CLEARINGHOUSE FOR FEDERAL SCIENTIFIC AND TECHNICAL INFORMATION, CFSTI
DOCUMENT MANAGEMENT BRANCH 410.11

LIMITATIONS IN REPRODUCTION QUALITY

Accession # AD 606360

☑ 1. We regret that legibility of this document is in part unsatisfactory. Reproduction has been made from best available copy.

☐ 2. A portion of the original document contains fine detail which may make reading of photocopy difficult.

☐ 3. The original document contains color, but distribution copies are available in black-and-white reproduction only.

☐ 4. The initial distribution copies contain color which will be shown in black-and-white when it is necessary to reprint.

☐ 5. Limited supply on hand; when exhausted, document will be available in Microfiche only.

☐ 6. Limited supply on hand; when exhausted document will not be available.

☐ 7. Document is available in Microfiche only.

☐ 8. Document available on loan from CFSTI (TT documents only).

☐ 9.

Processor: lah

NBS____ 9/64

AD 606360

DESIGN CHANGE IMPACTS ON AIRFRAME PARTS INVENTORIES

James W. Petersen
Wilbur Steger

P-1055
(Revised)

31 October 1957

Approved for OTS release

COPY 1 OF 1
HARD COPY $. 2.00
MICROFICHE $. 0.50

35p

DDC
RECEIVED
OCT 6 1964
DDC-IRA B

The RAND Corporation
1700 MAIN ST. • SANTA MONICA • CALIFORNIA

DESIGN CHANGE IMPACTS ON AIRFRAME PARTS INVENTORIES

James W. Petersen
Wilbur A. Steger

I. INTRODUCTION

Various theoretical systems have been developed which describe the requirements of an "optimal" inventory policy. Such systems normally require as inputs costs of reordering, stock depletion costs, and expenses associated with holding an item in inventory. Unfortunately, many of these cost elements are not readily available in the present military logistics system; as a result, it has not been possible to test these optimal inventory systems, or for that matter, to evaluate present military inventory policy. This study is an attempt to provide part of the information needed to assess the costs of holding a spares inventory, namely, the cost of airframe inventory which becomes obsolete as a result of design changes. Such information, for example, would be extremely useful in determining a suitable spares procurement policy for a new military weapon. The central problem of initially providing spares for this new weapon is that, at the time the first spares' buying decision is made, spares requirements are so uncertain. The phase-in of a typical Air Force weapon system occurs over a two-to-four year period. Airframe manufacturers, however, insist on production lead times of from one-to-three years on major components (which are the expensive ones). Consequently, the Air Force has, until now, been required to make its buying decisions several years prior to the delivery of the first end item, and several more years prior to the point where any sizeable block of experience with the end item has been obtained. It is not just that wearout rates on parts are uncertain. At the time the buying decision is made, the final configuration of the weapon is only a rough guess. About the only thing known with certainty is that parts purchased will later require modification or will become obsolete as a result of design change. The Air Force spares' provisioner is asked to state the requirements for a part with an unknown failure rate and for a somewhat uncertain model configuration.

As a solution to this problem it would, of course, be desirable to do anything that might reduce requirements uncertainty. There are some things that might be done in this regard, e.g., demand experience on similar parts used on similar aircraft could be used. In general, however, it would be a mistake to overemphasize the gain to be realized by working on improved forecasting methods alone. The technological race will be with us for some time to come -- we will be provisioning new and changing types of weapons. In short, as long as procurement procedures and policies require that the principal procurement decision be made years before the requirement exists, the initial buying decision will continue to be dominated by uncertainty.

The kind of system needed to minimize the adverse effects of poor requirements predictability is fairly clear, at least in concept. To take a limiting case, if the production process were perfectly flexible and highly responsive, the Air Force would order a part whenever a requirement arose. In this way demand uncertainties could be shifted backward and absorbed by the production process. Since such a perfectly responsive production system does not exist, and since weapons grounded for lack of support are of no use, it is necessary that some minimum support be ordered. Over and above this minimum, however, the object of the game should be to "live hand to mouth;" a policy would be pursued of placing numerous small stock orders to cover uncertainty in the immediate future and thus have a chance to let unfolding demand experience be reflected in follow-on orders. By not placing a large initial order, it would be possible to shift part of the requirements' uncertainty back to the contractor's production line.

Naturally, such a system change would not be costless. Only at some additional cost could the contractor's ability to turn out some parts on short order be increased. In other words, while it may be difficult to cut lead times for all items, it may be possible to evolve a system which could provide selective items on a responsive basis. A differential provisioning policy might be envisioned in which low cost items were initially procured in large amounts - possibly even "life-of-type" - so as to minimize reordering and handling costs, while efforts would be made to obtain shorter procurement lead times on high cost items.

The value of such a system revision depends, among other things, upon the savings that would result from a decreased impact of design change obsolescence upon spare parts inventories. Since high cost spare parts, while a relatively few items, account for the bulk of the inventory dollars, the saving potential (from this source alone[1]) would be high. To date no estimate of this saving, which might be called the "value of procurement deferral" has been made. Since the absence of an estimate of spares' obsolescence risk is partially responsible for this important gap in logistics' knowledge, the purpose of this study is to provide such an estimate.

---

[1]Other types of savings, such as a decrease in interest charges and warehousing costs, also are indicated for such a system of "deferring the procurement" of expensive spare parts. A future RAND report by the author explores this [illegible] ly.

