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AIR TO AIR TACAN

DME TEST

USAF review(s) completed.

27 January 1967

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SUMMARY

During the last six months of 1966 several incidents of range errors were reported in the Air to Air TACAN installed in the A-12 and F-101 #266. In all cases the indicated ranges were greater than actual range when the error appeared. An investigation was initiated, followed by a test plan to determine the cause of the error and to solve the problem if possible. It was theorized that the range errors were caused by signals reflecting off the ground. A KC-135 tanker was instrumented to prove or disprove this theory and an F-101 equipped with an Air to Air TACAN was used as the receiver. The test proved that the theory was correct. Eliminating the use of the tanker lower antenna greatly reduces the frequency of occurrence. This coupled with TACAN alignment checks and the adoption of various procedures to avoid known interference problems should result in DME reliability and accuracy comparable to that achieved by "accepted" rendezvous aids. Pending additional experience pilots will be briefed that the possibility of a DME error does exist; present procedures which require 1000 ft of altitude separation until the tanker is acquired visually will be continued.

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Attachment 1 (10 Pages)

Description of Equipment

Test Item

Test Instrumentation

Support Equipment

Test Methods & Limitations

Test Procedures

Data Collection & Reduction

Accuracy of Data

Test Results

Conclusions

Recommendations

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INTRODUCTION

25X1 1. Air to Air TACAN is used as a rendezvous aid for the pur-
poses of refueling the A-12 with a KC-135 tanker. All of the
25X1 KC-135's at Beale Air Force Base and all of the A-12's [redacted]
[redacted] are equipped with an Air to Air TACAN. In addition
one of the F-101's [redacted] is also equipped with an Air to
Air TACAN. During a rendezvous, range information is dis-
played to the A-12 pilot in two ways: (1) The ARC-50 (2)
Air to Air TACAN. Should the ARC-50 range feature fail, then
TACAN is the only means by which the A-12 pilot can obtain
information regarding tanker/receiver range separation. The
KC-135 also has a radar transmitter/receiver to display both
range and azimuth information.

2. There is no doubt that range information is critical to
the tanker and receiver. During IFR conditions, lack of
range information constitutes a termination of the rendezvous,
and an error in range information constitutes a safety of
flight item. Upon the report of range errors in the TACAN
a test was immediately initiated to investigate and solve the
problem if possible.

3. The cause of the range errors was thought to be associated
with multipath signals. That is, when either the tanker's
TACAN or the receiver's TACAN transmits the signal travels
directly and indirectly to the other aircraft. The indirect
path is a reflection off the ground and is consequently
longer than the direct path. If the TACAN locks on to the
indirect signal a greater than actual range will be indicated.

OBJECTIVES

4. The objectives of the test were to prove or disprove the
theory that multipath reflections are causing the range errors,
and to develop solutions to the problem if possible.

RESULTS & CONCLUSIONS

5. See the attached report for Description of the Equipment,
Test Methods and Limitations, Test Results and Conclusions. How-
ever, one comment needs to be added in the conclusions. That

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is, a new type of Air to Air TACAN with azimuth and range information will be installed in the A-12 aircraft within a few months. Because of this fact no major modifications to the present equipment were recommended. We agree with the recommendations presented in the attached report not only because they will decrease the frequency of range errors with the present equipment, but because most of them are sound procedures even if the range problem did not exist. The reliability of future Air to Air TACAN equipment will benefit from the adopted recommendations.

