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AIRCRAFT SIMULATOR DATA REQUIREMENTS STUDY

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AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

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The United States Air Force had encountered difficulties involving the availability, quality, and format of air weapon system design data required for the acquisition of simulators. In view of the increasing importance of modern digital computer-driven flight simulators in providing the required training, both for initial qualification and for the maintenance of readiness, it was determined that an up-to-date standard to identify the data required by simulator manufacturers was needed. This standard would then be included in the development

and acquisition contracts for future weapon systems to provide for the timely supply of the requisite data.

Systems Research Laboratories, Inc. was selected to perform a study of the simulator data requirements, resolve any difficulties incident to the timely supply of that data, and prepare a General Requirement for the acquisition of that data in future contracts. The study was conducted by surveying simulator manufacturers and simulator acquisition activities to determine the problems and requirements, then surveying aircraft, avionics systems, and engine manufacturers to determine data availability, problems in satisfying the requirements, and suggestions for alternate approaches.

As a result of this study, a proposed General Requirement was prepared which could be included in future weapon system procurement contracts to provide for the timely supply of the data required for simulator development. In addition to this "Data Specification," certain other actions are required to make the system work:

1. Order the data when the aircraft is ordered.
2. Place simulator data at a high enough precedence to ensure compliance.
3. Make certain that simulator data requirements are included in the procurement contracts for GFE items.
4. Have simulator data delivered to the Government.
5. Have an initial data package based on the best data available, probably wind tunnel, bench test, and engine test-stand supported estimations, delivered after the aircraft design freeze and before announcing the simulator development competition.
6. Have the initial data package updated at specific block intervals until all data is based on flight test results or equivalent "hot bench" data.
7. Task the Air Force Flight Test Center to make engineering simulations of each new aircraft development program and to derive the handling qualities and performance parameters from flight test data for the use of the simulator manufacturer. Make this an early item in the flight test program so that the simulator can be in operation at the operational command in time to support the receipt of the first aircraft.
8. Task AFFTC to supply a qualified test pilot current in type and a flight test engineer to assist in the simulator development from the initial contract award through acceptance testing.

Other recommendations for further studies to resolve certain simulation technical problems and to reduce the cost of simulators are included in the report.

FOREWORD

This report was prepared by Systems Research Laboratories, Inc. of Dayton, Ohio, under Contract F33615-76-C-0106. The work was performed under the direction of the Aeronautical Systems Division, Deputy for Development Planning, Wright-Patterson AFB, Ohio. Mr. Richard F. Worthey was the ASD Project Manager.

The program was conducted from 1 May 1976 through 15 December 1976. Mr. Harold L. Iffland and Mr. George A. Whiteside were the SRL principal investigators.

The authors wish to thank the representatives of the companies and Government activities surveyed during this investigation for their cooperation and assistance, without which this study would have been impossible to perform.

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The United States Air Force had encountered difficulties involving the availability, quality, and format of air weapon system design data required for the acquisition of simulators. In view of the increasing importance of modern digital computer-driven flight simulators in providing the required training, both for initial qualification and for the maintenance of readiness, it was determined that an up-to-date standard to identify the data required by simulator manufacturers was needed. This standard would then be included in the development and acquisition contracts for future weapon systems to provide for the timely supply of the requisite data.

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SECTION I
INTRODUCTION

1. BACKGROUND

The Aeronautical Systems Division, Air Force Systems Command, United States Air Force, Wright-Patterson AFB, Ohio, recognized problem areas in the acquisition of data required by aircraft simulator manufacturers for development of simulators having high fidelity of duplication of the performance of the weapon system. The need to establish sound business arrangements between the aircraft manufacturer, simulator manufacturer, and Air Force for the acquisition and transfer of data was apparent.

The rising procurement and operational costs of modern air weapon systems combined with a need to conserve fuel and to extend the service life span and inventory level of high performance combat aircraft dictate a requirement to perform more and more of the training necessary to attain and maintain combat efficiency in simulators. This will not only create requirements for a greater number of simulators but more importantly, it will require a great many more full mission simulators. The requirement for timely and accurate data is therefore escalating rapidly.

The current practice is to either make the simulator a separate procurement with each simulator manufacturer making his own arrangements to obtain the data he needs or to make the simulator a line item of the weapon system prime contract, thereby making the prime contractor responsible for the necessary data as well as the simulator. Neither of these approaches has proven to be entirely satisfactory. One approach resulted in encountering difficulties involving data availability, quality, format and timely delivery to the simulator manufacturer since there is no standard list of the data to be procured or its format. Also, the data is not ordered until after the aircraft prime contractor is well into the development program, which accou for extra costs as well as lack of availability. The other approach places the Government simulator experts "out of the loop" and in a position of reduced visibility of the simulator development and in a secondary position regarding the employment of assets in order to effect a timely delivery of the simulator.

In the fall of 1975 the Aeronautical Systems Division, Deputy for Development Planning, announced an intention to contract for a study of the aircraft simulator requirements and data acquisition areas. A subsequent competition resulted in award of a contract entitled "Aircraft Simulator Data Requirements Study" to Systems Research Laboratories, Inc. (SRL) of Dayton, Ohio. The study was commenced on 1 May 1976 with completion of all items required by 30 January 1977. The stated objective of the study was to improve the process of acquiring data required for aircraft simulators through the identification of problem areas in data acquisition and definition of standard data requirements through preparation of a proposed General Standard. MIL-D-23143 (Wep), "Data, Technical Aircraft; for the Design of Aviation Training Devices," was to be used as a guide for the preparation of the new standard.

2. METHODOLOGY

The study was divided into three parts. Part I consisted of those efforts necessary to determine the requirements for data through reviews of current specifications, meetings with simulator acquisition agencies, and through interviews with a selected list of simulator manufacturers. Part II consisted of those efforts necessary to determine the availability of data through interviews with aircraft manufacturers and Government Air Weapon System test activities. Part III consisted of an analysis and reconcilliation of the data requested versus the data available, a resolution of problems, and preparation of the recommended standard. It also included preparation of a final technical report and presentation material in addition to the proposed General Standard.

It was recognized from the beginning that good cooperation by the companies to be interviewed was essential to the success of this study. As a step to help achieve that cooperation, the Aeronautical Systems Division sent letters to a prospective list of aircraft and simulator manufacturers before the data study request for proposal was issued, explaining the objectives of the study, stating that contractors who manufacture either aircraft or aircraft simulators would not be permitted to perform the study and requesting that the companies voluntarily cooperate with the study on a non-reimbursement basis. After the contract was awarded, all simulator manufacturers who had responded to the ASD letter offering to cooperate in the study were invited to a kick-off meeting at SRL on 21 May. The purpose of the meeting was to explain what was planned, to solicit suggestions relative to the study approach, and to again point out the importance of cooperation. Representatives from the Aeronautical Systems Division's Deputy for Development Planning, Simulator System Program Office, and Deputy for Engineering, Flight Simulator and Trainer Branches, from the U.S. Naval Training Equipment Center and from the Air Force Human Resources Laboratory attended, as well as representatives of the various simulator manufacturers listed in Table 1 below.

TABLE 1
SIMULATOR MANUFACTURERS SELECTED

AAI Corporation
Goodyear Aerospace Corporation
Grumman Aerospace Corporation
McDonnell Douglas Electronic Company
Singer-Simulation Products Division

The proposed approach consisting of submission of a questionnaire to be followed in a short time by the SRL interview team was acceptable with no changes requested and was implemented in the study.

The status desired for the General Standard was discussed. Specifically, the applicability of the standard as to type of aircraft and whether or not it was to be a tri-service document. The decision was reached that this study was to address fixed wing, horizontal takeoff, turbojet, turbofan, or turboprop powered landplanes only. It would not address helicopters, seaplanes, and VTOL. It was decided that these could be handled better by separate standards rather than by one voluminous standard that applied to everything.

It was also directed that the study directly address the Air Force problem. If coordination with other services were desired it would be taken care of by the Air Force subsequent to this study. Whether to estimate a future simulator technology or base the study on current technology and performance requirements was discussed. It was determined that the study would address current simulator specifications. The investigation was conducted based on these clarifications of the ground rules.

SECTION II

DETERMINATION OF DATA REQUIREMENTS

2.1 SIMULATOR MANUFACTURERS SURVEY

The selection of simulator manufacturers to be interviewed was made based on the responses to the ASD letter of 25 November 1975, additional comments received at the kick-off meeting, and the need to cover the companies with Air Force simulator experience covering the spectrum of similar types from full mission to part task trainers. Based on these criteria, a proposed list of simulator manufacturers was recommended. This list, the companies listed in Table 1, was approved by the Air Force for implementation.

A proposed questionnaire was prepared and coordinated with the Air Force Program Monitor following which it was mailed to the companies previously listed. The forwarding letter requested that the questionnaires be completed and held for discussion with the interview team when they visited the plant in about two weeks. A copy of this questionnaire is attached as Appendix A. All companies listed were visited by the interview team during the simulator manufacturer's survey except Grumman. Due to the complete involvement of the key people in proposal activity, Grumman could not accommodate the survey during the period scheduled for it. Arrangements were made to review their simulator requirements when Grumman was visited as part of the aircraft manufacturers survey.

At the conclusion of the planned interviews, a review of the answers received disclosed good agreement as to the data required through a repetition of answers. It was therefore decided that additional simulator manufacturer interviews were not required as part of the requirements determination process.

2. RESULTS OF THE SIMULATOR MANUFACTURERS SURVEY

A. Aircraft General Requirements

The results of the survey will be discussed as general comments and comments on specific simulator subsystems in subsequent paragraphs.

The majority of simulator development problems have their origin in the data package supplied and in the specification. In some cases the format and annotation of the data package is such as to make the data inappropriate for use on a simulator, for example stick force data, without the corresponding gross weight and center of gravity. In other cases the fidelity is the problem in that the estimated or wind tunnel derived data do not represent the real airplane to the accuracy required by the simulator specification and flight test data is not available to the simulator manufacturer until the start of acceptance testing and even then it generally is supplied piece-meal. Although the examples are concerned with handling qualities, the source of the greatest number of complaints in the past, the other weapon system subsystems have similar problems as do part task trainers in general.

All respondees were in agreement on the point that in general the data does exist to the detailed level required once one is able to sit down and talk to the right man in the aircraft (or avionics or engine) contractor's engineering department. It would generally only be estimated data but is adequate for understanding the interactions of the various systems hence the way the mathematical model must be constructed. This has been proven repeatedly when management permits the direct engineer to engineer interface as reported by every respondee.

All the simulator manufacturers pointed out that the attitude of the management of the weapon system prime is essential to success in obtaining a good data package. In several cases the WS management has provided the names of the engineers who have the background knowledge of the development of the various portions of the weapon system design and have encouraged direct engineer to engineer interface. These have all been successful. Most of the simulator manufacturers stated that the flow of information is must less restrained when the WS prime does not have a close knit corporate relationship to a simulator manufacturer and the simulator contractor is similarly divorced from corporate ties to aircraft manufacturers.

As examples of good cooperation, there were three simulators studied where the simulator contractor supplied a well qualified simulator engineer on-site in the weapon system contractor's engineering department to assist in pulling together the data package. These men were given free access to all engineers. In all three cases the data packages were complete, supplied on time, and to the level of accuracy available to the aircraft manufacturers. The follow up inquiries were well organized and generally quite fruitful. Two of the simulators, involving different manufacturers in each case, were built on schedule and went through acceptance testing with a minimum of confusion. In the third case, the simulator manufacturer received a complete data package on time. This was a total package procurement with the simulator procured through the prime contractor, however, the simulator data requirement dates were well ahead of the design freeze dates on the airplane, hence numerous, time consuming and costly changes had to be made to the simulator. This was a procurement scheduling rather than a data problem.

In contrast, there are a few cases, including cases involving supply of the simulator as part of the WS prime contract, in which the simulator manufacturer has been prohibited from talking to anyone except his program monitor in the prime organization. In most cases these are procurement people, in one case a person in the AGE group, who do not understand the data problem and are not motivated to solve it. These situations lie at the bottom of the worst examples of simulator programs that were discovered during this study effort.

In several cases the simulator manufacturer has been supplied with an experienced pilot to attempt to get the simulator to fly like the airplane in the absence of a good data package. This has been successfully accomplished when the project pilot supplied is an experienced test pilot and where he has access to the aircraft being simulated so that he can alternate actual flight with simulator testing. The ability to continue to fly the actual aircraft regularly is essential to the maintenance of an adequate comparison base and from time to time to investigate a particular phenomenon. This procedure has been attempted utilizing pilots who have not been trained to perform test work. The results have not been satisfactory.

