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OPERATIONS EVALUATION GROUP
STUDY NO. 467

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**DAMAGE SUFFERED BY USN AND USMC GROUND-ATTACK
AIRCRAFT IN KOREA (U)**

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OPERATIONS EVALUATION GROUP
STUDY NO. 467

DAMAGE SUFFERED BY USN AND USMC GROUND-ATTACK
AIRCRAFT IN KOREA (U)

ABSTRACT

report
This study describes the kind of information that can be obtained from an analysis of Aircraft Vulnerability Report Forms, and reports the results of a preliminary, small-sample study that was made to determine the potentialities of a larger-scale analysis. (Among the conclusions to which this preliminary analysis leads are the following:

- (a) Of the ground fire encountered, jet aircraft receive a greater proportion from ahead and from directly below than do conventional aircraft. Hits are rather uniformly distributed over both types of aircraft.
- (b) In terms of aircraft lost per hit, the F4U is twice as vulnerable as the P9F, which is twice as vulnerable as the AD. Components contributing to aircraft losses are, in order of importance, pilot, oil system, fuel system, and engine; the high vulnerability of the F4U can be traced directly to the vulnerability of its oil coolers.
- (c) The fact that vulnerability varies so widely from aircraft to aircraft indicates that it can be markedly affected by design, and that attention to the vulnerability of aircraft now under development should pay dividends in the form of reduced loss rates.

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OPERATIONS EVALUATION GROUP
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DAMAGE SUFFERED BY USN AND USMC GROUND-ATTACK
AIRCRAFT IN KOREA (U)

I. INTRODUCTION

This study has two objectives. The first is to indicate the type of analysis that could be made from an IBM coding of the data given on Aircraft Vulnerability Report Forms, OpNav 3480-5. The second is to present certain preliminary conclusions, based on a limited number of forms which were hand-coded in the process of reaching the first objective, regarding the vulnerability of naval aircraft.

The analysis indicates that the following types of information are available:

(a) Distribution of hits:

- (1) by direction relative to the aircraft,
- (2) by location on the aircraft,
- (3) by aircraft component hit or affected.

(b) Types of projectiles encountered and relative frequency of each type.

(c) Aircraft damage:

- (1) relative frequency of various degrees of damage;
- (2) degrees of damage caused by various types of projectile.

(d) Aircraft losses:

- (1) frequency by type of kill;
- (2) by primary aircraft component responsible;
- (3) where the sample is large enough, losses by primary aircraft component responsible are also presented by type of aircraft.

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- (e) Aircraft vulnerability by type of aircraft (as measured by the probability that a hit will be a kill)

The results presented here are based on sufficient data to be reasonably reliable, but a larger sample would permit all of the above to be investigated specifically for each type of aircraft as well as a closer investigation of the effect of hits on various aircraft components. Coding by IBM would also permit the vulnerability data to be related to the information contained on Air Attack Forms: the type of mission, the amount of anti-aircraft present, the type of target, etc.

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II. LIMITATIONS AND INTERPRETATION OF THE DATA

This analysis is restricted to a limited number of Aircraft Vulnerability Reports covering roughly one month's operations (those of May 1951). The information on May operations is not complete, however, since three squadrons reported major damage only. Some data from August and September 1950 and January and April 1951 are also included. The data analyzed cover the damage or loss of 137 F4U's, 80 AD's, and 30 F9F's.

The accuracy and reliability of individual reports vary from squadron to squadron. Furthermore, the data on losses is often hard to interpret, though Aircraft Crew and Survival Reports and the statements attached to them are of great assistance in completing the picture.

An aircraft loss is here considered to be an aircraft incapable of flying more than one-half hour after being hit, or incapable of landing safely on the deck of a carrier. Many aircraft which are lost suffer multiple damage, and the primary cause of the loss is then not easily determined. If the pilot is rendered unconscious, then that is considered the primary cause of the loss. If the aircraft is known to have received a hit which stopped the engine, then that is considered the primary cause, even though the aircraft may also be on fire. However, if a loss of oil pressure preceded by an appreciable time the stopping of the engine, then the oil system damage is considered the primary cause of loss.

