essentially removed the flexibility normally considered desirable in a Research and Development contract.

Not withstanding the [illegible] Drive to utilize Fixed Price and Fixed Price Incentive [illegible] whenever possible, there is a logical reason for utilizing [illegible] type of contract covered by Air Force Procurement Regulations. Generally speaking a procurement activity normally progresses in contract type from a Cost Plus-Fixed Fee to Firm Fixed Price basis compatible with the degree of unknowns and Contractor/Air Force risk involved. Specifically, the progression from the conceptual to the acquisition phase.

One of the chief responsibilities confronting the Air Force in connection with procurement is the selection of the type of contract best suited to its purposes of contracting. Because of the variety of situations involved, a single contract form cannot be adopted. The nature of the procurement, the contractor's production and cost experience and the extent of control which can, and should be, maintained over the contractor's operations, must all be considered in arriving at a decision on the type to use. Throughout the XB-70 program, there has been a tendency by the Air Force to substitute contractual language for program management. To accomplish the Research and Development effort, a firm, demonstrable, manufacturing and flight test specification should be

written and contracted for on a Fixed Price basis or a general objective type specification written and contracted for on a Cost Plus Fixed Fee basis to enable the Air Force to exercise control and decision responsibility. A combination of firm fixed price incentive and CPIF contracts are variations on the theme and do not in themselves accomplish good management.

4. COST CONTROL

a. BACKGROUND

When the B-70 Program was redirected from a Weapon System with NAA as Manager to a three Air Vehicle Prototype Program, it was done on an austere funding basis and although fund control had been assiduously practiced during the Weapon System Development phase, further increased emphasis was placed on cost control under the three air vehicle program. Since the Contractor had a best-effort development contract, he felt that he should also have corresponding flexibility in funds control. It was felt by the Air Force; however, based upon the prior program fund history, that strict control by the Air Force was absolutely essential. As a result, the contractor was incrementally funded on a monthly basis with each succeeding month's funds requirement being requested by the contractor with written justification for such funds. This procedure was carried out from 1961 until mid 1965, just prior to delivery of Air Vehicle Nr. 2. Notwithstanding the above, the contractor has currently overrun Contract AF33(600)42058 by approximately $19.7M.

b. CONCLUSIONS

The above experience proved that cost reporting in itself is an inadequate management tool. The funding status reports developed and submitted by a contractor must also contain corresponding development, engineering and flight test program progress against which expenditures can be measured. For example, the contractor may underrun his dollar forecast due to two diametrically opposed reasons:

(1) He is doing an excellent job and exercising economical Program Management or

(2) He is behind schedule in procurements, engineering releases, or manufacturing accomplishment and, as such, the indicated below-schedule expenditures trend will be reversed with a greater magnitude later in the program. (i.e. prospective overrun).

Several attempts were made over a period of years to revise the contractor's cost reporting procedures along the lines indicated even to the extent of combining the contractor's cost and manpower reports with only marginal success. As a result, the B-70 SPO changed their procedure so that the funding report was reviewed with the manufacturing division to correlate the expenditure of funds against the contractor's manufacturing status. This resulted in a reasonably accurate assessment of the contractor's financial status and provided a basis from which to make realistic program dollar requirements forecasts. The basic lesson is that funds status reporting must include associated engineering, manufacturing, flight test, and logistics status so that a SPO can make a meaningful analysis of the contractor's financial position.

III. MANUFACTURING

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A. AIR VEHICLE ACCEPTANCE

1. BACKGROUND

The acceptance of XB-70 air vehicles was planned on the basis of a progressive buy-off in lieu of the standard CTCI approach since the method of welded construction resulted in areas of the air vehicle becoming inaccessible during sub and final assembly. These areas could not be opened for final inspection without damage to the structural area. The Air Force final inspection and buy-off of the closed areas were made just prior to the final operation closing out the area. Acceptance authority was vested in the AFPR Director of Quality Control.

Due to the air vehicle size, complexity, and the large number of Final and Pre-Flight Operations, the Air Force progressive inspection was made concurrently with the contractor's manufacturing, pre-flight and quality control personnel. The task was accomplished specifically by the use of an intercom system integrated into the air vehicle intercom system. Control of the operations was maintained by a three (3) man board consisting of: Contractor's Final Ops or Pre-Flight Test Director, Contractor Quality Control and The Chief of Air Force Quality Control. The test director indicated the operation to be accomplished and where the actions would take place. Quality control observers for the Contractor and Air Force were located with their respective contractor counterparts in the areas where the inspection activities were to take place. The results were monitored against the air vehicle process specification requirements reported through the intercom to the three man board. If the results were within tolerance or as prescribed in the process specification, the item was accepted by the board. When a discrepancy occurred that could not be resolved on the spot, a squawk was written on the item and the operation continued. When the discrepant item was of sufficient magnitude to endanger personnel or air vehicle function, the test was stopped until the problem could be solved. To facilitate the solving of problems, engineering support from the contractor, Air Force Plant Representative-Development Engineering and SPO personnel was provided on around-the-clock basis. These engineers also monitored the tests and results via the same intercom system, thus obtaining on the spot information for providing engineering decisions.

A Final Acceptance and Safety-of-Flight Inspection for all accessible areas was conducted prior to First Flight of each air vehicle by the B-70 SPO Deficiency and Acceptance Review Board established to review items that did not comply with the contractual requirements and for which a contractor/Air Force agreement could be reached. Disposition of these items were made as "fix before flight" or were entered in air vehicle deficiency document to be accomplished as a condition of acceptance. The recovery points for deferred deficiencies were established for completion by a specific date or to be accomplished prior to exceeding an appropriate flight parameter prior to inflight use, etc. This deficiency report was incorporated into the DD 250 as part

of the acceptance conditions.

To track progress on completion of such deficiency items, the contractor was required to provide a self deleting deficiency report every thirty (30) days from the date of first flight of the air vehicle. Those items accomplished and accepted by AFQC are lined out and the acceptance date placed in the "remarks" column. Any deviations granted by the Air Force on recovery points or conditions are so noted in the report. The deficiency report will be published every thirty (30) days until all items are completed or deleted in accordance with the contract.

2. CONCLUSIONS

The only practical method of inspecting and accepting a complex aircraft is one of progressive checks and "buy-offs". This procedure was mandatory on the XB-70 because of the type of construction used, i.e., welded steel panels for the most part which resulted in areas of the airplane becoming inaccessible as assembly progressed. While it was recognized early in the program that this kind of acceptance procedures would be necessary, there was little realization of the benefits to be derived from such a system. By participation in great detail, Air Force personnel became very knowledgeable of the aircraft and its systems, to an extent they could not have reached using any other acceptance method. The nature of a step by step process assures a greater degree of confidence in the end product than would a one time final inspection and acceptance which would very likely be more cursory. It is also likely that some time was saved since discrepancies were uncovered when corrective action took the least amount of time and effort. Finally, SPO personnel who took part gained an insight into the problems associated with building a large, high mach aircraft using new materials and processes, a knowledge unique within the Aeronautical Systems Division.

The success of a progressive inspection and acceptance plan requires close working relationships on the part of the Contractor and the Air Force personnel and a full understanding of their responsibilities.

For Research and Development Programs a progressive acceptance procedure is the most logical approach to the acceptance of complex aircraft.

B. REPORTING

1. BACKGROUND

From the inception of the B-70 Weapons System Program, it was recognized that the Procurement and Production function should be integrated into the Weapon System Development at the earliest possible date to assure that the air vehicle configuration developed during the design and development phase could be produced on a timely and economical basis. As a result, the WSPO Production (manufacturing) office was established in early 1958 to assure that the manufacturing effort associated with the development contracts was programmed, integrated and supported with respect to tooling, Ground Support Equipment and GFAE. Considering production, it was necessary to define the term in relation to a research and development effort. From a semantic standpoint, the term production need not necessarily be equated directly to the related rate of manufacture of airplanes, but it is applicable to the planning required to support the design effort as well as to control the manufacturing changes that occur with change in design. It was generally conceded that the basic functions required to manufacture and deliver a single air vehicle are as complex and essential as those required for a follow-on production run.

Since the program was required to operate with minimum data on an extremely austere basis, only two specific manufacturing reports were required under the contract. The first report being the contractor's basic manufacturing plan for all three air vehicles starting from fabrication through sub- and final assembly to air vehicle shop completion. This document consisted of the master assembly plan and all the associated sub-assemblies leading up to final assembly. The second document was the contractor's facility plan. These reports were revised only at the time of major program realignments. Specific manufacturing reporting was accomplished on a direct person-to-person basis with the contractor's personnel utilizing the contractor's internal schedules and management documents to carry out the master plan. Initially, manufacturing reviews were conducted on a monthly basis at which time contractor manufacturing personnel met with SPO Production personnel and reviewed all aspects of the fabrication, assembly, tooling and government property status at that time. This was combined into a monthly status report published for the System Program Director (SPD). These monthly reports extended from late 1960 through delivery of the second air vehicle, July 1965, and form an excellent history of the XB-70 manufacturing problems. As the program progressed, the manufacturing situation became more critical and a manufacturing status report was presented to the Program Director on a weekly basis. This information was obtained directly from the contractor's personnel and to some extent, was validated by on-site review by the AFPRO Production personnel. As the requirement for program

reporting increased, the SPO instituted what became known as the inchstone procedure. To support this procedure, SPO manufacturing/production personnel were rotated to the contractor's facility every two weeks on a bi-monthly basis and reported directly from the manufacturing floor to the Production Division of the B-70 SPO which, in turn, reduced the data and presented a daily status briefing to the SPD. This reporting procedure was possible only because of the excellent cooperation of the contractor who recognized that an accurate and timely status report by the Air Force was as much benefit to him as it was the Air Force in reaching timely program decisions.

2. CONCLUSIONS

Because of the intimate knowledge of the contractor's manufacturing problems and procedures, the SPD was provided with an accurate and up-to-date status report as to manufacturing difficulties encountered and appropriate recovery times, the impact on the funding situation, and an extremely accurate indication of the contractor's ability to meet his projected manufacturing schedule dates. For future programs, strong manufacturing organizations staffed by reliable production and industrial specialists should be integrated into the System Program concurrently with the design and development effort to assure that these personnel understand the design concept, the complexity, the necessary support required to produce hardware, and that PERT type networks must be established for initial planning and to forecast progress. Such initial planning should be followed during the manufacturing process cycle by actual, on-the-spot reporting. It is felt that this operation will materially assist any Program Director in determing the actual results to be expected from the design effort for a given dollar budget and will provide him with timely decision points in the event of program re-direction.

C. MATERIALS AND PROCESSES

1. BACKGROUND

When the XB-70 configuration was defined, the materials available did not have suitable characteristics. Through comparison studies and structural development tests, the materials and types of structure were selected to meet the specific parameters of heat, strength, and rigidity of the structure involved. Through a research and development program, basic stress allowables, quality criteria, and repair criteria were established. Target properties were established for one heat treatable stainless steel, one titanium alloy and one high strength steel. Preliminary work progressed on materials designated as "1958 PH steel," "1958 titanium" and "1958 High Strength Steel." Alloying and processing developments lead to the selection of the PH15-MO stainless steel, 4AL-3MO-1V and 6AL-4V titanium nickel based alloy of H-11 steel, Rene 41 and Inconel 718 as the materials to be used. Generally speaking, none of these materials were available from the mills in the shape, sheet thickness and tolerance required.

The XB-70 contains a total of 12,000 pounds of heat treated titanium. When titanium was first used, an unexpected amount of spring-back occurred during forming. This made it impossible to hold dimensional tolerances and required many hours of hand forming. A totally new metallurgical concept was developed which permitted the forming and hot sizing of titanium. The XB-70 program also required that the knowledge of titanium technology be expanded to cope with titanium alloys heat treated to high tensile strength levels of 160,000 to 180,000 PSI. More than 700 complex shapes were fashioned from 350 basic extrusions of titanium and high temperature, high strength steel. This also required that new techniques and die lubricants be developed.

In the interest of saving weight, fabrication and quality control personnel, recognizing the difficulties confronting them, requested technical assistance from the metal producing and processing industry to provide more optimum material thicknesses and shapes in previously unheard of tolerances. Until then, .002" was considered the thinnest produceable sheet. The XB-70 required thicknesses down to .0075" with a gauge variation of less than 25 millionths.

New techniques for sculpturing the face sheet were investigated, and as a result, chemical milling of titanium, corrosion resistant steel, and cobalt and nickel based alloys were developed to tolerances of five ten thousandths of an inch. However, prior to accomplishment of such techniques, it was necessary to form the face sheet by machining which caused mechanical problems as well as warping. The initial panel face sheets were made up of many small parts welded together or brazed together. Various densities of honeycomb core were used so that the

minimum material for strength requirements could be used. The problems resulting from this approach were reflected in the difficulties encountered as the air vehicle assembly proceeded.

The problems encountered in fabricating satisfactory panels to accomplish preliminary and final assemblies were many. For example, where the face sheet was not required to be smooth on the outside for aerodynamic reasons, the forming was done after brazing by chemical milling. The core problem was thus reduced to assuring that it was flat and matched the smooth surfaces of the face sheet. The process that solved this problem is known as Anocut which is a reverse plating process using a rotating electrode while flushing the core surface with the electrolytic solution. The deplated metal is washed away as a sludge by the electrolytical solution and a flat burr free cut results. All previous methods of sanding, milling, etc., used in the laboratory development of honeycomb failed when production techniques were used. Another example is the case where an exact mirror image of the mating surfaces of the face sheet must be reproduced on the core's surface. This mirror image was created by Elox machining, the controlled electrical spark erosion of metal. In this process, the electrical charges were sparked at high frequencies across a gap between the electrode and the work piece and required no rotating motion between the electrode and the work piece. The Elox process was subsequently adapted to cut holes of various sizes and shapes through honeycomb panels by forming the electrode as a "cookie cutter" and letting it move straight through or any desired angle.

Unicell honeycomb core was developed to replace the 1/8" cell size core used where greater core density was required for strength. The 1/8" cell size core was costly to manufacture and join with other core. Unicell honeycomb core is made by welding together alternate preformed and straight ribbons. The straight ribbon elements can be varied in thickness to provide the strength required for any specific application.

H-11 steel, a high strength material capable of being heat treated to the tensile strength range of 300,000 PSI had wide application in fuselage, wing box areas, landing gear and wing fold actuators. Previous use of H-11 steel had been primarily as a die material. Thus, its use in critical structure application was completely new. When first used, the H-11 cracked during heat treating as a result of vibration which requiring the development of forging configuration, surface finish heat treated processes and vacuum melting of the raw material to improve its ductility. Development of forging techniques enabled the production of the largest H-11 forging ever made weighing 13,000 pounds from which the landing gear bogie beams were made. The processing of H-11 steel is extremely critical, which may be illustrated by the requirement for drilling holes in some of the H-11 longerons and fittings in the aft body and wing stub area. Unless a stringent process control is used with regard to the type of drill bit, rotational speed, feed speed, and the

number of times a drill bit can be used without sharpening the amount or depth of untempered martensite around the drilled hole becomes excessive. Excessive untempered martensite around a hole in H-11 steel seriously affects the structural properties of the part. Untempered martensite is always present to some degree any time H-11 steel is machined unless extreme care is taken to assure that the machining temperature is kept low.

The development of manufacturing processes is markedly demonstrated in the area of fuel tank sealing because of the XB-70 design requirement for a "zero" fuel leakage rate. As a result new leak detection methods were required so that the air vehicle structure could be checked to determine that the tanks were leak free.

The engineering assumption was that honeycomb panels would require little or no repairs due to defects, an assumption which turned out to be completely incalid. As a result, methods of panel repair were also developed during the manufacturing cycle. The initial methods designed to repair the panel to its original design strength, were not satisfactory; however, each method created new problems in that the repairs were still not leak free. Continued development resulted in a sealing process using nickel plating and a secondary organic sealing agent called Viton to seal the porosity in the nickel plate itself.

The funding limitations on the program again dictated that "soft" tooling be constructed for air vehicle assembly. This, coupled with the welding distortion encountered, caused mismatch conditions throughout the entire air vehicle. It became necessary in most of the assembly joining operations to jury rig the components to be joined instead of using the tooling for which it was designed. In a few instances such as "six pak" mating and wing joining, mismatch adapters had to be designed and manufactured to accomplish the joining operation.

2. CONCLUSIONS

Funding limitations lead to the requirement to develop fabrication techniques on the air vehicle itself rather than to develop such techniques in advance. This resulted in an unnecessarily high expenditures and schedule delays. The prime contractor as well as subcontractors have repeatedly expressed the opinion that more effort directed towards basic processing and fabrication development would have led to overall program savings. Learning on the components for actual air vehicle usage is a costly and time-consuming process, occurring at a point in time when the contractor's burden rate is high. Also, laboratory development samples should have been more representative of actual size of the end components to be produced and fabricated in production. The fuel tank sealing effort is an outstanding example to justify the cost of advanced development of processes, techniques and materials; prior to actual manufacture of the end article.

It is an error to consider Materials and Processes, (machining, welding, etc.) as "off-the-shelf" (whether previously used or simply developed by the Air Force Laboratories). Each thickness, contour, size or alloy revision ultimately requires revision or development of new manufacturing techniques in the manufacture of the parts using shop production techniques and labor skills to production tolerances before the material or process can in fact be considered within the state-of-the-art.

A typical example to which manufacturing research and development was extended in the XB-70 program appeared in the early stages of the program when it became evident that during pre-weld trimming of parts and actual fusion welding, only very small deviations of the milling or welding heads from the path of the intended weld could be tolerated. Extensive experimental effort lead to the development of the "skate" technique to meet this rigid requirement. A 3" to 4" wide track with a rack was mounted directly to the parts to be joined, parallel to the path to be machined and welded. The track was held in place by vacuum cups and a small motor propelled itself and the milling or welding equipment along the track at the velocities required for the operation. By this means the edges of the parts to be welded could be milled simultaneously by the same cutting head, assuring a near perfect lateral fit for welding. By use of this technique, it is possible to machine, weld and inspect by x-ray large, hard to handle assemblies without expensive rigid tools with accuracies comparable and equivalent to that of highly specialized machines.

As the alternations of material development and improvement in techniques of fabrication continued, the use of mar-aging steel was contemplated to save weight and reduce processing costs; however, mar-aging steel was not used on the XB-70 because of the timing. Although it was not used, the development of the mar-aging steel has provided materials to the industry for use in the 300,000 PSI strength range.

D. HONEYCOMB PANELS

1. BACKGROUND

With limited testing and no previous experience the manufacturing departments found honeycomb panel fabrication, inspection, and assembly more difficult and problem laden than was anticipated. Most of the problems had their source in extra-manufacturing arenas.

The sheer size of the air vehicles in relationship to accumulative dimensional tolerances further upset by the warping affects of the welding processes was never fully grasped until the massive wings were moved in to mate along an eighty foot dog-legged joint with complex-curved surfaces.

As the problems arose and were recognized, to some extent, the ever mounting pressures to meet the contractors unrealistic over-optimistic schedules and prevent further costly slippages forced decisions to pursue courses of action which were fraught with risks. Unfortunately the odds were never favorable and most, if not all the gambles were lost. Some of the losses are still being reaped in the flight test program which has suffered from fuel leaks and structural failures.

The extensive weight savings drive coupled with minimum testing led to minimum and marginal quality panels being produced. The overpowering pressure to meet an optimistic schedule caused use of these panels as well as delaying their repair until late in the assembly sequence. Frequently, during the assembly process it was necessary to forcefully bend panels into joining position, thus producing built in stresses which, combined with weld shrinkage stresses induced during assembly welding and panel repair resulted in further panel failures.

