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PRELIMINARY EVALUATION
OF THE F/A-18
QUANTITY/MULTIPLE ENVELOPE EXPANSION

LCDR Win Everett (M)
USN/NAWCAD SA80

John Oster
NAWCAD SA80

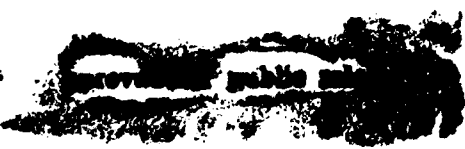
INTRODUCTION

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Currently the F/A-18 Hornet has restrictions on performing ripple salvo (quantity>multiple, multiple>1) releases when Vertical Ejection Racks (VER) or Canted Vertical Ejection Racks (CVER) are loaded on (the inboard) wing stations 3 and 7 due to bomb to bomb collisions upon release. Hornet test pilots assigned to the Ordnance System Department of the Flight Test and Evaluation Group (NAWCAD) located at Patuxent River MD, sought to remedy this restriction. As Strike Leaders in the fleet, we recognized the need to eliminate these release restrictions. By testing a representative sample of weapons loadouts, we sought to increase the Hornet's weapon delivery options.

Former Navy aircraft (F-4, A-4, A-6 and A-7) weapon release sequence was from their outboard stations inward. The F/A-18 weapon release sequence also followed this general rule with the release sequence, releasing the center line station first, then the outboard stations and finally the inboard stations (stations 5,2,8,3 &7).

In order to reduce the probability of bomb to bomb collisions, the release intervals would need to be increased. One option would be to increase the Minimum Release Interval (MRI) which would be unacceptable to strike planners. However, by changing the order of the weapon release sequence, you could change the intervals between the bombs. This re-ordering would reduce the potential of collisions. The Operational Flight Program (OFP) in the F/A-18 already has a 'STEP' option which allows you to select which station you wanted to be the priority station (the first station released). With this software capability, we began investigating ways to overcome the present restrictions regarding ripple salvo releases when a VER or CVER were loaded on stations 3 and 7. The results of this preliminary evaluation and flight tests along with its applicability to shape both the current Hornet and future F/A-18 E/F weapon software will be presented.



BACKGROUND

The air-to-ground delivery capability of the F/A-18 is often restricted to ripple single when multiple bomb racks are carried on stations 3 and 7 due to separation problems between stations

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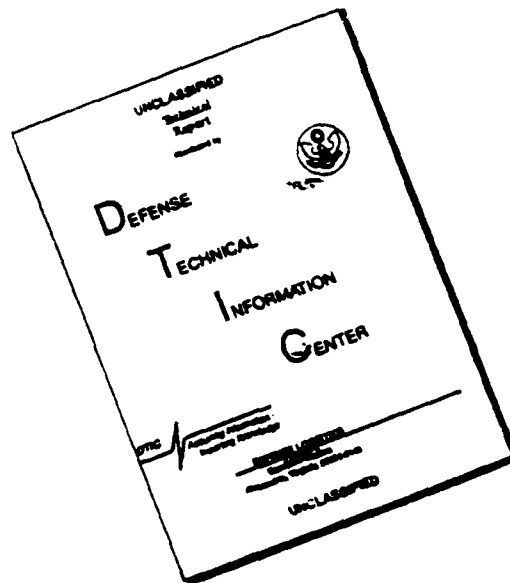
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and 7 inboard along with problems between stations 5 port and 3 inboard or 5 starboard and 7 inboard. Therefore, multiple release for many weapons is restricted to loadings with stations 3 and/or 7 downloaded. Ripple single release modes result in safe separation because the stations are not released simultaneously, but at least one interval apart.

In an effort to solve this problem, an in-depth analysis of the release sequence was conducted. The analysis indicated that with the current release sequence of the F/A-18, with station 5 releasing first, many of the ripple salvo release modes would result in simultaneous release from station 2 inboard and station 3 outboard, or station 7 outboard and station 8 inboard. The analysis also showed that using station 7 as the first station in the release sequence would eliminate the conditions listed above more often than any other priority station.