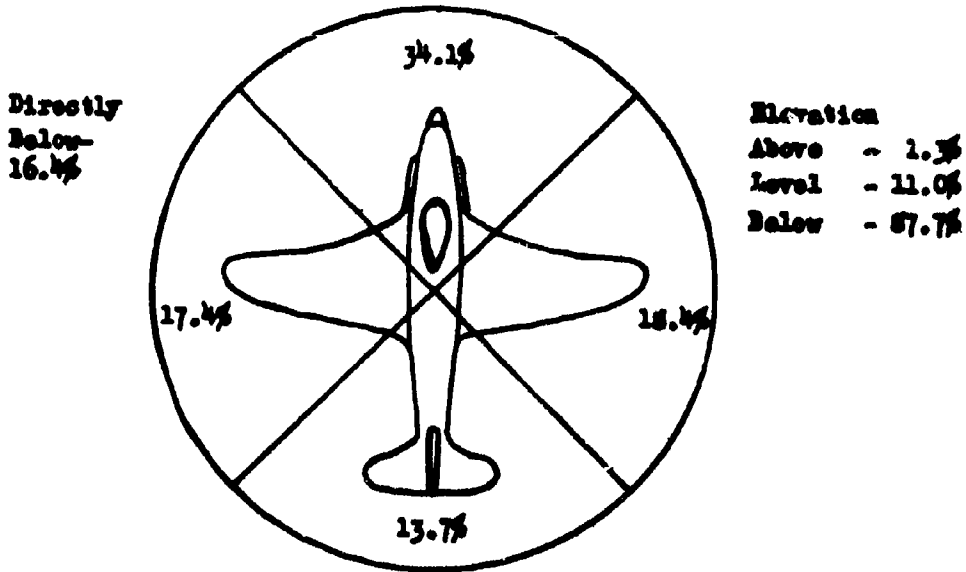
In reporting, the direction from which projectiles strike the aircraft the clock system is used in azimuth and the general terms "below", "level", "above", and "directly below" are used in elevation. The results are, therefore, not very precise, especially since 12, 3, 6 and 9 o'clock are strongly favored in reporting.

It is here assumed that in elevation the plane of reference is the plane of the wings, although in many cases fire from the ground is reported as being from "below" regardless of the attitude of the aircraft. Where possible, the path of the projectile through the aircraft has been used to change the reported direction to a direction relative to the plane of the wings.

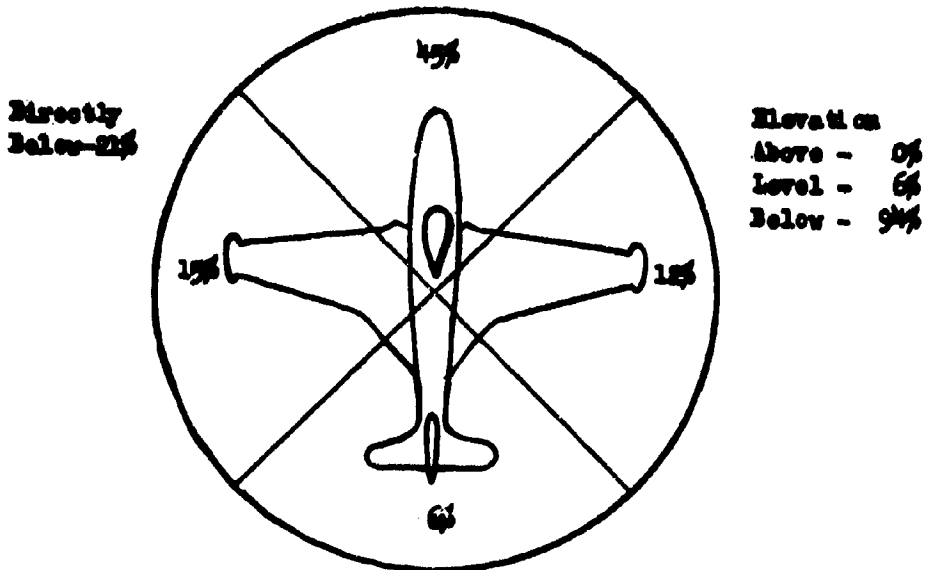
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(a) All Aircraft



(b) F3F Only

FIG. 1: DIRECTION OF GROUND FIRE

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III. RESULTS

A. DISTRIBUTION OF HITS

(1) Direction of Ground Fire: Figure 1 presents the distribution of ground fire by direction of approach. (Figure (1a) for all aircraft, Figure (1b) for the F9F only). Approximately twice as many projectiles come from the forward zone as come from any one of the others, including "directly below". Eleven percent of the projectiles come from an approximately level direction; practically all of the remaining hits come from below the plane of the wings. Approximately 16 percent come from directly below. Jet aircraft suffer a 30 percent higher fraction of hits from the forward quarter than do reciprocating-engine aircraft, and also suffer an increased relative amount of fire from directly below. (However, VMP-11 has reported that jet aircraft receive only half as many hits per combat hour, as do reciprocating-engine aircraft.) These effects could be the result of the higher attack speeds used by jet aircraft or of the fact that jets have different types of missions, e.g., armed reconnaissance.