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REVIEW AND APPROVAL

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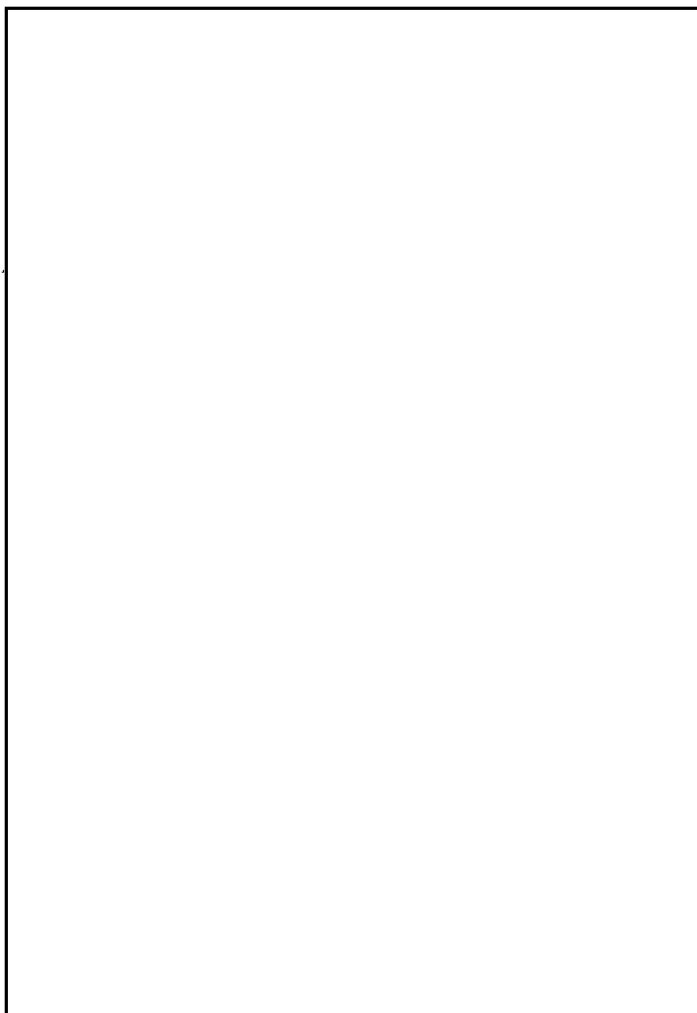
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Lockheed Aircraft Corporation

ADVANCED DEVELOPMENT PROJECTS
BURBANK, CALIFORNIA

REPORT NO. SP-1148
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MODEL	A-12
TITLE	AIR TO AIR TACAN

PREPARED BY

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REVISIONS

DATE	PAGES AFFECTED

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AIR TO AIR TACAN

I Configuration of aircraft involved in TACAN flight test.

A. KC-135

1. ARN-21 TACAN

- a. A/G capability only
- b. Gives range and bearing information from a ground station
- c. Can utilize one of two antennas. One located on the top and one located on the bottom of the fuselage.

2. ARN-52 TACAN

- a. A/G and A/A capability
- b. Gives range and bearing information from a ground station can range only from another aircraft.
- c. Can utilize one of two antennas separately or can automatically switch back and forth between the two. One antenna is located on the top, the other on the bottom of the fuselage.

3. APX-25 IFF

- a. Normal IFF system utilizing one antenna located on the bottom of the fuselage.

B. F-101

1. ARN-52V TACAN

- a. Temporary installation using one antenna centerline on the bottom of the fuselage.

II 28 November 1966

A. Preliminary

- 1. Tanker arrived and TACAN units were removed, checked and instrumented in Comm/Nav Lab.
- 2. Circuits that were monitored on the tanker's TACAN unit.
 - a. Video output
 - b. AGC voltage
 - c. Incoming reply pulses
 - d. Antenna switching voltage

B. Original condition of TACAN units received from KC-135 and F-101

- 1. S/N QK-27 (tanker): Antenna switching module inoperative.
16.5 DB signal rejection.
Bearing flag pulls on course bearing only.
- 2. S/N QK-28 (tanker): No A/A AGC which results in no rejection.
Unit generally in very poor shape.
- 3. S/N ALT 350 (F-101): No A/A AGC.

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III 29 November 1966

A. Preliminary

1. Installed units in tanker and checked same.
2. Installed test equipment in tanker.
3. Briefing for tanker and F-101 personnel.

B. Condition of TACAN units prior to flight

1. S/N QK-27: No AGC, hence no rejection - instrumented
2. S/N ATN805: Brand new unit received from Stewart Warner via Depot. Rejection was 14 DB - instrumented
3. S/N QK-28: Reset for 15 DB rejection - spare.
4. S/N ALF-350: Remained the same - no rejection as unit was received originally from depot for the F-101 in this condition.