II. SCOPE AND METHOD OF STUDY

The risk of design change varies between different classes of military property; therefore, the results of this study which relate solely to airframe property (aircraft structural components) should not be generalized to other dissimilar types of equipment. This report is not a general study of the costs of technological change. It considers only costs of the engineering obsolescence risk which a military service takes when it purchases quantities of airframe spare parts. Two other types of costs of technological change not covered in this report include:

1. The administrative costs of introducing and keeping up with design changes. (The constant stream of engineering changes for any weapon multiplies the complexities of managing the logistics system).

2. The costs of aircraft grounded while modification is being accomplished.

The obsolescence measures developed are based primarily upon the study of one Air Force weapon, the F-94 series of aircraft. This aircraft was chosen for several reasons, not the least of which was the fact that available data were more complete for this model than for others. In addition, the F-94 is currently being phased out of first line operational use,[1] during which almost all of the engineering changes affecting a given series aircraft occur. Data were also collected on the F-100 and the B-52 model aircraft; but, since these aircraft types are currently being phased into the Air Force inventory, the results are limited and serve primarily as a check on the estimates obtained for the F-94.

The study is mainly concerned with weapon modifications introduced by the airframe contractor; design changes affecting Government Furnished

---

[1]First line aircraft are those capable of being used to perform critical and essential Air Force missions.

Aeronautic Equipment sub-systems, such as engines and many of the electronic components, were excluded. Naturally the airframe modifications have an impact on other Air Force property classes, but the dollar value of such impacts is small and centered in such low cost classes as aircraft "hardware." No effort was made to segregate these costs.

The stock of spare parts effected by design changes includes all stock already delivered to the Air Force, plus all parts so far along in the production process that corrective action either is needed to bring the item to the latest configuration or is no longer possible. The impact of specific design changes can take the following lines:

1. Engineering obsolescence costs, defined as the dollar value of spares made totally obsolete by a design change.

2. Modification costs, which include both the material and labor required to rework a spare part to a new configuration.

3. Contractor "design-termination costs," which include the cost of spares material or work in process that must be discarded or reworked as a result of a design change.

In addition to the costs listed above, there is another cost which arises when the applicability of a spare part becomes limited as a result of a design change. For example, a part may be "common" to several different models or series of aircraft; but a design change on a particular series of aircraft will curtail the usefulness of the part. The item is not made obsolete, since it can still be used on other models; but the Air Force has on hand more of the item than is necessary to support the aircraft for which the part is still functional. This cost resulting from a reduction in applicability will eventually show up in the form of "terminal obsolescence," where the end item for which the spare was originally purchased phases-out of the Air Force inventory before the spare is used.

A true measure of the impact of design changes would include an estimate of the cost of limited applicability; but this cost is difficult to measure. In order not to neglect limited applicability altogether, two estimates of spares cost of design change were made. First, the direct spares cost of the change was measured, that is, engineering obsolescence, modification costs, and contractor design-termination costs. This estimate tends to understate the cost of design change, since it does not include the cost of limited applicability. In the second estimate, design change cost includes the full value of all delivered spares whose applicability is in any way limited by a change in design. Obviously this method overstates[1] the spares cost of design change, since many of these parts might still be useful on some other series of aircraft. Thus, in concept, method (1) puts a lower limit upon the cost of change -- method (2), an upper limit. The true cost probably lies between these two estimates.

The specific data used in this study are examined, in some detail, below. However, the methodology used can, doubtlessly, be applied to other areas. In general, the data requirements of the components of the problem are as follows:

1. Engineering Obsolescence Costs - The dollar value, preferably at current market prices less scrap value, of all spare parts' inventories that are condemned (i.e., the spare part is no longer applicable to any end item) as a result of the design change.

[1]The "overstatement" is only a conceptual one, since some data gaps are known to exist in both estimates. The effects of these gaps will be taken into account, below.

2. Modification Costs - The dollar value of "retrofit kits" purchased by the military service for the purpose of reworking the spare parts' inventories that were not condemned by the design change, plus the dollar cost to the military service of all labor required to perform this "retrofit" operation on the spare parts.

3. Design Termination Costs - The cost to the military service resulting from the effect of a design change upon the raw material and purchased parts (in the contractor's plant) which were about to be made into spares at the time of the design change, whether the design change causes a condemnation of this material or merely necessitates its rework.

Before turning to the specific results of the analysis, it is desirable that the reader obtains some idea of the numbers and types of design changes which affect a military aircraft.

III. TYPES AND TIMING OF DESIGN CHANGES

Various kinds of engineering changes affect modern aircraft. While only a relatively few of these modifications affect the inventories of delivered spare parts, almost all of them are important from a logistics viewpoint.

Chart I shows the number of design changes processed monthly over the period January 1955 to March 1956, by the Lockheed Engineering Department for five Lockheed aircraft, the F-104, T-33, T-2V and P-2V (Navy), and the 1049 (an older version of the commercial Constellation).[1] The T-33, P-2V, and 1049 aircraft represent older models, their basic design having been determined a decade or more in the past, (the T-33 is a development of the

[1] Unfortunately, similar data for the F-94 aircraft were not available. However, discussions with Lockheed personnel indicate that the characteristics of the types and timing of design changes are very similar from aircraft to aircraft.

F-80). While the T-2V is a T-33 altered for Navy carrier operations, major modernization and modification have gone into its design; therefore, the F-104 and, to a lesser degree, the T-2V can be classified as newly designed aircraft.