(2) Location of Hits on the Aircraft: Approximately 52 percent of the hits are located on the wings, 35 percent on the fuselage, and 13 percent on the empennage. A more detailed breakdown is shown in Figure 2. It can be seen that the distribution of hits corresponds roughly to the presented area in plan of the wings and tail surfaces, with the fuselage receiving a slightly larger proportion of hits. The density of the ground fire about the aircraft appears to be relatively uniform.

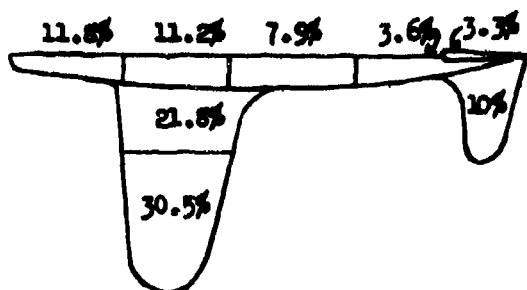


FIG. 2: DISTRIBUTION OF HITS

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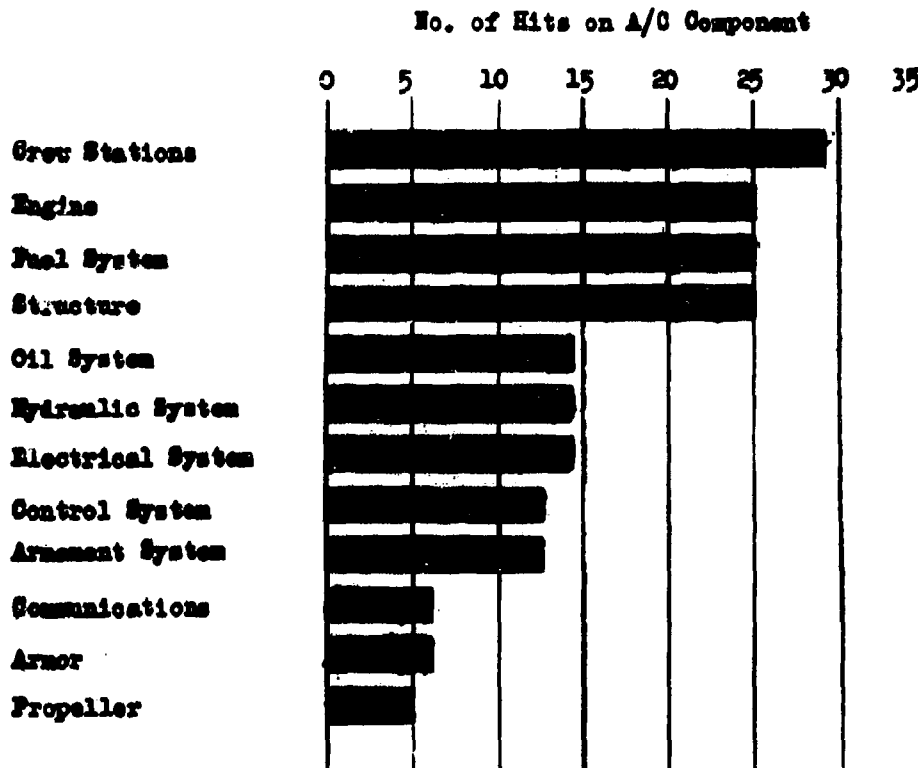


FIG. 3: DISTRIBUTION OF HITS BY AIRCRAFT COMPONENT

(3) Aircraft Components Hit or Affected: The distribution of hits by aircraft component is shown in Figure 3. The hits on crew stations include hits which pass close to personnel, or which would pass close to personnel if not stopped by armor plate or some other immediately adjacent object. Structural hits were counted only when more than a simple patch over a hole was required to repair them. Fifty-four percent of the recorded hits on the pilot's cockpit went through the canopy and 60 percent of the hits on fuel systems involved external auxiliary fuel tanks.

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B. TYPE AND RELATIVE FREQUENCY OF PROJECTILES ENCOUNTERED

The relative frequency of hits by type of projectile is presented in Figure 4. Hits were classified in the report forms studied as "fragments," "small arms," ".30 calibre," ".50 calibre," "20mm," "40mm," and "unknown." 12.3 percent of the total number of hits were reported simply as "small arms," 17.1 percent were reported as ".50 calibre," and 38.0 percent were reported as ".30 calibre." These are classed together in Figure 4 so that 67.4 percent of the total number of hits is credited to "small arms" fire.