C. Aircraft Involved in tests

1. F-101 (56-6291)
2. KC-135 (58-095)

D. Test flight

1. Made normal TACAN rendezvous with Article 131
 - a. Multipaths were not noticed at this time as equipment was being set up after tanker take off.
2. Flight plan was followed with the F-101 during the first rendezvous. (Flight plan and test schedule published by)
 - a. Multipaths were very prevalent a good portion of the time
 - b. Multipaths were apparently approx. 30 miles. Doesn't seem to be a problem until 15-20 miles. At this point the multipath signal is approximately the same strength as the direct signal.
 - c. F-101 obtained high readings of two (2) miles at approx. 10 miles down to 7 miles; at this point the F-101 broke lock and immediately locked on to the proper signal. No further errors were experienced during this rendezvous.
3. Deviated from flight plan.
 - a. Due to the abundance of multipath signals we changed the flight plan to allow the F-101 to make repeated rendezvous from a distance of 20-25 miles.
 - b. During these rendezvous a combination of antenna positions were tried in an effort to eliminate the multipath signals and/or break a false lock the F-101 might have had at any particular time. This had no effect.
4. Interference:
 - a. During the flight considerable interference was noted which caused the AGC and the PRF to increase. This would have a detrimental effect on sensitivity.
 - b. By process of elimination, the interference was isolated to the tankers' IFF and ARN-21 TACAN.

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5. Returned to flight plan inbound to homeplate.
 - a. Departed orbit path as briefed for homeward leg. During this period the F-101 attempted rendezvous from approximately 20 miles astern to a position 5 miles in trail.
 - b. Multipath signals were very prevalent as F-101 attempted to lock on false signal. A false lock was obtained at 5 miles and was maintained 2 1/2 miles high for 5-6 minutes over varying terrain.
 - c. During this phase all antennas positions were tried and the F-101 was asked to make various maneuvers all to no avail. The false lock was maintained.
 - d. When the false lock was manually broken by changing channels the proper lock was re-established. There is no guarantee of this however.

E. Post flight

1. Removed units from tanker and F-101.
2. Realigned units for next days flight.

IV 30 November 1966

- A. Condition of TACAN units prior to flight
 1. S/N 805 (tanker): 10DB rejection - instrumented
 2. S/N QK27 (tanker): 6.5 DB rejection - instrumented
 3. ALP350 (F-101): 12 DB rejection

B. Test flight

1. Aborted mission - pilots window shattered.
2. Returned to tanker's home station with crew

V 1 December 1966

A. Returned to

B. Condition of TACAN units prior to flight

1. Same as IV A.

C. Test flight - 12:15 T.O.

1. S/N 805 TACAN installed in tanker
 - a. Initial lock on was obtained by the tanker at 72 miles. F-101 had no lock on up to 57 miles. (during this period closure rate was very slow).
 - b. During this phase the IFF was muted to prevent interference and we changed channels to Ch 98. The F-101 still had no lock on.
2. Changed tanker's TACAN unit.
 - a. Installed S/N QK27
 - b. F-101 established lock at 55 miles. Tanker had no lock until 4 miles.

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3. Altitude change due to weather
 - a. After refueling, F-101 descended to 26M followed shortly by the tanker.
 - b. During this descent the maximum separation was approximately 20 miles and a lock was maintained by both aircraft. At this time a single multipath signal was observed. This signal was strong for approximately 30 seconds and then became weak and intermittent, and disappeared.
 - c. Another signal was observed momentarily at 7 1/2 miles but was very weak and intermittent.
 - d. No other problems were observed during this rendezvous.
4. Distance check with S/N QK-27 installed.
 - a. F-101 made a distance run to check sensitivity of 6.5 DB rejection level.
 - b. Tanker broke lock at 7.5 miles
 - c. F-101 maintained lock to 48 miles where he was recalled.

NOTE: Up to this time all the F-101 TACAN reply pulses were marginal at best. At this point they became weak and intermittent. No further lock on was obtained by the tanker.

