

**A PROPOSED USAF FATIGUE EVALUATION PROGRAM BASED
UPON RECENT SYSTEMS' EXPERIENCE**

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SUMMARY

The United States Air Force has published a document entitled, "Aircraft Structural Integrity Program" (ASIP). One phase of the program is concerned with the fatigue life certification of all types of military aircraft. The document describes the criteria, analyses, and tests that are necessary in order to satisfy the USAF fatigue life requirement. The authors have noted that some recent and valid criticism has been directed toward the document, particularly the fatigue-life requirements contained in it. This paper proposes some changes based on surveys conducted in the United States and abroad as well as some recent systems' experience. The surveys covered both military and civilian organizations. The paper contains the fatigue certification case histories of selected military and commercial aircraft. The design development element tests, preproduction design verification tests, and full-scale fatigue tests of each are described. The paper concludes with a brief status report on the revisions to the MIL-A-008860 series specifications.



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INTRODUCTION

In 1965, Miller and Lowndes presented a paper before this group entitled "The U.S. Air Force Weapon Systems Fatigue Certification Program." (See ref. 1.) Their paper described the evolution of the USAF fatigue life requirements up to that time. One section of the paper listed the aircraft which were considered to be the first line systems of the USAF in 1965. These aircraft are as follows:

Fighters	Bombers	Trainers	Transport
F-89	B-47	T-37	C-130
F-100	B-52	T-38	C-133
F-101	B-66		KC-135
F-102			
F-104			
F-105			
F-106			

Of these only the following aircraft were committed to a fatigue evaluation program:

Fighters	Bombers	Trainers	Transport
F-101	B-47	T-37	C-130
F-104	B-52	T-38	C-133
F-105			KC-135
F-106			

Five years later, the first line systems of the USAF are as follows:

Fighters	Bombers	Trainers	Transport
F-100	B-52	T-37	C-130
F-105	FB-111	T-38	KC-135
F-106			C-5
F-4			
F-5			
F-111			
A-37			

Of these currently operational systems, every one except the F-4 has undergone the U.S. Air Force fatigue evaluation program. The F-4 was procured by the U.S. Navy and has not been required to conform to Air Force Aircraft Structural Integrity Program (ASIP). It is also acknowledged that the F-100 although not originally designed or tested under any formal program has required several life extensions. Each one has been approved after additional fatigue testing. It is interesting to note that all aircraft now in our inventory have undergone a fatigue evaluation program of some kind. This statement was not true 5 years ago. With this as an introduction, we wish to expand on the USAF's fatigue evaluation program and how it has changed over the last 5 years.

HISTORY OF STRUCTURAL EVALUATION PROGRAM

1965 to 1968 Period

Figure 1 shows a typical structural evaluation program of the 1965 to 1968 time period. (Also see refs. 2 and 3.) At that time, ASIP required element and component tests, but the number and specimen sizes were left to the contractor's discretion. The static test, flight loads survey, and the first fatigue test were run concurrently. After initial operational capability (IOC) the program called for service-loads determination followed by a second fatigue specimen to be tested to the service-loads spectrum. At that

time, it appeared to be a good plan and the requirements formalizing the program were written as an ASD Technical Report 66-57 "Air Force Structural Integrity Program Requirements," dated January 1968 (ref. 4) and into various specifications and contracts. For those of you who are satisfied with your program now, please note that in 1968 we believed that this program was the best in the world. Events proved us to be wrong.

1968 to Early 1970 Period

In September 1968 the Assistant Secretary of the Air Force for Research and Development, Dr. Flax, requested that a study be performed addressing problems associated with structural test program planning and with scheduling practices. (This study is referred to as the Flax study.) Briefly restated, the action items were

- (a) Examine current Air Force structural test procedures and policies for aircraft in development.
- (b) Assess structural test program scheduling problems.
- (c) Assess past and present structural testing to determine problems or deficiencies in established policies and procedures.
- (d) Provide recommendations to revise present Air Force structural test verification practices and policies, considering proper balance between program risks and costs.

The approach used in the Flax study was to prepare case histories of the then current systems and a number of typical earlier systems on which information was available. Included in the study were such data as original test schedules, the details of static and fatigue tests, actual start and completion of the tests, and the production rates. The case histories were carefully studied to establish trends and to identify problem areas. With these thoughts in mind, let us consider the actual structural program schedules of some of the Air Force aircraft that were used in the study.

The first aircraft is a large transport, the C-141. Figure 2 shows the schedule. The C-141 comes as close as any airplane to fulfilling the total ASIP requirements. It has a static test, structural flight tests, full-scale fatigue tests of two articles, and a life-history recorder program, the data from which are being used for the second fatigue test. Figure 2 refers to fatigue test articles A, B, C, D, and E which are shown pictorially in figure 3.

There were a large number of engineering changes generated by the C-141 fatigue test program. Most of them were incorporated in production but very late in time. You can see that there were essentially no component tests. We did a static test and a flight loads survey almost concurrently as called for by the 1968 ASIP schedule shown earlier, but the fatigue test was very late in starting. We had aircraft out in the operational fleet before we had one lifetime on the fatigue test specimen.

Using hindsight, if we had started the first fatigue test earlier, we would have been able to incorporate the changes into earlier production airframes. Instead, we were unable to get changes into production earlier than the 200th airframe and we only had 285 airframes in the production contract. The fatigue test article had been identified early enough (it was the seventh airframe), but the actual start of the testing slipped because of management considerations. The lesson learned here was an important one. If you have a production airframe, get started on the fatigue test as early as possible.

In order to understand more about how the commercial manufacturers design and build airframes, we will deviate from the Flax study and show you a comparison we made between the C-141 and, with the assistance of the Boeing Company, the Boeing 727. We found that Boeing uses a modified form of ASIP. Boeing does everything that ASIP requires, but not in as much depth or detail as we in the Air Force do. For example, a flight loads survey was conducted on the 727 because the FAA was interested in the T-tail. Otherwise, the survey would not have been flown. Our load survey on the C-141 was very comprehensive.

Let us consider the fatigue tests of the two aircraft. The preparation of the fatigue spectra for the C-141 was complicated by the large number of missions assigned to the aircraft. Low level penetration, air delivery of cargo and wartime training missions had to be included in the spectrum. Therefore, the C-141 required about twice the fatigue test segments needed for the 727. The Boeing 727 has essentially a single logistic mission at altitude.