The shortcomings of the honeycomb panels were recognized and extensive redesign was initiated for A/V #2 and A/V #3 panels such as increasing the brazing foil thickness, increasing the face sheet thickness, tightening up the tolerances, repairing defective panels as soon as possible prior to the assembly sequence, monitoring the loads required to move panels into joining positions and keeping the built-in stresses at an acceptable level, were some of the actions taken which resulted in better quality honeycomb-panel assemblies. A development which was too late to influence very many A/V #2 panels was post braze chem-milling of entire honeycomb panels. This technique permitted simplified internal panels and put the complex surfaces outside where they could be seen and dimensions controlled. Use of this technique was fully realized on A/V #3 honeycomb panels with excellent results.

The problems of fuel tank sealing were significantly reduced by use of cove seals and a change in assembly sequence. The A/V #1 fuel tanks were initially sealed after the hydraulic tubing and electrical lines were installed in the tanks, the A/V #2 tanks were initially sealed prior to the tubing and line installations. Both the sealing time and the leakage rates

were significantly reduced by use of cove seals and improved assembly sequence.

2. CONCLUSIONS

The redirections which called for speed-ups, cut-backs, lay-offs, and hold-ups; the austere tooling, the unrealistic schedules, the austere funding and the incremental funding as well as design weight savings all funneled their cumulative affects on the manufacturing departments.

The peculiarities of honeycomb panels and the need for 'kid-glove' treatment of the panels from fabrication through assembly was not fully recognized early enough in the program to avoid many of the problems which turned up during the manufacturing process.

The limitations of available panel inspection equipment and processes were not fully appreciated early enough to prevent marginal and defective panels from being accepted and started into the assembly process.

It is apparent that the task of sealing structure to 'zero' leakage condition for air or nitrogen gas was not fully appreciated by the fuselage design teams.

a. Complex Panels

Weight savings emphasis generated large complex panels. These panels were difficult to fabricate, contained many as-brazed defects and proved to be excessively difficult to process through the production phase.

Weight savings can be achieved through large complex panels but these types of panels are prone to defects and damage, the repair of which is costly in time and weight. Smaller, less complex, thicker-face-sheet, panels would simplify the fabrication and assembly processes and through reduced repairs keep the weight within reasonable limits.

b. Repair Induced Damage

In many instances the repair induced damage was actually failure of a marginal panel due to the stresses caused by the heat, or failure of a panel which had a high level of previously induced stresses. Less frequent were failures from overheating due to non-compliance with existing process specification.

Hot repair techniques are hi-risk operations and should be closely monitored to assure complete compliance with existing process specifications. Even then the hot repair technique may set up stresses in the panel or ajoining panels which will make them subject to repair induced failures. Hot repairs may reveal marginal panels and panels with a high level of built in stresses. It is desirable to discover both these conditions during manufacture. Better panel assembly

controls should be used to prevent excessive stress build up. Better inspection techniques should be developed to discover marginal quality panels. Better processes controls should be used so stress build ups can be monitored and kept within a safe level.

The possibility of using a cold repair process should be investigated thoroughly prior to calling out a hot repair method.

c. Panel Contamination

During nickel plating operations there have been several instances of panel contamination with the corrosive nickel plating solutions some of which were not recognized until later in the production process.

Even with careful following of the process specification, nickel plating is a high risk operation. The conversion from a positive (gauge) pressurized plating box to a negative (gauge) pressure lessens but does not remove the risk. No non-destructive inspection method has been devised to assure, during or immediately after plating, there is no contamination of the panel. There have been instances where visual evidence of contamination has shown up weeks after the plating operation.

Careful and exacting adherence to the process specifications, including continuous alert monitoring of the nickel plating operation is required. Nickel plating should never be deferred until after a panel is joined to a second panel nor should it be deferred on a subassembly until after the subassembly is joined to another. Whenever possible, nickel plating should be accomplished early in the production process so as to permit detection of contamination prior to the panel being incorporated into a larger assembly.

d. Production Handling of Honeycomb Panels

An unacceptably high number of A/V #1 panels were damaged by workmen because they were not thoroughly indoctrinated in care and protection of honeycomb panels.

Worker education programs and panel protection were utilized on Air Vehicle #2 to a maximum extent and worker caused damage to panels was held to a minimum.

Worker education in the care and processing of honeycomb panels is a must and this type of training program applies to all personnel from the janitors to the engineers and managers. Equally vital is a panel protection plan which includes protection during all stages from panel fabrication to area close out.

E. WELDING

1. BACKGROUND

In the XB-70, the use of conventional mechanical fasteners is limited primarily to the forward fuselage section which is constructed of titanium sheet - the balance of the structure is fabricated of welded honeycomb panels. Each XB-70 required approximately six (6) linear miles of welding to join detail parts; and about two and one half (2½) linear miles to join major assemblies of nearly twenty-five thousand (25,000) gross square feet of brazed honeycomb panels. Considerable developmental effort was necessary to advance the welding and brazing techniques to meet XB-70 requirements.

The requirement for welding starts early in the individual component fabrication where individual panel face sheets require the welding of two or more separate pieces of stainless steel sheet material to make up the total panel area. The normal process of welding stainless steel sheet results in panel distortion, requiring hand finishing to obtain a clean, burr-free, flat finished sheet. To eliminate both the hand removal of the weld bead and the distortion of the welded parts, a welding technique known as "LANAR" (Low Amperage, no added Rod) was developed. "LANAR" welding uses conventional tungsten welding equipment but penetrates the weld area only 75% - 85% on one side. The work piece is turned over and a second weld penetrates enough for overlap of the first weld. No filler rod material is added. The lateral contraction of the second weld off-sets the lateral contraction of the first weld, leaving a small convex weld bead which was eliminated by slight roller burnishing.

The most important joining methods developed or refined for the XB-70 were resistance butt welding, resistance spot welding, fusion spot welding, fusion welding, electron beam welding and brazing.

Resistance butt welding was a new application of conventional resistance welding principles, consisting of panels joined with added strips on both sides of the inner and outer facing sheets and was initially used as the basic means of joining honeycomb panels. The strips served to contain the weld nugget as it was formed and prevented reduction in cross-section area of the sheets as the weld was made. Butt resistance welding initially provided a satisfactory, fuel-tight joint.

Fusion welding was the principle welding method used on the XB-70. In most cases, it is done by the tungsten inert gas process (TIG). The arc is shielded by an inert gas such as argon or helium as filler material is added to the molten metal. Several adaptations of fusion welding were developed. Each designed to weld different types of joints. TIG welding became the principle method of joining

honeycomb panels by use of what is known as key hole welding. In joining panels, the lower face sheet was TIG welded through a 1/8 inch slot in the upper face sheet. The upper face sheets were then joined by a double weld using a 1/8 inch filler strip to close the slot. This provided a weight savings, and permitted the honeycomb core to more closely approach the edge of the panel for greater strength.

A family of light weight titanium and PH15-7MO steel I beams were developed for the XB-70's inner structure. A thin corrugated web is sandwiched upright between two caps. The caps were welded to the web by the "burn-through" weld process. The weld heat penetrated through the cap and fused the web. Weld rod filling was used for any depression resulting from weld flow. The TIG welding technique was also used in some cases, the torch being programmed by an electric eye following a precise template, tracing the corrugated (sine wave) web exactly. A continuous weld fillet on each side of the web results. Because of the high strength to weight ratio inherent in this process and the cost advantage of weldments over machined parts, this type of structure was predominantly used in the structure of the XB-70.

Electron beam welding was taken out of its previous laboratory environment and was used to weld the wings to the fuselage of air vehicle #1. The upper and lower surfaces of the wings and wing stubs are honeycomb panels and both the inner and outer face sheets had to be joined. The inner face sheets were TIG welded by the keyhole method. The outer surface was joined by electron beam welding. This electron beam method was selected because heat is so localized that residual stresses and weld distortion were kept to a minimum and thick materials could be welded to thin gauges. A joint to be electron beam welded must be enclosed in a high vacuum. Basically this problem was solved by the development of a portable vacuum chamber with sliding seals. Maximum advantage of electron beam welding was not realized initially due to the vertical misalignment of the surfaces over the 80 ft length of wing joint to be joined and an adapter strip was required to achieve the required tolerances. Nontheless, the electron beam welding did afford an advantage by its ability to satisfactorily join materials in a confined joint with a minimum of residual stress being induced by conventional weld shrinkage.

Conventional resistance spot welding was also used where fuel tight joints were not required. Special long reach spot welders (72 inches) were designed and built to resistance spot weld forms attached to panels where a long reach was necessary within a restricted working area.

A great amount of hand welding was still required on the XB-70 demanding great skill of the individual workman. As a result, a new concept of welding at elevated temperatures was developed. Depending on the conditions, it was found necessary to heat the entire part before, during or after welding. For example H-11 welded assemblies

required preheating and holding at 600°F during welding with the welder working in an asbestos suit. After welding immediate stress relieving at 1200°F was required to prevent cracking in the weld and surrounding areas. Manual welding of titanium was done in an inert plastic "bubble" chamber containing argon to prevent contamination of the titanium during welding. This procedure was improved by a "trailing cup" method for assembly welds, which removed the "bubble" limitations. This method provided a traveling cup of inert gas as the weld progressed.

2. CONCLUSIONS

It has been found that the production department and quality control department personnel require an earlier input into the basic design, and in many cases, the individual worker can and has assisted in basic design and fabrication planning. With the advent of the super alloys, it is essential that the individual worker become highly skilled in the manufacturing processes. Not only is training required but proficiency must be maintained. Such requirements do not lend to changes in personnel without extensive retraining, thus early and specific labor requirements must be identified to keep optimum labor skills and allocations on a stable basis throughout the program.

F. QUALITY CONTROL

1. BACKGROUND

Due to the unique construction of the XB-70, the major quality control effort during the fabrication and assembly stages of the program centered around the fabrication of honeycomb panels. There are essentially five basic factors that cause poor quality in a honeycomb panel: improper node flow, faulty shear ties, crushed core, inadequate fillet size and faying surface faults for which inspection methods for finished panels were developed.

The problems of quality control increased with the introduction of the new materials and design concepts. The conventional inspection methods were generally incapable of establishing product integrity either because of inaccessability or critical inspection tolerances. The history of quality control on the XB-70 is one of continuous evolution of new applications of improvements upon tools, methods and techniques available to industry. Many times complete reliance had to be placed upon the worker until a meaningful inspection capability could be developed. An early problem was the difficulty of assuring an exact fit between large surfaces of honeycomb core to the varied levels and contours of panel facing sheets. A photographic method replaced a measuring and charting method. It in turn was supplanted by a carbon paper record of the degree of fit. The need for absolute cleanliness and purging of the panel components of gas-borne contaminants was discovered during the investigation of early failures of the honeycomb panels. Here again the individual workman provided the prime ingredient of quality control.

X-ray inspection was the initial method employed to determine the integrity of honeycomb panels. The ability of the reader to detect other than gross faults was highly questionable. Ultrasonic inspection of the panels was used as a supplementary inspection process. Although a permanent recording capability was developed, the requirement for immersing the panel in water dictated that this technique be abandoned since water entering the panel caused considerable corrosion. The inspection process returned to a procedure of in-motion radiography which blurs one side and causes the other side to stand out sharply. This method provided a readily readable record of inspection. The use of portable x-ray units moving on the skates was used to inspect all welds during sub and final assembly. It should be emphasized, however, that the real quality of the panel is vitally dependent upon the workmanship, knowledge and care of the individual worker on each detail of the panel components.

2. CONCLUSIONS

The failure to provide components manufactured and/or fabricated under actual production processes seriously impaired inspection and quality control; as well as the previously mentioned impact to the production program. The new techniques which were required to be developed, x-ray film reading as an example, and the required time necessary for training in the use of these techniques dictated that the learning process had to be accomplished during manufacture of the actual air vehicle hardware. It was late in the manufacturing of air vehicle #1 hardware, before any degree of reliability could be placed upon inspection identification of defects. The early unidentified defects in honeycomb panels, or the questionable classification of such defects were responsible for failures which are occurring under the present Flight Test Program. To make repairs and/or replacement of parts at this point in time has proven to be very costly to the program in both time and dollars.

The failure to provide an adequate development testing program has also hampered the development of an adequate inspection and quality control program. Since this was an austere program, there were insufficient funds to set up destructive testing of honeycomb panels so that actual comparison of defective areas versus the findings of the x-ray reading could be compared. Lack of such a procedure limited the quality control personnel in making adequate or timely adjustments in training or predicting quality trends. The testing program on honeycomb panels, as an example, were limited to a surface pull test at 80% of designed strength of the panels, as well as to suspected areas only.

As a result of not being able to properly identify and categorize the defects, the scrap rejection rate on the honeycomb panels was extremely high (34% of total square footage produced on Air Vehicle #1) and it was not until production of Air Vehicle #3 panels began that elimination of defects through quality control input on redesign and improved techniques was made possible. Air Vehicle #3 panel production was at a 2% scrappage rate at the point of termination, March 1964. It can be said that the major contributing factor to the program schedule delay and dollar overrun was due to panel defects and that repairs generated by these defects were the primary source of leaks which delayed the fuel tank sealing efforts. In addition, as the airplanes were built, the continuous repairs to the structure resulted in considerable weight penalty. It is estimated that the weight penalty due to the above repairs amounted to 22,920 pounds on the first XB-70A and 20,354 pounds on the second XB-70A.

IV. ENGINEERING

IV ENGINEERING

A. General Background

In the area of engineering experience, the influence of repeated program redirection and curtailment of funds have impacted upon the number and depth of the technological advancements that have been forthcoming. With the advent of the program as it exists today, the research and engineering efforts were restricted to the prime requirement of providing an Air Vehicle capable of performing within a speed and altitude flight envelope up to Mach 3 and 70,000 ft. Although hard tooling was available in most of the structural areas as a result of the previous weapon system program, the XB-70A Air Vehicles might be considered as having been designed and built on a model shop basis. Final engineering in the subsystem areas could not afford the luxury of optimum design for maintainability or extended reliability, and it became necessary to use airworthiness testing in lieu of extended subsystem and component qualification test programs. Two very critical areas that have been much more successful than would normally be expected in light of the drastic curtailment of subsystem testing prior to incorporation into the Air Vehicle are the flight control system and the hydraulic system. The number and complexity of problems that can be expected in attempting to provide technological breakthroughs in these areas without providing a full scale flight control simulator or hydraulic system simulator can be almost insurmountable. Although both of these areas have experienced severe problems both during the development program and during the initial portion of the flight test program, the validity of the basic design concepts and the compatibility of the components within the subsystems as demonstrated during initial testing of the Air Vehicle are considered to be without precedent in their degree of success.

B. Subsystem Discussion

In discussing the engineering experience and lessons learned, it is appropriate to cover the major subsystems more or less as separate entities. In such a discussion, however, it must be remembered that a very significant portion of the knowledge to be gained and lessons to be learned in the area of engineering design and development will result from that portion of the flight test program that is still in the future. To date our knowledge and experience have been primarily in the initial development, implementation and integration of subsystems into the basic Air Vehicle configuration.

1. Hydraulic Subsystem

Primary experience gained in this area is centered around the new subsystem requirements such as the use of 4000 PSI system pressures as opposed to current inventory aircraft systems that are

based on pressures of 3000 PSI. To accommodate this elevated pressure, it became necessary to develop and utilize seamless stainless steel tubing for hydraulic fluid transmission lines. This tubing varies in size from ¼ to 1-7/8 inches in diameter. The use of standard AN fittings in this system became prohibitive from the standpoint of preventing leaks and the excess weight encountered. Both of these problems were solved by the development and use of brazed tubing fittings. It is estimated that the use of such advanced fitting techniques resulted in a weight savings of some 10,000 pounds throughout the entire aircraft system. In order to utilize this 4000 PSI system it was necessary not only to drastically reduce the tolerances and clearances in valves, actuators, and hydraulic pumps, but it was necessary to remove foreign contaminants from the fluid system that were microscopic in size. The severity of this requirement is illustrated by the fact that the fluid filters installed in the on-board control valves are designed to remove foreign particles that are larger than 5 microns. In order to utilize the elevated pressure of the system it was also necessary to fabricate actuators and pump components of H-11 tool steel. The use of H-11 steel in these areas in turn necessitated the development of new machining techniques.

When the initial designed pumps and other components were first integrated into the system, components and transmission lines failed due to pressure surges and system pulsation. The absence of a full scale hydraulic system simulator required that these and similar flight control problems be resolved by tests conducted on the actual Air Vehicle subsystem. Experience has now shown that the decision to eliminate the full scale simulator was more costly in terms of aborted flights, extended down time and component failures. In consideration of this additional cost in money and time, and the potential damage that can be encurred during testing, future systems will find it more economical to make the development and fabrication of a hydraulic system simulator a mandatory requirement.

During the initial phases of the B-70 development program, the decision was made not to install cockpit instrumentation that would permit the flight crew to continuously monitor the pressure and fluid quantities in the various hydraulic systems. However, as the flight test program progressed, it became evident that such instrumentation is a necessity. Future systems should include the hydraulic pressure and quantity indication requirement on a mandatory basis.

Experience has also shown that in the area of hydraulic tubing, the use of only rigid lines throughout the system is a poor design approach. Major line failures have now been eliminated by the use of flexible lines in areas such as the attachment of hydraulic driven pumps. However, additional development is still required to make available flexible lines which will withstand high

pressures and temperatures while providing long life reliability.

2. Electrical Subsystem

In order to reduce the weight of electrical transmission lines, the electrical generation system was designed for 400 cycle, 416 volts. This system has been highly successful and the use of higher voltages at extreme altitude conditions has not presented problems of corona or arc over. The successful operation of the oil cooled brushless generator has also proven that arc supression around rotating rectifiers is not necessary if the system is designed correctly. The development of pure AC relays and solenoid valves under the XB-70A program has also allowed the elimination of transformer rectifiers for DC control power. Experience in this area has shown that although a small amount of direct current power has been used for certain equipments and for providing an emergency power backup source, the high voltage and pure alternating current powered Air Vehicle design is a proven concept. The use of such systems in lieu of conventional AC-DC low voltage systems results in an electrical subsystem weight savings of approximately 25%.

3. Propulsion Subsystem

The XB-70A is the first supersonic aircraft to utilize a single long air intake duct to provide combustion and cooling air to more than one engine. This arrangement of two air ducts, each providing air to three engines, has proven highly successful to date. Significant also is the successful use of a long (80 ft) duct with variable geometry control. Experience on this program has shown that at Mach 2 and above, the inlet geomotry must be variable so it can precisely control the varying shock patterns of the ram air. Optimizing of the inlet geometry has become one of the most critical design problems of air vehicles operating at high mach numbers.

A significant lesson learned as a result of the program slippages is that the engine development in any future program should be started at the earliest possible date. The two year program slippage which the XB-70A encountered permitted most engine problems to be resolved prior to the flight test program and on-board engine operation is now highly successful. The J-93 engine was developed by General Electric, Evendale, Ohio. This engine has satisfactorily demonstrated that with continuous afterburner operation it is possible to develop 30,000 pounds of thrust with an engine weighing less than 6000 pounds.

Another significant lesson learned is that the large quantity of JP-6 fuel carried on board can be successfully used as a heat sink not only for the heat generated by the on-board subsystems but also

for the aerodynamic heat accumulated at high mach numbers. Although the fuel absorbs sufficient heat to raise it above the flash point, safe operation has been obtained by first removing the entrained air from the fuel by bubbling nitrogen through the fuel as it is put on board. Secondly, the ullage space above the fuel in the tanks is filled with gaseous nitrogen under a positive pressure.

A major problem in this program has been fuel leaks in the fuel tanks. Numerous methods have been applied to sealing the honeycomb structure and although the leaks have been greatly reduced, further development is needed before a completely satisfactory high temperature, long life tank sealant can be made available.