- d. On the return from the distance run, the F-101 maintained lock all the way in to hook up. Tanker had no lock on whatsoever.
5. Reinstalled S/N 805 in tanker.
 - a. F-101 made another 20 mile run with no lock on by either aircraft.
 - b. Requested F-101 close to 3 miles and maintain trail with the tanker.
 - c. During this period a variety of equipment was changed in an effort to re-establish contact. This effort was in vain as the unit in the F-101 was not replying.
 - d. The test was terminated at this time.
6. Interference from tanker's IFF caused a rise in TACAN AGC of 0.7 volts.
 - a. TACAN on Ch 92 A/G with IFF on - AGC equals 3.5 V at 90.5 miles.
 - b. Same situation, but IFF off- AGC equals 2.8 V (TACAN unit adjusted for 10 DB rejection.)
 - c. Tried to obtain a suppression pulse from tankers (APX-25) IFF with a jumper cable, but to no avail.

D. Post flight

1. Inspected and repaired TACAN units.
 - a. The malfunctions that were found in the equipment explained the problems we were experiencing. A bad tube (V-2501) was found in the F-101 installation. A bad capacitor (C-2513) was found in S/N 805 installed in the tanker.

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- VI 2 December 1966
- A. Condition of TACAN units prior to flight
 1. S/N - 805 (tanker): 12 DB rejection - instrumented
 2. S/N - QK-27 (tanker): 8DB rejection - instrumented
 - S/N - ALF-350 (F-101): 12 DB rejection
 - B. Test flight
 1. Aborted mission - F-101 engine problems
 - a. Departed in KC-135 for normal refueling mission. Unfortunately this receiver was not A/A TACAN equipped. After completion, we returned to
- VII 8 December 1966
- A. Condition of TACAN units prior to test.
 1. Same as VI A
 - B. Aircraft involved in test
 1. F-101 (56-6291)
 2. KC-135 (59-1049)
 - C. Flight Test
 1. Tankers TACAN antennas.
 - a. With antenna select switch in "Top" the antenna actually in use was located on the bottom, and vice versa. This was due to the antenna coax being reversed on the antenna relay. This was remedied.
 - b. Also found an improperly assembled coaxial connector on the antenna coax. This was repaired as best we could under the circumstances.
 2. S/N 805 TACAN installed in tanker
 - a. While F-101 was in trail at distances varying from 0-25 miles from the tanker multipath signals were noted while on the tanker's bottom antenna.
 - b. The false signals were noted out to approx. 20 miles but were more prevalent between 4 to 9 miles.
 - c. Multipath signals were noted while using the tanker's top antenna but were few in number and seem to be no problem inside of 3 to 4 miles.
 - d. F-101 made a distance run of approx. 120 miles with no problems as far as sensitivity of the TACAN is concerned.
 3. S/N QK-27 TACAN installed in Tanker.
 - a. F-101 maintained 0-25 miles distance from tanker and in trail. Multipath signals were noted on the tanker's bottom antenna.
 - b. The false signals were noted out to approx. 20 miles but were most prevalent from 6 to 9 miles.
 - c. Multipaths signals were noted while using the tanker's top antenna but were very few in number and seem to be no problem inside of 5 - 6 miles.
 - d. F-101 made a distance run of approximately 165 miles with no problems as far as sensitivity of the TACAN is concerned.

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4. Interference from the tanker's own TACAN and IFF.
 - a. Owing to the location of the TACAN antennas on the tanker, interference is of prime importance.
 - b. If both of the tanker's TACANS are utilizing their top or bottom antennas simultaneously the interference is unbearable unless there is at least a 15 channel separation between the ARN-21 and the receiver's i.e. the article, F-101, etc.) TACAN.
 - c. If the two TACANS (i.e. the ARN-21 and ARN-52 on board the tanker) are using opposite antennas (i.e. one system on the top and one system on the bottom) the interference is reduced considerably, but still exists.
 - d. The tanker's IFF system also causes interference to a degree that is definitely noticeable.