Chart I shows that the number of engineering changes is greatest for the newer models of aircraft.[1] More than three-fourths of all the changes processed during this time period occurred on the F-104 and T-2V, whose first production models were completed during December 1955. This suggests that the number of changes for any one aircraft model is greater during the early stages of its production. It is interesting to note, however, that problems requiring some modification in the design of even the older aircraft continued to arise.

The design changes plotted in Chart I fall into two general types. First are those which can be performed within the aircraft's original contract specifications and with limited money expenditure. The aircraft contractor is given a rather free hand in introducing these modifications, and they make up the bulk of the changes listed in Chart I. As far as possible, the contractor attempts to make these modifications with a minimum disruption of the production line. In many cases the aircraft will continue to roll off the production line without incorporating the new improvement, while the contractor uses up the material and parts ordered or produced to meet specifications of the older configuration. From a logistics point of

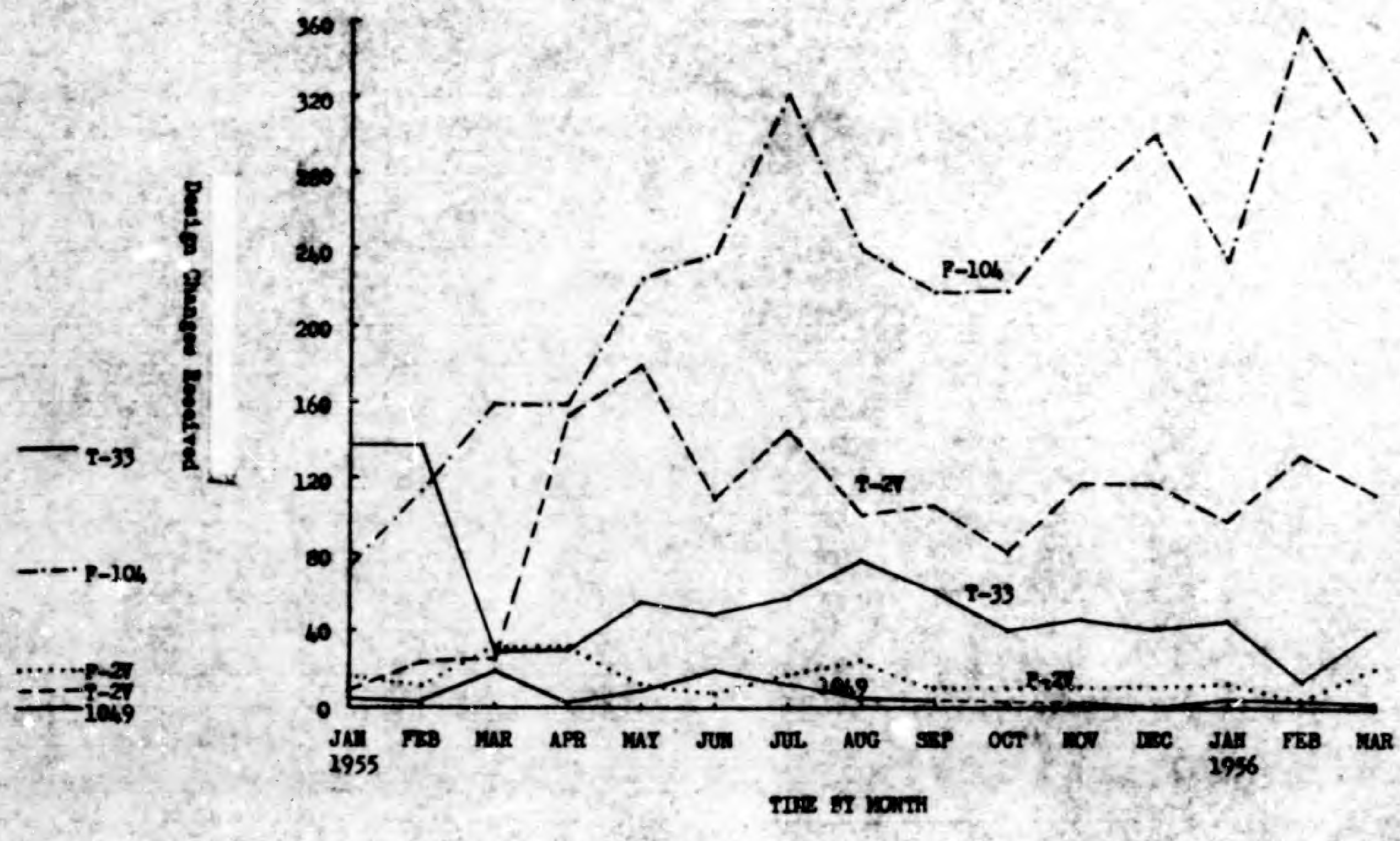
---

[1] While total costs of these design changes were not available, Lockheed personnel in charge of design change were convinced that Chart I would continue to reflect the same picture even if costs of design change, rather than their number, were used. In fact, their feeling was that the cost per design change was higher, during the period, for the F-104 and T-2V.

CHART I

MONTHLY NUMBER OF DESIGN CHANGES RECEIVED ON FIVE LOCKHEED AIRCRAFT

F-104, T-33, P-2V, T-2V, and the 1049, January 1955 through March 1956



P-1055
10-31-57

view, such design changes should not greatly influence spare parts inventory, for with the policy of concurrent delivery of spares,[1] the stock in the hands of the Air Force will be applicable to the aircraft delivered to date. The aircraft incorporating the new design will enter the system with the spares support associated with the new design.