The way we did our tests compared with the way Boeing performed their fatigue tests is also very interesting. A list of the fatigue test articles for the 727 and the 747 follow:

- 727 and 747 nose landing gear
- Main landing gear
- Airframe
- Wing
- Fuselage
- Vertical tail
- Horizontal tail
- Control surfaces

The horizontal tail was a separate test specimen for the 747. You have already seen those for the C-141 fatigue test specimen in figure 3. We chose to break the airframe up into components so that a failure on one specimen will not cause an interruption to the others. This method is more expensive than the method used by Boeing but it is less risky.

Figure 4 is a direct comparison between the test schedules of the C-141 and the 727. The differences in magnitude of the scope of the tests are significant. Our static test took longer because of down time and a need to retest the wing after uncovering a different load distribution than expected during the flight loads survey. Our fatigue test also took longer because of the multimission requirement of the C-141. The major differences between Boeing tests and the USAF tests are as follows:

13 missions	C-141
1 mission	727
Boeing tests whole structure	
USAF test major components	
Boeing performs modest flight loads survey	
USAF performs full flight loads survey	

Now let us consider another Air Force aircraft test program, that for the F-5 (fig. 5). This program was successful for two reasons: First, the F-5 airframe was essentially the same as that of the T-38 and the Norair N-156 which had undergone an extensive structural evaluation program. Secondly, the items that were changed on the F-5 from the T-38 were tested as components during the design development testing phase of the program. The primary difference between the T-38 and the F-5 was, of course, that the T-38 was a trainer type aircraft designed for the training environment, whereas the F-5 was a fighter type with external stores and tip tanks, leading-edge flaps, and drag chute; the F-5 was also designed for the close ground support fighter environment. This type of redesign readily lends itself to verification of structural adequacy by utilizing small components or element testing. In the development of the F-5, if it had not had the T-38 as a predecessor, the component tests would have been required.

It should be noted that the service-loads—life-history phase was limited on the F-5 evaluation. It started late and was stopped much too early. If a continuous program had been accomplished, the loss of an F-5 at Williams Air Force Base in early 1970 might have been averted. At Williams AFB, training is conducted for Military Assistance Program (MAP) pilots. During this training a large number of 2g to 3g maneuvers are accomplished. The fatigue damage accumulated from this training is much greater than the average damage accumulation and a fatigue crack developed in the center wing lower skin that caused the loss of pilot and aircraft. This fatigue critical area had been detected in the full-scale fatigue test. Had an adequate service-loads or life-history program been in being, the damage accumulation should have been detected and an adequate inspection program could have anticipated the need for repair.

The timing of the full-scale fatigue test also could stand some improvement in that it could have started sooner. Again, the previous T-38 tests along with the F-5 develop-

ment tests minimized the impact of the later start and did allow the use of a truly production configuration for the full-scale fatigue test.

Out of the Flax study came some very significant recommendations:

- (a) Continue early static and fatigue tests
- (b) Emphasize component tests
- (c) Establish firm policy on structural integrity program

(d) Perform cost effectiveness studies during contract definition phase between developmental and production testing and between production build-up and structural retrofit. These recommendations were accepted and we revised our ASIP requirements document ASD TR 66-57 (ref. 5). It was published in May 1970 and many of you are familiar with it.

Now we want to discuss the present ASIP schedule, the one called for by the 1970 version of ASD TR 66-57. Before doing that, let us agree on some definitions of element tests, design-development tests, preproduction design verification tests, and full-scale tests. Element tests involve relatively small parts of the structure, joints, small panels, or stringer to frame splices. These are very small pieces but, as you know, extremely important to the structure. Design development and preproduction design verification tests consist of those tests of materials, structural elements, and structural components performed early in the design phase to provide a realistic basis for the design analysis and major structural ground tests. The design development tests are the most basic and earliest tests and are conducted to establish basic design concepts and configurations such as choice of materials, panel sizes, splices, fittings, etc. Preproduction design verification (PDV) tests are conducted after the design development tests, but prior to the full-scale static and fatigue tests. These tests of full-scale components (wing carry through, wing pivots, horizontal-tail support, etc.) are conducted to provide early design information wherever analytical methods may be inadequate to achieve a high degree of confidence in the strength and fatigue properties of the design. These tests are intended to reveal design "glitches" prior to the full-scale ground tests.

With these thoughts as background, let us consider our present ASIP schedule. It is representative of the program now being used on the F-15 and provided the original scheme for the B-1 (fig. 6). It requires that the contractor conduct early preproduction design verification component tests of major assemblies. It also requires two full-scale fatigue tests, the first as early as possible and concurrent with the static test and the flight loads survey. After IOC it requires a service-loads program to obtain the spectrum for the second fatigue test.

1970 to Present

Thus far we have traced the changes to the ASIP fatigue evaluation program from 1965 to 1970. Then we had some structural problems which focused national attention on the structural integrity of some of our systems, notably the F-111 and the C-5.

At the direction of Secretary of the Air Force, Seamans, a group of experts was formed to look into the problems we were having or might have in the future. There followed a year and a half of study, reappraisal, reviews, audits, and an overall reevaluation of ASIP and its requirements.

One phase of the structural integrity review involved a trip to Europe. The authors had an opportunity to visit some of you in your home countries of France, Holland, and England. We learned quite a bit from our discussions with you and have since been involved in various meetings and conferences on ASIP.

We had thought of ASIP as a logical, step-by-step program, which, if followed, would insure a structurally sound airplane. But we were mistaken, those of you in Europe seem to be able to design and build sound airframes without a formal structural integrity program such as ASIP. Moreover, we found that ASIP as applied to programs here in the U.S. sometimes worked and sometimes it did not. The primary variable seemed to be the contractor or perhaps the type of contract and not ASIP itself. Thus, our experience has shown that the structural quality of an airplane is a function of who designs it and how he designs and builds it. It has had little to do with the ASIP documentation. This may be an oversimplification of the situation we face in the Air Force today. We realize that our treatment so far has not addressed the basic question of "Do we really need an ASIP at all?" Even so, permit me to pursue a line of reasoning based on the following premises:

- (a) ASIP should be effective regardless of the contractor or the contract selected.
- (b) It is not.
- (c) Therefore, ASIP should be changed.

As a result of recent systems' experience, structural development cost restraints, and a review of international structural test practices, the Air Force is proposing a structural development test program that is different from that used before. The significant change is in the method of fatigue evaluation, as you will notice (fig. 7). The preproduction tests of major assemblies and the early fatigue tests now required seem to be duplicative efforts rather than what is desired. The preproduction tests should identify deficiencies that can be corrected in time for validation on the early full-scale fatigue test.