4. Alighting Gear Subsystem

Design work in this area started early in the program. Unfortunately the original design size of the tires was held to a minimum to reduce tire weight but did not take into account the growth potential of the air vehicle in over-all gross weight. Consequently, the utilization of the total structural gross weight potential of the air vehicles now requires the tires to operate at temperatures and pressures in excess of the original design requirements and beyond the state-of-the-art of tire manufacturers. This situation has greatly reduced the reliability and life expectancy of the present tire configuration. The significant lesson learned from this situation is that in the initial design, the tire size chosen must be sufficiently large to accommodate the growth potential and resultant gross weight increase of the air vehicle.

Another major problem in this area has been brake chatter at low taxi speeds. Although this problem exists on all large aircraft, the problem has yet to be resolved. Because of the potential structural damage that can result from this situation, the XB-70A program now includes a rather extensive effort to establish design criteria for braking systems that will eliminate this problem.

C. Applied Technology Base

Weapon System 110A (XB-70) from its inception has required the maximum utilization of the latest laboratory and research advances in aerospace technology to meet the system objectives in performance, range, speed and accuracy. The application of these advances posed considerable problems. Although many of the advances in aerospace technology had been proven in the laboratory to the extent that they were commonly accepted to be within the then present state-of-the-art, little or no effort had been expended towards the technology required to generally apply these advances to aerospace system hardware.

One of the lessons learned on the XB-70 program is that this increasing lag between the laboratory and research breakthroughs and the technology base for application to design and manufacturing techniques have resulted in longer system development time periods and greatly increased system oriented costs. This lag has been caused by the rapid expansion of our research programs with an equal reduction in our programs to develop an applied technology base and proven manufacturing techniques congruent with the emphasis on point or system design. This emphasis on point or system design approach implies that there must be an end item system hardware need before application development is done on the manufacturing technology. This results in the concentration of know how within a small number of our industrial contractors and is often lost to the scientific community whole.

The expansion of the applied research base not oriented to point or system design is required on a continuing basis in order to bring future systems into the inventory which incorporate the latest proven technology at less direct cost and in a minimum time period.

In the XB-70 system program most of the advanced concepts had to be developed from the laboratory concept to specific hardware without the benefit of an applied technology base. For instance, stainless steel brazed honeycomb panel had been produced in small laboratory samples and was commonly recognized as a highly efficient structural material. To use this material for the manufacture of the XB-70 required development of rolling mills that could produce stainless steel in both thin and close tolerance sheet stock, development of brazing techniques and equipment, development of joining and welding techniques, and the development of a whole new family of quality control and inspection criteria. Once developed, the new procedures, techniques, processes and equipment had to be expanded to encompass the entire subcontract base. All costs in both time and dollars were directly oriented to the XB-70 program.

As the XB-70 was originally planned as a weapon system to be produced in quantity, a large development and subcontract structure was established which encompassed nearly all of the aerospace industrial complex of the United States. As breakthroughs were made in development or manufacturing, these were distributed to all vendors and subcontractors through newsletters and symposiums. Thus, the XB-70 advancements in the state-of-the-art and information gained were disseminated to the entire scientific community.

The technical lesson learned on the XB-70 System Program is that our programs of applied research and manufacturing technology are not adequate or timely to support the advancement made in the laboratory research programs. The emphasis on only system oriented development of applied research or manufacturing technology has increased the lag

between laboratory research advancements and their application in a system and has greatly increased the system development time and system oriented costs of any system which utilizes the latest research advances.

V. FLIGHT TEST

V. FLIGHT TEST

V. FLIGHT TEST

A. BACKGROUND

All areas of flight test support, and with the exception of the flight test contract planning, were completed to support the originally planned first flight date of December 1962. The Joint Test Force was organized and the services and support agreements between the AFFTC and the contractor were in being by that date.

Air Force personnel were trained by and with contractor personnel. The technician and engineers virtually lived with the aircraft during manufacture, thus acquiring a thorough background. The pilots received ground school with the contractor pilots and participated equally in the flight control simulator missions.

The contractor flight test maintenance personnel were employed in the manufacture of the aircraft, consequently they were well qualified in the configuration and systems operations. The contractor pilots completed Air Force B-52 crew training and received B-58 flight training to gain experience with large high speed aircraft.

Facilities in being at the AFFTC were adequate except for modification of building 1820, construction of a 10,000 barrel capacity storage tank for JP-6 fuel and construction of a run pad for the XB-70. This work was accomplished under the military construction program.

The flight test plan was developed by the contractor and approved by the Air Force. This plan was to the detail of each individual data point, (NA 61-620-2), as well as the more general overall plan and flight test program objectives. The plan was based on the contractor's estimate

of achieving an average of eight hours per month per air vehicle.

The contract for the flight test program was accomplished in July 1964, which was, of course, prior to the first flight of the air vehicle. Since the contract was of the incentive type, the contractor was therein recognized as the flight test program manager. Approval authority over the flight crew composition was, however, retained by the Air Force.

B. CONCLUSIONS:

The organization and manning of the Joint Test Force was, due to aircraft manufacturing slippage, almost two years early. This, however, was not a wasted effort. The additional time available resulted in much more thorough training than would have been possible otherwise, and enabled personnel to follow the air vehicle through the manufacturing as well as preflight phases. In addition, it made available to the SPO, on site knowledgeable Air Force personnel. The flight control simulator experience gained by the pilots was judged extremely valuable training, particularly in view of the fact that due to austerity no flight simulator was procured. The contractor procedure of utilizing flight test maintenance personnel in the manufacture of the air vehicle was a valuable expedient to provide trained maintenance personnel for the flight test program without incurring added training costs. The heavy and supersonic bomber training afforded the contractor pilots is felt to have contributed in a large measure to the safety of the early flights. This training was not considered necessary for the Air Force pilots due to their previous experience.

The formulation of the flight test program objectives and the development of the broad flight test plan early in the conceptual phase of the flight program is, of course, necessary. However, planning to the detail of individual data points is wasted effort. To date, in the XB-70 program, less than 50% of the data points accomplished were contained in the detail plan, the balance consisting of points for which the requirement was unknown when the plan was developed, yet accomplishment-wise, the program is proceeding approximately on schedule for the hours flown. A further consideration is that the detail plan of data points, (NA 61-620-2) was compiled for the originally planned flight test program of 415 hours.

The incentive type contract does not lend itself to the exercise of Air Force management of an experimental flight test program such as the XB-70. Any request by the Air Force to the contractor to alter projected flights will normally affect the achievement of the contract incentives and can, therefore, be expected to be met with opposition by the contractor. The Air Force is then faced with the alternatives of relinquishing management of the program or placing the contract in jeopardy. A type of contract which would permit Air Force to exercise management prerogatives would be highly desirable.

VI. CONFIGURATION MANAGEMENT

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A. AIR VEHICLE

1. BACKGROUND

a. In light of the very stringent funding limitation under which the B-70 program has operated and is being tested it was necessary in early 1963, to establish an effective and positive control of configuration changes. Control of B-70 design and fabrication has been achieved through SPO surveillance of specifications and engineering data. Change control procedures were negotiated with the contractor and included in an Exhibit which became a part of the contract. A B-70 SPO Office Instruction was prepared to list procedures for control of contractual changes to the configuration of the XB-70 Air Vehicle and YJ-93-GE-3 engines. SPO approved specifications in effect on the date of acceptance of each Air Vehicle, with deficiencies and shortages listed in the A/V Deficiency Report, defined the baseline configuration of each Air Vehicle. Major changes to the Air Vehicle after AF acceptance require B-70 SPO approval prior to making the change. Differences between the two A/V's required the use of separate specifications to define the baseline configuration; however, the same configuration control procedures apply to both A/V's.

b. Since only two XB-70 A/V's were procured, configuration identification and reporting at component level (which is the procedure for programs scheduled for the operational inventory) was considered unacceptable for the XB-70 development program. In lieu thereof, XB-70 configuration identification, control, and reporting is accomplished at subsystem level allowing the contractor sufficient design change flexability required for a development program. Since both A/V's were bailed back to the contractor after AF acceptance configuration status accounting is accomplished by the use of contractor internal reports rather than requiring the contractor to prepare formal status documents. The contractor's status reports are furnished to the Air Force at specified time intervals and provides, (1) a word description of engineering changes made since the previous flight of the A/V and lists the subsystem affected, (2) a listing of the subsystems which were either inoperative or partially inoperative for the flight being reported, and also includes a statement as to the reason for it being inoperative, (3) a listing of all subsystems which have had changes incorporated since baseline configuration was established with a cross reference to what the change consisted of, and (4) a two part listing, which provides a list of all changes that have been released for incorporation in the A/V. One part lists the changes that have been installed and the second part lists changes that have not yet been installed.

c. The AFPRO and the XB-70 Test Force personnel maintain close surveillance over all configuration changes as they are being formulated by participating in the contractor's meetings when proposed changes are discussed. This procedure provides the SPO with a technical engineering assessment relative to the necessity for the change, a contractual assessment, and a logistic support assessment relative to the effect the change will have on Ground Support Equipment, Spares, Technical Manuals and Maintenance procedures. Major changes are limited to those pertaining to Safety of Flight or to achieve contract flight test objectives. Major change proposals are reviewed and approved, or disapproved, by the B-70 Configuration Control Board, which meets at specified time intervals in the B-70 SPO.

2. CONCLUSIONS

a. The configuration procedures and management controls currently in effect for the XB-70 program affords the closest practical management surveillance of changes, thus insuring that only those essential to the safe and effective accomplishment of the flight test contract objectives are implemented. The configuration of the flight test A/V's is clearly and accurately defined as is necessary, not only to insure flight safety, but to permit interpretation of flight test results. Good day-to-day working coordination between the contractor, AFPRO, B-70 Test Force and the B-70 SPO has been established. The SPO is kept knowledgeable regarding potential configuration changes prior to their actual release and incorporation in the A/V's, by means of a weekly informal telephone conversation between the contractor and appropriate SPO personnel. This provides the necessary advance information without generating additional cost to the program which would be inherent in any regular written reporting. During these telecons progress toward accomplishment of changes already in process as well as a brief review of potential future changes is provided to the SPO. All changes are analyzed with respect to flight test objectives, program cost, impact on logistics, maintenance, spares, and ground support equipment. This type of continuous, close, but informal coordination provides the SPO and other AF agencies involved with knowledge and understanding of current status of the XB-70 flight test program without the generation of additional and unnecessary cost to the program. The XB-70 Configuration Management program is similar to and satisfies the intent of current AFR and AFSC series of regulations pertaining to AF configuration management. With the exception of making minor changes, activities to date have confirmed that XB-70 Configuration Management policy provides definition of A/V configuration and demonstrates the existence of tight management control of configuration changes.

B. DATA MANAGEMENT

1. BACKGROUND

a. In the 1958-59 time period when an experimental contract for the B-70 was executed, contracts for large quantities of aircraft were approaching a conclusion and most contracts being awarded were of the R&D type with a minimum of hardware as the deliverable end item. It was at that time that the B-70 contractor and the B-70 Weapon System Project Office realized that during the war and postwar years which had demanded the delivery of high quantities of aircraft, specific contract definition of data was of secondary importance and it was probable that up until then, neither had the contractor known completely what data he was obligated to supply under a contract, nor had the Air Force known completely what data they had procured under a contract. Completion of data in those days usually was constituted by submittal by industry of qualification test reports for equipment, equipment samples, preliminary handbooks and microfilm of final production drawings for the Air Vehicle.

b. With the advent of the R&D contracts, where weapon system and performance specifications were being introduced and with the advent of a new family of management reports, the application of data requirements contained in military specifications for hardware appeared questionable, and the requirement for a definitive document of line items of data in the contract became evident. Such a document was generated by the joint effort of the B-70 Weapon System Project Office and the North American Aviation, Los Angeles Division, and the subject document was attached to and made part of the B-70 contract. During the 18 months that followed, data submittal requirements of the subject contract were limited to those contained within the exhibit and the status reporting of such data was mechanized for internal control within the contractor's facility. The WSPO had as had the contractor, appointed one person through which all data requirements were coordinated and approved. The exercise included a very close coordination effort between the contractor and the B-70 SPO to resolve two basic factors: (1) Identification of data required by the SPO to fulfill its charter within the Air Force and (2) A definition of the data so identified in order that the contractor would have a clear understanding of the required contents of each end item of data. It was found necessary in some instances where definitions contained within certain paragraphs of Mil Specifications were ambigious, for the B-70 SPO to write an exhibit which fully defined the required contents of that specific line item of data. When all such data were identified and understood by both parties, it was attached as an appendix to the contract and prefaced by an introduction which contained the following two key statements:
"Data requirements of applicable specification and USAF design handbooks, except as defined herein are waived. These and other government documents requiring the preparation or delivery of data shall be used as a guide but shall not require Air Force approval for deviation thereto, relative to preparation and/or submittal of data."

The second key statement was: "Data shall be submitted in the format and content normally used by North American Aviation or by its subcontractors." Where the term "Test Reports" and "Test Results" were used, the meaning was synonymous. As of today, these words of the contract have not been amended nor has the contractor been requested to prepare "data" per se over and above that which was set forth in the exhibit.

c. The Air Force, in administering the B-70 program, did one additional thing which is particularly applicable to the management of data. It reflects a philosophy used by the B-70 SPO to maintain data at a minimum and was accomplished by the SPO exercising its prerogative to delegate approval of certain items to the contractor. The philosophy applied was that which was reflected in an early Air Force Bulletin MCP 71-533A, which when implemented, allowed the Air Force to accept contractors certification that end items of equipment below subsystem level had fulfilled the government approved airworthiness or qualification test requirements, such certification to be based upon the contractors laboratory test results. This meant that with the exception of a few selected end items of equipment in which the engineering personnel of the SPO had a special interest, it became unnecessary for the contractor to document test results in the form of formal test reports. This philosophy recognized that test laboratory log data sheets maintained on file by the contractor and readily available to the Air Force if required, would serve the same purpose as file cabinets, at Wright Field, full of formal test reports which might not be needed for the balance of the program. It is obvious the savings in manhours which were realized particularly in view of the fact that the contractor passed the same philosophy of certification on to his major subcontractors.

d. Following the definition of data which became part of the contract, the method of managing the effort in accordance with contract requirements was implemented. This consisted of a mechanized system for data status reporting to the WSPO as well as internal data management within the contractor's facility. The first step accomplished for the preparation of the master tab listing was the assignment for each line item of data, a sequence number, a report or drawing number, and a responsible group within North American. All items of data, as in the contract exhibit, were grouped by subsystem. The master tab, printed from punched cards, formed the basis for all subordinate reports which were machine sorted and printed as required. The original system established the use of an 083 card sorting machine and a 407 rapid printer... and the cost incurred for establishing the internal control and reporting system was a minimum. The original programming cost was about $600, and each combination of printouts thereafter cost in the neighborhood of $35. This represented some 350 data entries. As time progressed, additional reports, specifications and drawings were identified by number and periodically added to the tab run. Additionally, scheduled and actual dates were added and provisions made for the Los Angeles Division transmittal letter number to be recorded opposite each line item of data. The fact was recognized that the submittal of any data item, immediately opens the door for a myriad of questions which, when asked in writing by the customer must be answered in writing by the contractor. Such answers in writing usually represented additional

NOTE

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data even though it was contained in letter form. Thus it was found advantageous to reference all correspondence generated by either the customer or the contractor related to any end item of data adjacent to that line item of data in the tab run thus providing a ready reference for not only the data requirement but all correspondence related thereto. Each end item of data in the master tab was also coded to indicate when written approval of the WSPO contracting officer was required and/or granted. Each line of data in the data status report was assigned a sequence number, a number representing the office of prime responsibility (or group) at the contractor's plant, the assigned document number, a document title, a submittal schedule, a submittal date, and the contractor's letter number under which submittal was made. Beneath this line might appear 3 or 4 other references of correspondence from either the customer or from the contractor and the code indicating the approval status of that line item entry. The standard printouts which were used throughout the program for management purposes at North American were (1) the total list, (2) a printout list by office of prime responsibility of all scheduled data, and (3) a numerical index of all specifications and reports. In addition, printouts were made of all open approval items by office of primary responsibility and a working list of data scheduled for submittal within the next 60 days. Other combinations were issued as required. As, an example, in addition to the total list, which was printed and submitted to the WSPO on a monthly basis, frequently the SPO desired a list of items which had not as yet been approved. Because of the approval status coding, by instruction to the machine, such a list was made readily available. Conversely, suppose North American Aviation Management desired a list of items which required Air Force approval, but had not as yet been submitted, it was extremely simple to produce that information in a minimum of time. In the years which this system has been used on the XB-70 contract, the volume of data and related correspondence has grown to approximately 17,000 entries. Recently, the machine instructions have been taped and the printouts made using a 1401 series machine. An interesting statistic is the fact that the increase in volume of entries has been offset by the faster printout speed of the 1401 machine, allowing machine costs to remain nearly the same as when the program was started.

e. Throughout the development contract of the B-70, it was recognized that instances would arise when the contractor would submit something to the Air Force for his suggestion and/or coordination even though such data was not necessarily included as part of the contract data requirements. It seemed important that a record of such submittal together with an index of related correspondence be maintained, so as a result, these items were also included in the data status report.

f. To alleviate communication problems a plan for scheduled technical meetings between the engineering personnel of the contractor and his subcontractors and Air Force technical personnel was implemented. Such meetings were progressively scheduled by subsystem, were held at either the contractor or subcontractor's plant or at the system project office - included a minimum of personnel, were accomplished in one or two days, were informal in nature, and were conducted no less frequently than every 90 days for each subsystem. At such meeting, preliminary drawing, schematics, rough analyses, and concepts were discussed. Questions were asked and

answered on the spot. Recommendations and/or directions were obtained from Air Force technical personnel leading toward the ultimate formal approval of the applicable subsystem or components therein, as required. The purpose of the design reviews was actually two fold: (1) The Air Force was always current in the design techniques being employed by the contractor, and secondly, the contents of a report or drawing to fulfill a specific data requirement came as no surprise to the SPO when it was submitted for approval. Thus the written correspondence problem was maintained at a minimum. It is conceivable that had such conferences not been conducted, and the exchange of information had been by correspondence only, the current tab listing might contain not 17,000, but 30,000 entries.

2. CONCLUSIONS

a. Today the B-70 SPO has a status report that contains a reference for nearly every piece of paper submitted by the contractor to the Air Force as well as from the Air Force to the contractor, and it is segregated by Contract Data Item Number. The Air Force and the contractor use the same information to monitor contract data. The versatility of the status report is quite evident. The B-70 Data Management program conceived and implemented in 1958-59 is quite similar to the data management system currently being implemented by the Air Force. The similarity is evidenced in three specific areas. First, the appointment of a data manager within a system project office is a current requirement. However, since the inception of the B-70 program, there has been one key B-70 system project office person assigned responsibility for complete coordination of B-70 data. Secondly, exhibits prepared by the B-70 SPO to define the contents of end items of data closely resembles the documents rrently being implemented, which accomplish the same purpose. And third, the waiver of all data requirements, except those set forth by line items in the contract has become a standard of operation.

b. Since the B-70 is a development program consisting of two experimental aircraft with no follow-on operational requirement, and also due to program austerity, B-70 data requirements and the distribution thereof is very conservative. Essentially all B-70 data required by the Air Force is submitted in the format and content normally used by NAA or by NAA subcontractors. Only selected items of data are submitted to the Air Force consistent with management needs. This procedure does not waive the contractor's responsibility for compliance with applicable design and testing requirements and for maintaining on file, readily available for submittal to the Air Force upon request the information from which all data required in applicable government documents has been prepared. The B-70 Data Program has kept the dollar investment in engineering data to a minimum. It has prevented the procurement of unnecessary data by restricting purchase to valid requirements as they generate. It makes readily available any portion of B-70 data prepared by the contractor regardless of whether the item is listed in the Contract Data Exhibit.