No attempt has been made to compare the scale of anti-aircraft fire present in the Korean Theater with other opera-

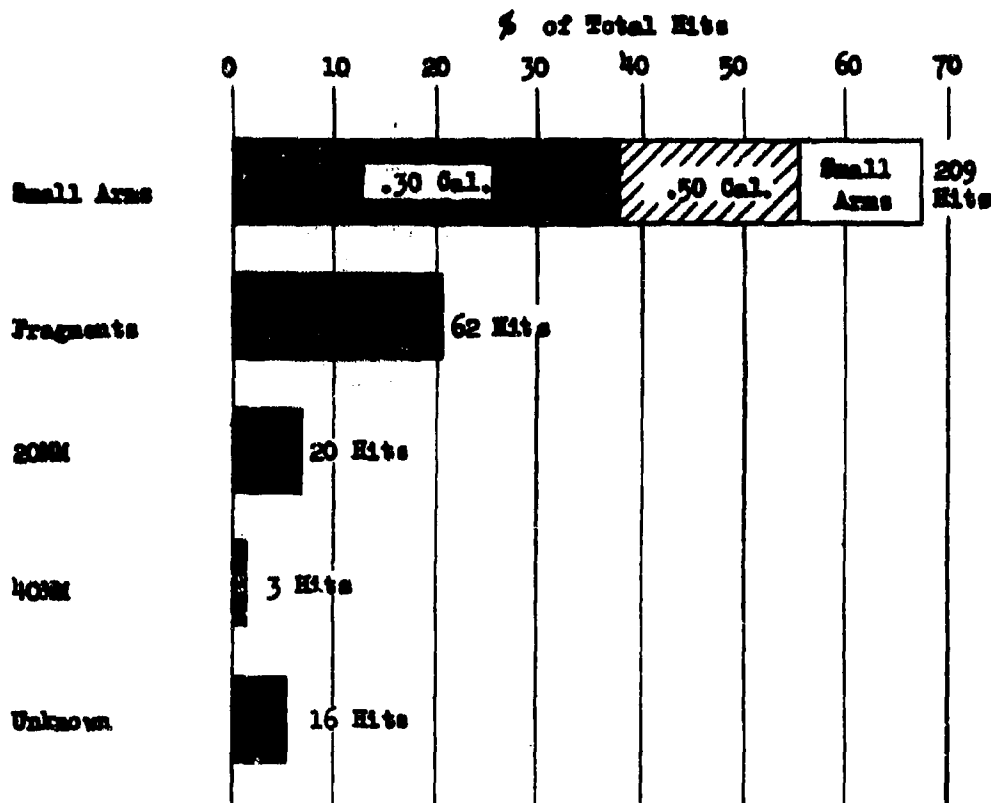


FIG. 4: RELATIVE FREQUENCY OF HITS BY VARIOUS TYPES OF PROJECTILES

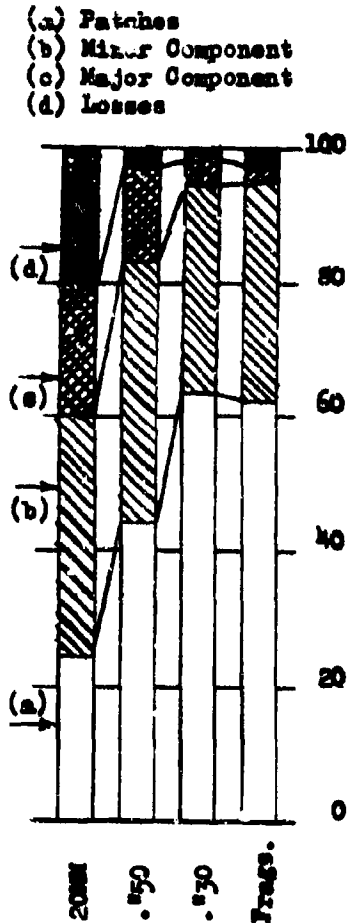


FIG. 5: DEGREE OF DAMAGE BY CALIBER

enough information to allow a rough check on one of the curves in Figure 2 of reference (a). Where that curve would predict that between 2 and 2.3 inches of aluminum-alloy would be required to stop a ".50 calibre projectile, such a bullet actually penetrated 2 inches into a main-wing spar.

C. AIRCRAFT DAMAGE

The degree of damage inflicted by projectiles which hit the aircraft have been classified into four groups according to

tions, so this distribution as to type of projectile must be considered as peculiar to Korean operations in the spring of 1951. While insufficient data are considered to make possible conclusive statements on the general trend in projectiles being used in Korea, it seems that during this period the use of incendiary ammunition has been increasing and that fuzes have progressed from instantaneous to a slight delay type. Enough references have been made to explosive ".30 calibre" and ".50 calibre" projectiles to indicate that these types are actually in use and, from the description of damage caused, they appear to be fairly effective.