In the proposed program, design development and preproduction design verification (PDV) tests that are more extensive than those originally identified by the USAF in 1970

are envisioned. The very early component tests must now provide for complete structural evaluation (strength, fatigue, fracture) of the major critical areas of the primary structure. This is necessary (mandatory, even) inasmuch as these component tests are to be the main basis for determining adequacy of the design, proof of compliance, and even early life flight safety since the full-scale fatigue test will be delayed under this proposal. The PDV tests must be comprehensive. Note that this requirement is an intrinsic part of the proposed program.

The important scheduling of the full-scale static test and the flight loads measurement program retain their original timing. These tests are to coincide with the delivery of the first flight article and are to receive equal priority with other subsystem evaluation requirements.

The major change that we are proposing focuses on the full-scale fatigue test. Until now we have identified, in the initial system plans, a requirement for two full-scale fatigue tests, one strictly an early design evaluation test and the other a delayed test (approximately two or more years after initial operational capability) that utilized the results of the earlier design evaluation tests (static test, fatigue test, and flight loads survey). This late fatigue test was also intended to be delayed until completion of the service-loads recording program so that accurate service environment data would be available. However, even when faced with the real-world past experience that all first line military aircraft systems (especially fighters) eventually undergo more than one full-scale fatigue test, USAF management was unwilling to identify funds for two full-scale fatigue tests during initial program definition.

Recognizing this situation and the increased emphasis that we are placing on early component PDV testing and the desire to make the PDV tests effectively impact the design phase as well as the full-scale testing, we are proposing to identify a single fatigue test which will be conducted later than the first test and earlier than the second test previously required. This revised scheduling of the single full-scale fatigue test is necessary so that it will incorporate the findings of the PDV tests, static test, and the flight loads survey. In all probability, it will not be delayed a sufficient amount of time to use the results of the service-loads recording program.

Finally, we recognize, and everyone else should also, that additional laboratory tests (even flight tests) may be required as extensive service experience is accumulated. However, no attempt will be made to identify any additional test requirements in the original development process.

There are definite critical control points in our proposed program that must constantly be reviewed as new systems are developed. There are also some important questions that must be answered:

(1) Can the structures discipline effectively divert major airframe components from the ever present push to get a flight article as early as possible? Our proposed fatigue evaluation program has as its very foundation a comprehensive PDV test program that will require major structural components early enough to complete the tests before flight articles are produced. Can we win out against the competition and acquire these early components in time for the structural evaluation?

(2) The full-scale fatigue test can no longer be used as contractual proof that the design fatigue life requirements have been met. The test will now be based on results of earlier design and test information that cannot be accurately foreseen. Demonstration of structural fatigue quality assurance requirements must utilize the PDV tests.

(3) USAF management must be aware that major changes in the aircraft structure or mission may require further validation. Also, further validation may be required if the single fatigue test did not contain inputs that are representative of the service environment for the original design missions.

We have outlined the proposed changes that the U.S. Air Force is planning in the fatigue evaluation program for future systems. These changes are planned to be incorporated into a revision of both the technical report ASD TR 66-57, dated May 1970, and the appropriate Structures Military Specifications, commonly referred to as the 8860 series specifications.

UPDATING OF SPECIFICATIONS

MIL-A-8860 Specifications

To conclude our treatment of the proposed fatigue evaluation program, it may be useful to review our recent progress in updating the MIL-A-8860 specifications. As a result of the Seamans' study, it was suggested that our organization (Aeronautical Systems Division) have the prime responsibility for the documents. Previously, the responsibility rested with the Flight Dynamics Laboratory. We propose to cover some of the significant changes we are making in three selected specifications as well as in the ASD TR 66-57.

The revision of the technical report ASD TR 66-57 will convert the format of the report from an ASD TR to a MIL-STD-(USAF). In addition to the fatigue evaluation changes just discussed, it is planned to include in the revised MIL-STD new or increased emphasis on materials selection, fracture mechanics requirements, and damage tolerance design.

The addition of the requirements for materials selection are presently being written. The area of fracture mechanics principles is, of course, directly related to materials selection and some of the research work being accomplished in this area is the subject of

a paper by Howard A. Wood, of the Air Force Flight Dynamics Laboratory (paper no. 14 of this compilation).

In the area of damage tolerance design requirements, we have made some progress in updating our requirements. Since the new MIL-STD will only summarize the damage tolerance requirements that are contained in the MIL-A-8860 series specifications, our initial effort has been concentrated on revising these specifications. In an attempt to expedite the revision, the Air Force elected to revise and publish "USAF only" revisions. These limited coordinated (USAF only) military specifications have been prepared by using currently available technical information, but they have not been approved for promulgation as a fully coordinated (USAF, Navy, and Army) revision of military specifications. They are subject to modification. Pending their promulgation as fully coordinated military specifications, they may be used in procurement (USAF). The damage tolerance design requirements contained in these revised specifications are covered in the following sections.

Damage Tolerance Requirements for Inclusion in MIL-A-008860A (USAF)

The primary structure shall incorporate materials, stress levels, and structural configurations which will minimize the probability of loss of the aircraft due to propagation of undetected flaws, cracks, or other damage. Slow crack growth, alternate load-paths and systems, and other available principles shall be employed to achieve this capability. For this damage tolerance requirement, the primary structure is defined as including all structural elements the failure of which will

(a) Cause uncontrollable motions of the aircraft within the speed limits for its structural design

(b) Prevent an aircraft from achieving speeds sufficiently low to effect a safe landing

(c) Reduce the ultimate factor of safety for flight design conditions from 1.5 to a value less than 1.0.

Damage Tolerance Requirements for Inclusion in MIL-A-008866A (USAF)

General requirements.- Safe-life design shall be employed as the primary means of satisfying the specified service life requirement established in appropriate contractual documents for each USAF aircraft system. In addition, damage tolerance concepts shall be applied as a design requirement for primary structure vital to the integrity of the vehicle or the safety of personnel. This latter requirement stems from the recognition that, despite concerted safe-life-insurance efforts through design, analyses, and tests, undetected flaws or damage can exist in critical structural components at some time during the life of the aircraft with attendant, serious consequences.

Safe life.- The fatigue critical areas of the airframe shall be identified through analyses and tests (developmental, preproduction component, and full-scale article). The structure shall be shown to withstand, without structural failure, the design repeated loads spectrum equal to the design fatigue-scatter factor times the service-loads spectrum. A service-loads spectrum is defined for one lifetime only and does not include a design fatigue-scatter factor. Modifications found necessary to satisfy this requirement shall be incorporated prior to aircraft delivery or by retrofit in fleet aircraft as agreed to by the procuring agency.