VII. LOGISTICS

VII. LOGISTICS

A. BACKGROUND

Like the contract and manufacturing effort, the program director recognized the requirement for the initiation of Logistics Support planning at the inception of the Weapon System Program. The Aeronautical Systems Center support office was established in 1958 utilizing ASC and Hqs AMC personnel who worked directly with the WADC Development Engineering personnel in establishing the design criteria for training devices, Ground Support Equipment and the W.S. Data, Spares and GSE provisioning criteria. As the program progressed, the ASC Support Office was expanded to assume more of the program management and provisioning efforts with the ARDC personnel doing less of the management and more of the engineering effort. In 1961 the Hqs AMC personnel attached to this SPO were SAAMA who established a liason within the SPO initially on a coordination and planning basis. In 1962, the Program Director recognized that under an austere program the AF as well as the contractor could not afford a duplication of personnel assigned the support office for accomplishing essentially the same planning effort. He, therefore, administratively established a single administration for support office under the San Antonio Logistics Support Manager utilizing both San Antonio and ASD SPO personnel to carry out the XB-70 Support function. This consolidation of effort and personnel resulted in some reduction in personnel/discontinuance of duplicate efforts and a closely integrated and rapidly responsive organization to the several program re-directions. A single set of operational procedures were established as well as consolidated planning and reporting systems such that facilities, Ground Support Equipment, GFAE and Spares were programmed and administered as a unit. An outstanding example of the benefits that resulted from this approach was the planned provisioning of Ground Support Equipment and Manufacturing Aids which could be used during the manufacturing effort and transferred with the air vehicle in support of the flight test program. Further, maximum utilization was accomplished of existing Government-Furnished Property throughout the program. Of particular note was the ability of the joint ASD/AFLC Office to anticipate manufacturing difficulties and resultant program realignments in the provisioning of spares requirements such that spares were not overprovisioned, configuration changes were anticipated and engine support requirements were kept in consonance with the air vehicle program. The latter was extremely difficult since the engine contract with General Electric was independent of the prime contract and yet was dependent upon prime contract program progress. Proof of this combined program management effort is illustrated by the fact that at the time of the 3rd air vehicle termination, the closely monitored lead time from need date procurement of engine spares resulted in a very small quantity of excess spares and such excess was only in the economical buy category. Consequently, with the cancellation of A/V #3, additional spares procurement were virtually nil during the first year of flying because the delivered engines plus the austere spares provisioning were adequate for the 2 A/V program.

B. CONCLUSIONS

1. It is quite evident that (a) the excellent support provided this complex Research and Development Program could be projected into the timely transferrence of the Weapon System support from the development to the Acquisition phase of the program with no disruption or provisioning delay and (b) that there is no necessity for independent ASD/AFLC duplicate organizations within a Weapon System if the joint objectives of the AFLC/AFSC organizations can be accomplished by a single office responsible to the Weapon System Director.

2. From the inception of a Weapon System Program, logistics functions and responsibilities should be established at a Deputy Director level within the SPO. This is essential to insure that maintenance, supply, transportation, tech manual requirements and implications receive proper consideration during early design, development, test and production phases of the program. In view of the ultimate role of AFLC to provide the Weapon Logistics operation, the Deputy Director for Logistics organization of the SPO should be staffed by AFLC personnel from the very beginning. This organization should not be a "dotted line" organization on the SPO organizational chart. They should be considered and treated as fullfledged key members of the team. The Deputy Director for Logistics should have control and authority in his field and should not be acting in a liason capacity. He should have the ability and the authority to speak for AFLC and answer to the System Program Director. If he and the System Program Director do not agree on a major area, then this certainly is a question to be resolved at the Command-to-Command level since each Command has its rules, regulations and operating procedures which obviously created the impasse. This Deputy for Logistics organization should be augmented as required by AFSC personnel whenever there is newly developed, complex GFAE for which AFLC has no experience and also to fulfill peculiar AGE requirements. As each item of AGE configuration becomes firm for Weapon System use, AFLC should assume responsibility to complete all remaining logistics tasks. The SPO Deputy Director for Logistics would operate under the current austere ASD provisioning exhibits. As engineering design and development progress and subsystem configurations are approved to meet the SOR, the logistics responsibility for these subsystems would be transferred to the particular IM/AMA through the SSM to establish the necessary records required for Air Force operation. This transfer should be on a progressive basis and not necessarily associated with an event such as category testing. The subsystem configurations not meeting SOR requirements would be listed in the AFSC/AFLC Transfer Agreement and the logistics responsibilities would be retained in the SPO until the configuration was approved and acceptable to the operating Command. This would complete the SPO logistics operation and the SSM/INs would have all necessary data to fulfill the AFLC logistics responsibility to the operating command. Since AFLC is primarily in the logistics field, then it seems that the bulk of the logistics talent should be in AFLC and the R&D talent in AFSC. If AFLC is to inherit the responsibility for logistics support of a weapon system, then it makes sense to have AFLC in the act from the very beginning, developing the plans and procedures that AFLC must live with to fulfill its responsibility to the operating Command.

B. CONCLUSIONS

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Terry

I don't know what AF organization prepared this report, but it was probably the B-70 SPO. It's not dated, but my guess is that it was done in late 1965. I'm sure you'll find it very interesting although a little difficult to read due to poor quality reproduction. I've noted two pages that are out of sequence.

Bill

T. PANOPALIS COLLECTION

from Bill Pelzer

THE B-70 PROGRAM - LESSONS LEARNED

THE B-70 PROGRAM - LESSONS LEARNED

I. MANAGEMENT

A. BACKGROUND

B. CONCLUSIONS

1. REDIRECTION

2. AUSTERITY

3. STUDIES

4. ORGANIZATION

5. PERT

II. PROCUREMENT

A. SPO - AFPR RELATIONS

B. CONTRACTING

1. GENERAL

2. INCREMENTAL FUNDING

3. INCENTIVES

4. COST CONTROL

III. MANUFACTURING

A. AIR VEHICLE ACCEPTANCE

B. REPORTING

C. MATERIALS AND PROCESSES

D. HONEYCOMB PANELS

E. WELDING

F. QUALITY CONTROL

IV. ENGINEERING

V. FLIGHT TEST

VI. CONFIGURATION MANAGEMENT

A. AIR VEHICLE

B. DATA MANAGEMENT

VII. LOGISTICS

I. MANAGEMENT

I. MANAGEMENT

A. BACKGROUND

The B-70 R&D program was initiated in 1955 by study contracts to North American Aviation and Boeing Airplane Company for design of the weapon system, and IBM for the B&N system. In 1957, General Electric was awarded a contract for the engine development. In December 1957, NAA was selected to begin Phase I weapon system development. This effort included development engineering and testing, performance specification development; selection of major subcontractors and a mockup inspection in March 1959. The initial program called for first flight by July 1962, and the first operational wing (45 A/V) by December 1965. In January 1958, the Air Force accelerated the program with first flight by January 1962 and first operational wing (65 A/V) by September 1964. In October 1958, the Air Force revised this schedule with a stretch out after first flight and the first operational wing (62 A/V) by September 1965. In October 1959, Air Force again went to an austere program searching for all the short cuts, deletions of high cost simulators, design simplifications, soft tooling, and discontinuance of intensive honeycomb brazing and welding development effort. Under this program, the first operational wing was scheduled for December 1965 with first flight still planned for January 1962.

By December 1959, basic solutions to major technical problems had been demonstrated and engineering drawings were being prepared. Development was well advanced on a broad front and considerable development hardware was in being. In December 1959, the B-70 program was redirected to a single air vehicle and a minimum effort airworthiness test program (first flight in December 1962) reducing the total personnel utilization from approximately 20,000 to 7,000. The IBM B&N System effort was transferred to an Air Force contract and continued at reduced rate, defensive subsystems and M&TC subsystem contracts were terminated and subcontracted airframe work at Boeing, Lockheed and Chance-Vought was withdrawn. On September 19, 1960, the contractor was advised to proceed with the design, development, fabrication and test of one XB-70 prototype and 11 YB-70 aircraft, including development of all the major systems needed for an operational Mach 3 bomber. The problem of recapturing the subsystem contractors at reasonable prices became difficult. The buildup of manpower under this program reached 31,000 people in March 1961, and was scheduled to reach a peak of 45,000.

As a result of the President's budget message on 30 March 1961, the program was again redirected to a prototype development. In April 1961 a three prototype aircraft program was approved (the SPO had recommended only 2 airplanes). The third airplane was to have a B&N system and subsystem development sufficient only for flight test purposes.

Manpower was once more reduced and a new austere look was taken to keep costs as low as possible. This included further simplifications of design, tooling and a model shop approach to fabrication techniques, system developments, etc. In early 1963, the Commander, AFSC, directed a concentrated analysis of the management arrangements and procedures to best meet the specific requirements of the B-70 program. As a result of this analysis, the management of the program became more like that of a specialized project rather than the full management requirements of a weapon system. Other than numerous scheduling and pricing exercises and 5 months of concentrated studies of an RS-70 configuration (Nov 1961 and Feb-June 1962), the 3 aircraft program remained stable until March 1964, at which time the #3 aircraft with military subsystems was terminated.

From the time the B-70 contract was awarded to NAA in December 1957, the program has been subjected to almost continuous exercising and threatened or actual changes. During this period, there have been a minimum of seven major changes distinguished by formal establishment of new schedules and program definitions, 110 other planning and scheduling exercises were carried out by the contractor in the period 1960 through 1965, and 44 program pricing exercises were conducted by the contractor under the one [illegible] program. From January 1961 to April 1961, the contractor submitted 13 program plans for the 3 airplane program which evolved from 38 different schedules and 12 total new plans. In addition to the responsibilities within the Air Force, the accomplishment of such plans involved contractor management and specialist personnel from engineering, manufacturing, financial and material departments plus many supporting people from these and other groups.

In 1961, the contractor's organizational structure, based on a functional concept came under scrutiny by the AF and DOD because of the success of project oriented organizations in the missile program where quick reaction and technical achievement were the major objectives. In October 1961, after many discussions, the contractor established the B-70 Division as an autonomous group.

In July of 1962, it became evident to the SPO that a significant first flight schedule slip could be expected due to the funding ceiling of $171M for FY63 and the total program ceiling of $1.3B. On 20 November 1962, the Secretary of the Air Force was advised that the first flight date would slip due to manufacturing problems and funding limitations. By January 1963, the under-funding had reached the point where it was necessary to curtail effort on the #2 and #3 A/V's in preference to the #1 A/V, keeping the subcontractors very near their required funding rate, and absorb the under-funding impact within the Los Angeles Division of NAA where it was felt that better control could be maintained. As a result, a number of key NAA personnel were reassigned to other divisions. Included were many engineers, particularly aerodynamicists and structural engineers. On 22 February 1963, $35.8M additional was

Note

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released against the FY 1963 funding and work was again resumed on the #2 and #3 A/Vs on a schedule that would provide the greatest overall program economy; however, the recapture of the released engineers was very small. Experience with manufacturing personnel was not as bad because most of them had been retained on other efforts.

As the magnitude of the schedule slippage increased, the results of the austere program became more evident. Combined with the short cut assembly methods hopefully employed to minimize shop flow time, the results of the curtailment of concentrated honeycomb structural system development and fuel and nitrogen sealing became overpowering and the procedures became one of cut-and-try due to the lack of resources. In early May 1963, General Holzapple chaired an Air Staff, on site review of the XB-70 program which was presented to Mr. Zuckert on 17 May. Again, it was recognized that problems still existed in fabrication, solutions were somewhat hampered due to lack of resources resulting from the previous program instability, but that it was still considered feasible and desirable to continue with the program, recognizing the schedule slip and increased cost. At this time, the air vehicle contract was converted from CPFF to CPIF in keeping with direction from Hq USAF. This could be considered a re-financing of the program and resulted in continual reassessment of the program progress and cost.

The first air vehicle was rolled out for public view on 11 May 1964. For a period of about 5 weeks during the preflight checkout, the airplane became, for all intents and purposes, a hydraulic system mock up and simulator to solve the problems that developed with the hydraulic system. Most of these problems could have been resolved on the hydraulic simulator but because of program austerity one had not been provided. What had been previously forecast as 30 days for preflight operations stretched into about 4½ months. Most of this time was consumed in correcting problems in the hydraulic system, fuel tank sealing, and a myriad of minor repairs to the air vehicle.

First flight occurred on 21 September and by 24 October 1964, four flights totaling 5 hours and 2 minutes had been accomplished and Mach 1.42 had been reached. On [illegible] 1964 the first airplane was returned to Palmdale to complete proof load testing to assure structural integrity for Mach 3.0 flight. The first air vehicle returned to flight status in February [illegible] and accumulated more than 20 hours of flight test time. The second XB-70 rolled out on 29 May 1965 and flew on 17 July reaching Mach 1.4 and 40,000 feet.

B. CONCLUSIONS

1. PROGRAM REDIRECTIONS. There have been three major B-70 redirections; weapon system to one prototype in 1959, one prototype to limited weapon system in 1960, and back to prototype development in 1960. A redirection from a weapon system program to a prototype development aside from the economic impact on the contractors involved, results in substantial costs to the Air Force. These costs can be determined to a degree where the terminated effort involved subcontracts for work related solely to a weapon system; however, in the case of the basic Air Vehicle; it forces some redesign, changes in tooling, reallocation of manpower, etc, all of which costs money; the exact amount is not capable of calculation since there is continuous contractor activity in these areas regardless of the kind of program. Another undesirable byproduct of redirection is the effort required by SPO personnel in reprogramming, contract changes and so forth. This effort is over and above the normal work of the SPO and means that time usually spent in performing the prescribed management actions must instead be devoted to getting the reoriented program functioning satisfactorily.

Program redirection from time to time is apparently inevitable; whatever measures that are available should be taken to lessen the impact both on the Air Force and the contractor. The SPO should be provided more complete direction and should be given a new approved program as soon after reorientation as possible. For example, the three XB program did not receive approval until [illegible] months after the weapon system effort was ended (from March 1961 to Mid-August 1961 when the PSPP was approved) and the program directive itself was not published until October 1961. The two air vehicle experimental program was directed in March 1964, the directive reflecting this decision was not received in the SPO until May 1964.

In effect, program [illegible] decisions require the expenditure of funds for which there is no ma[illegible] return except for accomplishing the redirection itself and results in a period of inefficient operation by the Air Force and the contractor

2. AUSTERITY. The program redirections which had funding limitations dictated the use of the most economic practices possible in achieving program objectives. Some of the things done were elimination of expensive simulators, the use of soft tooling, the discontinuance of most manufacturing development, and a minimal structural test program. The impact of these actions were felt at different times and to varying degrees. The extended period for fabrication of air vehicle #1 was due in great part to austerity measures; the soft tooling generated many problems such as wing-to-fuselage mismatch and the requirement to jack panels into position causing some panel voids which in turn required repairs. It took nearly two years to seal fuselage tank #3 in air vehicle #1. This was the result of using the aircraft itself to develop fabrication and tank sealing techniques, an extremely expensive method which could have been avoided to a large extent had there been adequate manufacturing development earlier in the program.

Hydraulic simulators were eliminated. The effect was manifested from air vehicle #1 roll-out until well into the flight test program. It was one of the primary reasons for the very long preflight period and caused difficulty on the first flight. The gear would not retract and remained down for the entire flight. If the reverse had happened, i.e., the gear retracted but would not extend, the result very likely would have been loss of the aircraft. The lesson from these examples is clear; the money saved by eliminating essential development is lost many times over later on through the necessity to solve the same problems the basic development was intended to solve. It is interesting to note that the engine development was not subjected to the same degree of short cutting as the air vehicles and the engines have proved to be very reliable and have demonstrated excellent performance. In summary, austere measures, unless very carefully applied, will not save time or money, on the contrary, if the objectives remain the same, the net results on advanced programs such as the XB-70 are increased costs and program stretch-out.

3. [illegible] REPORTING. The B-70 program has been the object of continuous attention [illegible] levels within the DOD as well as the Congress. This attention has resulted in requests for voluminous studies as well as program status reporting on a more frequent and detailed basis than normally required. Each of the studies was conducted in conjunction with the Los Angeles Division of NAA and in some cases directly by [illegible] Corporate management. To obtain the information necessary for [illegible], a deep penetration into the contractor's personnel was required. Many of these exercises were conducted under tight schedules involving extensive weekend and night efforts on the part of salaried personnel, both government and contractor. Although much of this was without direct charge to the program, it exacted a toll upon the organizations. It is impossible to place a price tag on the total cost, but it is certain that this cost can be measured in hundreds of thousands of dollars. Calculable costs incurred as a result of 2 major redirections, (the one XB program and the three XB program) indicate a cost of approximately $100M. The estimated cost incurred in the RS-70 planning exercise alone was $578,903.00. This does not represent the true magnitude of the effort since a large amount of uncompensated overtime hours were expended by supervisory personnel on the part of both the Air Force and the contractor.

Program progress reporting on the directed basis forced the SPO to place personnel on continuous TDY to the contractor's facility to personally observe manufacturing status and make daily progress reports to [illegible]AO. This information was evaluated and sent to higher headquarters on a weekly basis, sometimes more frequently. It should be emphasized that these [illegible] were instituted with no increase in SPO resources. If the people had been performing their normal functions it may be conjectured that more substantive manufacturing analyses could have been conducted which might have reduced production time and costs. Program management requires some given number of people and some finite amount of time for accomplishment. If additional requirements are imposed, these should be recognized as such and sufficient additional manpower authorized.

4. ORGANIZATION

a. NORTH AMERICAN AVIATION. In the early phases of the program, the NAA approach to weapon system management was to create a B-70 "program manager" with responsibility for overall direction of the technical development. His group acted essentially as a staff organization to the operating elements of the Los Angeles Division. This was in contradiction to at least two of the recognized functions of a manager, ie, to control and to direct. The situation was one of responsibility without authority with a predictable outcome; there was not sufficient emphasis placed on the B-70 within the Los Angeles Division. Although accepting the importance of the B-70 program, NAA executives were still loath to make organizational changes and it required Air Force intervention in an area traditionally a company prerogative; internal organization. At the behest of the Air Force, the Los Angeles Division was reorganized to give the B-70 manager the necessary status and authority. He was named an Los Angeles Division vice president, an autonomous B-70 Division was created, and the program was able to proceed on a sounder management basis. System developments are becoming more and more costly and it has become evident that the only acceptable method of organizing for the effort is to establish a group for the purpose and to endow it with the power and resources commensurate with the task.

b. THE B-70 SPO. During the first few years the SPO (WSPO) was in reality three separate organizations. There were the ARDC "managers", with their chief who was nominally the SPO director, there were the ARDC engineers with their chief, and there were the AMC people with their chief. In 1961, when AFLC and AFSC were formed, one of the three "heads" was absorbed, there remained however the engineers, who operated as an independent group for all intents and purposes and their chief was to be "responsive" to the needs of the AFSC Program Director. This is the situation today, there are AFSC program managers supported by RTD engineers who do not report to the program director. This type of organization does not always lend itself to efficient operations, differences of opinion sometimes have to be resolved at levels which should not be concerned with such details. Research people, if that is what they really are should not be a part of a SPO, but engineers who perform analyses and studies directly related to the program and on a recurring basis should be an integral part of the Program Directors team, not merely "responsive". A final observation is that the organization of each SPO should be tailored to the requirements of the program at hand, not be required to organize in accordance with a "standard" which is established by regulation.