Of the reported hits by fragments, 67 percent were attributed to our own bomb or rocket bursts; 16.5 percent were classified as unknown and 16.5 percent as anti-aircraft shells.

Few quantitative data on striking velocities are available from action reports.

However, one case reported gave

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the type of repair required:

- (a) patch only,
- (b) replace minor component,
- (c) replace major component,
- (d) aircraft lost.

The frequency with which the various types of damage occurred in the data reviewed is shown in Figure 5 by projectile type, and in Figure 6 for all cases.

While the number of hits by 20mm projectiles is relatively small, the large proportion causing aircraft loss and replacement of major components is considered to be significant. In the category of replacement of major components, ".50 calibre projectiles show considerably more effectiveness than ".30 calibre or fragments.

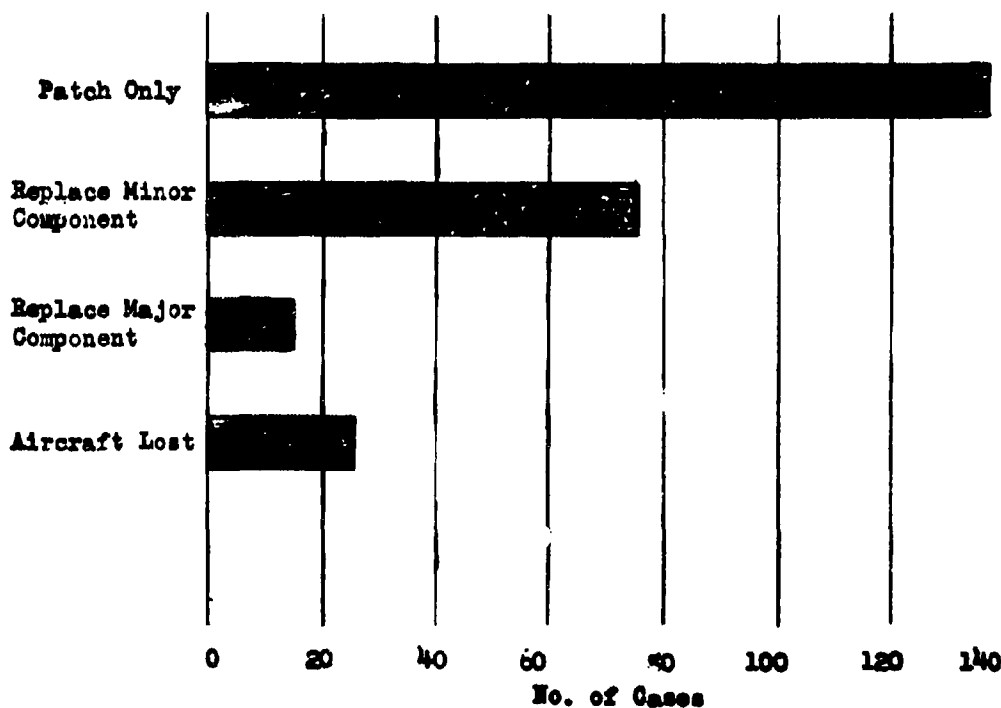


FIG. 6: DEGREE OF DAMAGE

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D. AIRCRAFT LOSSES

(1) Type of Kill: Aircraft losses have been classified in four groups:

- (a) K-kills - immediate destruction
- (b) A-kills - not more than 5 minutes of flight possible
- (c) B-kills - not more than $\frac{1}{2}$ hour of flight possible
- (d) D-kills - unable to land safely on a carrier