Design fatigue-scatter factor.- The design fatigue-scatter factor is a factor to provide protection against fatigue failure of those fleet airplanes that experience a service-loads spectrum more severe than the design service-loads spectrum and have fatigue-life capabilities less than those of laboratory test articles. The design fatigue-scatter factor shall be a minimum of 4.0 or as otherwise approved by the procuring activity.

Service-loads spectrum.- The service-loads spectrum is derived from a collection of loads spectra. Each loads spectrum in this collection shall define the expected (average) number of load cycles according to load magnitude for a given source of repeated loads. The loads spectrum for each significant source of repeated loads shall be based on a realistic interpretation of the design usage. The contractor shall include all significant sources of repeated loads. The sources of repeated loads may include, but not be limited to, ground handling and taxiing operations, landing operations, flight maneuvers, atmospheric turbulence, inflight refueling, autopilot, inputs, cabin pressurization, buffet-ing, terrain-following maneuvers, and the ground-air-ground cycle.

Damage tolerance.- The primary structure vital to the integrity of the vehicle or to the safety of personnel shall incorporate materials, stress levels, and structural configurations which minimize the probability of structural failure due to the propagation of undetected flaws, cracks, or other damage. The choice of damage-tolerant design concepts (fail safe, safe crack growth, or combinations thereof) for the design of specific critical structural components shall be as agreed between the procuring agency and the contractor. Analysis and supporting tests shall be conducted to evaluate the flaw growth and residual strength characteristics of the critical structural components.

Fail safe.- Primary structure that is designed fail safe shall be readily inspectable and meet the following requirements after failure of a principal structural element: (1) the remaining structure shall sustain without failure the maximum expected load or limit load, whichever is greater, (2) the airplane shall be controllable within the design speed limits, and (3) catastrophic failure of the remaining structure will not occur under repeated load conditions during the period to the next opportunity to detect the failure. Verification of the ability of the remaining structure to withstand the repeated loads shall be accomplished by determining the crack growth period from an initial flaw to failure of

a principal element, and then ensuring that the life (including the factor of four) of the remaining structure will equal or exceed the time interval established for the next inspection. Inspection intervals shall be as agreed to by the procuring agency, but, in general, these intervals shall be of reasonable duration commensurate with total system requirements. Readily inspectable structure is defined as that which can be inspected after removal of access panels, doors, etc. Removal of permanent type skins and fasteners is not included. The details of inspection shall be agreed upon by the procuring agency and the contractor.

Safe crack growth.- Critical primary structure that is not fail safe shall be designed so that initial flaws will not propagate to the critical crack length during the specified service life of the airplane. Through fracture data tests and analysis, the characteristics and dimensions of the smallest initial defect that could grow to critical size during the specified service life shall be determined. Once these initial flaw sizes have been identified, quality control procedures shall be developed so that parts containing initial flaws of these dimensions will not be accepted. In the event that the identified initial flaw sizes are smaller than the quality control detection capability, changes shall be made in the materials and/or stress levels so that larger initial flaws (compatible with quality control capability) can be tolerated.

Damage-Tolerance Test Requirements for Inclusion in MIL-A-008867A (USAF)

Fracture data tests.- Fracture data shall be generated during the design development test phase on all candidate materials for which no valid data base exists to support the analysis requirements. These tests shall include plane strain and plane stress tests to determine fracture toughness values as well as crack propagation tests to determine incremental crack extension rates. These data shall be used for comparative evaluation of proposed materials and designs. Fracture toughness values shall be determined in accordance with the procedures set forth in the current standards. Specifications shall be prepared to ensure that materials having minimum guaranteed fracture-toughness parameter (K_{1C}) values are used in manufacture where test specimens having dimensions that satisfy ASTM requirements can be obtained. Continued sampling of final manufactured parts shall be accomplished throughout the production life to ensure consistency with the required strength and toughness levels.

Crack propagation tests shall be conducted on element specimens to determine the conventional cyclic crack growth rate and sustained load growth rate data. These tests shall include the evaluation of the effects of various atmospheric environments (such as temperature, humidity, fuel, salt, etc.). Spectrum tests of flawed specimens shall also be conducted when insufficient data exists or when proven analytical capability to predict spectrum effects is lacking.

Crack growth tests.- Crack growth tests of preproduction components shall be conducted as required to verify that the damage tolerance criteria have been met. These tests shall be accomplished by applying a spectrum of loads and environment that simulates operational usage which will determine the time to crack initiation and the time to failure of a single principal element. These tests shall utilize, wherever possible, the existing component structures fabricated for evaluation of the strength and fatigue properties as an "add-on" test effort. When necessary, additional component structures shall be fabricated.

The revised structural specifications are as follows:

Specification number	Short title
MIL-A-008860A (USAF)	General
MIL-A-008861A (USAF)	Flight loads
MIL-A-008862A (USAF)	Ground loads
MIL-A-008865A (USAF)	Miscellaneous loads
MIL-A-008866A (USAF)	Fatigue
MIL-A-008867A (USAF)	Ground tests
MIL-A-008869A (USAF)	Nuclear
MIL-A-008870A (USAF)	Flutter
MIL-A-8871A (USAF)	Flight test
MIL-A-8892A (USAF)	Vibration
MIL-A-8893A (USAF)	Sonic fatigue

These specifications listed are dated 31 March 1971 and are presently in printing; the estimated distribution date is July 1971. The MIL-A-008860A, 61A, 62A, 65A, 67A, 69A, and 70A are former ASG (joint) specifications which have been revised as USAF only specifications. MIL-A-008871A has always been a USAF only specification. MIL-A-8892 and MIL-A-8893 are new specifications which apply to USAF only.

The next two major efforts that are presently being accomplished are, revision of ASD TR 66-57 into a MIL-STD, and full coordination on the revised specification will result in ASG type specifications.

CONCLUDING REMARKS

We are proposing the elimination of one full-scale fatigue test article and replacing it with early full-scale component tests. The full-scale fatigue test is performed later than present requirements state but earlier than the previously required second fatigue test. To formalize this change in the fatigue evaluation program, we are revising the 8860 series of specifications and writing the USAF ASIP into a separate Military Standard.

The authors wish to express their appreciation to Mr. Troy King for his assistance in preparing this paper.