The primary impact of this type of design change is in the added administrative problems that limited applicability br... about in cataloguing and record keeping. Furthermore, as the sheer num..rs of spares line items increase, the problems of requirements determination become more complex. However, the complexity is primarily a matter of increasing the numbers of requirement computations rather than the difficulty of each computation. Naturally, this holds only if the data processing system underlying the requirements determination is capable of correlating each spare with all the end items to which it is applicable.

More serio s design changes are those which either alter the basic specifications of the aircraft or entail appreciable costs. In either case, the contractor does not wish to go ahead with the change without specific approval from the Air Force, since major modification to the aircraft and the spares already delivered may be involved. Most of the design changes that seriously effect delivered spares fall into this category.

Reasons for airframe modification vary: (1) The prime contractor may submit a change which he feels will improve performance or simplify production; (2) contractor vendors may alter their components so that airframe modification becomes necessary; (3) customer experience or change in

---

[1]With concurrent spares' delivery, the spares' order is delivered in the same proportion as the end item they support; for example, when half the aircraft are delivered, half of the spares initially purchased for these aircraft is also delivered.

requirements may indicate the desirability of a change. Chart II indicates the per cent of the number of engineering changes by cause for the T-33 and T-2V for the period January 1955 to March 1956. Of interest is the fact that the relative importance of contractor design improvements is similar between these two models, even though the T-2V is a much newer model having a greater number of design changes.[1] The T-2V shows a larger number of customer, rather than vendor or production improvement, changes. No data exist showing whether this difference arises because of the age difference of these two aircraft models.

IV. DESIGN CHANGE IMPACTS ON DELIVERED F-94 AIRFRAME SPARE INVENTORY

The F-94 series of aircraft was purchased under five separate contracts negotiated between 1949 and 1951. Approximately 800 F-94 aircraft were delivered between early 1950 through mid-1954. The airframe spares initially purchased for these aircraft amounted to approximately $64.3 million.[2]

To analyze design change impacts on F-94 spares the following components were estimated:

a. Engineering obsolescence

b. Spares modification

c. Contractor design-termination costs

d. Limited applicability

The results obtained and the method used to measure each of these types of spares design change impact are discussed in turn.

---

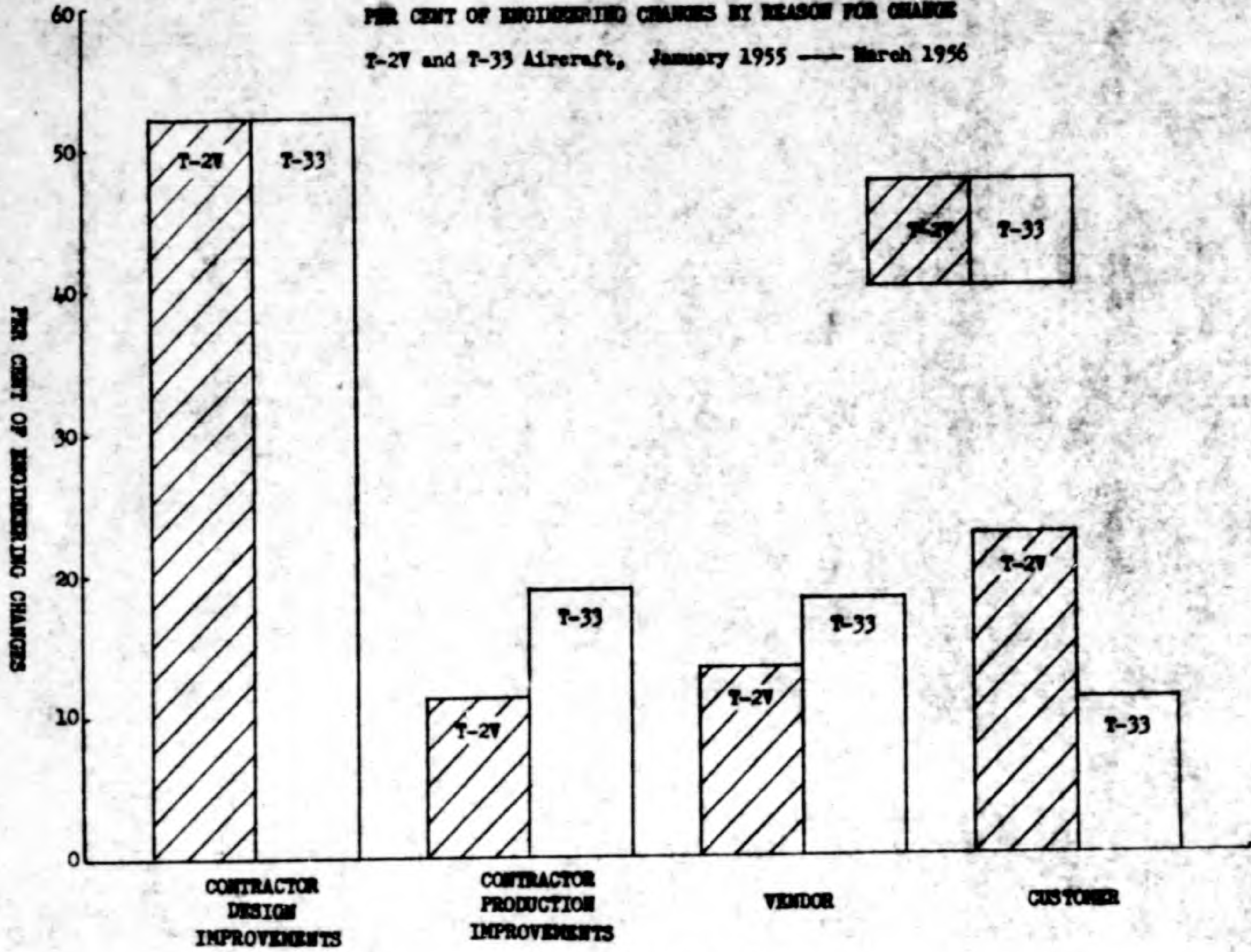
[1] Lockheed officials believe that the relative importance of the various causes of design change is very similar from model to model.