5. PERT. This management control system was started on the B-70 Program in late 1960. Prior to this time, the status of milestones or "events" was tracked through a system whereby information on each milestone was recorded on punch cards, updated monthly and the printout of these data supplied to the SPO as a milestone report. There were upwards of 1000 of these milestones, and shown for each one were the scheduled date, a reschedule date if applicable, and the responsible contractor department. Also provided, as a supplement to the milestone report, was a "Variance Report" which contained analyses of the critical areas of effort as well as reasons for milestone slips, rescheduling actions, etc. These reports coupled with frequent trips to the contractor's plant enabled the SPO to maintain adequate surveillance of the program.

The introduction of PERT in 1960 was expected to improve the Air Force's ability to detect incipient trouble areas and to give a more comprehensive picture of the overall situation. As applied to the B-70 program, however, PERT did little to increase SPO knowledge of contractor activities or to provide timelier status information. There were several reasons for this: (1) PERT reporting was on a monthly basis, therefore no improvement over the old system in this respect, (2) scheduled completion dates for events were forecast using single time estimates instead of the three normally used with PERT, in effect then, these "events" were no different than the milestones previously used, (3) because of austerity the contractor was unable to furnish all the resources necessary to support a classic PERT program, (4) the SPO was likewise not able to provide the manpower for adequate network design, analysis, etc., which is a must if the potential of a PERT system is to be realized, and (5) during the latter stages of fabrication of Air Vehicle #1, SPO personnel were on continuous TDY at the contractor's plant and were able to report the status of critical areas as much as 30 days in advance of the publication of the PERT report containing the same information. Largely because of these factors, the decision was made in mid 1964 to terminate further PERT reporting.

Following some three years of the use of PERT as a management control system, the following conclusions were reached:

a. PERT should be used from the start; later applications do not realize the full benefits of the system and may in fact produce reporting not significantly better than before at a much higher cost.

b. The contractor should train personnel in how to properly use PERT before it is put into operation; the results derived are only as good as the information inputs.

c. A full scale PERT system should be used. Lesser versions are little or no better than conventional methods of progress reporting.

d. PERT should not be required on austere programs since one of the features of the system is the detection of critical areas needing additional resources. If these are not available, then the use of PERT was not economical to start with.

II. PROCUREMENT

II. PROCUREMENT

II. PROGRAM [illegible]

A. SYSTEM PROGRAM OFFICE/AFPR PLANT REPRESENTATIVE RELATIONS

1. BACKGROUND

Throughout the XB-70 Program, the relationships between the XB-70 SPO and the Los Angeles AFPRO have not been significantly different than the relationships between other SPO's and associated AFPRO's. The SPO's mission is primarily to establish program requirements in conjunction with engineering and support personnel and implement these requirements by means of a contract. The AFPR is responsible for implementation and monitoring the accomplishment of each contract. There has always been an attitude that once the contract has been established, the AFPR was responsible for its implementation and essentially the SPO should not be concerned with the details of how it is done. This is probably a carry over from the days when programs were on a CPFF basis and the function of the ACO was that of determining overhead rates, preparing shortage reports, conducting price analyses, monitoring facilities, and coordinating the supplying of Government Furnished Property. This is practiced on routine lo-value contracts, however, not on programs of the magnitude of the XB-70 which encompasses a potential $1.5B expenditure. Detailed surveillance of contractor activities by the ACO and other elements of the AFPR's organization is absolutely essential. The AFPR has always maintained that he is not adequately staffed to perform the depth of surveillance which the Program Director feels he requires and this is undoubtedly true in view of the fact that most ACO's have multiple contracts to administer. On the other hand, when the Program Director, due to the lack of on-site surveillance, established his engineering and manufacturing review teams, there was a tendency to deal directly with the contractor which resulted in the AFPR's being still less informed of the direction and status of the program. This cycle of events tends to perpetuate itself to the point that the ACO can become completely ineffective. This lack of coordination and unified control of the contractor's efforts was recognized first in the development and engineering area and a team was established by AFSC in September 1962 to provide an on-site development engineering office to support and work with the SPO development engineers in carrying out the engineering effort. A comparable effort was attempted by the AFPR Production personnel; however, this was not so completely successful, again due to the assigned manpower limitations and the rapid reaction time required by the SPO. Therefore, the manufacturing monitoring was essentially accomplished directly between the SPO Manufacturing Division and the contractor. In the contract area, contractual operations between the ACO and the PCO were handled strictly by the prescribed regulation procedures.

2. CONCLUSIONS

It is absolutely essential that the AFPRO be provided sufficient personnel at the onset of any program of the magnitude of

the B-70 so that the AFPR can properly support mission objectives on a continuous basis at every level of the organization. Written agreement should be reached defining the responsibilities and procedures to be exercised between the Program Director and the AFPR and a similar agreement made between the corresponding organizations of each should also be established. Daily or at least weekly discussions be held between SPO and AFPR personnel to discuss current plans and problems. Otherwise, the Air Force may find itself in the position of the contractor playing one organization against the other, or either organization may take unilateral action with the contractor without the knowledge of the other. There has been considerable searching over a period of years for a solution to this problem, an example being a proposal to establish the Program Director's organization on-site at the contractor's facility jointly with the AFPRO.

If an AFPRO is properly staffed and adequate coordination efforts are accomplished, no new organizational realignments are required to carry out a program objective.

B. CONTRACTING

1. GENERAL

In the carrying out of the contract function of the procurement organization from the design phase through the manufacturing and test of XB-70 air vehicles, a basic change in concept of procurement occurred. The initial Contracts AF33(600)-38669 and follow-on letter contract AF33(600)42058, contemplated a design which would form the basis for the development of a complete operational weapons system. This in turn would be converted to firm procurement specifications for the acquisition of the required operational weapons system. Therefore, although the initial contract was on a CPFF basis due to the design and development of the initial effort, it was contemplated that the resulting procurement specifications would be firm, demonstrative requirements and that the associated flight test program would require specific demonstrative performance criteria. Subsequent to the initiation of letter Contract AF33(600)42058, re-direction was received to limit the development to a prototype effort. As a result, a firm contract, AF33(600)42058 was negotiated for the design and fabrication of three (3) XB-70 air vehicles. At this time, the concept was changed from a requirement for the delivery of air vehicles in strict compliance with firm specifications to a best efforts approach under the philosophy of a research and development effort only. The performance specifications were changed from requirements to objectives. Notwithstanding the further amendment of the CPFF contract to a CPIF cost incentive sharing arrangement, the contractor was only required to attempt to build three (3) air vehicles on a best efforts basis. In anticipation of a follow-on flight test program, a decision had to be made whether to amend the basic development Contract AF33(600)-42058 to include the flight test effort or to negotiate a separate flight test contract. Based upon the factors and conditions existing at the time the decision was made to negotiate a separate flight test contract on a CPIF basis, containing not only cost, but also air vehicle performance incentives. The basic philosophy of the contract was that the contractor in an R&D environment, would attempt on a best efforts basis to meet the general flight performance parameters. As a result, several contract administrative problems arose:

a. The change procedures implemented under Contract AF33-(600)42058 were materially different (due to the nature of the contract) than that implemented under the flight test contract. For example, a change common to all three (3) aircraft was handled differently between the aircraft in the flight test inventory and those still in the process of manufacture under the development contract and were of necessity handled by two separate contract instruments. In addition, some cases were of necessity negotiated at a different rate of fee.

b. The air vehicles were produced under a development contract and became government property upon acceptance by the Air Force. They were then bailed to the contractor to support the flight test program, which left the Air Force responsible for possible contractor

non-accomplishment of flight test objectives, due to use of unsatisfactory government property developed (by the contractor) on a best efforts basis. If repair or re-design of the government property is required, it would be new work chargeable to flight test contract and would necessitate a corresponding adjustment in target cost and fee.

2. CONCLUSIONS

a. From the above, several significant problems resulted from a configuration standpoint. It was necessary under the best efforts development concept to provide the contractor with the flexibility in configuration control. Any non-concurrence with the contractor's design approach resulted in the requirement for re-negotiation of the target price and schedule which in turn presented some difficulty in controlling program cost. Also, there was no assurance that the aircraft delivered by the contractor for acceptance by the Air Force would, in fact, be capable of meeting the objectives of the flight test program which relieved the contractor of responsibility for flight capability and transferred it to the Air Force upon acceptance of the air vehicle. Since the program schedule dictated the necessity for accepting air vehicles with items incomplete, it was necessary that recovery schedules for the incomplete effort be negotiated in conjunction with the projected flight test contract. This further complicated the contract negotiation of delays which occurred during the flight test program as to the responsibility for program delay being chargeable to the contractor under Contract AF33(600)42058, as being due to the uncompleted work, or being chargeable to the Air Force under flight test Contract AF33(657)-12395 as new work resulting from the flight test effort.

b. It would appear that for a Research and Development effort such as the XB-70, the design development and flight test program should be procured by a single contract with specific cost and performance incentive negotiated for the total design development and flight test effort. The resultant developed air vehicles would then not be an end in themselves but would be the means utilized by the contractor to demonstrate his flight test criteria, and provide the contract data to substantiate the feasibility of his development called for under the contract. This would have several specific benefits:

(1) The contractor would have the responsibility and flexibility necessary to carry out the program without continuous contract amendments.

(2) He would have the responsibility to provide an aircraft to meet the flight test objectives and if aircraft were not

capable of doing so, the responsibility for redesign or modification of the air vehicles to meet the program objectives procured without further charge to the government.

(3) The Air Force would not take title to the air vehicles until satisfactory completion of the flight test contract or close out of the contract due to unsatisfactory performance.

2. INCREMENTAL FUNDING

a. BACKGROUND

The availability of funds has always been a basic problem as reflected by the various program redirections. The B-70 Program was confronted initially with the problem of procuring a program within the limitation of funds incrementally allocated on a fiscal year basis and subsequently as approved for the three (3) air vehicle $1.3B program. Program decisions for continuing or extending the program have always been based upon factors which outweigh the question regarding the method by which the effort should be funded. Incrementally funding of the B-70 Program has, therefore, been accepted by B-70 SPO Directors and the contractor, not by choice, but as a matter of necessity.

b. CONCLUSIONS

As a management tool, the B-70 SPO incrementally funded the contract on a monthly and quarterly basis. The basic reasoning for funding the contract on a monthly basis was to encourage the contractor to maintain his expenditures within reasonable limits. This approach is not considered to be realistic for several reasons. If the basic contract requirements, the efforts and schedule to be accomplished are not amended accordingly and the contractor has a high degree of development and manufacturing difficulties such as NAA had during the period of 1963-1966, the contractor will not stop incurring costs and it will only tend to prolong and add to the contractor's management problems. Assuming he has taken the normal management actions of reducing personnel to the minimum in cutting down in his overhead costs, he must either extend his program schedule or delay some of his development efforts. This results in expanding his continuing operational costs over a longer period of time and incurring a more rapid buildup in both expenditures at a later date—The ultimate result being greater program costs in the end for the same or less effort. It is, therefore, the opinion that if incrementally funding is applied to a program, it should be on no less than a quarterly basis which would allow the contractor a firmer base on which to plan his outlay of expenditures and provide him the program flexibility necessary to a Research and Development type contract. This does not relieve a Program Manager of any of his management responsibilities but requires him to maintain closer surveillance of the contract and funds management in respect to the contractor's progress in meeting delivery schedules, provisioning and engineering changes which effect the overall objectives of the contract.

Incremental funding has no specific advantage in the provisioning of Spare Parts and FTGSE since they were procured as separate items under the contract and have been purchased by individually priced exhibits with only lo-value or interim release hi-value items below $1,000 per unit for a total of $30,000 aggregate being released for procurement prior to D-70 SPO authorization. Each priced production list is contractually authorized and funded on an individual basis. It is considered that, in negotiating a contract which provides for incremental funding, the clause for POOBing (Provisioning Order Obligation Document), Spare Parts and FTGSE should be included in the contract terms and conditions to become effective at such time as the contract enters into an overrun condition. This is particularly important when the contract provides for interim release provisioning procedures covering the lo-value Spare Parts and FTGSE as indicated above. Although the UP-70 Contract, AF33(600)42058, now contains such a POOBing clause, essentially most elements of the clause were accomplished in programming contract funds requirements thereby a minimum amount of funds were set aside to cover any substantial contractor interim release of lo-value items or unanticipated permissive specification changes which could result in an increase to the contract target price prior to final contractual coverage.

3. [illegible]

a. BACKGROUND

Based on the Research and Development nature of the B-70 program, first during the conceptual stage under Contract AF33(600)38669 and the later realigned XB-70 program for eleven XB-70 air vehicles, one XB-70 and one static test air vehicle, as well as the subsequent three air vehicle program under Contract AF33(600)42058, the program was negotiated on a CPFF basis. This approach provided the contractor with maximum management flexibility necessary in a best efforts program with the associated risk involved.

As the program progressed, the contractor began to encounter manufacturing problems in attempting to meet basic design criteria, particularly in metal to metal fuel tank sealing. The result was an increased cost over-run position.

Since the contractor had stated positively that the three air vehicle program could be accomplished within a [illegible] billion dollar ceiling, the Air Force felt that the contractor should assume more of the financial risk in carrying out the program. Consequently in April 1963, the Air Force entered into a negotiation with the contractor to establish under the AF33(600)42058, a Cost Plus Incentive Fee (CPIF) arrangement. This was accomplished by means of a Supplemental Agreement, a negotiated adjustment was made for the then current overrun condition and a new target price established with a [illegible] incentive sharing arrangement for cost exceeding the adjusted target price.

At the time of the third air vehicle termination in March 1964, the contract was again adjusted by negotiation to a new target for the remaining two air vehicles with an 80/20 sharing arrangement, which is the current contractual arrangement with North American under Contract AF33(600)42058.

The flight test contract, although basically a research and development effort, was not considered as great a contractor risk due to his prior experience. Therefore the cost incentive was established on an 80/20 share arrangement and performance incentives for Mach No. and flight hours were added.

b. [illegible]

The result of injecting [illegible] into the XB-70 manufacturing and flight test contracts, instead of improving the contractor's cost control procedures and over-all [illegible] created other problems: (1) Any Air Force decision which [illegible] contractor's design or delivery schedule resulted in a [illegible] for negotiating an adjustment to the contract target price and [illegible] incentives. (2) The contractor was obviously reluctant [illegible] any development design changes as being within the scope of [illegible] and not subject to fee adjustment, which in fact reduced [illegible] for timely design changes. This situation required extensive [illegible] the contractor to determine actual responsibility for the change [illegible] specification which consists of design and performance [illegible] rather than firm requirements. In an apparent contradiction, due [illegible] of the program and with no immediate follow-on contract in view, the contractor earlier in the program evidenced a willingness to accept an [illegible] in order to keep the program in existence. As Air Vehicle [illegible] delivery approached, this tendency did not continue.

Under the flight test contract, the contractor has taken every opportunity provided by the contract to increase his right to renegotiate the target price of the contract [illegible] claims or engineering changes which would put him in an [illegible] position. While this may be desirable from a financial and [illegible] management position, it has essentially removed the flexibility [illegible] considered desirable in a Research and Development contract.

Not withstanding the [illegible] drive to utilize Fixed Price and Fixed Price Incentive [illegible] whenever possible, there is a logical reason for utilizing [illegible] type of contract covered by Air Force Procurement Regulations. [illegible] speaking a procurement activity normally progresses in [illegible] type from a Cost Plus-Fixed Fee to Firm Fixed Price basis compatible with the degree of unknowns and Contractor/Air Force risk involved. Specifically, the progression from the conceptual to the acquisition phase.

One of the chief responsibilities confronting the Air Force in connection with procurement is the selection of the type of contract best suited to its purposes of contracting. Because of the variety of situations involved, a single contract form cannot be adopted. The nature of the procurement, the contractor's production and cost experience and the extent of control which can, and should be, maintained over the contractor's operations, must all be considered in arriving at a decision on the type to use. Throughout the XB-70 program, there has been a tendency by the Air Force to substitute contractual language for program management. To accomplish the Research and Development effort, a firm, demonstrable, manufacturing and flight test specification should be

written and contracted for on a Fixed Price basis or a general objective type specification unbuilt and contracted for on a Cost Plus Fixed Fee basis to enable the Air Force to exercise control and decision responsibility. A combination of firm fixed price incentive and CPIF contracts are variations on the theme and do not in themselves accomplish good management.

4. COST CONTROL

a. BACKGROUND

When the B-70 Program was redirected from a Weapon System with NAA as Manager to a three Air Vehicle Prototype Program, it was done on an austere funding basis and although fund control had been assiduously practiced during the Weapon System Development phase, further increased emphasis was placed on cost control under the three air vehicle program. Since the Contractor had a best-effort development contract, he felt that he should also have corresponding flexibility in funds control. It was felt by the Air Force; however, based upon the prior program fund history, that strict control by the Air Force was absolutely essential. As a result, the contractor was incrementally funded on a monthly basis with each succeeding month's funds requirement being requested by the contractor with written justification for such funds. This procedure was carried out from 1961 until mid 1965, just prior to delivery of Air Vehicle Nr. 2. Notwithstanding the above, the contractor has currently overrun Contract AF33(600)42058 by approximately $19.7M.

b. CONCLUSIONS

The above experience proved that cost reporting in itself is an inadequate management tool. The funding status reports developed and submitted by a contractor must also contain corresponding development, engineering and flight test program progress against which expenditures can be measured. For example, the contractor may underrun his dollar forecast due to two diametrically opposed reasons:

(1) He is doing an excellent job and exercising economical Program Management or

(2) He is behind schedule in procurements, engineering releases, or manufacturing accomplishment and, as such, the indicated below-schedule expenditures trend will be reversed with a greater magnitude later in the program. (i.e. prospective overrun).

Several attempts were made over a period of years to revise the contractor's cost reporting procedures along the lines indicated even to the extent of combining the contractor's cost and manpower reports with only marginal success. As a result, the B-70 SPO changed their procedure so that the funding report was reviewed with the manufacturing division to correlate the expenditure of funds against the contractor's manufacturing status. This resulted in a reasonably accurate assessment of the contractor's financial status and provided a basis from which to make realistic program dollar requirements forecasts. The basic lesson is that funds status reporting must include associated engineering, manufacturing, flight test, and logistics status so that a SPO can make a meaningful analysis of the contractor's financial position.

III. MANUFACTURING

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A. AIR VEHICLE ACCEPTANCE

1. BACKGROUND

The acceptance of XB-70 air vehicles was planned on the basis of a progressive buy-off in lieu of the standard CTCI approach since the method of welded construction resulted in areas of the air vehicle becoming inaccessible during sub and final assembly. These areas could not be opened for final inspection without damage to the structural area. The Air Force final inspection and buy-off of the closed areas were made just prior to the final operation closing out the area. Acceptance authority was vested in the AFPR Director of Quality Control.

Due to the air vehicle size, complexity, and the large number of Final and Pre-Flight Operations, the Air Force progressive inspection was made concurrently with the contractor's manufacturing, pre-flight and quality control personnel. The task was accomplished specifically by the use of an intercom system integrated into the air vehicle intercom system. Control of the operations was maintained by a three (3) man board consisting of: Contractor's Final Ops or Pre-Flight Test Director, Contractor Quality Control and The Chief of Air Force Quality Control. The test director indicated the operation to be accomplished and where the actions would take place. Quality control observers for the Contractor and Air Force were located with their respective contractor counterparts in the areas where the inspection activities were to take place. The results were monitored against the air vehicle process specification requirements reported through the intercom to the three man board. If the results were within tolerance or as prescribed in the process specification, the item was accepted by the board. When a discrepancy occurred that could not be resolved on the spot, a squawk was written on the item and the operation continued. When the discrepant item was of sufficient magnitude to endanger personnel or air vehicle function, the test was stopped until the problem could be solved. To facilitate the solving of problems, engineering support from the contractor, Air Force Plant Representative-Development Engineering and SPO personnel was provided on around-the-clock basis. These engineers also monitored the tests and results via the same intercom system, thus obtaining on the spot information for providing engineering decisions.