The main drawback of this approach is that the simulator manufacturer may not learn of fairly significant problems until quite late in the program, a very expensive situation. In addition, it ties up a test pilot, an airplane, a simulator and a simulator design team for an extended period of time, which is also very expensive. Unless great care is exercised, the adjustments to correct current problems may mask serious simulator problems that will emerge in later use of the simulator.

It was universally agreed that a good data specification, if enforced, would go a long way towards solving the problems. Enforcement, "clout," was repeatedly pointed out to be essential. In this regard the Government procurement activities are in the best position to apply any pressures necessary to achieve a satisfactory solution of any data problems. It was also stated to be preferable for the Government to obtain the data and then deliver it to the simulator manufacturer. Being a subcontractor to the WS prime completely deprives the simulator manufacturer of "clout" to obtain data and other services they might require. Because of this the simulator manufacturers, with one exception, stated a preference to be direct contractors to the Government and not subcontractors to the weapon system prime. The one exception is a WS prime contractor who also is a simulator contractor.

It was determined beyond question that the situation can be improved vastly by including a proper simulator data specification in aircraft prime contracts and enforcing timely compliance with it.

In the present situation each simulator manufacturer must make his own arrangements for obtaining an adequate data package. Just how thorough and accurate this package must be hence its cost is not known until acceptance testing. As a result, the simulator proposal must contain a cost figure which is at best an estimate. For example, in a recent procurement the WS manufacturer was quoting one million dollars for a simulator data package. Inclusion of such a data cost would have placed a simulator manufacturer in a poor competitive position hence he must estimate what is a competitive cost and trust that he can obtain a good enough data package to get by at that figure.

Nearly everyone was emphatic in their statements that this was not a good business relationship. One man (not a company) wanted the situation to continue on the grounds that he felt that his personal contacts were better than anyone else's hence he had a competitive edge in the present situation.

What the simulator manufacturers would like is for the Government to collect the data package in one place. When an RFP is contemplated announce the fact and send all manufacturers who qualify for the RFP a list of the data collected and an invitation to review the data package. Have the competition based on that data package, which will be delivered to the winning contractor, and have all simulator specifications referenced to that data baseline. Of course provisions will have to be made for updating this data package at intervals, preferably not more than two, while the simulator is being developed.

All parties pointed out that regardless of how perfect the specification and resulting data package may be it would still be necessary to have consultation with the engineers who prepared the data in order to understand the package well enough to develop a simulator from it. Consultation may also prove to be fruitful as the simulator design begins to firm up. This was desired to be attained as an individual problem since the capabilities of the various simulator manufacturers differ hence the amount of consultation each may require in order to understand and employ a given data package is different. Such differences in capability are proper sound business competitive factors and would receive recognition in costing (as opposed to personal contacts for back door information).

The simulator manufacturers would also like to have a project pilot (test pilot) and project crewmembers designated early in the program to provide qualitative guidance from time to time in the early phase of development and to provide both qualitative and quantitative guidance as the simulator progresses to where it can be operated. The contributions of a qualified team making regular visits would greatly aid the development of an acceptable simulator since the comments can be incorporated into the design early in the program. This is far better than waiting until the simulator is ready for acceptance testing when the comments can only be accommodated by trimming or adjustments which may not be adequate in all cases, or by expensive and time-consuming redesign. Several cases were brought out in which trimming of a simulator was performed to correct one problem and the simulator accepted without discovering that this adjustment had severely degraded the fidelity of the simulation in some other area. Since there is extensive interaction between the various equations of motion which affect the various coefficients (most coefficients are partial derivatives), the trimming process will never be satisfactory unless the mathematical model in the simulator correctly reflects the true aircraft equations of motion, all the various parameters and coefficients are very close to the true values and the adjustments are kept to minor changes and are made with a thorough understanding of the effect this change will have on other handling qualities throughout the entire flight envelope. After each such adjustment to the coefficients in the equations of motion a trained test pilot would have to evaluate the simulator to assure that other flying qualities are still satisfactory.

Making a simulator duplicate the performance of an aircraft throughout its entire flight envelope as well as beyond the envelope and during abnormal operation is very demanding on a data package as well as requiring very expensive hardware and software in the simulator.

The means of specifying accuracy as a percent of the value of a function becomes meaningless as the function gets very small but some people insist on trying to meet it. The specification should state a basic error or percent of a function, whichever is greater. It was also pointed out that whereas not all portions of the envelope and of abnormal operation are of the same importance to all simulators they are treated as if they were in many specifications with a consequently more complex and costly simulator.

Several problems have arisen in the past where the aircraft manufacturer did not believe that the simulator manufacturer needed data to the detail he requested hence was very reluctant to supply it. In almost every case the simulator manufacturer was requesting fine grain detail in order to obtain fidelity in simulation of malfunctions. This is being approached by making mathematical models of each subsystem then combining them in a system model. Failures or degradation of performance of any subsystem can then be duplicated and the result on system performance determined with good fidelity. This is an expensive approach which is required to meet a literal interpretation of current requirements. It requires an excessive amount of expensive data and results in a tremendous amount of unusable capability. For example, one simulator manufacturer estimated that it would take a full year of two shifts, seven days a week operation of one of his aircraft simulators just to run through all of the failures his simulator could duplicate. It is apparent that considerable savings could be realized in this area by only simulating a few of the most important failures (e.g., 25) and implementing the pilot's cues of these impending failures, abnormal operation or failures, from the instructors station.

All manufacturers consider that the instructor's stations is the real key to the training system. It can be simplified in most cases, and be made in modular form with the majority of the modules standardized, which would result in a considerable reduction in acquisition cost and a far greater reduction in life cycle costs, including instructor training. Instructor station decisions are dictated by the training objectives and must lead any simulator design.

The various companies estimated reductions in the acquisition cost of simulators that could be realized by specifying the high fidelity of replication of handling characteristics and mission equipment over only that portion of the total flight envelope that is important to success of the mission instead of the entire envelope, and by allowing the same spread of accuracy of the parameters in the simulator that would be encountered in a production lot of aircraft. Savings can also be realized by providing incipient and actual malfunctions cues under instructor control and only for the limited number of malfunctions for which the pilot can and should take remedial action in flight, and by standardizing major portions of instructor stations and associated interfaces. The estimated savings range from 15 percent for the flight envelope only to 40 percent for the entire package.

B. Avionics and Display System Discussion

All the general problems discussed for the aircraft portion of the simulators also apply to the avionics and display subsystems. In addition these subsystems have some unique problems.

The newer weapon systems, represented by the F-16 and DAIS, have onboard computers which operate as a central processing station for many displays and operational equipments. These systems present vastly different demands than older off-line computer systems such as the A-7D. The sensors make inputs to the central computer (processor) which performs the preprogrammed or commanded operations on this data and generates the data that will appear on the pilot's display. Target acquisition, navigation, ECM, aircraft performance and similar subsystems all make inputs to the computer and accept commands only from it. The outputs are displays of prioritized targets, aimpoints, steering orders, weapon launch computations, threat evaluations, present position, etc. The ways the inputs are manipulated to determine certain outputs are controlled by tactical tapes. To date each tape has taken about one year to prepare and debug and they are issued on a frequency of greater than one per year. If the simulator manufacturer does not use these tapes directly, including automatic translation, it will probably take him about one year after a tactical tape is issued to transpose the information to his tape and debug it. Since automatic translation efforts are reported to be unsuccessful and not likely to be useable, the simulator will never be able to be representative of the tactical aircraft, and the process is extremely expensive. It was unanimously stated that simulators must be able to use tactical flight tapes with minor editing to delete unnecessary routines.

A straightforward solution would be to utilize the onboard computer in the simulator, or utilize a non-flight qualified machine which could use the tactical tapes. The first situation results in expensive hardware and some computational speed problems which can be overcome by simulator design. The second approach presents the Air Force with a limited number of special systems to support, thereby creating a logistic problem which could prove to be far the most expensive. A requirement to [illegible] computer [illegible] the same functions in the simulator it performs in the aircraft appears to be the best approach to the tactical tape problem. The simulator manufacturer would then have to determine means to functionally simulate sensors and other computer input sources so that the proper stimulations can be presented to the control processor. There is a good possibility for commonality in the sensor functional simulations due to the Air Force program to standardize sensor output interfaces.

The newer weapon systems have special sensors to detect threats. Preparation of mathematical models to synthesize these sensors requires access to intelligence level data. This presents a clearance problem which can be solved. The residual problem of where to go to get the required data and how to extract the data once the proper repository is identified is a difficult problem. The various agencies that collect the required data each have their own repository and documentation method. Since there is no one central agency that collects all the required data and since the data detail is scenario dependent (even for the same threats) the problem is indeed formidable.

The first step is identification of the sources of data which is a Government responsibility. The Kilting file that NSA used to maintain was a good start. It should be expanded down to the level of a name, organization and phone number for each type of data. Preferably the data would be pulled together by a single man or source for the Government who would also be responsible for sorting, resolving conflicts, etc. to generate a data package the Government will "buy-off." This must be accomplished by the simulator design baseline, two to four months after contract award. If this is not done the expanded Kilting file would be required by the simulator manufacturer with the Government acquisition activity utilizing every opportunity to expedite the necessary clearances. It is expected that certain data, for example antenna scan patterns, will not be in the data bank. In such a case the Government will either have to obtain the data or accept the contractor's best estimate.

In these types of systems the training information must often be extracted from quite subtle changes in visual or aural presentations. Not

[illegible]

C. [illegible] System

[illegible] covering the steady state performance of the engine [illegible] test stand [illegible] available at the time the simulator contract [illegible]. No problems in this area, including ground starting data, were [illegible]. This is not the case for installed performance data, air starts, instrument lags [illegible] on power level changes and similar dynamic data. Much [illegible] information is either inaccurate or has not been generated or recorded. [illegible] to rationalize running air start evaluations early in the [illegible] program of a new single engine fighter for example.

In order to lend fidelity to their malfunction simulations, the simulator manufacturers attempt to construct a math model of each subsystem [illegible] a propulsion system and then to combine these models into the complete system by a master math model. The detail required to accomplish this has from time to time resulted in difficulty in obtaining the needed data from engine manufacturers for various reasons, generally considered to be caused by proprietary considerations.

D. Data Requirements Schedule

It is universally recognized that data to the accuracy finally required would not normally be available when the simulator development contract was awarded. Working to data in the proper format but possibly of lesser accuracy, for example wind tunnel data instead of flight test data, is [illegible] schedules as shown in Figures [illegible] and [illegible] these are generally [illegible] of the development [illegible] of a full mission simulator, of a part task flight trainer and of an [illegible] part task trainer.