VIII Conclusions:

NOTE: All the conclusions and recommendations mentioned in this report are based on a flight test utilizing a KC-135 tanker and an F-101.

There was no way we could switch antenna locations, measure video output, or the effect of local interference on the F-101 during this flight test. Therefore we are assuming that the F-101 will react basically the same to multipath signals as the KC-135.

Also, there is no guarantee that the Cygnus will react the same as an F-101 to multipath signals. However, we feel reasonably sure that it will.

- A. KC-135 Tankers
 1. The first tanker (58-095) used on the test was not working properly as there was no appreciable difference in the quantity or quality of the multipath signals when using the top or bottom antennas.
 2. The second tanker (59-1490) was miswired resulting in the antennas being reversed and a bad coaxial connector.

RECOMMENDATIONS

- a. That all KC-135's be carefully inspected for the condition and location of all coaxial cables and connectors pertaining to the ARN-52V.
- B. Rendezvous
 1. Multipath signals are definitely present and can cause erroneous range readouts in either/or both aircraft.
 2. The false signals cannot be avoided by alignment of the TACAN equipment alone if the tanker utilizes its bottom TACAN antenna position.
 3. These false signals can be avoided at the critical ranges by proper alignment of the equipment and if the tanker utilizes its top antenna position only.

NOTE: SEE EXCEPTION UNDER INTERFERENCE !

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4. A rendezvous can be made with the tanker using the top ARN-52(V) TACAN antenna only.
5. While the tanker is turning to maintain its orbit, the possibility of breaking TACAN lock is greatly increased. This creates more of a problem at closer ranges than at distant ranges.
6. The situation can exist where one aircraft cannot obtain a lock on and the fault is in the other aircraft's unit.

RECOMMENDATION

- a. That the tanker maintain the TACAN antenna selector switch in the "TOP" position for all A/A TACAN rendezvous.
- b. That all Article pilots and tanker navigators be informed of the possibility of breaking lock when either or both aircraft are in a turn.
- c. That all TACAN units be modified to allow the distance readout on the indicator to reset to 000 miles and then go into "search" the first time a lock is broken and the aircraft are within 50 miles of each other.
- d. If there is an A/A discrepancy in either or both aircraft, that both aircraft are written up, checked and the results made known to the opposite interested party.

C. Interference

1. Interference from the tanker's ARN-21 TACAN is so severe that an A/A lock is all but impossible. This condition exists anytime the tanker is using both TACAN systems on their top or bottom antennas simultaneously and the ARN-21 is within 15 channels of the receiver's (i.e., the article, F-101, etc.) TACAN.
2. With proper channel and antenna separation, interference is still apparent but is not as harmful. It does cause the system AGC to rise which impairs the sensitivity of the TACAN at greater distances.
3. The tanker's IFF also interferes with the A/A TACAN in much the same manner as described in (2) above. This interference is not apparent at the closer ranges but starts to become a factor at approximately 90 miles.
4. If the interference described in items 2 and 3 above were eliminated, the maximum TACAN A/A distance should be increased.
5. It is foreseeable that an interference problem may arise when all the aircraft (i.e., tanker, article and chase) are A/A equipped unless certain precautions are taken.
6. It is possible that a minor interference problem already exists when numerous A/A equipped aircraft are in the same general area (e.g., more than one AR scheduled). The procedure at present is to maintain a one (1) channel (i.e., one (1) megahertz) separation between conflicting aircraft. This may not be adequate to prevent minor interference.

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C. Interference (Continued)

a

RECOMMENDATION

- a. That the tanker maintain the ARN-21 TACAN antenna select switch in the "BOTTOM" position and the function switch in the Rec. position during all A/A TACAN rendezvous.
- b. That if the ARN-21 TACAN must use the "TOP" antenna position for some reason, a channel separation of at least 15 channels be maintained between the ARN-21 and whatever channel the receiver (i.e., the article, F-101 etc.) has set up.
- c. That supression pulses be fed to the ARN-52 TACAN from the tankers IFF.
- d. That all pilots are briefed on the possibilities of interfering with other aircraft once the F-101 is equipped with A/A TACAN. This briefing can take place at anytime upon request.
- e. That a spacing of three (3) channels be maintained (e.g., One article on CH 95, another article on Ch 92, etc) between aircraft during multiple refuelings. Channel 95 should remain the primary A/A refueling channel.