A Final Acceptance and Safety-of-Flight Inspection for all accessible areas was conducted prior to First Flight of each air vehicle by the B-70 SPO Deficiency and Acceptance Review Board established to review items that did not comply with the contractual requirements and for which a contractor/Air Force agreement could be reached. Disposition of these items were made as "fix before flight" or were entered in air vehicle deficiency document to be accomplished as a condition of acceptance. The recovery points for deferred deficiencies were established for completion by a specific date or to be accomplished prior to exceeding an appropriate flight parameter prior to inflight use, etc. This deficiency report was incorporated into the DD 250 as part

of the acceptance conditions.

To track progress on completion of such deficiency items, the contractor was required to provide a self deleting deficiency report every thirty (30) days from the date of first flight of the air vehicle. Those items accomplished and accepted by AFQC are lined out and the acceptance date placed in the "remarks" column. Any deviations granted by the Air Force on recovery points or conditions are so noted in the report. The deficiency report will be published every thirty (30) days until all items are completed or deleted in accordance with the contract.

2. CONCLUSIONS

The only practical method of inspecting and accepting a complex aircraft is one of progressive checks and "buy-offs". This procedure was mandatory on the XB-70 because of the type of construction used, i.e., welded steel panels for the most part which resulted in areas of the airplane becoming inaccessible as assembly progressed. While it was recognized early in the program that this kind of acceptance procedures would be necessary, there was little realization of the benefits to be derived from such a system. By participation in great detail, Air Force personnel became very knowledgeable of the aircraft and its systems, to an extent they could not have reached using any other acceptance method. The nature of a step by step process assures a greater degree of confidence in the end product than would a one time final inspection and acceptance which would very likely be more cursory. It is also likely that some time was saved since discrepancies were uncovered when corrective action took the least amount of time and effort. Finally, SPO personnel who took part gained an insight into the problems associated with building a large, high mach aircraft using new materials and processes, a knowledge unique within the Aeronautical Systems Division.

The success of a progressive inspection and acceptance plan requires close working relationships on the part of the Contractor and the Air Force personnel and a full understanding of their responsibilities.

For Research and Development Programs a progressive acceptance procedure is the most logical approach to the acceptance of complex aircraft.

B. REPORTING

1. BACKGROUND

From the inception of the B-70 Weapons System Program, it was recognized that the Procurement and Production function should be integrated into the Weapon System Development at the earliest possible date to assure that the air vehicle configuration developed during the design and development phase could be produced on a timely and economical basis. As a result, the WSPO Production (manufacturing) office was established in early 1958 to assure that the manufacturing effort associated with the development contracts was programmed, integrated and supported with respect to tooling, Ground Support Equipment and GFAE. Considering production, it was necessary to define the term in relation to a research and development effort. From a semantic standpoint, the term production need not necessarily be equated directly to the related rate of manufacture of airplanes, but it is applicable to the planning required to support the design effort as well as to control the manufacturing changes that occur with change in design. It was generally conceded that the basic functions required to manufacture and deliver a single air vehicle are as complex and essential as those required for a follow-on production run.

Since the program was required to operate with minimum data on an extremely austere basis, only two specific manufacturing reports were required under the contract. The first report being the contractor's basic manufacturing plan for all three air vehicles starting from fabrication through sub- and final assembly to air vehicle shop completion. This document consisted of the master assembly plan and all the associated sub-assemblies leading up to final assembly. The second document was the contractor's facility plan. These reports were revised only at the time of major program realignments. Specific manufacturing reporting was accomplished on a direct person-to-person basis with the contractor's personnel utilizing the contractor's internal schedules and management documents to carry out the master plan. Initially, manufacturing reviews were conducted on a monthly basis at which time contractor manufacturing personnel met with SPO Production personnel and reviewed all aspects of the fabrication, assembly, tooling and government property status at that time. This was combined into a monthly status report published for the System Program Director (SPD). These monthly reports extended from late 1960 through delivery of the second air vehicle, July 1965, and form an excellent history of the XB-70 manufacturing problems. As the program progressed, the manufacturing situation became more critical and a manufacturing status report was presented to the Program Director on a weekly basis. This information was obtained directly from the contractor's personnel and to some extent, was validated by on-site review by the AFPRO Production personnel. As the requirement for program

reporting increased, the SPO instituted what became known as the inchstone procedure. To support this procedure, SPO manufacturing/production personnel were rotated to the contractor's facility every two weeks on a bi-monthly basis and reported directly from the manufacturing floor to the Production Division of the B-70 SPO which, in turn, reduced the data and presented a daily status briefing to the SPD. This reporting procedure was possible only because of the excellent cooperation of the contractor who recognized that an accurate and timely status report by the Air Force was as much benefit to him as it was the Air Force in reaching timely program decisions.

2. CONCLUSIONS

Because of the intimate knowledge of the contractor's manufacturing problems and procedures, the SPD was provided with an accurate and up-to-date status report as to manufacturing difficulties encountered and appropriate recovery times, the impact on the funding situation, and an extremely accurate indication of the contractor's ability to meet his projected manufacturing schedule dates. For future programs, strong manufacturing organizations staffed by reliable production and industrial specialists should be integrated into the System Program concurrently with the design and development effort to assure that these personnel understand the design concept, the complexity, the necessary support required to produce hardware, and that PERT type networks must be established for initial planning and to forecast progress. Such initial planning should be followed during the manufacturing process cycle by actual, on-the-spot reporting. It is felt that this operation will materially assist any Program Director in determing the actual results to be expected from the design effort for a given dollar budget and will provide him with timely decision points in the event of program re-direction.

C. MATERIALS AND PROCESSES

1. BACKGROUND

When the XB-70 configuration was defined, the materials available did not have suitable characteristics. Through comparison studies and structural development tests, the materials and types of structure were selected to meet the specific parameters of heat, strength, and rigidity of the structure involved. Through a research and development program, basic stress allowables, quality criteria, and repair criteria were established. Target properties were established for one heat treatable stainless steel, one titanium alloy and one high strength steel. Preliminary work progressed on materials designated as "1958 PH steel," "1958 titanium" and "1958 High Strength Steel." Alloying and processing developments lead to the selection of the PH15-MO stainless steel, 4AL-3MO-1V and 6AL-4V titanium nickel based alloy of H-11 steel, Rene 41 and Inconel 718 as the materials to be used. Generally speaking, none of these materials were available from the mills in the shape, sheet thickness and tolerance required.

The XB-70 contains a total of 12,000 pounds of heat treated titanium. When titanium was first used, an unexpected amount of spring-back occurred during forming. This made it impossible to hold dimensional tolerances and required many hours of hand forming. A totally new metallurgical concept was developed which permitted the forming and hot sizing of titanium. The XB-70 program also required that the knowledge of titanium technology be expanded to cope with titanium alloys heat treated to high tensile strength levels of 160,000 to 180,000 PSI. More than 700 complex shapes were fashioned from 350 basic extrusions of titanium and high temperature, high strength steel. This also required that new techniques and die lubricants be developed.

In the interest of saving weight, fabrication and quality control personnel, recognizing the difficulties confronting them, requested technical assistance from the metal producing and processing industry to provide more optimum material thicknesses and shapes in previously unheard of tolerances. Until then, .002" was considered the thinnest produceable sheet. The XB-70 required thicknesses down to .0075" with a gauge variation of less than 25 millionths.

New techniques for sculpturing the face sheet were investigated, and as a result, chemical milling of titanium, corrosion resistant steel, and cobalt and nickel based alloys were developed to tolerances of five ten thousandths of an inch. However, prior to accomplishment of such techniques, it was necessary to form the face sheet by machining which caused mechanical problems as well as warping. The initial panel face sheets were made up of many small parts welded together or brazed together. Various densities of honeycomb core were used so that the

minimum material for strength requirements could be used. The problems resulting from this approach were reflected in the difficulties encountered as the air vehicle assembly proceeded.

The problems encountered in fabricating satisfactory panels to accomplish preliminary and final assemblies were many. For example, where the face sheet was not required to be smooth on the outside for aerodynamic reasons, the forming was done after brazing by chemical milling. The core problem was thus reduced to assuring that it was flat and matched the smooth surfaces of the face sheet. The process that solved this problem is known as Anocut which is a reverse plating process using a rotating electrode while flushing the core surface with the electrolytic solution. The deplated metal is washed away as a sludge by the electrolytical solution and a flat burr free cut results. All previous methods of sanding, milling, etc., used in the laboratory development of honeycomb failed when production techniques were used. Another example is the case where an exact mirror image of the mating surfaces of the face sheet must be reproduced on the core's surface. This mirror image was created by Elox machining, the controlled electrical spark erosion of metal. In this process, the electrical charges were sparked at high frequencies across a gap between the electrode and the work piece and required no rotating motion between the electrode and the work piece. The Elox process was subsequently adapted to cut holes of various sizes and shapes through honeycomb panels by forming the electrode as a "cookie cutter" and letting it move straight through or any desired angle.

Unicell honeycomb core was developed to replace the 1/8" cell size core used where greater core density was required for strength. The 1/8" cell size core was costly to manufacture and join with other core. Unicell honeycomb core is made by welding together alternate preformed and straight ribbons. The straight ribbon elements can be varied in thickness to provide the strength required for any specific application.

H-11 steel, a high strength material capable of being heat treated to the tensile strength range of 300,000 PSI had wide application in fuselage, wing box areas, landing gear and wing fold actuators. Previous use of H-11 steel had been primarily as a die material. Thus, its use in critical structure application was completely new. When first used, the H-11 cracked during heat treating as a result of vibration which requiring the development of forging configuration, surface finish heat treated processes and vacuum melting of the raw material to improve its ductility. Development of forging techniques enabled the production of the largest H-11 forging ever made weighing 13,000 pounds from which the landing gear bogie beams were made. The processing of H-11 steel is extremely critical, which may be illustrated by the requirement for drilling holes in some of the H-11 longerons and fittings in the aft body and wing stub area. Unless a stringent process control is used with regard to the type of drill bit, rotational speed, feed speed, and the

number of times a drill bit can be used without sharpening the amount or depth of untempered martensite around the drilled hole becomes excessive. Excessive untempered martensite around a hole in H-11 steel seriously affects the structural properties of the part. Untempered martensite is always present to some degree any time H-11 steel is machined unless extreme care is taken to assure that the machining temperature is kept low.

The development of manufacturing processes is markedly demonstrated in the area of fuel tank sealing because of the XB-70 design requirement for a "zero" fuel leakage rate. As a result new leak detection methods were required so that the air vehicle structure could be checked to determine that the tanks were leak free.

The engineering assumption was that honeycomb panels would require little or no repairs due to defects, an assumption which turned out to be completely incalid. As a result, methods of panel repair were also developed during the manufacturing cycle. The initial methods designed to repair the panel to its original design strength, were not satisfactory; however, each method created new problems in that the repairs were still not leak free. Continued development resulted in a sealing process using nickel plating and a secondary organic sealing agent called Viton to seal the porosity in the nickel plate itself.

The funding limitations on the program again dictated that "soft" tooling be constructed for air vehicle assembly. This, coupled with the welding distortion encountered, caused mismatch conditions throughout the entire air vehicle. It became necessary in most of the assembly joining operations to jury rig the components to be joined instead of using the tooling for which it was designed. In a few instances such as "six pak" mating and wing joining, mismatch adapters had to be designed and manufactured to accomplish the joining operation.

2. CONCLUSIONS

Funding limitations lead to the requirement to develop fabrication techniques on the air vehicle itself rather than to develop such techniques in advance. This resulted in an unnecessarily high expenditures and schedule delays. The prime contractor as well as subcontractors have repeatedly expressed the opinion that more effort directed towards basic processing and fabrication development would have led to overall program savings. Learning on the components for actual air vehicle usage is a costly and time-consuming process, occurring at a point in time when the contractor's burden rate is high. Also, laboratory development samples should have been more representative of actual size of the end components to be produced and fabricated in production. The fuel tank sealing effort is an outstanding example to justify the cost of advanced development of processes, techniques and materials; prior to actual manufacture of the end article.

It is an error to consider Materials and Processes, (machining, welding, etc.) as "off-the-shelf" (whether previously used or simply developed by the Air Force Laboratories). Each thickness, contour, size or alloy revision ultimately requires revision or development of new manufacturing techniques in the manufacture of the parts using shop production techniques and labor skills to production tolerances before the material or process can in fact be considered within the state-of-the-art.

A typical example to which manufacturing research and development was extended in the XB-70 program appeared in the early stages of the program when it became evident that during pre-weld trimming of parts and actual fusion welding, only very small deviations of the milling or welding heads from the path of the intended weld could be tolerated. Extensive experimental effort lead to the development of the "skate" technique to meet this rigid requirement. A 3" to 4" wide track with a rack was mounted directly to the parts to be joined, parallel to the path to be machined and welded. The track was held in place by vacuum cups and a small motor propelled itself and the milling or welding equipment along the track at the velocities required for the operation. By this means the edges of the parts to be welded could be milled simultaneously by the same cutting head, assuring a near perfect lateral fit for welding. By use of this technique, it is possible to machine, weld and inspect by x-ray large, hard to handle assemblies without expensive rigid tools with accuracies comparable and equivalent to that of highly specialized machines.

As the alternations of material development and improvement in techniques of fabrication continued, the use of mar-aging steel was contemplated to save weight and reduce processing costs; however, mar-aging steel was not used on the XB-70 because of the timing. Although it was not used, the development of the mar-aging steel has provided materials to the industry for use in the 300,000 PSI strength range.

D. HONEYCOMB PANELS

1. BACKGROUND

With limited testing and no previous experience the manufacturing departments found honeycomb panel fabrication, inspection, and assembly more difficult and problem laden than was anticipated. Most of the problems had their source in extra-manufacturing arenas.

The sheer size of the air vehicles in relationship to accumulative dimensional tolerances further upset by the warping affects of the welding processes was never fully grasped until the massive wings were moved in to mate along an eighty foot dog-legged joint with complex-curved surfaces.

As the problems arose and were recognized, to some extent, the ever mounting pressures to meet the contractors unrealistic over-optimistic schedules and prevent further costly slippages forced decisions to pursue courses of action which were fraught with risks. Unfortunately the odds were never favorable and most, if not all the gambles were lost. Some of the losses are still being reaped in the flight test program which has suffered from fuel leaks and structural failures.

The extensive weight savings drive coupled with minimum testing led to minimum and marginal quality panels being produced. The overpowering pressure to meet an optimistic schedule caused use of these panels as well as delaying their repair until late in the assembly sequence. Frequently, during the assembly process it was necessary to forcefully bend panels into joining position, thus producing built in stresses which, combined with weld shrinkage stresses induced during assembly welding and panel repair resulted in further panel failures.

The shortcomings of the honeycomb panels were recognized and extensive redesign was initiated for A/V #2 and A/V #3 panels such as increasing the brazing foil thickness, increasing the face sheet thickness, tightening up the tolerances, repairing defective panels as soon as possible prior to the assembly sequence, monitoring the loads required to move panels into joining positions and keeping the built-in stresses at an acceptable level, were some of the actions taken which resulted in better quality honeycomb-panel assemblies. A development which was too late to influence very many A/V #2 panels was post braze chem-milling of entire honeycomb panels. This technique permitted simplified internal panels and put the complex surfaces outside where they could be seen and dimensions controlled. Use of this technique was fully realized on A/V #3 honeycomb panels with excellent results.

The problems of fuel tank sealing were significantly reduced by use of cove seals and a change in assembly sequence. The A/V #1 fuel tanks were initially sealed after the hydraulic tubing and electrical lines were installed in the tanks, the A/V #2 tanks were initially sealed prior to the tubing and line installations. Both the sealing time and the leakage rates

were significantly reduced by use of cove seals and improved assembly sequence.

2. CONCLUSIONS

The redirections which called for speed-ups, cut-backs, lay-offs, and hold-ups; the austere tooling, the unrealistic schedules, the austere funding and the incremental funding as well as design weight savings all funneled their cumulative affects on the manufacturing departments.

The peculiarities of honeycomb panels and the need for 'kid-glove' treatment of the panels from fabrication through assembly was not fully recognized early enough in the program to avoid many of the problems which turned up during the manufacturing process.

The limitations of available panel inspection equipment and processes were not fully appreciated early enough to prevent marginal and defective panels from being accepted and started into the assembly process.

It is apparent that the task of sealing structure to 'zero' leakage condition for air or nitrogen gas was not fully appreciated by the fuselage design teams.

a. Complex Panels

Weight savings emphasis generated large complex panels. These panels were difficult to fabricate, contained many as-brazed defects and proved to be excessively difficult to process through the production phase.

Weight savings can be achieved through large complex panels but these types of panels are prone to defects and damage, the repair of which is costly in time and weight. Smaller, less complex, thicker-face-sheet, panels would simplify the fabrication and assembly processes and through reduced repairs keep the weight within reasonable limits.

b. Repair Induced Damage

In many instances the repair induced damage was actually failure of a marginal panel due to the stresses caused by the heat, or failure of a panel which had a high level of previously induced stresses. Less frequent were failures from overheating due to non-compliance with existing process specification.

Hot repair techniques are hi-risk operations and should be closely monitored to assure complete compliance with existing process specifications. Even then the hot repair technique may set up stresses in the panel or ajoining panels which will make them subject to repair induced failures. Hot repairs may reveal marginal panels and panels with a high level of built in stresses. It is desirable to discover both these conditions during manufacture. Better panel assembly

controls should be used to prevent excessive stress build up. Better inspection techniques should be developed to discover marginal quality panels. Better processes controls should be used so stress build ups can be monitored and kept within a safe level.

The possibility of using a cold repair process should be investigated thoroughly prior to calling out a hot repair method.

c. Panel Contamination

During nickel plating operations there have been several instances of panel contamination with the corrosive nickel plating solutions some of which were not recognized until later in the production process.

Even with careful following of the process specification, nickel plating is a high risk operation. The conversion from a positive (gauge) pressurized plating box to a negative (gauge) pressure lessens but does not remove the risk. No non-destructive inspection method has been devised to assure, during or immediately after plating, there is no contamination of the panel. There have been instances where visual evidence of contamination has shown up weeks after the plating operation.

Careful and exacting adherence to the process specifications, including continuous alert monitoring of the nickel plating operation is required. Nickel plating should never be deferred until after a panel is joined to a second panel nor should it be deferred on a subassembly until after the subassembly is joined to another. Whenever possible, nickel plating should be accomplished early in the production process so as to permit detection of contamination prior to the panel being incorporated into a larger assembly.

d. Production Handling of Honeycomb Panels

An unacceptably high number of A/V #1 panels were damaged by workmen because they were not thoroughly indoctrinated in care and protection of honeycomb panels.

Worker education programs and panel protection were utilized on Air Vehicle #2 to a maximum extent and worker caused damage to panels was held to a minimum.

Worker education in the care and processing of honeycomb panels is a must and this type of training program applies to all personnel from the janitors to the engineers and managers. Equally vital is a panel protection plan which includes protection during all stages from panel fabrication to area close out.

E. WELDING

1. BACKGROUND

In the XB-70, the use of conventional mechanical fasteners is limited primarily to the forward fuselage section which is constructed of titanium sheet - the balance of the structure is fabricated of welded honeycomb panels. Each XB-70 required approximately six (6) linear miles of welding to join detail parts; and about two and one half (2½) linear miles to join major assemblies of nearly twenty-five thousand (25,000) gross square feet of brazed honeycomb panels. Considerable developmental effort was necessary to advance the welding and brazing techniques to meet XB-70 requirements.