[2] Obtained from AMC Budget Program Summaries for the appropriate years.

CHART II

PER CENT OF ENGINEERING CHANGES BY REASON FOR CHANGE

T-2V and T-33 Aircraft, January 1955 —— March 1956



A. Engineering Obsolescence Costs

The basic data used to evaluate the dollar value of airframe spares made totally obsolete as a result of design change were the 151 Time Compliance Technical Orders[1] issued by the Air Force for the purpose of introducing changes on F-94 aircraft. Design Change Technical Orders, known as T.O.'s or T.O.C.'s, are usually prepared by the manufacturer after negotiations with the Air Force. Each T.O. will describe the change to be accomplished, the serial numbers of the aircraft affected, and the dates within which the change should be made. Normally a design improvement will specify a 24-month span within which to accomplish the change. A safety change, on the other hand, specifies immediate compliance.

The T.O. will specify whether or not the design change affects the end item in such a way that the usability of delivered spare parts is also affected. In each technical order, there is a separate list of spares that are affected as well as the disposition of such parts. Disposition possibilities fall into one of the following categories:

a. Condemn and dispose as surplus

b. Retain for use on unmodified aircraft

c. Retain for use until modification of the aircraft is accomplished

d. Modify per instructions contained in the technical order

Spare parts made obsolete through design change were defined as the sum of categories (a) and (c) above. The dollar value of these condemned parts was obtained by multiplying the on-hand asset position of each part by its unit price.

---

[1]As of the month in which the data were collected (June 1956), these 151 Tech Orders were all the Tech Orders issued to modify the F-94 aircraft.

Table I (and column one of Summary Table V)[1] shows the dollar value of delivered airframe spare parts condemned by Technical Orders in the F-94 series of aircraft. Less than 25 per cent of the design changes specified in T.O.'s resulted in the condemnation of delivered spares;[2] and comparatively few spare parts actually were condemned.[3] Furthermore, less than 30 per cent of the condemned spares had a unit price of more than ten dollars. Only one T.O. lists a spare with a unit price of more than $500 to be condemned. Most of the condemned items were bits and pieces connected with the relatively expensive items that had been affected by the design change. The very sharp increase in the value of condemned parts in 1955 is due to one T.O. which involved a major modification of the F-94.

B. Spares Modification Costs

The costs of changing delivered spare parts to a new configuration include the dollar value of components and labor used in the modification. The total value of the component ("retrofit") kits purchased by the Air Force to modify delivered spares is obtained by multiplying the cost of the parts contained in the kit by the number of kits purchased. Labor cost of modifying spares was obtained by multiplying the labor hours involved (estimated on the T.O.) by the number of kits, times the cost per labor maintenance hour (estimated at $5.75).[4]

---

[1]The difference between the Table I - IV and their corresponding columns in Table V is that the latter cumulates the data shown in Table I - IV.

[2]At least another 15 T.O.'s list spares to be condemned, but these spares were found to have no asset position. Another seven T.O.'s, showing inexpensive spares to be condemned, are not included in the total because the asset positions of these inexpensive items could not be determined. Several very inexpensive items are omitted due to difficulty in ascertaining their asset positions. However, even if the number of spares condemned as a result of design change were actually doubled, the derived figure would not alter the picture considerably; very few spares were condemned on the T.O.'s.

[3]Of these 78 condemned part numbers, four had more than a simple application per plane.

[4]This figure was estimated by the RAND Cost Department in connection with another study. In addition to direct personnel costs, this estimate is meant to include training costs, base overhead, and investment costs.

TABLE I

Number and Value of Condemned Spares, F-94 Aircraft, by Year

Year	Number of T.O.'s Showing Condemned Spares	Number of Condemned Spares	Dollar Value of Condemned Parts	Per Cent of Total
1951	1	4	1,229	.12
1952	2	4	290	.03
1953	5	11	3,461	.35
1954	11	29	26,575	2.66
1955	9	32	967,669	96.79
Through June 1956	1	1	87	.01
No Date	1	1	418	.04
	30	78	999,729	100.00

Approximately 60 per cent of the 151 Technical Orders call for modifying delivered spares in some way. The total cost of performing these modifications was approximately $600,000 of which about one-third was for retrofit kits and two-thirds for labor. The dollar value of spares modification cost is allocated by year in Table II (and column 2 of Table V).

C. Contractor Design Terminat   osts

Design Termination Costs include spare parts material or work in process that must be reworked or discarded as a result of a design change. Estimates are based on Lockheed records covering design change termination costs, and the scrap and rework costs of inventory material.

When a design change occurs, a Termination Design Change Cost Account (TDC) is set up, and the expenses of rework and obsolescence arising from a reduction in parts ordered are accumulated. These costs cover both production and spare parts; therefore, to isolate TDC charges associated with spares, the total TDC costs were multiplied by the ratio of airframe spares value to total value airframe plus spares. For the F-94 this ratio was 24.1 per cent of the TDC costs.