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1968 STRUCTURAL EVALUATION PROGRAM

LIFE PHASES

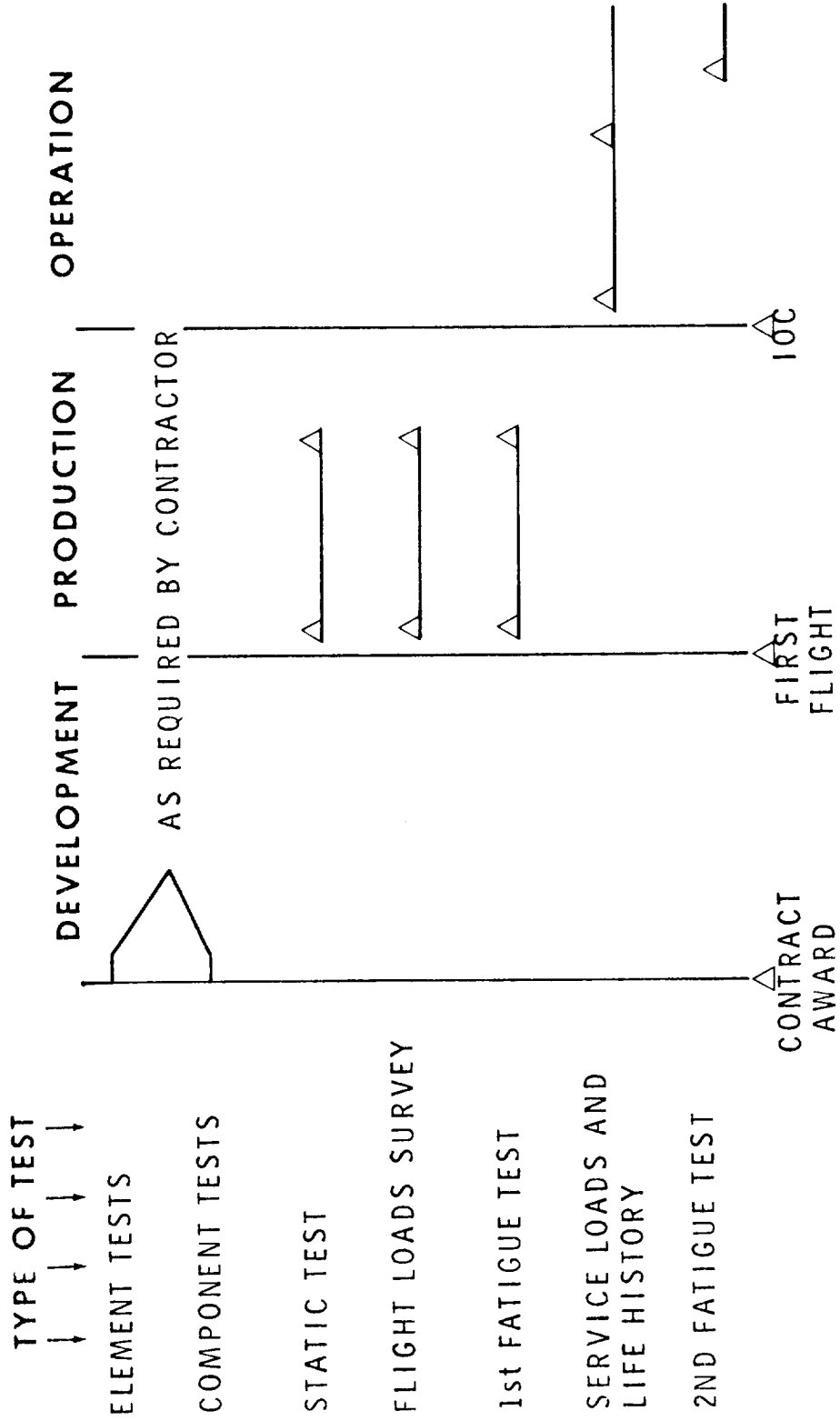


Figure 1

C-141 STRUCTURAL EVALUATION PROGRAM

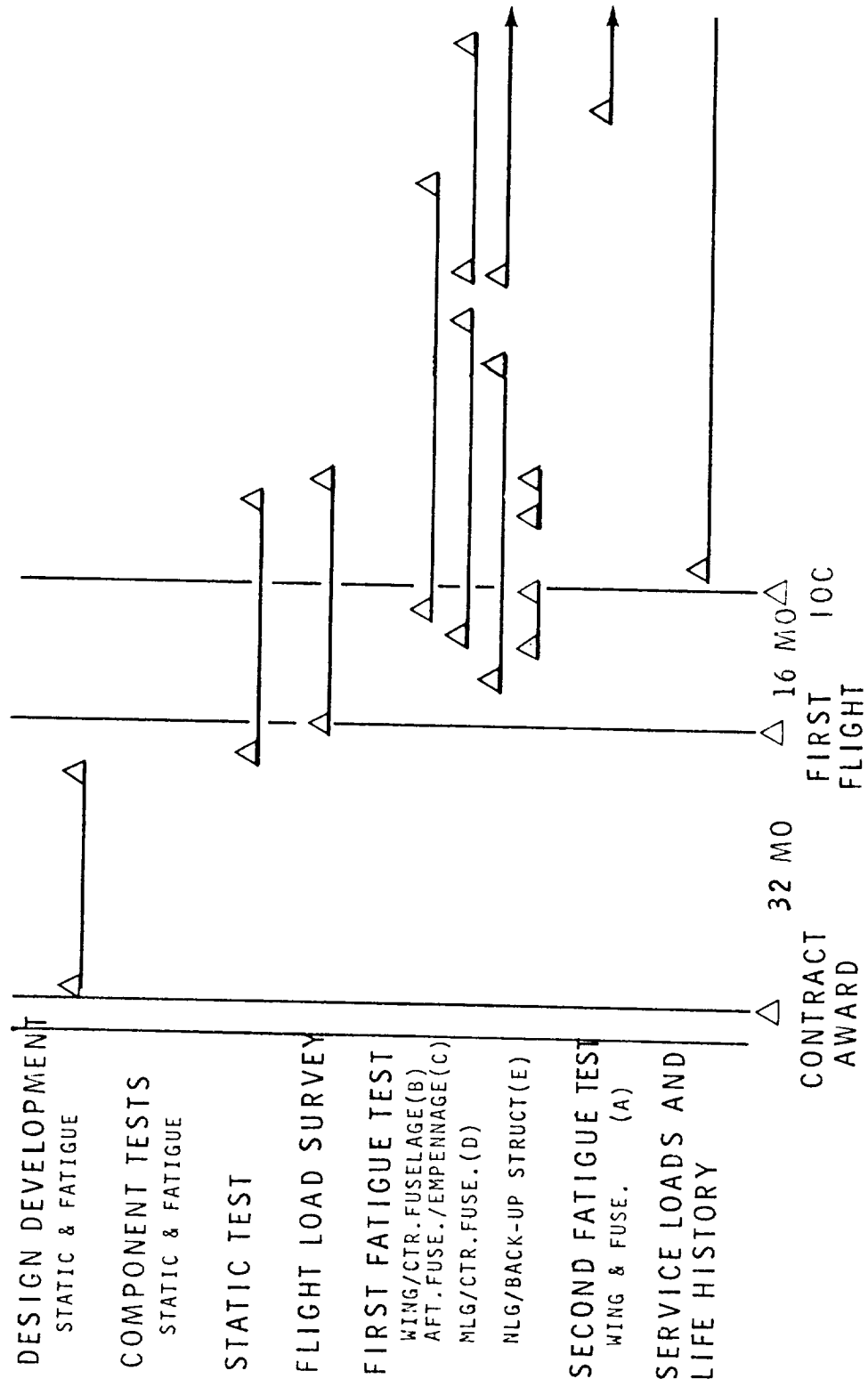