The requirement for welding starts early in the individual component fabrication where individual panel face sheets require the welding of two or more separate pieces of stainless steel sheet material to make up the total panel area. The normal process of welding stainless steel sheet results in panel distortion, requiring hand finishing to obtain a clean, burr-free, flat finished sheet. To eliminate both the hand removal of the weld bead and the distortion of the welded parts, a welding technique known as "LANAR" (Low Amperage, no added Rod) was developed. "LANAR" welding uses conventional tungsten welding equipment but penetrates the weld area only 75% - 85% on one side. The work piece is turned over and a second weld penetrates enough for overlap of the first weld. No filler rod material is added. The lateral contraction of the second weld off-sets the lateral contraction of the first weld, leaving a small convex weld bead which was eliminated by slight roller burnishing.

The most important joining methods developed or refined for the XB-70 were resistance butt welding, resistance spot welding, fusion spot welding, fusion welding, electron beam welding and brazing.

Resistance butt welding was a new application of conventional resistance welding principles, consisting of panels joined with added strips on both sides of the inner and outer facing sheets and was initially used as the basic means of joining honeycomb panels. The strips served to contain the weld nugget as it was formed and prevented reduction in cross-section area of the sheets as the weld was made. Butt resistance welding initially provided a satisfactory, fuel-tight joint.

Fusion welding was the principle welding method used on the XB-70. In most cases, it is done by the tungsten inert gas process (TIG). The arc is shielded by an inert gas such as argon or helium as filler material is added to the molten metal. Several adaptations of fusion welding were developed. Each designed to weld different types of joints. TIG welding became the principle method of joining

honeycomb panels by use of what is known as key hole welding. In joining panels, the lower face sheet was TIG welded through a 1/8 inch slot in the upper face sheet. The upper face sheets were then joined by a double weld using a 1/8 inch filler strip to close the slot. This provided a weight savings, and permitted the honeycomb core to more closely approach the edge of the panel for greater strength.

A family of light weight titanium and PH15-7MO steel I beams were developed for the XB-70's inner structure. A thin corrugated web is sandwiched upright between two caps. The caps were welded to the web by the "burn-through" weld process. The weld heat penetrated through the cap and fused the web. Weld rod filling was used for any depression resulting from weld flow. The TIG welding technique was also used in some cases, the torch being programmed by an electric eye following a precise template, tracing the corrugated (sine wave) web exactly. A continuous weld fillet on each side of the web results. Because of the high strength to weight ratio inherent in this process and the cost advantage of weldments over machined parts, this type of structure was predominantly used in the structure of the XB-70.

Electron beam welding was taken out of its previous laboratory environment and was used to weld the wings to the fuselage of air vehicle #1. The upper and lower surfaces of the wings and wing stubs are honeycomb panels and both the inner and outer face sheets had to be joined. The inner face sheets were TIG welded by the keyhole method. The outer surface was joined by electron beam welding. This electron beam method was selected because heat is so localized that residual stresses and weld distortion were kept to a minimum and thick materials could be welded to thin gauges. A joint to be electron beam welded must be enclosed in a high vacuum. Basically this problem was solved by the development of a portable vacuum chamber with sliding seals. Maximum advantage of electron beam welding was not realized initially due to the vertical misalignment of the surfaces over the 80 ft length of wing joint to be joined and an adapter strip was required to achieve the required tolerances. Nontheless, the electron beam welding did afford an advantage by its ability to satisfactorily join materials in a confined joint with a minimum of residual stress being induced by conventional weld shrinkage.

Conventional resistance spot welding was also used where fuel tight joints were not required. Special long reach spot welders (72 inches) were designed and built to resistance spot weld forms attached to panels where a long reach was necessary within a restricted working area.

A great amount of hand welding was still required on the XB-70 demanding great skill of the individual workman. As a result, a new concept of welding at elevated temperatures was developed. Depending on the conditions, it was found necessary to heat the entire part before, during or after welding. For example H-11 welded assemblies

required preheating and holding at 600°F during welding with the welder working in an asbestos suit. After welding immediate stress relieving at 1200°F was required to prevent cracking in the weld and surrounding areas. Manual welding of titanium was done in an inert plastic "bubble" chamber containing argon to prevent contamination of the titanium during welding. This procedure was improved by a "trailing cup" method for assembly welds, which removed the "bubble" limitations. This method provided a traveling cup of inert gas as the weld progressed.

2. CONCLUSIONS

It has been found that the production department and quality control department personnel require an earlier input into the basic design, and in many cases, the individual worker can and has assisted in basic design and fabrication planning. With the advent of the super alloys, it is essential that the individual worker become highly skilled in the manufacturing processes. Not only is training required but proficiency must be maintained. Such requirements do not lend to changes in personnel without extensive retraining, thus early and specific labor requirements must be identified to keep optimum labor skills and allocations on a stable basis throughout the program.

F. QUALITY CONTROL

1. BACKGROUND

Due to the unique construction of the XB-70, the major quality control effort during the fabrication and assembly stages of the program centered around the fabrication of honeycomb panels. There are essentially five basic factors that cause poor quality in a honeycomb panel: improper node flow, faulty shear ties, crushed core, inadequate fillet size and faying surface faults for which inspection methods for finished panels were developed.

The problems of quality control increased with the introduction of the new materials and design concepts. The conventional inspection methods were generally incapable of establishing product integrity either because of inaccessability or critical inspection tolerances. The history of quality control on the XB-70 is one of continuous evolution of new applications of improvements upon tools, methods and techniques available to industry. Many times complete reliance had to be placed upon the worker until a meaningful inspection capability could be developed. An early problem was the difficulty of assuring an exact fit between large surfaces of honeycomb core to the varied levels and contours of panel facing sheets. A photographic method replaced a measuring and charting method. It in turn was supplanted by a carbon paper record of the degree of fit. The need for absolute cleanliness and purging of the panel components of gas-borne contaminants was discovered during the investigation of early failures of the honeycomb panels. Here again the individual workman provided the prime ingredient of quality control.

X-ray inspection was the initial method employed to determine the integrity of honeycomb panels. The ability of the reader to detect other than gross faults was highly questionable. Ultrasonic inspection of the panels was used as a supplementary inspection process. Although a permanent recording capability was developed, the requirement for immersing the panel in water dictated that this technique be abandoned since water entering the panel caused considerable corrosion. The inspection process returned to a procedure of in-motion radiography which blurs one side and causes the other side to stand out sharply. This method provided a readily readable record of inspection. The use of portable x-ray units moving on the skates was used to inspect all welds during sub and final assembly. It should be emphasized, however, that the real quality of the panel is vitally dependent upon the workmanship, knowledge and care of the individual worker on each detail of the panel components.

2. CONCLUSIONS

The failure to provide components manufactured and/or fabricated under actual production processes seriously impaired inspection and quality control; as well as the previously mentioned impact to the production program. The new techniques which were required to be developed, x-ray film reading as an example, and the required time necessary for training in the use of these techniques dictated that the learning process had to be accomplished during manufacture of the actual air vehicle hardware. It was late in the manufacturing of air vehicle #1 hardware, before any degree of reliability could be placed upon inspection identification of defects. The early unidentified defects in honeycomb panels, or the questionable classification of such defects were responsible for failures which are occurring under the present Flight Test Program. To make repairs and/or replacement of parts at this point in time has proven to be very costly to the program in both time and dollars.

The failure to provide an adequate development testing program has also hampered the development of an adequate inspection and quality control program. Since this was an austere program, there were insufficient funds to set up destructive testing of honeycomb panels so that actual comparison of defective areas versus the findings of the x-ray reading could be compared. Lack of such a procedure limited the quality control personnel in making adequate or timely adjustments in training or predicting quality trends. The testing program on honeycomb panels, as an example, were limited to a surface pull test at 80% of designed strength of the panels, as well as to suspected areas only.

As a result of not being able to properly identify and categorize the defects, the scrap rejection rate on the honeycomb panels was extremely high (34% of total square footage produced on Air Vehicle #1) and it was not until production of Air Vehicle #3 panels began that elimination of defects through quality control input on redesign and improved techniques was made possible. Air Vehicle #3 panel production was at a 2% scrappage rate at the point of termination, March 1964. It can be said that the major contributing factor to the program schedule delay and dollar overrun was due to panel defects and that repairs generated by these defects were the primary source of leaks which delayed the fuel tank sealing efforts. In addition, as the airplanes were built, the continuous repairs to the structure resulted in considerable weight penalty. It is estimated that the weight penalty due to the above repairs amounted to 22,920 pounds on the first XB-70A and 20,354 pounds on the second XB-70A.

IV. ENGINEERING

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A. General Background

In the area of engineering experience, the influence of repeated program redirection and curtailment of funds have impacted upon the number and depth of the technological advancements that have been forthcoming. With the advent of the program as it exists today, the research and engineering efforts were restricted to the prime requirement of providing an Air Vehicle capable of performing within a speed and altitude flight envelope up to Mach 3 and 70,000 ft. Although hard tooling was available in most of the structural areas as a result of the previous weapon system program, the XB-70A Air Vehicles might be considered as having been designed and built on a model shop basis. Final engineering in the subsystem areas could not afford the luxury of optimum design for maintainability or extended reliability, and it became necessary to use airworthiness testing in lieu of extended subsystem and component qualification test programs. Two very critical areas that have been much more successful than would normally be expected in light of the drastic curtailment of subsystem testing prior to incorporation into the Air Vehicle are the flight control system and the hydraulic system. The number and complexity of problems that can be expected in attempting to provide technological breakthroughs in these areas without providing a full scale flight control simulator or hydraulic system simulator can be almost insurmountable. Although both of these areas have experienced severe problems both during the development program and during the initial portion of the flight test program, the validity of the basic design concepts and the compatibility of the components within the subsystems as demonstrated during initial testing of the Air Vehicle are considered to be without precedent in their degree of success.

B. Subsystem Discussion

In discussing the engineering experience and lessons learned, it is appropriate to cover the major subsystems more or less as separate entities. In such a discussion, however, it must be remembered that a very significant portion of the knowledge to be gained and lessons to be learned in the area of engineering design and development will result from that portion of the flight test program that is still in the future. To date our knowledge and experience have been primarily in the initial development, implementation and integration of subsystems into the basic Air Vehicle configuration.

1. Hydraulic Subsystem

Primary experience gained in this area is centered around the new subsystem requirements such as the use of 4000 PSI system pressures as opposed to current inventory aircraft systems that are

based on pressures of 3000 PSI. To accommodate this elevated pressure, it became necessary to develop and utilize seamless stainless steel tubing for hydraulic fluid transmission lines. This tubing varies in size from ¼ to 1-7/8 inches in diameter. The use of standard AN fittings in this system became prohibitive from the standpoint of preventing leaks and the excess weight encountered. Both of these problems were solved by the development and use of brazed tubing fittings. It is estimated that the use of such advanced fitting techniques resulted in a weight savings of some 10,000 pounds throughout the entire aircraft system. In order to utilize this 4000 PSI system it was necessary not only to drastically reduce the tolerances and clearances in valves, actuators, and hydraulic pumps, but it was necessary to remove foreign contaminants from the fluid system that were microscopic in size. The severity of this requirement is illustrated by the fact that the fluid filters installed in the on-board control valves are designed to remove foreign particles that are larger than 5 microns. In order to utilize the elevated pressure of the system it was also necessary to fabricate actuators and pump components of H-11 tool steel. The use of H-11 steel in these areas in turn necessitated the development of new machining techniques.

When the initial designed pumps and other components were first integrated into the system, components and transmission lines failed due to pressure surges and system pulsation. The absence of a full scale hydraulic system simulator required that these and similar flight control problems be resolved by tests conducted on the actual Air Vehicle subsystem. Experience has now shown that the decision to eliminate the full scale simulator was more costly in terms of aborted flights, extended down time and component failures. In consideration of this additional cost in money and time, and the potential damage that can be encurred during testing, future systems will find it more economical to make the development and fabrication of a hydraulic system simulator a mandatory requirement.

During the initial phases of the B-70 development program, the decision was made not to install cockpit instrumentation that would permit the flight crew to continuously monitor the pressure and fluid quantities in the various hydraulic systems. However, as the flight test program progressed, it became evident that such instrumentation is a necessity. Future systems should include the hydraulic pressure and quantity indication requirement on a mandatory basis.

Experience has also shown that in the area of hydraulic tubing, the use of only rigid lines throughout the system is a poor design approach. Major line failures have now been eliminated by the use of flexible lines in areas such as the attachment of hydraulic driven pumps. However, additional development is still required to make available flexible lines which will withstand high

pressures and temperatures while providing long life reliability.

2. Electrical Subsystem

In order to reduce the weight of electrical transmission lines, the electrical generation system was designed for 400 cycle, 416 volts. This system has been highly successful and the use of higher voltages at extreme altitude conditions has not presented problems of corona or arc over. The successful operation of the oil cooled brushless generator has also proven that arc supression around rotating rectifiers is not necessary if the system is designed correctly. The development of pure AC relays and solenoid valves under the XB-70A program has also allowed the elimination of transformer rectifiers for DC control power. Experience in this area has shown that although a small amount of direct current power has been used for certain equipments and for providing an emergency power backup source, the high voltage and pure alternating current powered Air Vehicle design is a proven concept. The use of such systems in lieu of conventional AC-DC low voltage systems results in an electrical subsystem weight savings of approximately 25%.

3. Propulsion Subsystem

The XB-70A is the first supersonic aircraft to utilize a single long air intake duct to provide combustion and cooling air to more than one engine. This arrangement of two air ducts, each providing air to three engines, has proven highly successful to date. Significant also is the successful use of a long (80 ft) duct with variable geometry control. Experience on this program has shown that at Mach 2 and above, the inlet geomotry must be variable so it can precisely control the varying shock patterns of the ram air. Optimizing of the inlet geometry has become one of the most critical design problems of air vehicles operating at high mach numbers.

A significant lesson learned as a result of the program slippages is that the engine development in any future program should be started at the earliest possible date. The two year program slippage which the XB-70A encountered permitted most engine problems to be resolved prior to the flight test program and on-board engine operation is now highly successful. The J-93 engine was developed by General Electric, Evendale, Ohio. This engine has satisfactorily demonstrated that with continuous afterburner operation it is possible to develop 30,000 pounds of thrust with an engine weighing less than 6000 pounds.

Another significant lesson learned is that the large quantity of JP-6 fuel carried on board can be successfully used as a heat sink not only for the heat generated by the on-board subsystems but also

for the aerodynamic heat accumulated at high mach numbers. Although the fuel absorbs sufficient heat to raise it above the flash point, safe operation has been obtained by first removing the entrained air from the fuel by bubbling nitrogen through the fuel as it is put on board. Secondly, the ullage space above the fuel in the tanks is filled with gaseous nitrogen under a positive pressure.

A major problem in this program has been fuel leaks in the fuel tanks. Numerous methods have been applied to sealing the honeycomb structure and although the leaks have been greatly reduced, further development is needed before a completely satisfactory high temperature, long life tank sealant can be made available.

4. Alighting Gear Subsystem

Design work in this area started early in the program. Unfortunately the original design size of the tires was held to a minimum to reduce tire weight but did not take into account the growth potential of the air vehicle in over-all gross weight. Consequently, the utilization of the total structural gross weight potential of the air vehicles now requires the tires to operate at temperatures and pressures in excess of the original design requirements and beyond the state-of-the-art of tire manufacturers. This situation has greatly reduced the reliability and life expectancy of the present tire configuration. The significant lesson learned from this situation is that in the initial design, the tire size chosen must be sufficiently large to accommodate the growth potential and resultant gross weight increase of the air vehicle.

Another major problem in this area has been brake chatter at low taxi speeds. Although this problem exists on all large aircraft, the problem has yet to be resolved. Because of the potential structural damage that can result from this situation, the XB-70A program now includes a rather extensive effort to establish design criteria for braking systems that will eliminate this problem.

C. Applied Technology Base

Weapon System 110A (XB-70) from its inception has required the maximum utilization of the latest laboratory and research advances in aerospace technology to meet the system objectives in performance, range, speed and accuracy. The application of these advances posed considerable problems. Although many of the advances in aerospace technology had been proven in the laboratory to the extent that they were commonly accepted to be within the then present state-of-the-art, little or no effort had been expended towards the technology required to generally apply these advances to aerospace system hardware.

One of the lessons learned on the XB-70 program is that this increasing lag between the laboratory and research breakthroughs and the technology base for application to design and manufacturing techniques have resulted in longer system development time periods and greatly increased system oriented costs. This lag has been caused by the rapid expansion of our research programs with an equal reduction in our programs to develop an applied technology base and proven manufacturing techniques congruent with the emphasis on point or system design. This emphasis on point or system design approach implies that there must be an end item system hardware need before application development is done on the manufacturing technology. This results in the concentration of know how within a small number of our industrial contractors and is often lost to the scientific community whole.

The expansion of the applied research base not oriented to point or system design is required on a continuing basis in order to bring future systems into the inventory which incorporate the latest proven technology at less direct cost and in a minimum time period.

In the XB-70 system program most of the advanced concepts had to be developed from the laboratory concept to specific hardware without the benefit of an applied technology base. For instance, stainless steel brazed honeycomb panel had been produced in small laboratory samples and was commonly recognized as a highly efficient structural material. To use this material for the manufacture of the XB-70 required development of rolling mills that could produce stainless steel in both thin and close tolerance sheet stock, development of brazing techniques and equipment, development of joining and welding techniques, and the development of a whole new family of quality control and inspection criteria. Once developed, the new procedures, techniques, processes and equipment had to be expanded to encompass the entire subcontract base. All costs in both time and dollars were directly oriented to the XB-70 program.

As the XB-70 was originally planned as a weapon system to be produced in quantity, a large development and subcontract structure was established which encompassed nearly all of the aerospace industrial complex of the United States. As breakthroughs were made in development or manufacturing, these were distributed to all vendors and subcontractors through newsletters and symposiums. Thus, the XB-70 advancements in the state-of-the-art and information gained were disseminated to the entire scientific community.

The technical lesson learned on the XB-70 System Program is that our programs of applied research and manufacturing technology are not adequate or timely to support the advancement made in the laboratory research programs. The emphasis on only system oriented development of applied research or manufacturing technology has increased the lag

between laboratory research advancements and their application in a system and has greatly increased the system development time and system oriented costs of any system which utilizes the latest research advances.

V. FLIGHT TEST

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A. BACKGROUND

All areas of flight test support, and with the exception of the flight test contract planning, were completed to support the originally planned first flight date of December 1962. The Joint Test Force was organized and the services and support agreements between the AFFTC and the contractor were in being by that date.

Air Force personnel were trained by and with contractor personnel. The technician and engineers virtually lived with the aircraft during manufacture, thus acquiring a thorough background. The pilots received ground school with the contractor pilots and participated equally in the flight control simulator missions.

The contractor flight test maintenance personnel were employed in the manufacture of the aircraft, consequently they were well qualified in the configuration and systems operations. The contractor pilots completed Air Force B-52 crew training and received B-58 flight training to gain experience with large high speed aircraft.

Facilities in being at the AFFTC were adequate except for modification of building 1820, construction of a 10,000 barrel capacity storage tank for JP-6 fuel and construction of a run pad for the XB-70. This work was accomplished under the military construction program.

The flight test plan was developed by the contractor and approved by the Air Force. This plan was to the detail of each individual data point, (NA 61-620-2), as well as the more general overall plan and flight test program objectives. The plan was based on the contractor's estimate

of achieving an average of eight hours per month per air vehicle.

The contract for the flight test program was accomplished in July 1964, which was, of course, prior to the first flight of the air vehicle. Since the contract was of the incentive type, the contractor was therein recognized as the flight test program manager. Approval authority over the flight crew composition was, however, retained by the Air Force.