For a weapon system full mission simulator, a [illegible] description of the system, the operation of the system, the mission(s) to the level presented in dash one manuals and drawings of the crew stations are required in order to respond to the RFP. At least one conference with the aircraft prime contractor to assist in understanding the system and to arrange for required consultation, availability of parts, and data availability schedules (as necessary to round out the RFP data package) will be required prior to submission of the proposal. This data will suffice through the award, about five months (15% of total time) into the program. At this time a complete initial data package with breakdown manufacturing drawings of the crew station area to permit the ordering of hardware components, aerodynamic data, performance data, and a functional block diagram of the onboard systems is required. All of this should be the best data available which is assumed to be estimated data not yet verified by test data. By PDR, 10 months ARO, a complete data package consisting of everything requested in the data specification all to the best accuracy available is required. [illegible] estimated data which has generally been revised to reflect the results of the wind tunnel and similar level system tests. The acceptance test procedure should be written to reflect this data package and the updates of it received by CDR, 17 months ARO. At this time the ATP should be approved, the data package frozen and the simulator built and tested accordingly. Although the data package was frozen at CDR it is still possible to incorporate the results of flight test on handling qualities and performance during the contractor's evaluation period which is intended as a debugging and trimming period to make the simulator meet the specification. During this period the assistance of a qualified test pilot and a flight test engineer who are familiar with the subject aircraft would be invaluable. They can quickly assist in determining not only what is wrong but also probably why it is wrong and where corrections should be made. At the end of this period the formal acceptance testing will be initiated, 26 months ARO, to verify by flying a previously

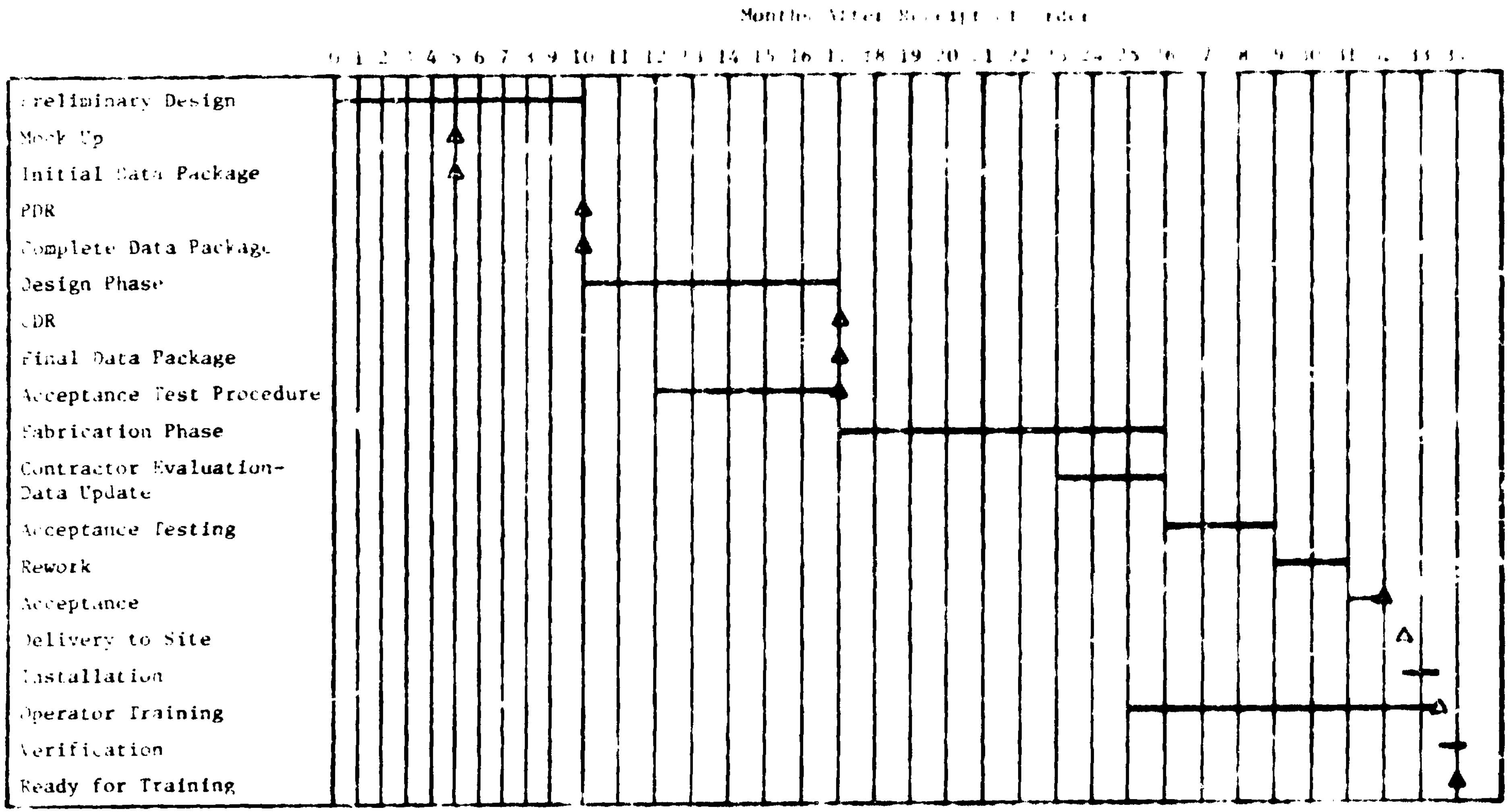

Months After Receipt of Order
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
Preliminary Design
Mock Up
Initial Data Package
PDR
Complete Data Package
Design Phase
CDR
Final Data Package
Acceptance Test Procedure
Fabrication Phase
Contractor Evaluation-
Data Update
Acceptance Testing
Rework
Acceptance
Delivery to Site
Installation
Operator Training
Verification
Ready for Training

Figure 1.

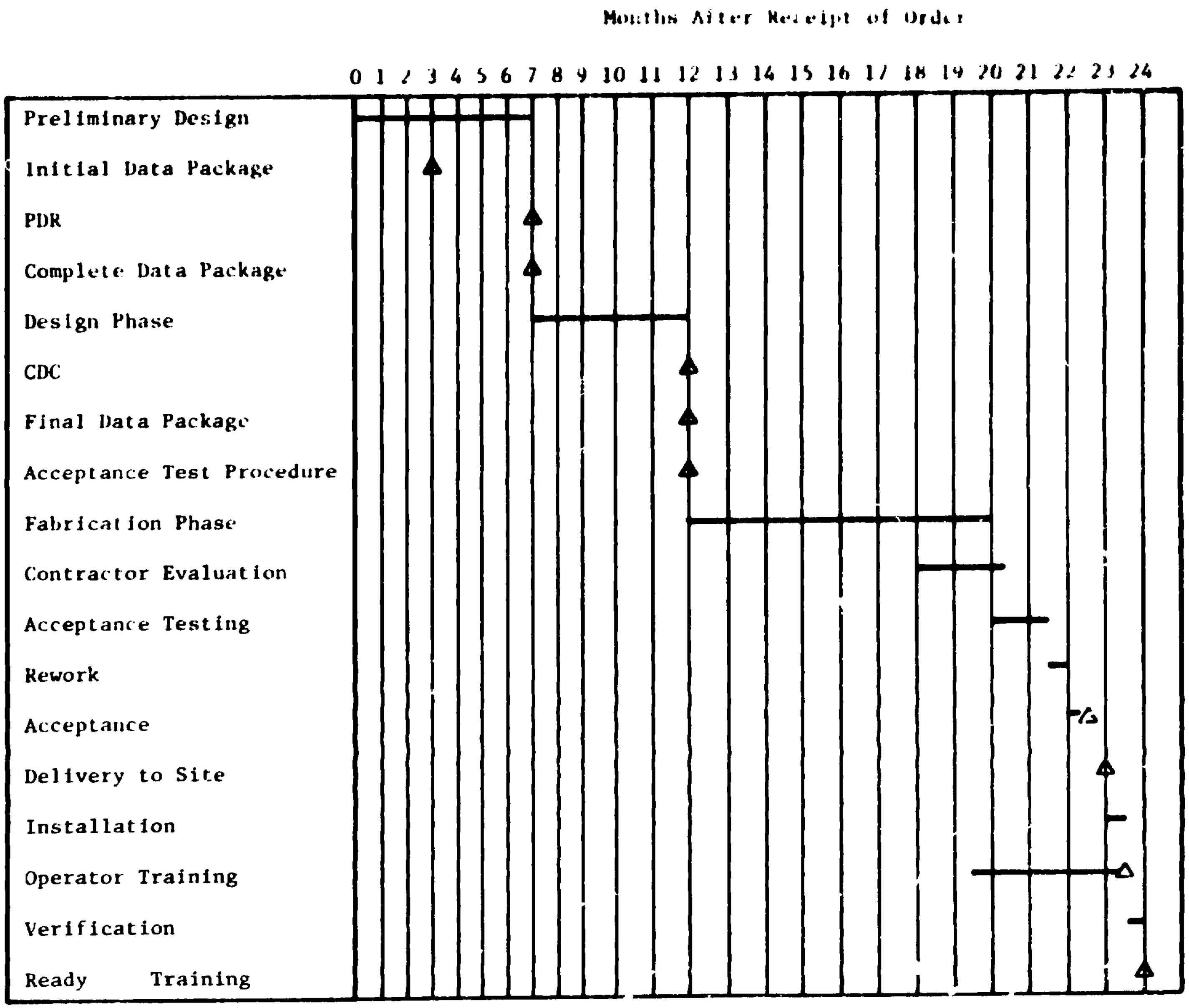


Figure 2. Requested Schedule for a Part Task Flight Trainer - Simple Aircraft

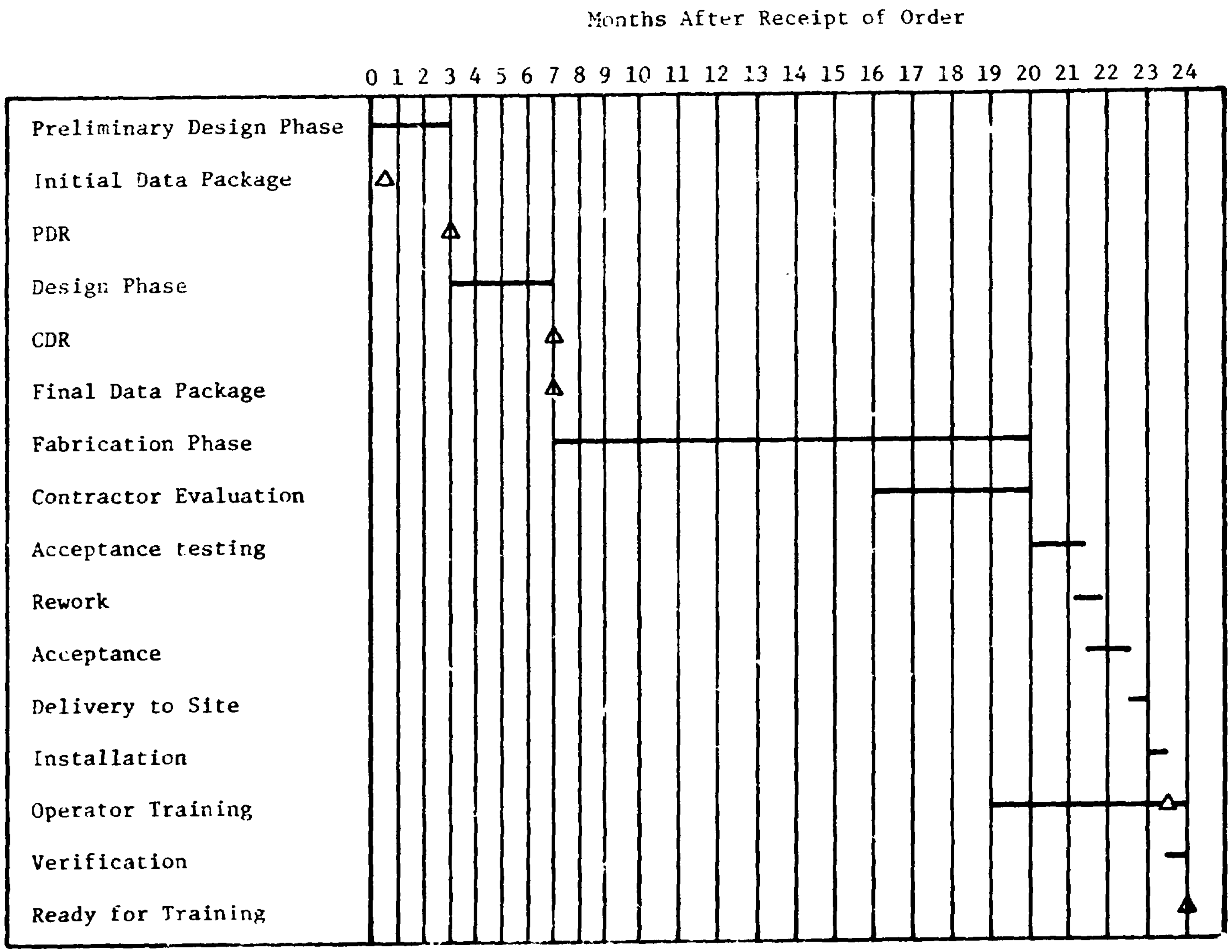


Figure 3. Requested Schedule for a Part Task Trainer (EW)

approved test procedure (ATP) that the simulator does in fact satisfy th specification and is suitable for service use.

A long span is shown for operator training. It is not intended that operator training would extend full time over that period rather that operators (and maintenance personnel) would be trained and utilized as part of ATP and other operations from time to time during that span of time.

Not all flight trainers are full mission trainers. Some will concentrate on only a portion of the mission (for example instrument flight) which will result in a greatly simplified trainer since only the systems used for that portion of the mission need be simulated accurately. Some latitude could also be given in the amount of the flight envelope to be accurately simulated without any reduction in the accuracy required over the portions of interest. A trainer of this type would have a development schedule typified by Figure 2. The data packages are as previously described for the full mission simulator, however, only those systems to be simulated need to be covered. The data package is therefore smaller and required on a tighter schedule as shown with the initial package, three months ARO, the complete package at seven months and the final package at 12 months with actual aircraft test data being incorporated between the 18th and 20th months. Although the data package is less voluminous the reduced schedule will in many instances make this more demanding than the schedule shown in Figure 1.