Figure 2

FATIGUE TEST SPECIMEN

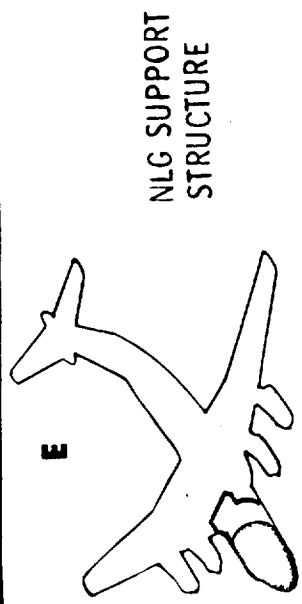
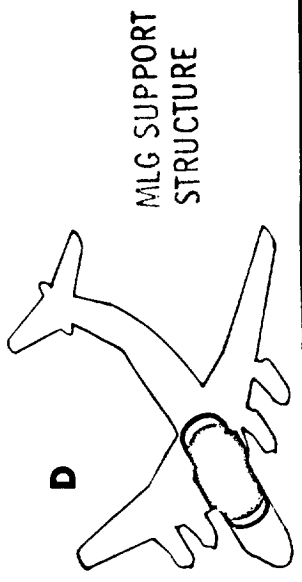
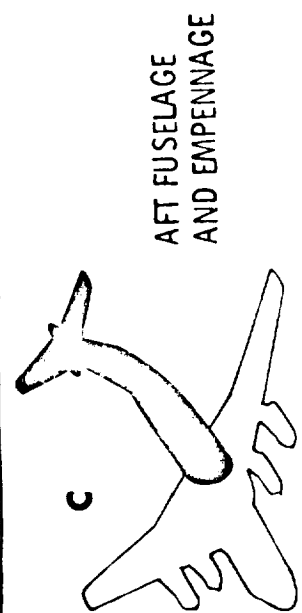
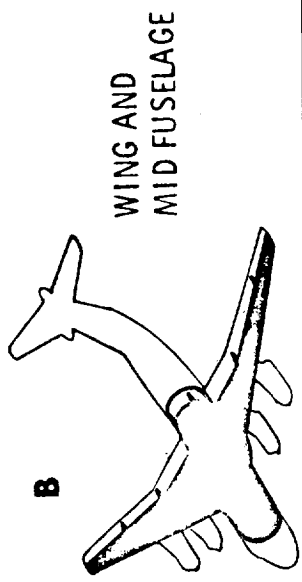