A TDC cost account is held open, accruing costs in the years they arise, until all of the expenses arising from the design change are recorded. This may cover a considerable time period. In this study such expenses have been tabulated as they were recorded (i.e., accrued) in each year regardless of the year that the particular TDC account originated.

Concerning the inventory material scrap and rework cost, the contractor felt that most of this cost could be attributed to design change, with some unknown percentage traceable to careless handling of material in the shops. No correction was made for this factor. The Lockheed cost system does not segregate material scrap and rework costs between production and spares;

TABLE II

Materiel and Labor Costs of Modifying Spares, F-94 Model, by Year

Year	Number of** Tech Orders	Dollar Value of Kits for Spares	Dollar Value of Labor for Spares	Total	% of Total
1951	1	$ 5,940	$ 12,765	$ 18,705	3.02
1952	2	173	1,282	1,455	.23
1953	5	1,554	2,260	3,814	.62
1954	53	126,560	273,177	399,738	64.55
1955	23	84,749	102,051	186,800	30.16
No Date	6	904	7,866	8,770	1.42
	90	219,880	399,401	619,282	100.00

** This list includes only those Tech Orders which show some spares modification costs.

therefore, the same percentage factor of 24.1 was used here to separate the spares portion of the material scrappage cost from the production portion.

Table III (and column 3 of Table V) presents the totals of spares termination design change costs and inventory scrap and rework costs for the F-94's by time period.

D. Limited Applicability Cost

A design change on a particular aircraft model may make a spare item no longer useable in the new configuration. The item is not obsolete, since it can still be used on other series of the aircraft; but, the Air Force supply will be more than needed for the remaining demand potential. In the final disposal of parts, records do not permit separation of this excess resulting from design change. Because this cost could not be measured directly, the upper limits of reduced applicability were determined by finding the full dollar value of all parts whose use was in any way curtailed by a design change. This method, of course, overstates cost, for many parts would have been used before the end item was phased out of service.

The basic data for estimating this cost were taken from the contractor's "exhibits" or lists showing reductions in spares' quantities on order, by reason for the reduction. Where the indicated cause was design change, Air Force and contractor's records established the remaining applicability of each such spare item. The cost of these affected spares was measured by tabulating the dollar value of all such spares delivered to the Air Force. Four types of applicability limitation were established:

a. Only applicable to specified serial number F-94C;

b. Not applicable to F-94C, but to another type, model or series of aircraft;

TABLE III

Termination Design Change Costs, and Inventory Material[1] Scrap and Rework Costs, F-94 Spare Parts, by Year

Year	Inventory Material Scrap & Rework Costs (Dollars)	Termination Design Change Costs (Dollars)	Total (Dollars)
1948	$ --	$ 830	$ 830
1949	480	10,940	11,420
1950	8,710	14,065	22,775
1951	39,435	30,500	69,935
1952	56,915	207,820	264,735
1953	108,250	85,655	193,905
1954	101,510	77,150	178,660
1955	690	6,855	7,545
	$315,990	$433,825	$749,805

1 Obtained from cost accounting records of the Lockheed Aircraft Corporation, Burbank Division.

c. Applicable to specific serial F-94C aircraft, and also to another type, model, and series of aircraft;

d. No remaining applicability (totally obsolete).

The sum of (a), (b), and (c), above, represent the cost of limited applicability, as found by this "exhibit" method.[1]

The dollar value of airframe parts whose applicability was in some way limited by design change is shown in Table IV (and in column 4 of Table V). More than 90 per cent of the total cost falls into category "a," applicable to specified serial number F-94C aircraft only. Close to 400 different spare line items had their applicability limited by design change. Of these, about 50 items were expensive assemblies with costs of more than $500 per unit. This group of expensive items accounted for almost 80 per cent of the value of spares with limited applicability.

E. Aggregation of Spares Design Change Impacts

The various elements of design change impact are now aggregated, and cumulated over the six years. These elements, cumulated from Tables I - IV above, are shown in columns (1) - (4) of Table V. Columns 5 and 6 of Table V present the cumulative dollar value of spares design change cost. The figures in Column 5 exclude the costs of limited applicability; these numbers constitute minimum estimates. Column 6 includes the full value of

---

[1]The total value of parts in the (d) category provided an independent* estimate of the importance of engineering obsolescence. This method of estimating design change obsolescence established an upper limit for this cost factor, because the figure obtained is that of spares delivered to the Air Force, not, as in the Technical Order method, (see p. 12-13, above), of spares on hand at the time of the design change. The scope of the data provided in the Exhibits was not identical to that covered in the Technical Orders. However, when the coverage of the two methods was reconciled, somewhat less than $40,000 of F-94 airframe items were made obsolete by design change via the Exhibit method compared to a $32,000 estimate on the basis of the Technical Order method. Since the Exhibit method produces a known over-estimate of such impacts, these two results were taken to be in basid agreement.

*(which we call the "Exhibit method")

TABLE IV

Dollar Value of Air frame Parts with Applicability Limited by Design Change, F-94 Spares, by Type of Limitation and Year

Year	Type of Limitation[1] a	b	c	Total
1951	$ 425	$ —	$ --	$ 425
1952	87,730	3,988	387	92,105
1953	968,441	41,937	41,007	1,051,385
1954	507,445	23,972	21,208	552,625
	$1,564,041	$69,897	$62,602	$1,696,540

1 a Only applicable to specified serial number F-94C.

b Not applicable to F-94C, but to another type, model or series of aircraft.

c Applicable to specific serial F-94C aircraft, and also to another type, model, and series of aircraft.