The last trainer data schedule presented is for a part task trainer for electronic warfare, Figure 3.

A clear statement of the training objective and general information on kinds, type, number, displays and controls, crew station layout and tactical doctrine is required well before the RFP. These data are required in order to "size" the task. These data must be augmented if necessary and approved at a contract kick-off meeting immediately after award. The accumulation of data is a continuous process from then until CDR, seven months ARO. By PDR the threats (number, type disposition), the approach to simulating the threat, the approach to the equipments (simulate or use actual equipment) and a complete layout of the crew station will have been completed, three months ARO. The final data package will have to be received and approved by CDR. This involves many decisions based on judgment for which an experience "user expert" assigned to the program team would be invaluable. For some equipments this data package should contain aural and video recordings of the equipment in operation if the equipment is in service.

During the contractor's evaluation phase the effects of anomalies, unusual responses, etc. will be incorporated into the simulation (stimulation) in order to make the simulator capable of realistic training of a mission capable EWO.

E. Acceptance Test Procedure

The acceptance test procedure is perhaps the most important single document in the entire simulator data regime. It is the document which governs the activity which determines whether or not the simulator is satisfactory for delivery. For the contractor it determines final payments on the contract; for the procuring activity it determines whether or not they will have a satisfied user command.

A great many problems have centered around the ATP in the past. In general these are caused by writing the ATP around a data package that is different from the one that has been approved as the basis for the design of the simulator. The simulator is then tested to this later data. Whether or not the simulator passes these tests is a measure of how accurately the approved data package represented the real air weapon system and not of how accurately the contractor has duplicated a system represented by the data package. The simulator contractor should not be considered a party to the creation of the data package, even though he had to procure it from the weapon system prime contractor, since he was constrained to procure what the prime had prepared (recorded, etc.) on another Government contract and not to conduct tests, etc. to ascertain the validity of that data or to procure any needed additional data. It was unaminously stated that changes which result from testing to later data or from clauses such as "or any other thing" should be at Government expense. There appears to be no advantage of the present system which in effect says "build a simulator to a data baseline but if the acceptance test team does not like--change it."

Better business relationships would result by requiring that the ATP be prepared to reflect the data package supplied, that the tolerances specified be the same as allowed for a production lot of aircraft and that the simulator test procedure be flown exactly according to the test procedure. This will establish whether or not the simulator contractor has fulfilled the terms of the contract and will verify the performance of the simulator to the math model based on the approved data package. All the changes resulting from this qualitative evaluation would be "within scope" changes. The other portion of the procedure is to validate the data package (math model) to the aircraft. This is the portion that has not been performed in a timely fashion in the past. The greatest difficulty has arisen from the lack of flight test data in time to incorporate it into the simulator. (The simulator manufacturers state that often the first time they see any flight test data is during acceptance testing.) It is considered that changes resulting from an incorrect data package are "out of scope" changes or at least questionable. By mixing both portions of the procedure into one acceptance test activity is patently undesirable.

If enough emphasis is placed on obtaining the required aerodynamic, flight control, weight and balance, and iner data early in the flight test program it would be possible to have this data, including flight measured derivatives, to the simulator manufacturer in time to use it in the contractor's evaluation program. Unless the original data package were grossly in error it is doubted if incorporation of this data into the simulator at this time would result in additional costs to the program. With the changes incorporated to bring the data package to the aircraft it is now possible to conduct a formal acceptance test which is for the purpose of verifying that the simulator is like the aircraft in those areas where it is supposed to be as specified in the contract which is reflected in the ATP.

If for some reason it is not possible to update the data package to reflect flight test or equivalent system data by the start of contractor debugging then it would be advantageous to go through the ATP based on the specified data package solely and update to the aircraft at a later time. In no case should the two efforts be mixed into a single formal evaluation period.

3. DATA REQUIREMENTS

A. Data Precedence

It is recognized that all the data required will generally not all be available in the most accurate version at the time the initial data package is required. Provision must therefore be made for updating the initial data package as data based on more accurate sources become available. The various data sources on which the simulator data packages could be based are listed below in order of desirability.

Aerodynamic (Handling Qualities and Performance)

1. Flight Tests
2. Wind Tunnel Tests
3. Theoretical Estimation

Aircraft Systems

1. Flight Tests for Requirement
2. Hot Bench Mock Up
3. Component Tests and Specifications
4. Theoretical Estimation

Avionic Systems

1. Flight Tests (where display or aural responses are involved)
2. Hot Bench Mock Up
3. Component Tests and Specifications
4. Theoretical Estimation

Propulsion Systems

1. Flight Test
2. Tests in Installation Mock Up
3. Bare Test Stand Data
4. Theoretical Estimations

Weight, Balance and Inertia

1. Tests of Actual Aircraft
2. Theoretical Estimations

Crew Stations

1. Formally released drawings supplemented by photographs of actual aircraft
2. Preliminary drawings supplemented by photographs of mock ups or illustrations

Ground Operations

1. Taxi Tests
2. Component Tests
3. Theoretical Estimations

Although the simulator design can get started with data of lower precedence it must have all data items based on precedence one sources. Trainers would only need that portion of the data applicable to the part task they address from precedence one and can use data from lower precedence sources in other areas.

B. Aerodynamic Data

This data is desired in the form of derivatives for the standard handling qualities and curves for the various performance parameters. It is very important to have an understanding of the deviation of the data that would be anticipated in a reasonably large lot of production aircraft so that the curves can be made into bands and the inevitable compromises necessary in the simulator's math model be made with the guidance of staying within that realistic spread of data.

C. Aircraft Systems - Non-Avionics

The data for these systems should initially consist of an engineering description of each system which will define the system, how it works, and the performance specifications. This will suffice for planning the approach to simulation and the initial efforts on the program. Before designing the simulation, a functional block diagram as well as schematics and wiring diagrams, diagrams, etc. will be required. It is essential that the transfer function for each block as well as the end to end system be given so that the system dynamics can be determined. All instrument or indicator readings for normal and abnormal operations should be provided.

D. Avionics Systems

The same data is required for avionics systems as for the aircraft systems plus these additional items.

Systems that present information in the form of displays or audio signals in the crewmember's headset require that these presentations eventually be video and audio recordings.

Some new aircraft have avionic and other mission equipment integrated through a central digital computer or computer complex hence have unique problems since the computer software determines how the system responds to various stimuli. The computer is programmed by loading tactical tapes. It is essential that complete details of the central computer, its programming and tactical tape content be understood by the simulator manufacturer.

E. Propulsion System

(1) Turbojet and Turbofan Engines

It is desired to be able to prepare math models of the various subsystems of the propulsion system as well as a system model to bring all of the subsystems together as a propulsion system. Engine installed performance data consisting of thrust, fuel flow, instrument readings, etc. for steady state conditions at increments of altitude throughout the entire envelope of the aircraft is required as well as information as to how to correct this data for nonstandard conditions. Dynamic performance, response to sudden power level movement, acceleration time histories, deceleration time histories, windmilling rpm vs dynamic head, air starts and ground starts are required for both the normal and emergency control systems.

The moment of inertia of the compressor about its axis of rotation is desired. Descriptions of the indications of the most likely malfunctions, the proper corrective action, the response to corrective action and the consequences of a failure to take timely corrective action are required.

(2) Turboprop Engines

In general the engine data required is the same as for a turbojet except that the simulation has been made more difficult by the addition of a reduction gear, propellor, a propellor governing and feathering system.

A complete description of the propellor, blade, activity factor, governor and feathering system is required. The rate of change of propellor blade angle when under normal governor control and during feathering is required. The windmilling rpm vs blade angle vs dynamic head vs time for various blade angle settings is required.

A vital function is the time delay of the automatic and back up feathering systems and the build in drag during this period as well as any control or other surface blanking effects.

F. Weight, Balance and Inertia

The weight and three first movements and six second moments of the empty aircraft and all items capable of being loaded, consumed, moved or dropped in flight are required.

G. Maximum Values

The maximum values of acceleration, speed, altitude and other performance items is required in tabular form for use in scaling these factors in the computer.

4. SUMMARY OF PROBLEM AREAS - SIMULATOR MANUFACTURER'S VIEWPOINT

The major problem revolves around the lack of correlation between what the data provided defines as the aircraft, the actual aircraft and the attempt to marry the two in the acceptance testing process.

The management attitude of some aircraft prime contractors respecting simulator data is reflected by the assignment to the data supply job of anyone who is available rather than only one who is qualified (in one case it was treated as a piece of AGE). This attitude also results in keeping the simulator engineers at arm's length from the aircraft (or any major subsystem) engineers and is the major problem in obtaining the basic calculated data to the same level of accuracy as the prime contractor has it. The major missing data concerns ground handling and ground effects. In general the prime con-contractor does not have the required data.

Flight test (or equivalent level system tests) covering the breadth of items the simulator manufacturer needs has not been available to the simulator contractors in time to be of use in the design and preliminary checkout of the simulator.

The excessive number of malfunctions included and the insistence on performing in abnormal operation with the same accuracy as in normal operation is a major cost problem. How far to go into the abnormal flight region, for example how many turns of a spin, is not well defined. Inclusion of numerous malfunctions with high fidelity is extremely expensive.

The data to define performance in emergency situations, for example the engine response during air starts, is extremely limited. The requirement for accuracy of response in these situations is questioned.

Design of the instructor's station is a completely different ball game from designing a simulator. This gets into the philosophy of training, the task load breakdown between the instructor and automation and a whole series of considerations which must be decided before the simulator design can be commenced. Often this is not done, which then becomes a serious simulator design problem. The total data package must very definitively pin down the design of the instructor's station.

The use of aircraft instruments is sometimes specified. This causes a whole series of serious problems from reliability (really short life) to the lack of internal detailed congruence between instruments that have the same part number and are interchangeable in the aircraft. The reason for the problem is that detailed voltages, etc. have to be picked off (or supplied) to use the instrument in a simulator, whereas these voltages are not used discretely in the aircraft. Since interchangeability is not controlled to that detailed level it is the rule, rather than the exception, that when the same instrument is procured from more than one source they will not be interchangeable for simulator use.

5. ASSESSMENT OF THE DATA REQUIREMENTS

All of the data requests are valid and reasonable if the simulator manufacturer is to perform to the level required by current simulator contracts. Since the data for all simulators (trainers) of lesser complexity than a full mission simulator are included in the data required for it, the further discussion will concentrate on procurement of that one complete data package from which all other data packages can be derived as required. The remaining surveys and analyses were conducted accordingly.

SECTION III

DETERMINATION OF DATA AVAILABILITY

The data required by the simulator manufacturers must be generated by the aircraft manufacturers, engine manufacturers, vendors to these contractors, other Government contractors (GFE) or Government activities. The data stated to be required by all the simulator manufacturers was consistent, therefore it was pulled together as a consensus opinion and a survey of the possible sources for this data undertaken to determine (1) is the requested data available, (2) if it is available what is the schedule, (3) what is the accuracy of the estimated and windtunnel (laboratory) based data relative to flight test results, (4) to whom would they prefer or demand to deliver the data, and (5) the answers to all other questions raised by the simulator manufacturers.

1. AIRCRAFT MANUFACTURERS SURVEY

The consolidated data desires expressed by the simulator manufacturers were arranged by aircraft subsystem or equivalent and documented as the "Aircraft Simulator Data Requirements Study--Air Weapon System Prime Contractor Questionnaire," Appendix B. A list of air weapon system prime contractors was prepared from the answers received to the Aeronautical Systems Division's letter of 25 November 1975 which has been discussed previously. The list was modified to ensure that all required sources were visited and that it included the aircraft manufacturers who had worked with the simulator manufacturers on the projects for which comments had been received. It was also determined that an engine manufacturer should be added to the list. This resulted in the survey list shown in Table 2.