A description of the F/A-18 armament system and station priority is as follows:

F/A-18 Armament System

The F/A-18 armament system was designed to provide several delivery combinations of weapon release modes. The options are programmed through the stores management display and include quantity, multiple, and interval selections. The term quantity refers to the total number of bombs that are released from the aircraft weapon stations during a bombing run. The term multiple refers to the number of bombs released simultaneously from the aircraft weapon stations. The interval option is applicable and provided by the Software Management System (SMS) whenever the quantity being used in the selected program is greater than the multiple being used. The interval represents the time between weapon releases from the aircraft, in milliseconds, in the manual mode. The combinations of the quantity and multiple are as follows:

- a. Single (Quantity=1, Multiple=1) - One weapon is released for each weapon release button depression.
- b. Salvo (Quantity=Multiple, Multiple>1) - The selected quantity of weapons is released simultaneously for each weapon release button depression. The weapons are released from multiple stations but only one weapon is released per station.
- c. Ripple Single (Quantity>1, Multiple=1) - One weapon is released at the interval being used in the program until the total quantity selected has been released.

d. Ripple Salvo (Quantity>Multiple, Multiple>1) - The selected multiple of weapons is released simultaneously from multiple stations (one weapon per station) at the selected interval until the total quantity of weapons selected has been released. If release of the final multiple of weapons in the sequence would exceed the quantity of weapons selected for release, the final multiple is reduced accordingly so that exactly the selected quantity is released.

The current release sequence for the F/A-18 is as follows: stations 5, 2, 8, 3, and 7. The SMS releases the weapons from the outboard VER/CVER station from the wing stations in the priority sequence, then cycles to release the weapons from the inboard VER/CVER stations. When station 5 is loaded with a VER/CVER, the SMS releases the weapon from the starboard station first. Once the release sequence has cycled back to station 5, the weapon from the port station is released. The standard priority station from which the first bomb is released for the F/A-18 is station 5 unless either:

- 1) The pilot selects another station as priority.
- 2) The weapon selected is not loaded on station 5.

In this case, the station priority becomes the next selectable station in the release sequence. The release sequence for the five air-to-ground weapon stations of the F/A-18 is shown in figure 1.

This test program evaluated ripple salvo releases using a station priority of seven. The release sequence for the five air-to-ground weapon stations of the F/A-18 for a station priority of seven is shown in figure 2. Release mode analysis conducted by SA80 indicates that using a station priority of seven for ripple salvo reduces the chances of simultaneous releases and maximizes the interval between weapons in the following three conditions: (a) station 2 inboard and station 3 outboard as well as station 8 inboard and station 7 outboard, (b) station 3 inboard and station 5 port as well as station 7 inboard and station 5 starboard, and (c) stations 3 and 7 inboard, than any other priority station provided. An example of this increased interval is illustrated in figure 3, where the interval between weapons on station 8 inboard and station 7 outboard as well as station 3 and 7 inboard are compared for a Quantity=8, Multiple=2 release.

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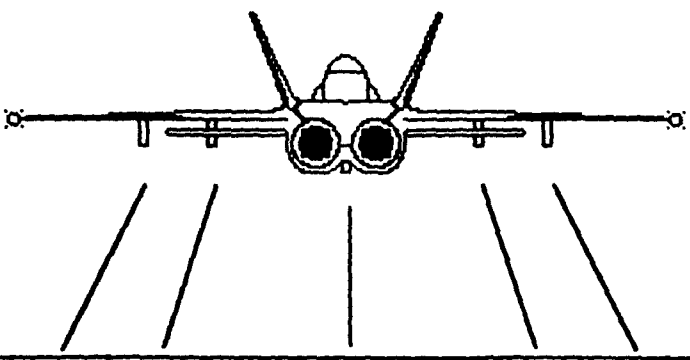
									
ARMAMENT STATIONS	1	2	3	4	5	6	7	8	9
CONVENTIONAL BOMBS FROM PARENT RACK (QUANTITY=5, MULTIPLE=1)		2	4		1		5	3	
CONVENTIONAL BOMBS FROM VER/CVER RACK (QUANTITY=10, MULTIPLE=1)		 2 7	 4 9		 6 1		 10 5	 8 3	