Figure 7 presents the aircraft losses by type of kill. The

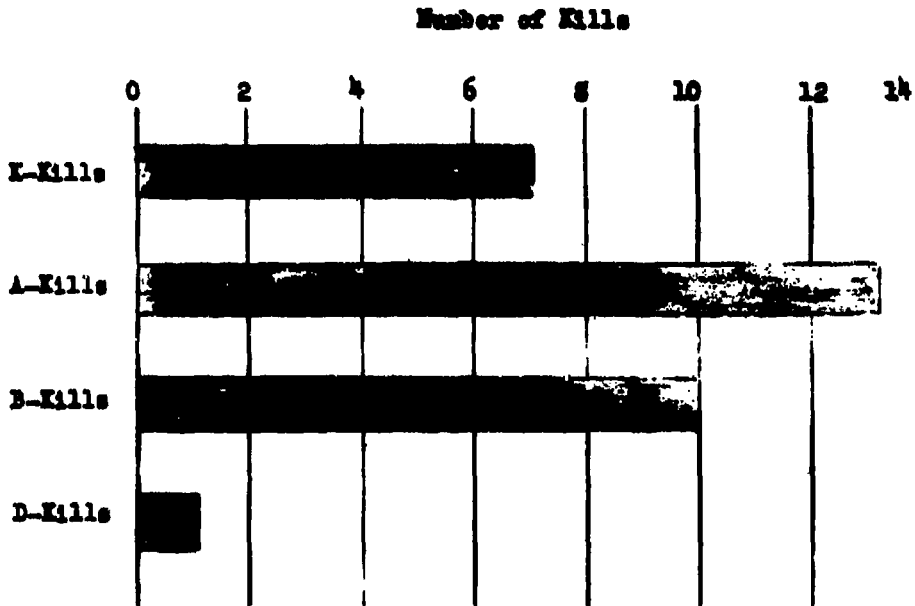


FIG. 7: AIRCRAFT LOSSES BY TYPE OF KILL

* Note: Aircraft losses reported here have no relation to figures given in Aircraft Inventory Reports because of the definitions employed.

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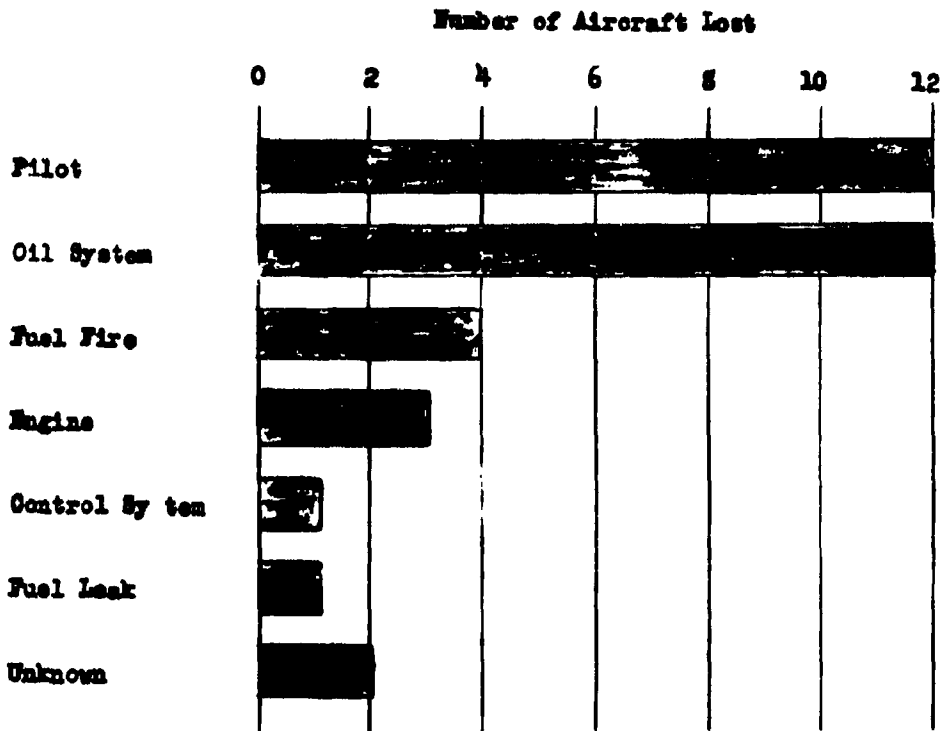


FIG. 8: PRIMARY AIRCRAFT COMPONENT CONTRIBUTING TO AIRCRAFT LOSS

number of B-kills would probably have been larger had all emergency landings been reported.

(2) Aircraft Component Responsible for Loss: Aircraft losses have also been classified according to the primary aircraft component contributing to the loss, as shown in Figure 8. The oil system appears to contribute much more to aircraft losses than would appear from the data presented in Figure 3. However, many of the hits on the engine stopped the engine only by affecting the oil system, so that the loss of oil is considered to be the primary cause of the aircraft loss. The oil system and the pilot appear to overshadow all other components contributing to aircraft losses; there is considerable difference, however, between

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the two groups of losses. In the case of the oil system, the losses are mostly B-kills; in the case of the pilot, the losses are almost all K-kills. In addition, many of the cases in which the pilot is considered the primary cause are "overkilled" -- there would have been an aircraft loss even if the pilot had been protected.