Both the proposed questionnaire and the proposed composition of the survey sample were reviewed with the Program Monitor and other Air Force representatives at a program review of 15 July 1976. Both items were approved, accordingly; the survey was undertaken as planned. As in the case of the simulator manufacturers, the letter of transmittal of the [illegible] requested that the questions be answered and the answers [illegible]

TABLE 2
SURVEY LIST

AIRCRAFT MANUFACTURERS	
Boeing Commercial Airplane Division	B-1 avionics Commercial aircraft EWACS
Douglas Aircraft Company	Commercial aircraft
General Dynamics	F-16 F-111
Grumman Aerospace	F-14 (also EF11A simulator)
Lockheed Georgia Company	C-5A C-130
McDonnell Aircraft Company	F-4 F-15
Northrop Aircraft Division	T-38 F-5 F-18 data system International market
Vought Corporation	A-7D International market
AVIONICS MANUFACTURER	
Hughes Aircraft Company	Large complex system (F-14) - central computer control Avionics systems - no computer control Individual sensors
ENGINE MANUFACTURER	
General Electric Company	
GOVERNMENT ACTIVITIES	
Simulator Acquisition	
U.S. Air Force, Simulator System Program Office, Aeronautical Systems Division	
U.S. Navy, Naval Training Equipment Center	
Test Activities	
U.S. Air Force, Flight Test Center, Flight Test Division	
U.S. Naval Air Test Center	

of the survey team. No questionnaire was submitted to the Government activities, since they were being visited to obtain guidance and overall assessment rather than answers to specific questions.

All planned visits were accomplished except the one to McDonnell Aircraft Company. They were unable to either answer the questionnaire or spend a day with the interview team during the possible survey period. It as considered that an adequate coverage of the aircraft primes representing a wide enough cross section of aircraft types was available in the remainder of the list so the survey was conducted as planned omitting that company. Excellent cooperation and an open discussion of th problems was enjoyed by the interview team in all their visits.

2. RESULTS OF AIRCRAFT MANUFACTURER'S SURVEY

A. General Discussion

General comments concerning the availability of data and other simulator problem areas are presented in this paragraph from the point of view of the aircraft manufacturers. In later paragraphs the comments on specific types of data are submitted. In general there was excellent agreement in the answers received. Where there were dissenting opinions in the answers both opinions are reported along with our opinion as to the basis for the different answers if one could be discovered.

One manufacturer made a statement which is an excellent summary of what was found to be the unaminous attitude of the group visited: "We do not like to give out the details of our aircraft that are required for the developmen of a simulator but we recognize that this is a requirement of doing business so we go along with it." That does not mean, however, that they will give out anything the simulator manufacturer asks for or that they will give the same level of data to every manufacturer.

All the aircraft companies have data reduction and detailed performance [illegible] procedures, for example base drag estimation, [illegible] on their own funds and which they consider to be proprietary. These data they will not give out. They are perfectly willing to give out the results of their calculations, for example drag data, but not the details of how they went about calculating it. In their opinion the simulator manufacturer does not need that backup data anyway.

All companies agreed that most of the data required to build a simulator is or was available during the development of the aircraft hence it could have been supplied with little or no additional effort had it been ordered at the time the aircraft was ordered into development. The one exception is the upgrading of aerodynamic and other system data as a result of flight tests. In all cases these data are only reduced and put into coefficient or similar format that a simulator could use if they concern a contract guarantee point or if trouble is being experienced in some area. For example, lift and drag data is vital to the contract guarantees of a commercial transport. For these parameters, the initial estimated data is constantly updated throughout the development cycle of the aircraft including flight tests. Very little of the other data is updated unless a problem is encountered and then only that data that bears on the problem. It was found that the military aircraft manufacturers followed an identical procedure except that the critical parameter they follow would vary from design to design. Producing an update of the simulator data package based on flight test results would entail additional effort, hence costs, in the weapon system prime contract. All contractors are well equipped to perform this service if requested to do so however.

If the data is not ordered when the aircraft is ordered into development, the aircraft manufacturer will, in fact must in a competitive environment, order from his vendors only that data required by him to build the aircraft and supply the aircraft data requirements. Similarly, in his own engineering department he will only prepare in report format that data he needs for his own use or for his CDRL requirements. Much of the lower detail data does not become formalized in the normal course of business although it was generated in order to prepare some report. This is often the very data the simulator manufacturer needs in order to prepare his mathematical model. When the simulator data package is ordered a year or two later it is necessary for the aircraft contractor to go back and resurrect this detail data and possibly expand on it, change the format, etc. This can be a very expensive effort due to personnel changes, disruption of the engineering department, etc. The costs may appear, on the surface, to be way out of line compared to the data delivered and the point of view "you needed this to build the airplane." The same situation exists in all the vendor plants with the added problem that since there is no other source for the data the suppliers are in an extremely strong negotiating position (as are the primes with respect to the Government) which tends to make the data cost much more than it would have in a competitive environment. The necessity to define and order the data in the initial aircraft acquisition contract was very strongly emphasized.

Parts of the data package are the design details of various controls, levers, pedals, panels, etc. that are in the cockpit or crew station and must be in the simulator. Many of these components are long lead time items. If they are not ordered until after a simulator contract is awarded and the successful contractor has had time to digest the data package and place them on order, it is almost assured that many components cannot be supplied until after the required simulator delivery date. The suggested solution is to order a few of these probable simulator items in the initial aircraft order and have them scheduled for early delivery. If, for some reason, they are not required for the simulator, they can be cycled back into production, delivered as spares or a combination of both. The configuration consideration is probably of little or no concern for the types of components involved.

Throughout the survey of the simulator manufacturers and during the visits to the Government activities the statement was repeatedly heard that aircraft manufacturers would not give the same detailed data to simulator manufacturers who were part of a competing aircraft company as they would those who had no such corporate ties. It was found that all the aircraft manufacturers who have current or recent development programs have a very firm position supporting that contention. They absolutely will not give drag and similar detailed data to a direct competitor. In one case they did give such data to a simulator contractor who was a division of a competing corporation but it was done only in consideration of the fact that the divisions were half a continent apart, that an ironclad legal agreement to protect the data was executed and that the chairman of the board of the simulator coprcration pledged his personal assurance that there would be no data leakage. Were the two divisions in the same complex or within commuting distance, the opinion was expressed that these arrangements would not have been adequate and probably that the data would not have been supplied under any conditions. None of the companies expressed any serious concern about supplying data to simulator manufacturers who have no corporate ties to aircraft manufacturers. All that is required in this case is the execution of an agreement between the parties to protect proprietary data. No cases of a violation of such an agreement were known to those being interviewed, which supported their opinion that this procedure would continue to be viable in the future.

Two companies who do not now have aircraft development contracts nor who have any specific near term future prospects stated that they would have no reservation to releasing the data to any simulator manufacturer. It is doubtful if either of them would express the same willingness if they had a new aircraft development contract or were top contenders for any specific near term development contract.

Questions were pursued to determine if there was any preference as to whether the data package was delivered to the Government or directly to the simulator manufacturer. All respondees expressed a complete willingness to deliver the data to the Government with the majority expressing a slight preference for that approach. One manufacturer stated that he would not deliver data directly to a simulator manufacturer; rather, he would insist on delivering it at least through his local Government representative. The reasoning behind this very strong objection was stated to be based on a proper business relationship with the WS customer and possible legal involvement should the package be delivered direct to the simulator manufacturer and later prove to be defective. The business relationship portion of the position is clearly evident. It would appear that terms of the contract under which the data were procured rather than the method of delivery would govern responsibility for accuracy.

All the people surveyed were in agreement on the desirability of putting a simulator data requirement specification in the WS contract, and scheduling the delivery of data with aircraft development milestones. They all also pointed out that direct engineer to engineer contacts would be required in addition to the best possible data package in order to transmit adequate guidance to enable the simulator engineer to understand and use the data. They also all expressed the opinion that they could be of considerable service to the simulator development by having their engineers and pilots review the simulation as an early part of the debugging and trimming effort, prior to the start of acceptance testing. They also agree that having a properly qualified simulator engineer on-site in their plant is a great aid in getting the data interface off to a good start, at least the first two or three months of the program.

All contacts were in agreement that the desire to have a simulator on-site at the operating squadron's location and in operation before the first production aircraft arrived requires ordering the simulator before final data has been determined for the aircraft. This requires a submission of a complete initial data package based on the best data available at the time, usually wind tunnel verified aerodynamic and performance data, calculated data for systems and detailed configuration layouts and follow this with updates as required. No problem is envisioned in keeping the data package current with engineering changes that are released against the aircraft if a good procedure is established at the start of the program and maintained. It was pointed out that this must continue throughout the service life of the aircraft. There was considerable difference of opinion as to what was the best system. In general the primes did not want to accept the responsibility for determining whether a given change did or did not affect the simulator because they did not have the required detailed knowledge as to how the simulator manufacturer had utilized the various data items supplied in his design. They would prefer to check a block, "simulator possibly affected," and have the Government or simulator manufacturer determine whether or not the simulator is affected.

(1) Data Accuracy

The subject of the accuracy of the various types of data developed a group of consistent general answers and a wide variation of detailed quantitative estimates as did a discussion of the data accuracy requirement.

In general it was agreed that for many parameters data derived from flight test (or equivalent systems full scale tests) are required for simulators. For many other parameters the estimated data should be accurate enough. It was also pointed out that the flight test data is not as accurate as the fidelity with which simulator specifications require that the data be matched, therefore the very tight simulator specifications are a waste of money.

The question of setting the simulator tolerance to at least the variation of the various parameters over a production lot of aircraft was not opposed; however, it was repeatedly pointed out that these tolerances would have to be merely estimates since to obtain measured data would require instrumenting and testing a considerable number of aircraft. This expense could never be justified since regardless of how perfect the data package and the specification may be it will still be necessary to make final trimming adjustments based on "flight" tests of the simulator.

Some companies expressed the opinion that due to the limitations that must be placed on simulators it is doubted if a "full mission simulator" is a realizable objective. The reasoning was that adequate flight fidelity, cues, etc. could only be generated for a small portion of the mission, for example air-to-ground weapon delivery, with other "part task trainers" to cover other portions of the mission that are suitable for synthesis. The reasoning was that the added computer capacity to be able to do all of these in any one simulator was unrealistically expensive hence excessive compromises would be required.

The estimates of the accuracy of various types of data, compared to flight test data, which were received are presented below.

For the prototype (fly before buy) case: Aerodynamic propulsion and all non-avionic systems data can be extrapolated from the prototype flight test data to represent the production aircraft with an error of less than five percent. Avionics experience may be applicable to the production configuration but generally it would not.

For the new development case - aerodynamic data: In the case where the new aircraft is a normal progression of designs the manufacturer has previously carried through full scale development, the agreement between estimated and wind tunnel data should be very good and within the ranges as follows:

Large, standard, subsonic aircraft

Derivatives, 5-10 percent

Base "0" values, 5-10 percent

From time to time a calculated parameter may be off 30-40 percent, even though it was previously estimated with excellent success.

High performance, supersonic aircraft

Derivatives, 5-10 percent

"0" values, 20-30 percent

The number of parameters that may exhibit large error is greater than for the previous case and the errors on these could go to 40-50 percent.

For very new concepts such as a lifting body the calculated values cannot be relied on for errors of less than 40 percent, although wind tunnel data is reasonably good, 10-20 percent, for the derivatives.

(2) Government Furnished Equipment

Aircraft manufacturers point out that they have only the data that they need on GFE and are not in a position to supply the simulator manufacturers a data package covering such equipment. The Government procuring activity for such equipment will have to ensure that the required simulator data [illegible]

[illegible]

C. Aerodynamic and Performance Data

For the basic airplane there is no problem anticipated in supplying the derivatives, coefficients, maximum values and other handling and performance data requested based on estimated or wind tunnel supported data. This should be a combination of curves and tabulated data. Going to all tabulated data is possible but not recommended due to the volume of the data and the difficulty in communicating all the necessary background to understand that data. There is a problem in delivering an explanation of the methodology by which certain of the data were derived or massaged and this background will not be given to the simulator manufacturer as previously discussed. Also, as previously pointed out, most of these data are not updated as a result of flight test. Such updating will result in additional, though minimal, costs if the requirement is included in the basic aircraft development contract.

Some of the external store data requested, the incremental effects of dropping one item at a time, presents a considerable problem. Due to the sheer magnitude of the numbers of combinations, aircraft are designed and tested with standard configurations of external stores. Incremental effects are not tested either in the wind tunnel or in flight test. Obtaining this data based on other than theoretical estimates would be an extremely time-consuming and expensive process and is therefore not recommended. Estimated data of the effects on flying qualities of the standard configurations can be updated by wind tunnel and flight test data.

D. System Data

There is no problem anticipated in supplying the required data on all the aircraft's basic systems. The tactical systems in the newer aircraft present a unique problem.

In the newer high performance types the various sensors, controls and displays talk to each other through an onboard digital computer and in many cases the transmission is multiplexed onto a single circuit. There is no way to simulate this system without building a functional equivalent with simulations of the sensors to stimulate the central processor (computer). The flight hardware may as well be used.