D. Terrain

1. It appears that terrain has no bearing on the quantity of multipath signals. Although the false signals were more prevalent at one time than another, this could not be correlated with any type terrain. Maybe with additional flights and/or special equipment this could be accomplished.

E. Maintenance

1. The present "Minimum Performance Check" contained in NAVWEPS 16-30 ARN-52-2 to 12R5-2 ARN52-2 revised, March 1966 does not completely check the A/A portion of the TACAN. Therefore a unit that may not function properly in the A/A mode will pass a bench check.
2. The present "Module Alignment Procedure" in the above mentioned technical publications contain no procedure for aligning the range decoder module to the 12 db rejection level required to help eliminate the multipath signals.
3. At present there is no A/A TACAN pre-flight capability at the tankers' home station.

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E. Maintenance (Continued)

RECOMMENDATION

- a. That a common "Minimum Performance Standard", which includes a complete A/A check be adopted by [] maintenance facilities. 25X1
- b. That a common "Module Alignment Procedure" which includes a complete A/A check be adopted by both maintenance facilities..
- c. That a pre-flight capability for checking the A/A TACAN mode be established at the tanker's home station. This would insure the soundness of the installation before take-off.
- d. The maintenance procedures mentioned in (a) and (b) above are presently being tested at [] and will be available upon their validation. 25X1
- e. That three TACAN units from the tanker organization be aligned using the new procedure. These units would be used in the same tankers (or [] should be kept informed as to what tankers do have these units installed) so the new maintenance procedure can be properly evaluated. These units can be aligned []

IX Summary

- A. The multipath signals which cause the abnormal TACAN A/A distance readouts are definitely present and will continue to exist. However, we feel with proper maintenance, informed crews, adequate hardware, and rendezvous procedures that are closely adhered to a successful A/A TACAN rendezvous can be made without the danger of false information being displayed due to multipath signals.

This test was conducted using the RT-384/ARN-52(V) TACAN which is capable of displaying range only in the A/A mode. A modification is pending which will allow the TACAN to provide both range and bearing in the A/A mode. The modification requirements for the involved aircraft are as follows:

- A. KC-135
1. The ARN-52(V) TACAN system is to be replaced by the ARN-90 TACAN system. This involves structural and wiring changes.
 2. The ARN-90 consists of:
 - a. AS-2057 Antenna
 - b. MX-7731 Bearing Data Unit
 - c. CU-1688 Directional Coupler
 - d. MT-3834 Shock Mount, Base
 - e. RT-863 Receiver-Transmitter
 3. Delivery Schedule of RT-863 R-T units.
 - a. 15 Jan 1967 5 units
 - 15 Mar 1967 5 units
 - 15 May 1967 10 units
 - 15 Jul 1967 10 units
- B. A-12
1. No additional aircraft wiring is required

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B. A-12 (Continued)

2. The RT-384/ARN-52V is to be modified by a kit consisting of a new module and a printed circuit board.
3. After this modification is completed with the unit will be designated RT-864/ARN-52(V).
4. Delivery schedule of modification kits.
 - a. 10 Jan 2 kits
 - b. 31 Jan 2 kits
 - c. 15 Feb 2 kits
 - d. 15 Mar 5 kits
 - e. 15 Apr 10 kits
 - f. 15 May 9 kits

C. F-101

1. Replace the existing ARN-21 TACAN with the RT-384/ARN-52(V)
 - a. This naturally involves rewiring the F-101
2. The RT-384/ARN-52(V) is to be modified by a kit consisting of a new module and a printed circuit board.
3. Delivery schedule for the RT-384/ARN-52(V)
 - a. Start of delivery is 1 April 1967 to be completed by 30 April 1967.
4. Delivery schedule of modification kits
 - a. Same as B4 above (A-12 will get first kits)

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