(3) Reliability of Data on Aircraft Losses: For most aircraft which were actually lost, the primary aircraft component responsible for loss cannot be definitely established. However, because of the definition of aircraft losses used in this study many of the aircraft classified as lost actually made emergency landings in friendly territory, so the primary component responsible for loss (as defined here) was definitely determined. In other cases the rescued pilot or radio contact after damage establishes the component responsible for loss. In addition, the statements usually attached to Aircraft and Crew Survival Reports often show the aircraft component probably responsible for the loss. Only a few cases occurred where the component responsible for loss was definitely unknown. The proportion of losses in these three classifications are:

Component responsible for loss definitely known - 52%
Component responsible for loss probably known - 41.5%
Component responsible for loss definitely unknown - 6.5%

(4) Aircraft Vulnerability: Classification of losses by aircraft type shows large variation in the probability that an aircraft will be killed if it sustains a hit. The ratios of aircraft kills to aircraft hit by type follow:

Aircraft Type	No. of Aircraft Hit	No. of Aircraft Killed	Ratio
F4U	137	17	.124
AD	80	3	.038
P9F	30	2	.067

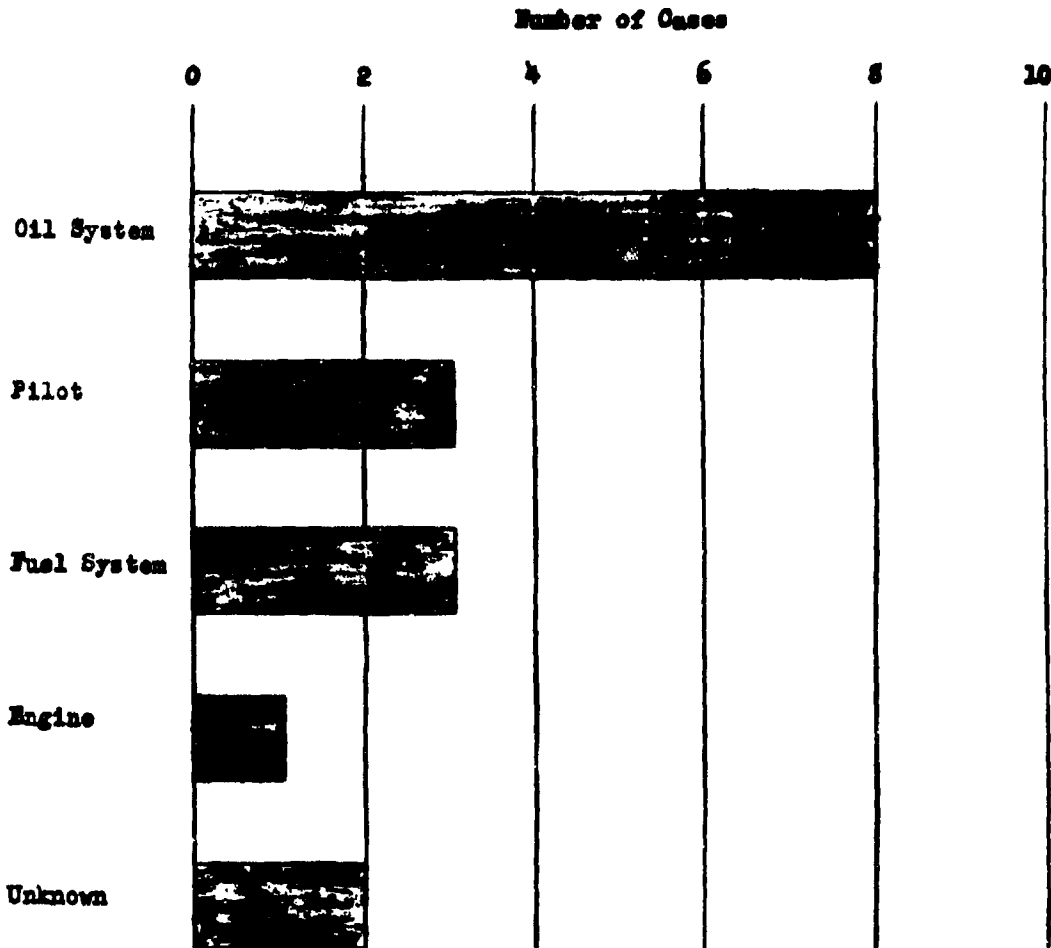


FIG. 9: PRIMARY COMPONENTS CONTRIBUTING TO THE KILL OF F4U AIRCRAFT

(5) Aircraft Components Responsible for F4U Losses: Aircraft components contributing to the loss of F4U aircraft are shown in Figure 9. The vulnerability of the oil system of the F4U is immediately apparent. (It is this high vulnerability of the F4U oil system, combined with the relatively large number of F4U's which received hits, that is responsible for the importance of oil-system damage in the all-aircraft category. (See Figure 8.)) The small number of

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kills for AD and F9F aircraft precludes a similar analysis of their vulnerability.