How this system responds to certain inputs is controlled by tactical tapes which are changed from time to time in the service aircraft and in reality reconfigure the aircraft. Since these tape programs are quite time consuming to prepare and debug, it is essential that the simulator use the tactical tapes. The manufacturer then has three choices as to how to go in selecting the simulator's "onboard" computer, i.e., use the one in the aircraft, emulate the aircraft's computer or attempt to simulate the entire system on a general purpose machine. The aircraft manufacturers estimate that using the actual computer is 2 to 1 less costly than emulation (non-flight qualified equivalent hardware) and orders of magnitude less costly than the general purpose hardware approach.

If use of the onboard computer is specified then the data requirements reduce to a physical and wiring schematic of all controls, indicators and displays, copies of the tactical tapes applicable to the tail number of the aircraft being simulated and transfer functions to determine the dynamic inputs the various sensors will make to the computer in response to commands from the computer, external simulus or malfunctions.

Mathematical models that describe the output of the various sensors are well understood and can be readily obtained from the sensor manufacturers. They could be optimized for simulation application (primarily programming) and probably standardized so that little new effort will be required for successive applications.

All of this system data will initially be estimates based on the specification performance of the several components properly combined. The major data update, except for system configuration changes, will be as a result of full scale "hot mockup" tests. For most subsystems this will be the most accurate data to be obtained. A few of the subsystems will require flight test data to finally pin down their performance. All companies prepare formal engineering reports on each system and these are [illegible] with test reports from tests such as the "hot mockup." These reports should contain everything the simulator manufacturer ne ds and will be supplied.

Supplying the visual and aural recordings should present no problem. Some preliminary visual recordings could be made, displays, etc., utilizing the "hot mockup." The really useful data can only result from flight tests and can be obtained at any time after the first few flights of the fully equipped tactical airplane.

(1) Vendor Data

Much of the required subsystem data will be developed by vendors of the aircraft prime contractor. A number of the details of these items usually have been developed by the vendor on his own funds and probably will not be divulged. There is no problem anticipated in obtaining functionally equivalent data however.

Fr time to time the simulator manufacturer will desire to go directly to the vendor for information. All of the aircraft primes (with one exception) object (some rather strongly) to this procedure. They want the simulator manufacturer to come to them with the data (or conference) requirement and let them make any necessary meeting arrangements. Of course if proprietary data becomes involved there probably will have to be an agreement executed between the simulator manufacturer and the vendor to provide for the protecti of data.

(2) Propulsion Data

As for all systems, very detailed engineering reports are prepared on the propulsi system and supplemented as later test data becomes available. These would satisfy all of the simulator manufacturer's requests except for a math model of the engine and its various subsections. The aircraft manufacturer has no requirement for such data and suggests it be obtained directly from the engine manufacturer.

There was no reluctance discovered concerning the supply of math models of engines on the part of engine manufacturers. In fact, a very detailed math model is supplied to the Government for each new engine design. The problem with these models is that they account for so many variables that the simulator manufacturer cannot afford the computer capacity they require nor the computation time. Nearly all the past efforts with simulator manufacturers have been devoted to accuracy versus computer requirements trade-offs to produce an acceptable compromise. Several companies expressed the opinion that a simplified and possibly standard engine model should be developed. The model could provide for the adjustments the various installations would require.

E. Flight Test Data

Aircraft are instrumented and tests conducted to extend the flight envelope to its full specification value and to obtain the demonstration points data required by the contract. In general very little data is taken in the middle of the flight envelope. It would be a simple matter to record data in this area if it is ordered.

There are two approaches to obtaining the required aerodynamic data from flight tests. The first is to perform classical flight test maneuvers (control pulses for example) at the various points throughout the envelope. The second is to apply special algorithms to the reduction of other currently required flight test data to derive the desired coefficients. Neither approach requires any significant increase in the current flight test data acquisition effort. An increase in the flight test data reduction efforts needed for the basic aircraft would be necessary, however, the total aircraft plus simulator data costs should be decreased by routinely reducing the flight test data to update estimated aerodynamic and performance coefficients.

F. Data Availability Schedule

As previously pointed out it was assumed that in most cases it would be necessary to supply an initial data package then institute a procedure for keeping the data package current with the aircraft as the data is developed. If the initial package is delivered too soon the recipient will be swamped with detailed changes as the aircraft is developed. For a new development aircraft it is considered to be undesirable to deliver the initial package until after completion of the critical design review and mock up inspection milestones. These will be completed normally between 50-60 percent of the elapsed time from go-ahead to first flight or from 15 to 18 months into the program. This package will contain data based on wind tunnel tests with some system bench test data, however, most of the systems data will be estimated data. The configuration, cockpit arrangement and similar data in this package can be formally released drawings and supplemented with photographs of the crew stations, instrument panel, side panels and similar essential details.

Although the simulator manufacturer should be kept informed of all configuration, layout, indicator and similar changes as they occur, the first update of the data package should be submitted at the release of the aircraft for first flight, 27 to 30 months after contract go ahead. This package may have minor refinements of the aerodynamic and performance data. Primarily it will contain all the engineering reports of the tests of all the aircraft and avionics systems individually and as integrated into the "hot mockup" and the preliminary tactical tape used in the tests. It will represent the best system data that will generally be obtained.

The last data package should consist of aerodynamic, performance, propulsion, visual and aural recordings and other final system data based on flight test results. This package should also contain a copy of the tactical tape to be used during the acceptance testing period. The availability of this data package revision except for aerodynamic and performance data can be delivered between 50 and 60 percent of the elasped span of the flight test program, 6-9 months after start of flight tests or for the typical schedule assumed (F-15), 36 to 39 months after award. The estimates of the AC manufacturers as to the update of aerodynamic and performance data based on flight test results were all given in months after completion of flight tests which varied from 5 to 8 months which would 41 to 44 months after contract award. More importantly, it is one year before the training equipment is required to be in place at the Tactical Air Command. Although this schedule would support the simulator schedule, an alternate and more rapid method is discussed in Section 4.2.

G. Summary of Problem Areas, Aircraft Manufacturers Viewpoint

The aircraft manufacturers consolidated opinion is that there are no problems with aircraft simulator data that cannot be solved by straightforward sound business procedures incorporating the following actions:

1. Define the data to be supplied.
2. Order the required data in the initial aircraft contract.
3. Schedule the data delivery to be consistent with the aircraft development milestones.
4. Assign a high enough priority to the data to give it a proper place in the employment of assets.
5. Require that each respondee to the simulator RFP submit an executed agreement for the protection of proprietary data with the aircraft prime and identified key vendors to ensure that data of this nature will be exchanged properly.

Although not a data problem, serious consideration should be given to ordering a few long lead time crew station controls and furnishings, which will normally be requested by the simulator manufacturer in the initial aircraft production release to assure availability of the simulator need schedules.

SECTION IV

SURVEY OF GOVERNMENT ACTIVITIES

1. ACQUISITION ACTIVITIES

The United States Air Force, Aeronautical Systems Division, Simulator Program Office and the Naval Training Equipment Center, Orlando, Florida, were visited to receive their assessment of the situation and their guidance.

The information obtained from both of these activities is in complete agreement and is summarized in this paragraph.

Although both activities have for some time been making the acquisition of the aircraft data package the responsibility of the simulator manufacturer, the results have not been entirely satisfactory. In view of the increased emphasis being place on training and maintenance of readiness through simulation it is believed that the Government should assume the responsibility for obtaining the data package required for the development of a simulator. To this end they consider the development of a proper data specification to be incorporated in future aircraft acquisition contracts to be a vital first step. Trends in simulator development were inquired into so that the data requirements could be developed to be compatible with the future needs. This developed the guidance that the study should address the requirements for a current full mission simulator which would produce a specification which would yield a data package adequate for any of the foreseeable future needs. Full cooperation with the study effort was pledged and received throughout the study.

2. FLIGHT TEST ACTIVITIES

Visits were made to the United States Air Force, Air Force Systems Command, Flight Test Center at Edwards AFB, California, and to the United States Navy, Naval Air Test Center, Patuxent River, Maryland, to obtain information as to what data normally will be available during flight tests, what additional data could be made available relatively easily and to discuss their experiences in trying to obtain adequate fidelity in flight simulators.

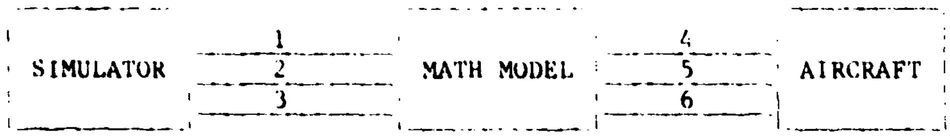
A. Air Force Flight Test Center

The Flight Test Center frequently makes engineering simulations of important flight test projects in their Flight Test Engineering Technology Branch supported by the Flying Qualities Branch. In the future they would like to make a full engineering simulation of each new aircraft undergoing flight test and reduce aerodynamic parameters and performance characteristics during the course of the flight test. They are now in a position where they believe that they can produce a complete set of flying qualities parameters from flight test data as well as a map of performance characteristics within five months after the start of the Air Force/contractor flight test program. This could be done without delay of the normal flight test program if integrated with the flying qualities tests currently required. If not integrated these data can normally be obtained in three flights with six flights as the maximum. Changing the flying qualities specification to include the derivatives would save considerable time since the required tests would extend the flight test data acquisition time very little (about 25 seconds after trimming).

In working with simulators in the past it has been found that in many cases the poor performance of a simulator gets blamed on the aerodynamic data when the culprit really is the inertia and weight data (calculated data is often in error as much at 30%) or an inadequate representation of the equations of motion in the simulator.

In order to check out a simulator for acceptance an expanded step by step procedure as presented herein is recommended. Basically it consists of ensuring that the math model correctly describes the aircraft and then determining that the simulation accurately reproduces the math model. Much of this effort can and should be performed at various times throughout the simulator development cycle leading up to formal acceptance testing, really formal demonstration of a simulator that has already been determined to be acceptable.

Figure 4 is a block diagram of the suggested checkoutout procedure.



1. EQUATIONS OF MOTION. The performance of the simulator in reproducing handling qualities and performance is determined. This is done by comparing the time history response to specific standard inputs generated by the simulator with those generated by a fully verified digital program. The programs utilized by AFFTC to accomplish these tests are available to Government simulator activities on request.

2. AERODYNAMIC DATA (SIMULATOR). Aerodynamic data must be smoothed and the correctness of the data actually programmed into the computer must be verified. As a minimum generate set of plots from the simulation cards or tape to check for keypunch errors.

3. FLIGHT CONTROL SYSTEM (SIMULATOR). Some of the basic aerodynamic checks discussed should be made with the flight control system turned off, even if that is not possible in flight. The FCS must pass both static and dynamic tests. End to end static checks to verify system gains, forces and displacements are straightforward. Dynamic checks of a digital system are more difficult. Comparing time histories generated by the simulator with those of a verified program is a possibility for making this check.

The above steps should verify that the simulator with its math model can reproduce the aircraft if proper inputs are provided.

4. AERODYNAMICS DATA (AIRCRAFT). It is essential to have the proper derivatives programmed in the computer. Accomplishing this by pilot testing and adjustment is not entirely satisfactory. Every attempt should be made to procure flight measured derivatives for programming the simulator.

5. FLIGHT CONTROL SYSTEM (AIRCRAFT). Schematics with components and their transfer functions have not proven to be accurate enough for simulator use. The end to end transfer function of the actual aircraft hardware should be measured and programmed into the simulator.

6. WEIGHT AND BALANCE. It is highly desirable to measure the various inertias of the aircraft, particularly in roll, as well as determine other weight and balance data by full scale aircraft tests since calculated data has proven to be insufficiently accurate for good simulation performance.

Figure 4. Block Diagram of Suggested Checkout Procedure

(1) "Time Compression"

A phenomenon of "time compression" has been observed by AFFTC which could have a very significant impact on simulator design.

It has been observed that when faced with a time critical heavy task load, a pilot can accomplish a greater number of tasks in a simulator in a given span of time than he can in the actual aircraft. The difference between the two performances varies with the severity of the task loading, (the heavier the load the greater the difference) and has been observed to be as high as 40 percent. It was found, for example, that pilots who could regularly complete all the tasks on a flight card, for a tightly time constrained test such as a lifting body drop, in the simulator would only be able to complete 60 percent of the card in actual flight. The same phenomenon was found in RPV drop tests when comparing the performance during practice in the simulator with results obtained when controlling the actual drops.