TABLE V

CUMULATIVE COSTS OF DESIGN CHANGE ON

F-94 AIRFRAME SPARES INVENTORY

(Thousands of Dollars)

	Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9
								Percent of Delivered Spares Affected by Design Change	
Year	Cumulative Spares Obsolescence	Cumulative Spares Modification	Cumulative In-Plant Spares Obsolescence	Cumulative Limited Applicability	Total Cols. 1, 2 and 3, Cumulative Cost Excluding Limited Applicability	Total Cols. 1, 2, 3 and 4. Cumulative Costs Including Limited Applicability	Value of Delivered F-94 Airframe Spares (Cumulatively)	Col.5 Divided by Col. 7	Col. 6 Divided by Col. 7
1950			34.8		34.8	34.8	5,811	.6	.6
1951	1.2	18.7	104.9	.4	124.8	125.2	21,816	.6	.6
1952	1.5	20.2	369.6	92.5	391.3	483.8	26,403	1.5	1.8
1953	5.0	24.0	563.6	1143.9	592.6	1736.5	54,415	1.1	3.2
1954	31.6	423.7	742.3	1696.5	1197.6	2894.1	64,290	1.9	4.5
1955	999.7	619.3	749.9	1696.5	2368.9	4065.4	64,290	3.7	6.3

all airframe parts which have had their applicability limited in some way by a design change; these can therefore be viewed as maximum estimates. The last three columns of Table V relate the estimates of spares design change cost to the dollar value of delivered F-94 airframe spares.[1] Column 8 shows the minimum estimate of spares design change cost in per cent of the value of delivered spares, while Column 9 shows similar information for the maximum estimate.

It appears that at the end of the first six years of the F-94 program, between 3.7 and 6.3 per cent of the value of delivered airframe spares had been made obsolete as a result of design change. Surprisingly, despite the fact that the bulk of design change occurs early in the phase-in of a weapon, the impact on delivered spares appears to be relatively small during this early period.

Contrary to expectations, therefore, the spares cost of design change appears to be lowest during the early phase-in of the weapon. During the first two years of an aircraft program, between one and two per cent of the value of delivered spares are affected by design changes. Since the greatest number of engineering changes occur early in the program, one would expect the spares design change impact to fall rather than rise over the life of the weapon. Some of the reasons for the reverse situation are:

1. In general, while airframe changes are more numerous during the early phase-in period, they tend to be relatively minor in scope. Many, if not most, of the early design changes affect expensive major assemblies;

[1] Estimated from AMC Budget Program Summaries for the relevant years. These data include only the spares initially purchased while the F-94 was in production. They do not include "follow-on spares," which were less than 10 per cent of all F-94 spare parts through 1955.

however, most cases involve relatively minor modifications rather than condemnation of the assembly itself. Parts condemned by reason of design change tend to consist of low-cost components for such major assemblies. Further, even if modification costs per unit are substantial, the fact is that most major airframe items have relatively low expected demand rates; hence, early in the phase-in, few such spares tend to be in the system. As a consequence, total spares modification cost tends to be low at this time.

2. Later in the life of a weapon, major modification programs may occur in order to improve the performance of the aircraft rather than to correct an early design deficiency. For example, an interceptor model may receive extensive modification to take advantage of new air-to-air missile. Or, an aircraft designed in an era of reciprocating engines may undergo major modifications by having jet engines added to its power complement. Apparently, during these major modification programs, the bulk of spares design change impact occur. For the F-94, one Tech Order covering a major modification late in the program accounted for 90 per cent of the roughly one million dollar value of spares condemned by reason of design change over a period of five years.[1]

3. Expensive spare parts are not often condemned by a design change. They are ordinarily modified, while the associated bits and pieces are condemned or limited in applicability. Only one item with a unit cost of greater than $500 was condemned by all the F-94 Tech Orders. Similarly, less than 25 items with a unit cost of greater than $500 were limited in their application by design change.

---

[1]The purpose of this T.O. was to improve the cold weather performance of the F-94. The change essentially consisted of a new de-icing system for the aircraft, making components for the old system obsolete.

4. Contractors and Air Force show a good deal of administrative flexibility in reacting to design changes. The large number of reductions in orders for parts affected by design change shows the system's responsiveness in this area. For example, on one F-94C contract, approximately $9.5 million of airframe spares were placed on order. While the aircraft under this contract were in production, approximately $4.1 million of the items originally placed on order were cancelled as a result of design change, and spares associated with the newly designed configuration were produced and delivered. Had these design changes not been caught, about $3.1 million of useless spares would have been delivered to the Air Force.

5. In the case of the F-94, most of the spare parts were delivered by 1953. However, the greatest spares impact of design changes occurred after 1953, because the majority of the costly design changes (in terms of limited applicability and spares condemnations) occurred after 1953. Also, the Air Force policy of concurrent delivery of spares,[1] which ensures that the spares delivered have applicability (at least at the time of delivery) to a certain number of end items, would tend to delay the impact of design change on delivered spare parts.

V. DESIGN CHANGE IMPACTS ON F-100 AND B-52 SPARES INVENTORY

Information covering selected elements of design change impact was also collected for two other weapons, the F-100 and B-52 aircraft, to serve as a limited check on the results obtained for the F-94. Because both the F-100 and the B-52 are relatively new weapons, spares design change costs for only the first two years of the phase-in could be gathered and only two elements, engineering obsolescence and spares modification, could be studied.

---

[1] See Footnote 1, page 10 above.