Figure 3

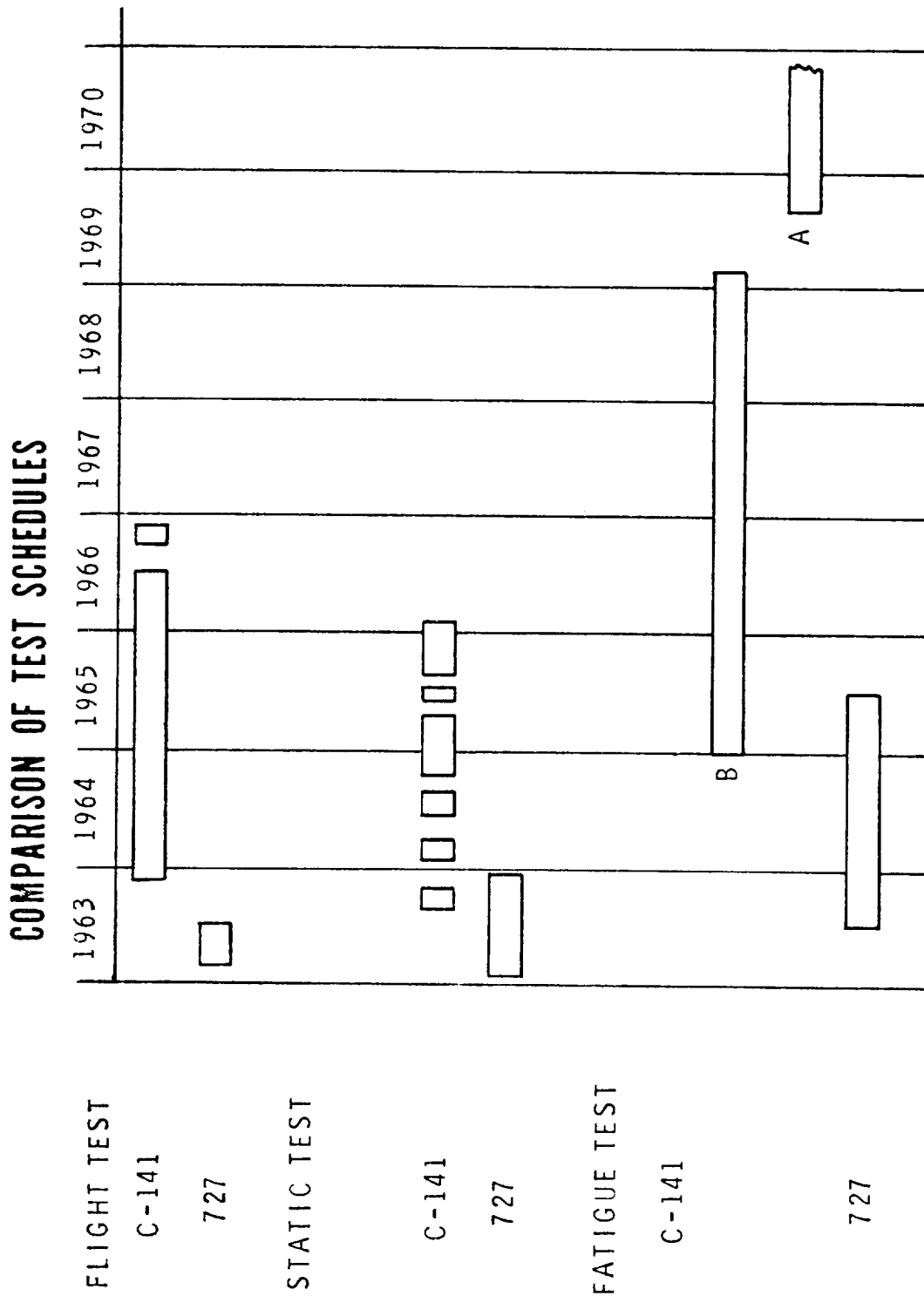


Figure 4

F-5 STRUCTURAL EVALUATION PROGRAM

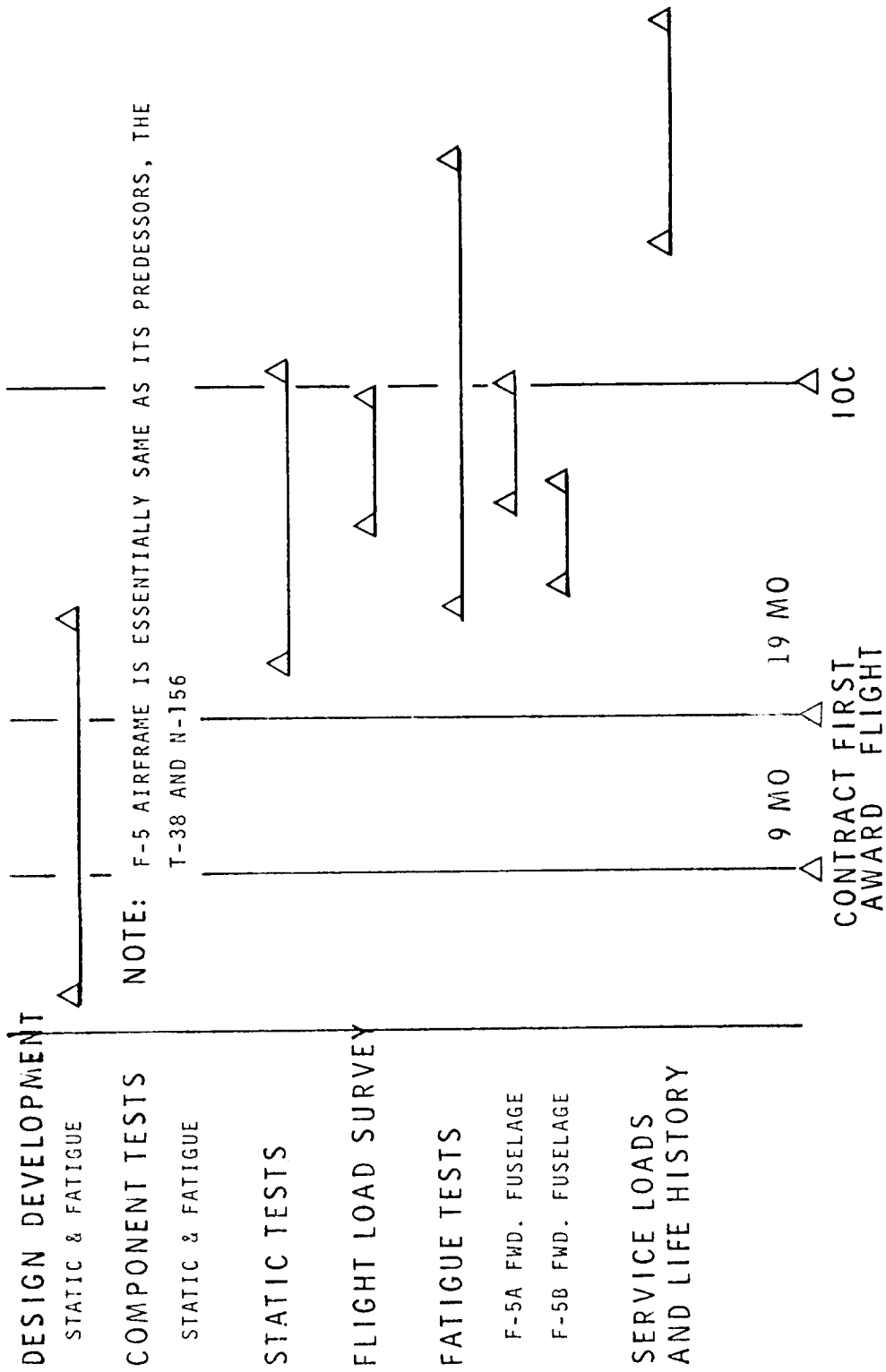


Figure 5

1969-1970 STRUCTURAL EVALUATION PROGRAM LIFE PHASES