If this phenomenon exists generally then some account of it will have to be taken in training simulators when very time demanding evolutions, such as low altitude target conversion and weapon delivery, are involved. AFFTC does not have enough data to make this determination at this time.

B. Naval Air Test Center

The simulator problems observed by NATC engineers were stated to be the result of:

1. Inaccurate or incomplete data supplied to the simulator contractor.
2. Mistakes in interpreting and implementing the data supplied.
3. Timing problems with the simulator response (most pronounced with a visual system and tends to cause pilot induced oscillations).
4. Control force system inaccuracies (improper feel).

These design problems are supplemented by errors introduced due to improper maintenance and can result in gross flight system errors.

Corrections to these problems will be pursued by supplying the simulator manufacturer with the necessary NATC published and unpublished test reports supplemented with flight test engineer and test pilot support throughout the program.

The Navy has a number of Navy preliminary evaluations during the testing of an aircraft and before it is delivered for formal Navy flight tests. It is planned to follow the same procedure with simulators to help spot flaws early in the development program. A team of flight test engineers and test pilots would conduct a series of NPEs scheduling the first as soon as the simulator was flyable. The purpose of these would be to help the manufacturer define his problems and the preferred solutions. The formal acceptance testing will therefore become a demonstration program.

The need for a periodic certification of simulators in service was strongly pointed out. Some routine method and requirement for performing this needs to be established. Perhaps adding simulator fidelity to a unit's annual operational readiness inspection would be an adequate requirement. A source of qualified test pilots and flight test engineers to aid the commands and perform the inspections is also necessary. Probably the Service Flight Test Centers are the best sources for this assistance. NATC has, at the request of user commands, performed required modifications to simulators in the field to improve fidelity with excellent results. From time to time it was necessary to determine some data in the actual aircraft to supplement the flight test data that in some cases was several years old. Simple, hand held instrumentation has been found to be adequate to accomplish this.

SECTION V

DISCUSSION AND RECOMMENDATIONS

1. DATA ACQUISITION SYSTEM

This study indicates that the data required for the development of simulators can be supplied on time and at minimum cost if the data is ordered in the initial aircraft contract, and the Government Flight Test Facilities are utilized to assist in the process. The initial package should be scheduled for delivery after CDR (the later the better) with provision made for updating it as better data becomes available. The supply of simulator data must be emphasized in the contract and by the Aircraft SPO in order to make any system work.

It is recommended that the simulator data package procured from the aircraft prime contractor be comprehensive enough to support development of a full mission simulator unless a positive determination can be made that no such simulator will ever be developed during the life of the aircraft. Data packages can be defined from this master package and duplicates provided to support simulators and trainers of less complexity.

The precedence order of the various classes of data is data derived from the following:

Aerodynamics

1. Flight tests
2. Wind tunnel tests
3. Theoretical estimations

Propulsion

1. Flight tests
2. Test data in installation mock up
3. Bare test stand data
4. Theoretical estimations

Crew stations

1. Formally released drawings supplemented by photographs of actual aircraft
2. Preliminary drawings supplemented by photographs of mock ups.

Aircraft systems

1. Flight tests (timing)
2. Hot bench mock up (transfer functions)
3. Component tests
4. Theroetical estimations

Avionics systems

1. Flight test (video and audio recordings)
2. Hot bench mock up
3. Component tests
4. Theoretical estimations

Ground operation

1. Taxi tests
2. Components tests
3. Theoretical estimations

Weight, balance, and inertias

1. Tests of actual aircraft
2. Theoretical estimations

It is recommended that the initial data package consist of the highest precedent data available when it is submitted. The aircraft prime contractors data requirements will not, however, be completed until all classes of data ordered from him are based on information of precedence number 1.

The aircraft manufacturer can supply all the data needed except for Government furnished equipment. It is necessary for the Government to obtain the required data from their GFE suppliers in those procurement documents. The aircraft manufacturer will have to describe any modifications to the GFE or modifications to its performance caused by his installation (for example engine installation loses) as part of his package.

An alternative to the aircraft manufacturer for the supply of flight test derived handling qualities derivatives and performance parameters exists in the Government Flight Test Centers. It is desirable for them to prepare an engineering simulation of each major flight test project regardless of simulator requirements. The question then is whether or not to have them or the aircraft contractor responsible for deriving handling quality derivatives and performance parameters based on flight test results. Since the Government Flight Test activity will work with every new aircraft and an aircraft manufacturer only with his own designs, it is logical to assume that greater learning and advancement in the techniques would result from requiring that these data be supplied on every new design by the Government Flight Test activity conducting the aircraft tests. It would also appear to be in the best interest of the program to schedule the acquisition of the flight test data required for simulators early in the flight test program. This would permit the training equipment to be in place to support the arrival of the first aircraft to the first operational user.

The Government Flight Test activity is in an excellent position to assist the simulator manufacturer in the early debugging of the simulator by the supply of a flight test engineer and qualified test pilot to perform informal assistance evaluations. This would supplement, and in general come later in the program than, the assistance the simulator manufacturer would procure from the aircraft prime by direct contract.

It is recommended that AFFTC be tasked to perform the required data reductions, simulations and validations and perform the update of the data package with flight test derived handling quality derivates and performance parameters. To avoid duplication the aircraft prime would not be tasked to update these functions beyond data based on wind tunnel results.

It is recommended that the Government have the initial data package delivered to them, as well as all updates, by the aircraft prime contractor. The prime contractor should deliver, as part of the data package, an accession list of the data in the package and of supporting data, including unpublished data, they may have to augment it. This list should be updated with each data update.

It is further recommended that the Government announce the intended simulator procurement in the Commerce Business Daily well in advance of the RFP. Each respondee to this announcement who has been selected to receive the RFP should be notified of the availability of the data package for review prior to the release of the RFP, given a copy of the accession list, a[illegible] rmed that the data package will be delivered to the winning [illegible]tractor. They should also be informed that each will have to obtain any additional data or technical support he requires direct from the prime contractor and the proposal will require evidence of an agreement with the prime contractor for the protection of proprietary data and the supply of the desired additional data.

After the simulator manufacturer is selected the data package should continue to be updated for higher precedence data, or for any changes, until the simulator is delivered.

It is recommended that the simulator SPO be included in the review of all procurement contracts for GFE or replacement stock items that have indicators, displays or controls located at crew stations in order to ensure that adequate simulator data requirements are included in the procurement package.

The final data system recommendation is that the simulator data package and the acquisition of flight test data for the derivation of handling qualities and performance simulator inputs be placed at a high enough priority to ensure compliance so that the aircraft and training equipment can both be delivered to the user commands on schedule. A concurrency plan to prohibit the aircraft from moving to the next milestone (for example prohibit the acceptance of an aircraft) until the simulator data package is delivered is recommended to achieve schedule compliance.

2. PROCUREMENT OF PARTS

It is recommended that the aircraft prime contractor prepare a list of long lead time crew station detailed parts, controls and furnishings normally required to be in a simulator and that enough of these be placed on order and scheduled for delivery early in the aircraft production contract to cover the first year of simulator production. These parts must be to the configuration applicable to the specific tail number airplane being simulated of course. This will support the simulator lead time so that a "buy" decision for these parts is practical. The terms of purchase should provide for phasing these parts back into the production line if not required for delivery to the simulator manufacturer by a specific date.

SECTION VI

RECOMMENDATIONS FOR FURTHER STUDY

The information reported by the Air Force Flight Test Center concerning "time compression" is of vital concern to the design of some part task and all tactical full mission simulators. It is recommended that a study be undertaken to define this problem so that simulators can be developed to accommodate it.

It is recommended that mission analyses, which will cut across the ISD efforts of the various commands and address the total training mission of the Air Force as well as the various commands, be undertaken to determine training requirements, and synthesize instructional systems to provide optimal service-wide solutions to these requirements. This will define the family of training devices required, including the required performance of each type. Simulator specifications could then be confidently based on this foundation.

It is recommended that a study of commonality of subsystems of simulators be undertaken. The instructor's station is a function of training objective rather than simulator design and lends itself to a standard modular design approach. Simulation of sensors to provide the input to an onboard computer is another area in which it appears that commonality could be achieved.

It is recommended that further studies of the accuracy of simulation required to achieve the phased training objectives of the user commands be undertaken. These should be cost versus performance trade-off design studies. Major questions having a very large potential impact on data requirements and simulator cost involve accuracy of replication of the aircraft characteristics as related to the flight envelope of the aircraft, motion base requirements and visual subsystem requirements.

It is recommended that a study be undertaken of the reasons why previous simulators have not been utilized to a greater portion of their capability. The study should not only define the reasons for low utilization but develop recommended corrections to the objections and also develop an educational and motivational program to be conducted in the user commands to motivate the instructors, line pilots and commanders in the employment of simulators.

A study of the various approaches to ensure continued fidelity of simulators in the field is recommended. This study should involve the user commands and AFLC and result in a standard scheduled procedure to be implemented to accomplish this vital function.

A study of cost versus effectiveness of simulator maintenance methods is recommended. The results of this study may impact data requirement and could define additional technical training requirements.

APPENDIX A

AIRCRAFT SIMULATOR MANUFACTURERS QUESTIONNAIRE

The purpose of this questionnaire is to gather information concerning aircraft simulator data requirements to be used in a study having the objective of devising better ways to satisfy those requirements. The design data required, its accuracy, format and schedule, is the information desired. Also desired is your experience on past contracts in obtaining the required data and how any problems were solved. Experiences where no problems were encountered in obtaining data are equally important.

Since it is considered that your data requirements will vary considerably (even for the same type of data) for the various classes of simulators, this questionnaire requests that answers be broken down into a section for each of the three basic classes: full mission, flight, and part task trainers.

One of the study objectives is to make appropriate recommendations for improvements in the acquisition cycle. This is why the questionnaire starts with pre-proposal activity and carries on through the full material life cycle. Any recommendations for acquisition process improvements are welcomed. This is also why the scheduling of data requirements in elasped time is stressed and why your estimates of the optimal elapsed time for the several phases of the simulator development cycle have been requested.

For purposes of this analysis the simulator acquisition process has been broken down into phases and tasks as shown below, and the questionnaire organized accordingly.

ACQUISITION PROCESS
PHASES

CONCEPTUAL	DEVELOPMENT	PRODUCTION	OPERATIONAL
PHASE	PHASE	PHASE	PHASE

Please answer the following questions for each type of simulator with which you have experience. Please be candid. Your comments will not be related to your company in any report. Please have your response prepared by the time of arrival of the interview team or within two weeks of receipt, whichever is earlier.

FULL MISSION SIMULATOR

Please answer the following general questions for each phase/functional area as applicable.

What data do you need, what format (coefficients, etc.) and on what schedule? What accuracy is required? Is this data generated by aircraft manufacturers (including flight test) to this accuracy for other requirements or is it unique to simulator requirements? If the data you require is not available on the schedule you have specified, would it be possible to utilize data of less accuracy (other format) now if the full accuracy data were made available later? If so, please define the interim data (for example, engineering estimates vs flight test data) and the revised schedule for receipt of the full requirement.

What has been your experience in obtaining the data of the types defined in response to the above question? Has it been readily available, required extraction, or not recorded at all? How many meetings, over what period of time, and about how much expense was involved in obtaining the required data?

What, in your opinion, is the basic cause of any problems encountered?

What impact has data availability had on the quality of proposals or the performance, delivery or cost of simulators?

In your experience, what have been the major criticisms of simulators as realistic substitutes for actual flight training and what data would be required to overcome these limitations or objections?

The following topical outline is submitted with the request that your answers be arranged accordingly as an aid to collation in a later task of the study.

PRE-PROPOSAL TASK - CONCEPTUAL PHASE

<u>Mission considerations</u>

Scenario

Profiles

Tactics

<u>Weapon system considerations</u>

Performance

Crew station layout

Armament

Avionics

<u>Simulation or training objectives</u>

PROPOSAL TASK - CONCEPTUAL PHASE

<u>Mission definition</u>

Profiles

Targets

Threats

Tactics

<u>Weapons system definition</u>

Armament

Avionics

Crew stations layout anf furnishing

Crewmember task loadings

Aircraft abd oiwer okabt oerfirnabce data

Simulator requirements

Aural simulations

Crew stations

Displays and operable equipment

Environment

Flight envelope and maneuvers

Scanning area

Instructor stations - emergencies

Mission phases (T.O., cruise, search, weapon delivery, etc.)

Mission situations (threats, targets, etc.)