The results, therefore, are restricted to the early phase-in period and neglect the impact of both in-plant or contractor obsolescence and limited applicability. The data used for estimation consisted of the Technical Orders written on the F-100 and B-52 up to May 1956. The method of analysis was the same as that followed on the F-94 (pp. 11-15).

A. Spares Engineering Obsolescence Costs

As of May 1956, 57 Tech Orders had been issued covering F-100 airframe design changes. Of these, 13 called for the condemnation of one or more delivered airframe spares. The dollar value (unit price x quantity on hand) of such condemned spares was approximately $17,500. As in the case of the F-94, almost all of the condemned parts were inexpensive (unit price less than $10). By March 1956, slightly more than $30,000,000 worth of F-100 airframe spares had been delivered to the Air Force.[1] Thus, less than 0.1 per cent of the value of delivered airframe spares had been made obsolete by reason of design change during the first two years of the F-100 program. The F-100 program is still too embryonic to make any sweeping generalizations about the ultimate importance of spare engineering obsolescence; but the results obtained appear to corroborate the estimates of design change impact for the F-94 during the early phase-in period.

The importance of spares engineering obsolescence in the B-52 program to date parallels that for both the F-100 and F-94. Of the 256 B-52 Tech Orders issued by July 1956, 36 made some delivered spares totally obsolete. The total dollar value of the roughly 150 condemned parts (as of the most approximate date following the T.O.) came to $133,000. By May of 1956,

---

[1] Obtained from the Spares Administration Division, North American Aviation Corporation.

about 0.3 per cent of the $44 million of delivered B-52 airframe items had been made obsolete by reason of design change.[1] Again, the low value of spares engineering obsolescence during the early B-52 program bore out the F-94 results.

B. Spares Modification Costs

Only eight of the 57 F-100 Technical Orders called for modification of delivered spares. The cost of parts and labor required to perform the necessary modifications totaled $34,000, of which almost 90 per cent represented labor expense. Thus, the cost of spares modification came to about 0.1 per cent of the value of F-100 airframe spares delivered during the first two years of the F-100 program.

Spares modification was called for on 35 of the 256 B-52 Tech Orders. The value of material and labor required to perform the modification comes to $267,000, of which about 60 per cent was for modification kits and 40 per cent for labor. As of mid-1956, B-52 spares modification costs amounted to about 0.6 per cent of the value of delivered airframe spares.

During the first two years of the F-100 and B-52 program, the cost of spares modification required by design change was less than one per cent of the value of delivered spares. These results are consistent with the estimates derived for the F-94 during the early phase-in period.

VI. DISCUSSION OF RESULTS

The cost estimates of spares design changes developed in this study should be interpreted as approximate values. A variety of problems, including changing definitions of key words in Air Force records over time and

[1] The value of B-52 airframe assets was obtained from USAF Property Class Management Digest, Directorate Supply and Services, OCAMA.

gaps in available data, made precise results impossible to obtain, but this should not negate the general conclusions drawn from the estimates. While it is impossible to evaluate, precisely, how much has been missed due to gaps in the data, experience with the available data indicate it is highly unlikely that the obsolescence costs under consideration have been underestimated by more than 10 per cent. The data were such that we could at least know where the gaps existed and also what kinds of design changes were involved. In no case is there a data gap involving the impact of a major design change.

In considering the results, the fact that the study examines only one weapon, the F-94, over its first line operational life should be kept in mind. Data on engineering changes indicate, however, that most aircraft behave in basically the same fashion with respect to the timing and the number of engineering changes. Furthermore, the analysis of the design change impact upon the first years of spares support for the B-52 and F-100 weapons support the estimates obtained for the F-94.

In evaluating these results, the fact that the present study estimates the spares impact of design change as it occurs under present Air Force provisioning and procurement policies should be kept in mind. For example, were all aircraft designs frozen, for a given weapon, when a specific number of that weapon had been produced, the results would have been different. Also, were the Air Force to spend relatively more resources on design changes of older model aircraft and less in producing new models, in the future, the results of this study would not be immediately applicable to the future. However, no such institutional changes appear in the offing.

The broad conclusion of this study, then, can be stated: over the life of a weapon the cost of airframe spares design change, including obsolescence and modification of delivered spares, in-plant obsolescence, and limited use may eventually be as much as 10 per cent of the value of delivered spares. For the F-94 model, a spares cost of five to seven per cent appears more nearly correct.

It is not possible to state, with assurance, what provisioning policies are "optimal" in the light of such obsolescence costs. Other costs, such as reordering and warehousing, must also be considered. However, in the light of this study's introductory comments, it appears that the value of purchasing expensive spare parts on a "hand-to-mouth" basis until the design configuration of the end article becomes hardened might be considerable. Expensive (having a unit cost of more than $500) spare parts, which consist of only two per cent of the Air Force line items but more than 50 per cent of total spares' dollar value, are beginning to be controlled under an Air Force Hi-Valu program. In this "hi-valu" area, the gain that would result from a decrease in spares' obsolescence costs might be considerable, at a relatively small cost. However, the obsolescence costs indicated by this study do not seem to warrant by themselves a change in the present procurement policy for "low-valu" items, for which the Air Force is tending toward large (possibly life-of-type) initial buys. For "low-valu" items, the costs of reordering and handling probably are predominant. These are, of course, only tentative conclusions but it is hoped that the obsolescence estimates supplied by this study will be helpful in reaching a firm conclusion regarding provisioning policies.

BLANK PAGE