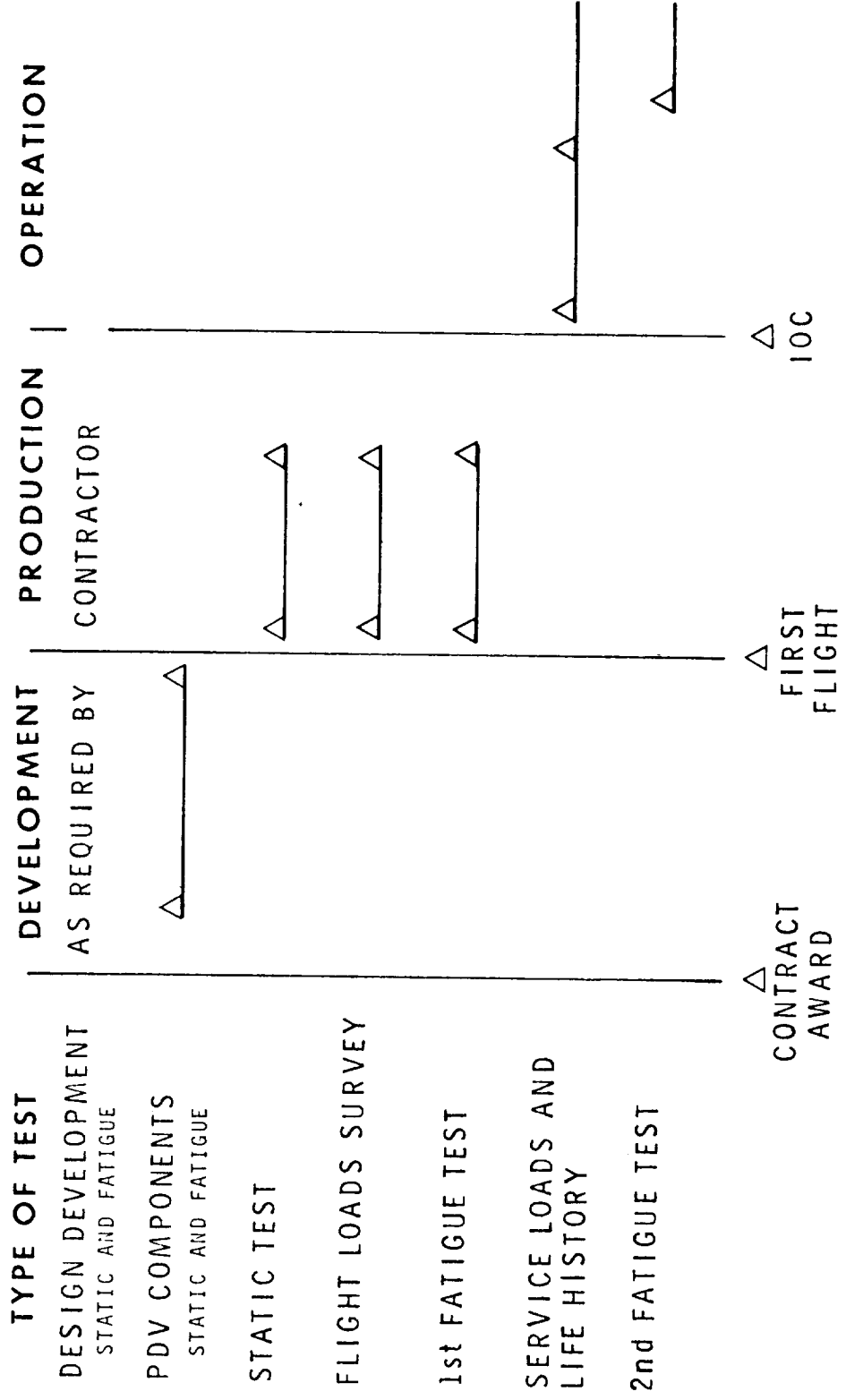


Figure 6

PROPOSED STRUCTURAL EVALUATION PROGRAM LIFE PHASES

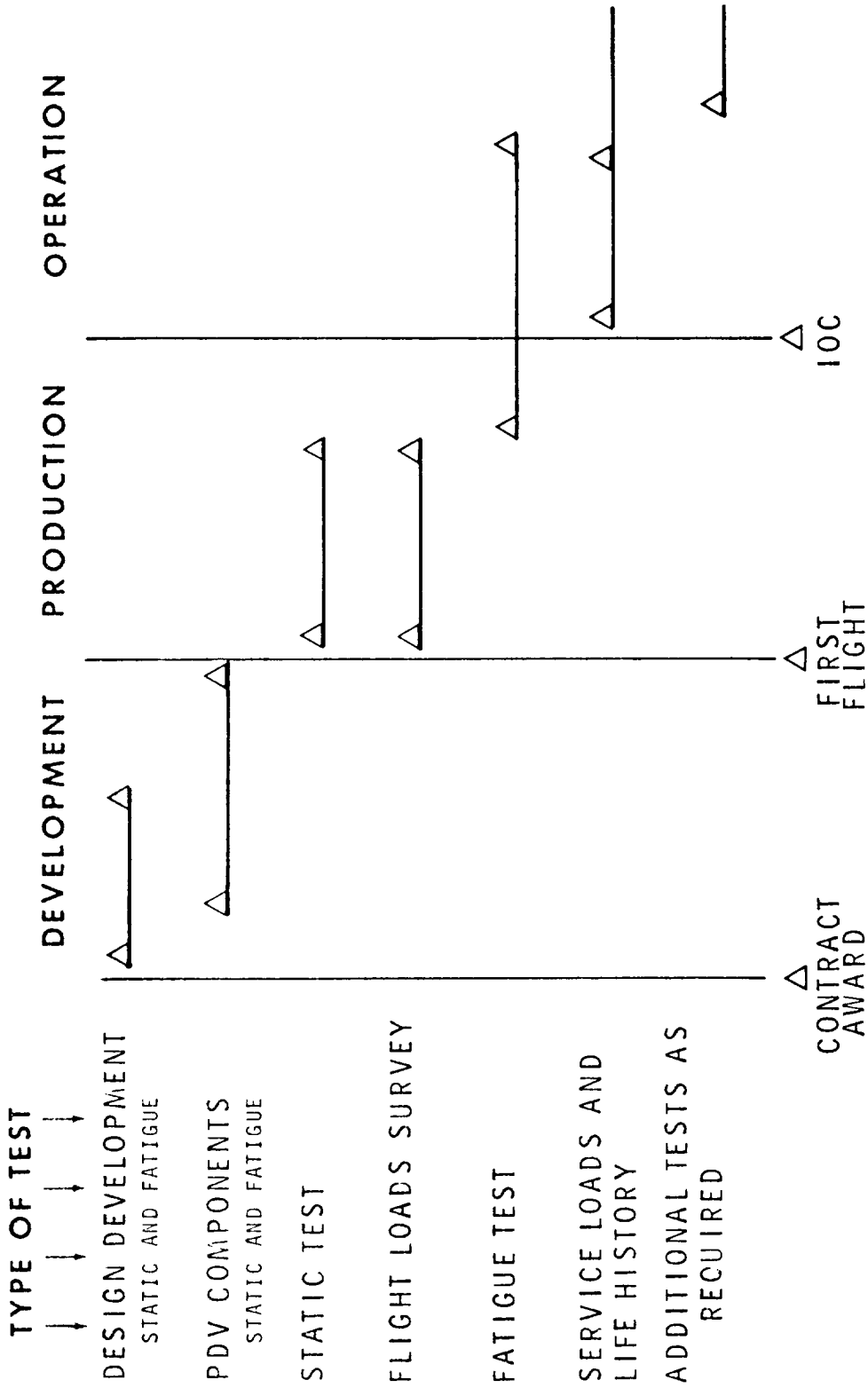


Figure 7