Motion

Power plant

Visual subsystem

Referenced specifications and standards

Source of detailed data for use after award

SOURCE SELECTION TASK - CONCEPTUAL PHASE

It is assumed that there are no manufacturer technical data requirements during this Government-conducted task.

ALL TASKS - DEVELOPMENT PHASE

Aerodynamic performance

Clean airplane--steady state, accelerated flight, full envelope, boundary effects.

Change in performance (flying qualities) with CG shift, gross weight, flap position, slat position, gear extension, speed brake position, buffet, Mach no.

Effects of altitude

Effects of external stores

Effects when exceeding flight envelopes

Maneuvering effects, flight controls, engine performance, etc.

Stall and post-stall effects

Avionics

Armament monitor and control

Communications

Electronic warfare

Homing

Identification

Intercommunications

Navigation

Sensors

Weapon delivery

Crew stations

Controls, monitors, instruments, display and warning (caution) indicators.

Detailed layout, furnishings and adjustments

Ejection system

Environmental control system

Life support system

Lighting

Aural environment due to vibration, wind, system operations, power plant, brakes, touchdown, alarms, etc.

Electrical system

Bus logic

Cockpit controls and indicators

Emergencies

Flight controls

AFCS operation

Control loading and feel throughout envelope--various configurations--normal and emergency systems.

Control loading beyond envelope and all abnormalities

Power plant

Trim system

Flaps and slats

Arresting gear

Landing gear

Speed brakes

Fuel system

Cockpit controls and indicators

In-flight refuel procedures

Internal transfer procedures

Emergencies

Ground handling

Brakes

Nose wheel (or other) steering

Motion due to taxiway roughness (pitching)

Hydraulic system (and pneumatic system)

- Controls and indicators
- Load/demand characteristics
- Pump-accumulator performance
- Emergency procedures

Instructor station

- Communication with student, tactical simulation, tutorial controls: emergencies, instrument readings, mission situation.
- Monitors of crew performance--hard copy

Missions

- Gaming area--size--features--dynamics
- Tactics
- Targets
- Threats
- Weapons and weapon delivery modes

Motion

- Requirements

Power plant performance and controls

- Before start
- Engine start
- Ground operations, response, fuel consumption
- Flight operations, response, thrust, fuel consumption, temperature, altitude and maneuver effects
- Emergencies

Visual system

- Collimation
- FOV
- Light conditions
- Resolution
- Scene content
- Weather effects

FABRICATION AND QUALITY TEST TASK - DEVELOPMENT PHASE

What are the problems with acceptance test procedures?

Is the AC performance data to which the simulator is compared in these tests available on time?

PRODUCTION AND OPERATIONAL PHASES

What are the problems in keeping the simulator configuration current with the aircraft configuration?

FLIGHT TRAINERS

Use the same qeustions and acquisition cycle phase breakdown as before and arrange answers using the applicable portions of the outline presented for the full mission simulator. Identify the type of flight simulators (instrument training, operational procedure, etc.) for which your answers are intended.

PART TASK TRAINERS

Pick a cockpit procedure, navigation, electronic warfare or other PTT with which you have had experience and answer the same questions using applicable portions of the full mission simulator outline as before. If your answers are applicable to more than one type, please so state. If you feel that more than one answer is required to present the experiences you have had, please submit as many replies as you desire.

APPENDIX B

AIRCRAFT SIMULATOR DATA REQUIREMENTS STUDY - AIR WEAPON SYSTEM PRIME CONTRACTOR QUESTIONNAIRE

The purpose of this questionnaire is to determine the availability of the data that simulator contractors need to develop simulators that duplicate the instrument indications, control forces, etc. of the actual aircraft within tolerances acceptable for production units of that aircraft.

Since it is not practical to dictate the point in the development cycle of the aircraft where the simulator contract will be let, it is necessary to provide for the various possibilities which will range from overlapping development of the simulator and the Weapon System to procurement of a simulator for an out-of-production aircraft. Accordingly, information is desired concerning data in various levels of maturity, i.e., flight test (or equivalent system tests), wind tunnel (or equivalent system mock up), and calculated (estimated) data.

AERODYNAMIC DATA

Taking flight test results as the baseline, what does your experience indicate as the accuracy of aerodynamic coefficients and other parameters derived from wind tunnel data? From calculated data?

When could a complete set of aerodynamic coefficients based on estimated (calculated) values and the functions showing the dependence between applicable coefficients be supplied? Months after award of contract for engineering development of a fighter such as the F-15.

When could this same package be made available based on wind tunnel data?

When could it be made available if based on flight test results?

Do you object to supplying any of these data to simulator manufacturers who do not manufacture aircraft? To those who do? If so, what alternates do you suggest?

AIRCRAFT SYSTEMS - electrical, environmental control, hydraulic, pneumatic, life support, warning, etc.

For each system it is desired to have a description of the system with a functional block diagram along with schematics. The location and function of all circuit breakers (or other protection devices), switches, controls and indicators are needed. The normal readings of all instruments are needed as well as the variations of these readings to be expected with the operation of a connected load, shut down of a pump or other normal operation, malfunction or abnormal system condition. If applicable to the system, load analyses are required as well as the changes in system operation, if any, with airspeed, altitude, engine rpm or other functions.

When could the above data be supplied based on calculated (estimated) data? When based on operating mock up test data? When based on flight test data?

Do you have an alternate data package to suggest?

AIRCRAFT INSTRUMENTS

A description of the instrument power supply systems and which instruments are lost as alternate power supplies are selected. What instrument malfunction indications have been provided? A drawing showing the layout of the instrument panel and panel lighting which is keyed to a list of suppliers and part numbers of all the cockpit instruments and indicators being employed is required. Details of any modifications to standard instruments, such as inactivating one servo of a multi-indication indicator, are required as well as schematic wiring diagrams.

When could an initial data package be supplied? How would you suggest keeping it current for a given tail number of aircraft?

AVIONICS - armament control and release system, communication, navigation, sensors, defensive systems, and onboard computers

Initially a system description including functional block diagrams with all equipment nomenclatures is required. This will have to be expanded to include schematics of the system and the transfer function including schematics and logic of each item of equipment. If this is not releasable for a few items of equipment, such as EW equipments which contain computational capability, functionally equivalent data, appropriately so noted, may be supplied. If an onboard computer is used either centrally or as part of a subsystem, the details of the computer and the programs included will be required.

Details of an avionics systems' controls, indicators, outputs and displays will be required. If an output is an audible signal a high fidelity recording of the signal is desired. If the output is a display, photographs of typical outputs appropriately annotated are required. At a later date a properly narrated flight video tape of the equipments' display is highly desirable for systems (such as sensors) that have a dynamic video display.

It is necessary that the data cover abnormal as well as normal operation. What does a poorly adjusted scope look like for example? What is the effect of actuating switches in an improper sequence? What are the most likely failures and what is the evidence of such failure apparent to the flight crew?

When could an initial data package (estimated data) with sketches instead of photographs) and a final package be supplied?

Would you clear a simulator contractor for visits to your vendors to determine details of equipments being developed for you?

FLIGHT CONTROL SYSTEM - autopilots, automatic stabilization systems, dampers, surface control systems, cockpit controls and artificial fuel systems

A description of the systems supported by functional (signal) flow diagrams, schematics, and transfer functions will be required. Movements of controls as well as applied torques must be capable of being related to the deflections of appropriate surfaces under all normal conditions within and slightly beyond the full flight envelope of the aircraft. The effects on these functions when in an abnormal mode (one generator out for example) is required. All indicator readings are needed for both normal and abnormal operation. What are the backup modes and how does the crew bring them into use? What happends if the procedure to deploy units is incorrect, for example throws switches in the wrong sequence?

When could this data package by supplied based on calculated data? When if based on flight test data?

Are there any data items in these systems which you would be reluctant to supply to another company?

PROPULSION SYSTEM - engine and its auxiliaries, fuel system, oil system

Engine (turbojet engines, turbofan engines). Data to permit a complete analog of the performance of the engine including ground start, taxi, takeoff, the entire speed-altitude regime of the aircraft, and air starts for both normal and abnormal (standby systems only) operating conditions. These data must be such as to correctly time relate the location of the power lever to the indication of all instruments, the fuel flow and the performance of the aircraft for standard conditions, and data for correcting these figures for nonstandard conditions, over the full operating range of the engine and aircraft. The data for correcting test stand data to installed performance data is also required.

The readings of all instruments with their appropriate lags and dynamics to control movement or actuation is needed.

When could estimated data be supplied? When could it be based on mock-up test stand running? When based on flight tests?

When could a high fidelity recording, properly narrated, of the engine sounds at the crew stations be supplied?

Is there any of this data that you would not desire to deliver to another manufacturer?

FUEL SYSTEM

Fuel tankage, a functional diagram of how the system works, and fuel management requirements are needed. All pumps, indicators, switches, etc. must be spelled out and the readings of all indicators as a function of switch position and fuel demand is required for both the primary and emergency fuel systems. In-flight refueling controls and operation should be included.

When could the fuel system data package be supplied if based on estimated data? On flight test data?

OIL SYSTEM

Description of the system and system management along with the indicator readings as a function of engine operation and other variables is needed.

When could this data package be supplied?

PERFORMANCE

A description of the maximum performance envelope of the aircraft in terms of airspeed (limits for each configuration), Mach no., accelerations and rates of climb or dive, altitude, angle of attack and angle of sideslip is required along with a statement of the range of the appropriate values.

A description of boundary conditions such as buffet boundary, stall warning, stall and spin entry are also required for the clean configuration and with various external stores attached.

When could calculated data be supplied? When could the applicable portions of the data be available from flight tests.

PHYSICAL DATA AND CONFIGURATIONS

Dimensional data of the cockpit section forward to the nose of the aircraft is required. Drawings to the lowest level are needed for the cockpit area. Profiles with pilots eye locations are required. Cockpit photographs would be helpful. The part number and supplier of each panel and item in the cockpit (ejection seat, instrument panel, etc.) is desired. In addition to drawings, full scale loft lines including the windshields and canopies is desired.

Dimensional kinematic diagrams and kinematic equations of the flight control system is required including special flight systems such as tabls, bob weights, dampers, etc.

Moments of inertia of the aircraft about each axis and dimensional data of mavable masses (external stores) to permit calculation of moments of interia in any configuration.

Gross weight and center of gravity data and design limits.

V-N diagrams for all the design conditions of flight.

Rates and limits of movement of tabs and controls.

Maximum design values of rates of pitch, yaw, normal acceleration and longitudinal acceleration (both in flight and on the ground) are required.

When in the development cycle of a new airplane can this data package be supplied if based on estimated data? When if based on flight test or other full scale operational test data?

Is there any of this data that you would not give to a simulator manufacturer who did not manufacture aircraft? Would there be if he did compete in the military aircraft market?

DATA FORMAT

It is important that all data be properly annotated as to the conditions under which it was taken, the method of recording, the analysis and reduction methods applied, and the methods used for calculation and estimation for estimated data. Curves which are not supported by the tabular data from which they were drawn are generally not accurate enough for the simulator final data package.

For all data it is desired to have an estimate of the range of values over which it is expected these data items will range due to variations in production aircraft, measurement techniques, etc.

Although much of the required data has not existed in formal reports experience has shown that nearly all data that is required for the initial package exists in the form of engineering working papers, engineering in house reports, engineering memoranda and similar working level informal documentation. These documents, properly annotated, would be very useful for the initial data package.

Having supplied an initial data package it is necessary to keep it current as better data becomes available or changes are made which effect the particular serial number aircraft selected as the baseline for simulation, throughout the service life of the aircraft. Direct engineer to engineer conferences, supply of all drawing mods and supply of all pertinent ECP's to the simulator manufacturer have proven to be effective.

Do you object to supplying any of the data or participating in any of the conferences outlined above? If so, what is your recommended alternative?

Would you prefer to supply the data to the Government pursuant to a CDRL item as opposed to delivering it direct to a selected simulator manufacturer on notification by the Government contracting officer? How about data from your subcontractors?

Assuming that it is determined that an on-site representative is required, would you prefer to have a representative of the simulator manufacturer on-site in your plant or send one of your well qualified engineers to be on-site in the simulator's manufacturer's facility for the purpose of engineer to engineer consultation and gathering additional understanding of the subsystems of the air weapon systems?

SUMMARY

The above covers the types of data which the simulator manufacturers have indicated they need to design and build an adequate aircraft simulator. This, of course, would be detailed were it to be put into a specification. If you have alternate suggestions please be assured that they are earnestly solicited.