(6) Comparison of the Vulnerability of the Oil Systems of the Aircraft Considered: In the case of reciprocating engines complete loss of oil or oil pressure very quickly results in engine failure. Although no hits on the oil system of the F9F aircraft are recorded, loss of oil or oil pressure in jet engines does not appear to be quite as serious. At least two cases have been reported in which jet engines continued to run for considerable periods after complete loss of oil or oil pressure. The oil systems of reciprocating engines are affected most frequently by hits on the engine and hits on the oil coolers. A comparison of hits on the engine by aircraft type is given in the following table:

	F4U	AD	F9F
Probability that the engine will be hit if the aircraft is hit	.095	.088	.067
Probability that the oil system will be affected if the engine is hit	.38	.43	---

There is no marked difference in these data between the F4U and the AD aircraft. The number of cases reported for the F9F is too small to have significance. A comparison of hits on the oil coolers of the F4U and the AD aircraft shows a very great difference by aircraft type:

	F4U	AD
Probability that the oil coolers will be hit if the aircraft is hit	.044	.013

The AD oil coolers are placed behind the engine in the fuselage and are protected by deflector plates. On the other hand, the oil coolers of the F4U are located near the leading edge of the wing, just outboard of the fuselage, and may or may not be protected by deflection plates. The operational results quoted above are considered to be the direct result of this difference in location; they illustrate the importance of taking advantage of existing less vital components for protection or providing adequate armor for vital components.

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III. CONCLUSIONS

1. Aircraft attacking ground targets receive ground fire from all directions below the level of the wings. Approximately twice as much ground fire is received from the forward zone as from any one of the others, including "directly below".

2. For jet aircraft, the relative amount of fire from both the forward quarter and "directly below" is approximately 30 percent greater than for propeller-driven aircraft.

3. Jet aircraft receive only 50 percent as many hits per combat hour as do propeller-driven aircraft. The influence on this ratio of the type of mission to which jet aircraft are assigned has not been investigated.

4. Hits from ground fire of the type encountered in Korea are rather uniformly distributed over the aircraft.

5. The aircraft components which receive the most hits are:

- (a) crew stations,
- (b) engine,
- (c) fuel system,
- (d) primary structure.

This may appear to be at variance with the conclusions of 4 above; but hits on the aircraft structure requiring only a simple patch are not included in (d).

6. Aircraft components contributing to aircraft losses are in order of importance:

- (a) pilot,
- (b) oil system,
- (c) fuel system,
- (d) engine.

7. Although the hydraulic, electrical, control, armament, and communications systems received many hits and undoubtedly affected the efficiency of the aircraft and probably its ability to carry out its mission, very few losses could be traced to these components.

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8. Aircraft losses could be significantly reduced by protecting the pilot from ground fire.

9. ".50 calibre projectiles are significantly more damaging to aircraft structure and components than ".30 calibre projectiles or fragments. 20mm projectiles are significantly more damaging to aircraft structure and components than ".50 calibre projectiles.

10. The F4U aircraft is twice as vulnerable (in terms of aircraft lost per hit) as the F9F aircraft, which is in turn twice as vulnerable as the AD aircraft. A large portion of the vulnerability of the F4U can be directly attributed to the vulnerability of its oil coolers.

11. The great variation in vulnerability of operational aircraft indicates that vulnerability could be decreased, and that the application of passive defensive measures to the aircraft now under development would ensure minimum losses.

12. Analysis of a larger sample of data by IBM coding would give additional and more reliable information on the vulnerability of our operational aircraft. Of particular interest are:

- (a) The overall vulnerability of the F9F aircraft.
- (b) The vulnerability of the jet engine of the F9F aircraft.
- (c) A reliable indication of the components contributing most to the vulnerability of the AD and the F9F aircraft.
- (d) A reliable indication of the ability of installed armor to stop projectiles encountered in attack of ground targets.
- (e) A comparison of the piston engine of the F4U and the nose section of the F9F as protection for the pilot during ground attack.
- (f) The effect on hit and loss rates of mission or target types.

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IV. RECOMMENDATIONS

It is recommended that:

- (a) A current analysis of operational vulnerability data be maintained so that significant changes in enemy weapons or tactics may be detected and so that operational data may be available to guide (from the standpoint of vulnerability) design trends in aircraft under development.
- (b) That the data contained on Aircraft Vulnerability Report Forms, OpNav 3480-5, be coded by IBM methods so that larger samples of data can be treated efficiently.

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O. A. HOFFMAN
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Operations Evaluation Group

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