B. CONCLUSIONS:

The organization and manning of the Joint Test Force was, due to aircraft manufacturing slippage, almost two years early. This, however, was not a wasted effort. The additional time available resulted in much more thorough training than would have been possible otherwise, and enabled personnel to follow the air vehicle through the manufacturing as well as preflight phases. In addition, it made available to the SPO, on site knowledgeable Air Force personnel. The flight control simulator experience gained by the pilots was judged extremely valuable training, particularly in view of the fact that due to austerity no flight simulator was procured. The contractor procedure of utilizing flight test maintenance personnel in the manufacture of the air vehicle was a valuable expedient to provide trained maintenance personnel for the flight test program without incurring added training costs. The heavy and supersonic bomber training afforded the contractor pilots is felt to have contributed in a large measure to the safety of the early flights. This training was not considered necessary for the Air Force pilots due to their previous experience.

The formulation of the flight test program objectives and the development of the broad flight test plan early in the conceptual phase of the flight program is, of course, necessary. However, planning to the detail of individual data points is wasted effort. To date, in the XB-70 program, less than 50% of the data points accomplished were contained in the detail plan, the balance consisting of points for which the requirement was unknown when the plan was developed, yet accomplishment-wise, the program is proceeding approximately on schedule for the hours flown. A further consideration is that the detail plan of data points, (NA 61-620-2) was compiled for the originally planned flight test program of 415 hours.

The incentive type contract does not lend itself to the exercise of Air Force management of an experimental flight test program such as the XB-70. Any request by the Air Force to the contractor to alter projected flights will normally affect the achievement of the contract incentives and can, therefore, be expected to be met with opposition by the contractor. The Air Force is then faced with the alternatives of relinquishing management of the program or placing the contract in jeopardy. A type of contract which would permit Air Force to exercise management prerogatives would be highly desirable.

VI. CONFIGURATION MANAGEMENT

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A. AIR VEHICLE

1. BACKGROUND

a. In light of the very stringent funding limitation under which the B-70 program has operated and is being tested it was necessary in early 1963, to establish an effective and positive control of configuration changes. Control of B-70 design and fabrication has been achieved through SPO surveillance of specifications and engineering data. Change control procedures were negotiated with the contractor and included in an Exhibit which became a part of the contract. A B-70 SPO Office Instruction was prepared to list procedures for control of contractual changes to the configuration of the XB-70 Air Vehicle and YJ-93-GE-3 engines. SPO approved specifications in effect on the date of acceptance of each Air Vehicle, with deficiencies and shortages listed in the A/V Deficiency Report, defined the baseline configuration of each Air Vehicle. Major changes to the Air Vehicle after AF acceptance require B-70 SPO approval prior to making the change. Differences between the two A/V's required the use of separate specifications to define the baseline configuration; however, the same configuration control procedures apply to both A/V's.

b. Since only two XB-70 A/V's were procured, configuration identification and reporting at component level (which is the procedure for programs scheduled for the operational inventory) was considered unacceptable for the XB-70 development program. In lieu thereof, XB-70 configuration identification, control, and reporting is accomplished at subsystem level allowing the contractor sufficient design change flexability required for a development program. Since both A/V's were bailed back to the contractor after AF acceptance configuration status accounting is accomplished by the use of contractor internal reports rather than requiring the contractor to prepare formal status documents. The contractor's status reports are furnished to the Air Force at specified time intervals and provides, (1) a word description of engineering changes made since the previous flight of the A/V and lists the subsystem affected, (2) a listing of the subsystems which were either inoperative or partially inoperative for the flight being reported, and also includes a statement as to the reason for it being inoperative, (3) a listing of all subsystems which have had changes incorporated since baseline configuration was established with a cross reference to what the change consisted of, and (4) a two part listing, which provides a list of all changes that have been released for incorporation in the A/V. One part lists the changes that have been installed and the second part lists changes that have not yet been installed.

c. The AFPRO and the XB-70 Test Force personnel maintain close surveillance over all configuration changes as they are being formulated by participating in the contractor's meetings when proposed changes are discussed. This procedure provides the SPO with a technical engineering assessment relative to the necessity for the change, a contractual assessment, and a logistic support assessment relative to the effect the change will have on Ground Support Equipment, Spares, Technical Manuals and Maintenance procedures. Major changes are limited to those pertaining to Safety of Flight or to achieve contract flight test objectives. Major change proposals are reviewed and approved, or disapproved, by the B-70 Configuration Control Board, which meets at specified time intervals in the B-70 SPO.

2. CONCLUSIONS

a. The configuration procedures and management controls currently in effect for the XB-70 program affords the closest practical management surveillance of changes, thus insuring that only those essential to the safe and effective accomplishment of the flight test contract objectives are implemented. The configuration of the flight test A/V's is clearly and accurately defined as is necessary, not only to insure flight safety, but to permit interpretation of flight test results. Good day-to-day working coordination between the contractor, AFPRO, B-70 Test Force and the B-70 SPO has been established. The SPO is kept knowledgeable regarding potential configuration changes prior to their actual release and incorporation in the A/V's, by means of a weekly informal telephone conversation between the contractor and appropriate SPO personnel. This provides the necessary advance information without generating additional cost to the program which would be inherent in any regular written reporting. During these telecons progress toward accomplishment of changes already in process as well as a brief review of potential future changes is provided to the SPO. All changes are analyzed with respect to flight test objectives, program cost, impact on logistics, maintenance, spares, and ground support equipment. This type of continuous, close, but informal coordination provides the SPO and other AF agencies involved with knowledge and understanding of current status of the XB-70 flight test program without the generation of additional and unnecessary cost to the program. The XB-70 Configuration Management program is similar to and satisfies the intent of current AFR and AFSC series of regulations pertaining to AF configuration management. With the exception of making minor changes, activities to date have confirmed that XB-70 Configuration Management policy provides definition of A/V configuration and demonstrates the existence of tight management control of configuration changes.

B. DATA MANAGEMENT

1. BACKGROUND

a. In the 1958-59 time period when an experimental contract for the B-70 was executed, contracts for large quantities of aircraft were approaching a conclusion and most contracts being awarded were of the R&D type with a minimum of hardware as the deliverable end item. It was at that time that the B-70 contractor and the B-70 Weapon System Project Office realized that during the war and postwar years which had demanded the delivery of high quantities of aircraft, specific contract definition of data was of secondary importance and it was probable that up until then, neither had the contractor known completely what data he was obligated to supply under a contract, nor had the Air Force known completely what data they had procured under a contract. Completion of data in those days usually was constituted by submittal by industry of qualification test reports for equipment, equipment samples, preliminary handbooks and microfilm of final production drawings for the Air Vehicle.

b. With the advent of the R&D contracts, where weapon system and performance specifications were being introduced and with the advent of a new family of management reports, the application of data requirements contained in military specifications for hardware appeared questionable, and the requirement for a definitive document of line items of data in the contract became evident. Such a document was generated by the joint effort of the B-70 Weapon System Project Office and the North American Aviation, Los Angeles Division, and the subject document was attached to and made part of the B-70 contract. During the 18 months that followed, data submittal requirements of the subject contract were limited to those contained within the exhibit and the status reporting of such data was mechanized for internal control within the contractor's facility. The WSPO had as had the contractor, appointed one person through which all data requirements were coordinated and approved. The exercise included a very close coordination effort between the contractor and the B-70 SPO to resolve two basic factors: (1) Identification of data required by the SPO to fulfill its charter within the Air Force and (2) A definition of the data so identified in order that the contractor would have a clear understanding of the required contents of each end item of data. It was found necessary in some instances where definitions contained within certain paragraphs of Mil Specifications were ambigious, for the B-70 SPO to write an exhibit which fully defined the required contents of that specific line item of data. When all such data were identified and understood by both parties, it was attached as an appendix to the contract and prefaced by an introduction which contained the following two key statements:
"Data requirements of applicable specification and USAF design handbooks, except as defined herein are waived. These and other government documents requiring the preparation or delivery of data shall be used as a guide but shall not require Air Force approval for deviation thereto, relative to preparation and/or submittal of data."

The second key statement was: "Data shall be submitted in the format and content normally used by North American Aviation or by its subcontractors." Where the term "Test Reports" and "Test Results" were used, the meaning was synonymous. As of today, these words of the contract have not been amended nor has the contractor been requested to prepare "data" per se over and above that which was set forth in the exhibit.

c. The Air Force, in administering the B-70 program, did one additional thing which is particularly applicable to the management of data. It reflects a philosophy used by the B-70 SPO to maintain data at a minimum and was accomplished by the SPO exercising its prerogative to delegate approval of certain items to the contractor. The philosophy applied was that which was reflected in an early Air Force Bulletin MCP 71-533A, which when implemented, allowed the Air Force to accept contractors certification that end items of equipment below subsystem level had fulfilled the government approved airworthiness or qualification test requirements, such certification to be based upon the contractors laboratory test results. This meant that with the exception of a few selected end items of equipment in which the engineering personnel of the SPO had a special interest, it became unnecessary for the contractor to document test results in the form of formal test reports. This philosophy recognized that test laboratory log data sheets maintained on file by the contractor and readily available to the Air Force if required, would serve the same purpose as file cabinets, at Wright Field, full of formal test reports which might not be needed for the balance of the program. It is obvious the savings in manhours which were realized particularly in view of the fact that the contractor passed the same philosophy of certification on to his major subcontractors.

d. Following the definition of data which became part of the contract, the method of managing the effort in accordance with contract requirements was implemented. This consisted of a mechanized system for data status reporting to the WSPO as well as internal data management within the contractor's facility. The first step accomplished for the preparation of the master tab listing was the assignment for each line item of data, a sequence number, a report or drawing number, and a responsible group within North American. All items of data, as in the contract exhibit, were grouped by subsystem. The master tab, printed from punched cards, formed the basis for all subordinate reports which were machine sorted and printed as required. The original system established the use of an 083 card sorting machine and a 407 rapid printer... and the cost incurred for establishing the internal control and reporting system was a minimum. The original programming cost was about $600, and each combination of printouts thereafter cost in the neighborhood of $35. This represented some 350 data entries. As time progressed, additional reports, specifications and drawings were identified by number and periodically added to the tab run. Additionally, scheduled and actual dates were added and provisions made for the Los Angeles Division transmittal letter number to be recorded opposite each line item of data. The fact was recognized that the submittal of any data item, immediately opens the door for a myriad of questions which, when asked in writing by the customer must be answered in writing by the contractor. Such answers in writing usually represented additional

data even though it was contained in letter form. Thus it was found advantageous to reference all correspondence generated by either the customer or the contractor related to any end item of data adjacent to that line item of data in the tab run thus providing a ready reference for not only the data requirement but all correspondence related thereto. Each end item of data in the master tab was also coded to indicate when written approval of the WSPO contracting officer was required and/or granted. Each line of data in the data status report was assigned a sequence number, a number representing the office of prime responsibility (or group) at the contractor's plant, the assigned document number, a document title, a submittal schedule, a submittal date, and the contractor's letter number under which submittal was made. Beneath this line might appear 3 or 4 other references of correspondence from either the customer or from the contractor and the code indicating the approval status of that line item entry. The standard printouts which were used throughout the program for management purposes at North American were (1) the total list, (2) a printout list by office of prime responsibility of all scheduled data, and (3) a numerical index of all specifications and reports. In addition, printouts were made of all open approval items by office of primary responsibility and a working list of data scheduled for submittal within the next 60 days. Other combinations were issued as required. As, an example, in addition to the total list, which was printed and submitted to the WSPO on a monthly basis, frequently the SPO desired a list of items which had not as yet been approved. Because of the approval status coding, by instruction to the machine, such a list was made readily available. Conversely, suppose North American Aviation Management desired a list of items which required Air Force approval, but had not as yet been submitted, it was extremely simple to produce that information in a minimum of time. In the years which this system has been used on the XB-70 contract, the volume of data and related correspondence has grown to approximately 17,000 entries. Recently, the machine instructions have been taped and the printouts made using a 1401 series machine. An interesting statistic is the fact that the increase in volume of entries has been offset by the faster printout speed of the 1401 machine, allowing machine costs to remain nearly the same as when the program was started.

e. Throughout the development contract of the B-70, it was recognized that instances would arise when the contractor would submit something to the Air Force for his suggestion and/or coordination even though such data was not necessarily included as part of the contract data requirements. It seemed important that a record of such submittal together with an index of related correspondence be maintained, so as a result, these items were also included in the data status report.

f. To alleviate communication problems a plan for scheduled technical meetings between the engineering personnel of the contractor and his subcontractors and Air Force technical personnel was implemented. Such meetings were progressively scheduled by subsystem, were held at either the contractor or subcontractor's plant or at the system project office - included a minimum of personnel, were accomplished in one or two days, were informal in nature, and were conducted no less frequently than every 90 days for each subsystem. At such meeting, preliminary drawing, schematics, rough analyses, and concepts were discussed. Questions were asked and

answered on the spot. Recommendations and/or directions were obtained from Air Force technical personnel leading toward the ultimate formal approval of the applicable subsystem or components therein, as required. The purpose of the design reviews was actually two fold: (1) The Air Force was always current in the design techniques being employed by the contractor, and secondly, the contents of a report or drawing to fulfill a specific data requirement came as no surprise to the SPO when it was submitted for approval. Thus the written correspondence problem was maintained at a minimum. It is conceivable that had such conferences not been conducted, and the exchange of information had been by correspondence only, the current tab listing might contain not 17,000, but 30,000 entries.

2. CONCLUSIONS

a. Today the B-70 SPO has a status report that contains a reference for nearly every piece of paper submitted by the contractor to the Air Force as well as from the Air Force to the contractor, and it is segregated by Contract Data Item Number. The Air Force and the contractor use the same information to monitor contract data. The versatility of the status report is quite evident. The B-70 Data Management program conceived and implemented in 1958-59 is quite similar to the data management system currently being implemented by the Air Force. The similarity is evidenced in three specific areas. First, the appointment of a data manager within a system project office is a current requirement. However, since the inception of the B-70 program, there has been one key B-70 system project office person assigned responsibility for complete coordination of B-70 data. Secondly, exhibits prepared by the B-70 SPO to define the contents of end items of data closely resembles the documents rrently being implemented, which accomplish the same purpose. And third, the waiver of all data requirements, except those set forth by line items in the contract has become a standard of operation.

b. Since the B-70 is a development program consisting of two experimental aircraft with no follow-on operational requirement, and also due to program austerity, B-70 data requirements and the distribution thereof is very conservative. Essentially all B-70 data required by the Air Force is submitted in the format and content normally used by NAA or by NAA subcontractors. Only selected items of data are submitted to the Air Force consistent with management needs. This procedure does not waive the contractor's responsibility for compliance with applicable design and testing requirements and for maintaining on file, readily available for submittal to the Air Force upon request the information from which all data required in applicable government documents has been prepared. The B-70 Data Program has kept the dollar investment in engineering data to a minimum. It has prevented the procurement of unnecessary data by restricting purchase to valid requirements as they generate. It makes readily available any portion of B-70 data prepared by the contractor regardless of whether the item is listed in the Contract Data Exhibit.

VII. LOGISTICS

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A. BACKGROUND

Like the contract and manufacturing effort, the program director recognized the requirement for the initiation of Logistics Support planning at the inception of the Weapon System Program. The Aeronautical Systems Center support office was established in 1958 utilizing ASC and Hqs AMC personnel who worked directly with the WADC Development Engineering personnel in establishing the design criteria for training devices, Ground Support Equipment and the W.S. Data, Spares and GSE provisioning criteria. As the program progressed, the ASC Support Office was expanded to assume more of the program management and provisioning efforts with the ARDC personnel doing less of the management and more of the engineering effort. In 1961 the Hqs AMC personnel attached to this SPO were SAAMA who established a liason within the SPO initially on a coordination and planning basis. In 1962, the Program Director recognized that under an austere program the AF as well as the contractor could not afford a duplication of personnel assigned the support office for accomplishing essentially the same planning effort. He, therefore, administratively established a single administration for support office under the San Antonio Logistics Support Manager utilizing both San Antonio and ASD SPO personnel to carry out the XB-70 Support function. This consolidation of effort and personnel resulted in some reduction in personnel/discontinuance of duplicate efforts and a closely integrated and rapidly responsive organization to the several program re-directions. A single set of operational procedures were established as well as consolidated planning and reporting systems such that facilities, Ground Support Equipment, GFAE and Spares were programmed and administered as a unit. An outstanding example of the benefits that resulted from this approach was the planned provisioning of Ground Support Equipment and Manufacturing Aids which could be used during the manufacturing effort and transferred with the air vehicle in support of the flight test program. Further, maximum utilization was accomplished of existing Government-Furnished Property throughout the program. Of particular note was the ability of the Joint ASD/AFLC Office to anticipate manufacturing difficulties and resultant program realignments in the provisioning of spares requirements such that spares were not overprovisioned, configuration changes were anticipated and engine support requirements were kept in consonance with the air vehicle program. The latter was extremely difficult since the engine contract with General Electric was independent of the prime contract and yet was dependent upon prime contract program progress. Proof of this combined program management effort is illustrated by the fact that at the time of the 3rd air vehicle termination, the closely monitored lead time from need date procurement of engine spares resulted in a very small quantity of excess spares and such excess was only in the economical buy category. Consequently, with the cancellation of A/V #3, additional spares procurement were virtually nil during the first year of flying because the delivered engines plus the austere spares provisioning were adequate for the 2 A/V program.

B. CONCLUSIONS

1. It is quite evident that (a) the excellent support provided this complex Research and Development Program could be projected into the timely transferrence of the Weapon System support from the development to the Acquisition phase of the program with no disruption or provisioning delay and (b) that there is no necessity for independent ASD/AFLC duplicate organizations within a Weapon System if the joint objectives of the AFLC/AFSC organizations can be accomplished by a single office responsible to the Weapon System Director.

2. From the inception of a Weapon System Program, logistics functions and responsibilities should be established at a Deputy Director level within the SPO. This is essential to insure that maintenance, supply, transportation, tech manual requirements and implications receive proper consideration during early design, development, test and production phases of the program. In view of the ultimate role of AFLC to provide the Weapon Logistics operation, the Deputy Director for Logistics organization of the SPO should be staffed by AFLC personnel from the very beginning. This organization should not be a "dotted line" organization on the SPO organizational chart. They should be considered and treated as fullfledged key members of the team. The Deputy Director for Logistics should have control and authority in his field and should not be acting in a liason capacity. He should have the ability and the authority to speak for AFLC and answer to the System Program Director. If he and the System Program Director do not agree on a major area, then this certainly is a question to be resolved at the Command-to-Command level since each Command has its rules, regulations and operating procedures which obviously created the impasse. This Deputy for Logistics organization should be augmented as required by AFSC personnel whenever there is newly developed, complex GFAE for which AFLC has no experience and also to fulfill peculiar AGE requirements. As each item of AGE configuration becomes firm for Weapon System use, AFLC should assume responsibility to complete all remaining logistics tasks. The SPO Deputy Director for Logistics would operate under the current austere ASD provisioning exhibits. As engineering design and development progress and subsystem configurations are approved to meet the SOR, the logistics responsibility for these subsystems would be transferred to the particular IM/AMA through the SSM to establish the necessary records required for Air Force operation. This transfer should be on a progressive basis and not necessarily associated with an event such as category testing. The subsystem configurations not meeting SOR requirements would be listed in the AFSC/AFLC Transfer Agreement and the logistics responsibilities would be retained in the SPO until the configuration was approved and acceptable to the operating Command. This would complete the SPO logistics operation and the SSM/INs would have all necessary data to fulfill the AFLC logistics responsibility to the operating command. Since AFLC is primarily in the logistics field, then it seems that the bulk of the logistics talent should be in AFLC and the R&D talent in AFSC. If AFLC is to inherit the responsibility for logistics support of a weapon system, then it makes sense to have AFLC in the act from the very beginning, developing the plans and procedures that AFLC must live with to fulfill its responsibility to the operating Command.