Figure 1

F/A-18 RELEASE SEQUENCE - STANDARD STATION PRIORITY OF FIVE

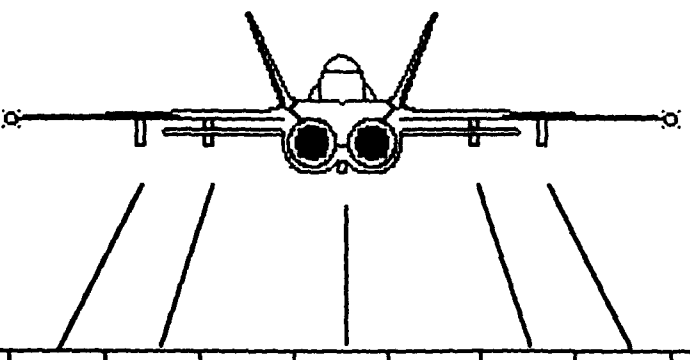
									
ARMAMENT STATIONS	1	2	3	4	5	6	7	8	9
CONVENTIONAL BOMBS FROM PARENT RACK (QUANTITY=5, MULTIPLE=1)		3	5		2		1	4	
CONVENTIONAL BOMBS FROM VER/CVER RACK (QUANTITY=10, MULTIPLE=1)		 3 8	 5 10		 7 2		 6 1	 9 4	

Figure 2

F/A-18 RELEASE SEQUENCE - STATION PRIORITY OF SEVEN

Using a station priority of five results in;

- 1) One interval between release from station 7 outboard and station 8 inboard.
- 2) Simultaneous release from stations 3 and 7 inboard.

Using a station priority of seven results in;

- 1) Three intervals between release from station 7 outboard and station 8 inboard.
- 2) One interval between release from stations 3 and 7 inboard.

This increased interval will reduce the chances of a bomb to bomb collision.

A second comparison is shown in figure 4, using the other release mode to be tested during this evaluation, Quantity=10, Multiple=3.

Using a station priority of five results in;

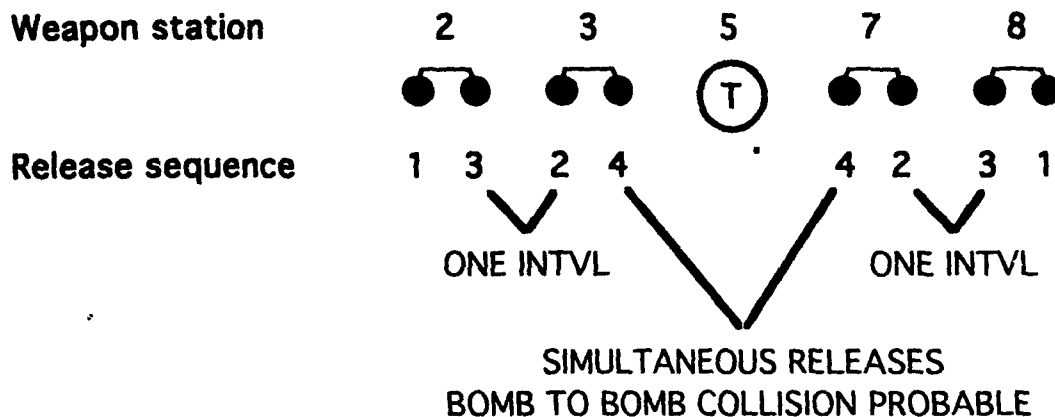
- 1) One interval between release from station 7 outboard and station 8 inboard.
- 2) One interval between release from stations 3 and 7 inboard.

Using a station priority of seven results in;

- 1) Two intervals between release from station 7 outboard and station 8 inboard.
- 2) Two intervals between release from stations 3 and 7 inboard.

This increased interval will reduce the chances of a bomb to bomb collision.

Station priority five (Quantity=8, Multiple=2)



Station priority seven (Quantity=8, Multiple=2)

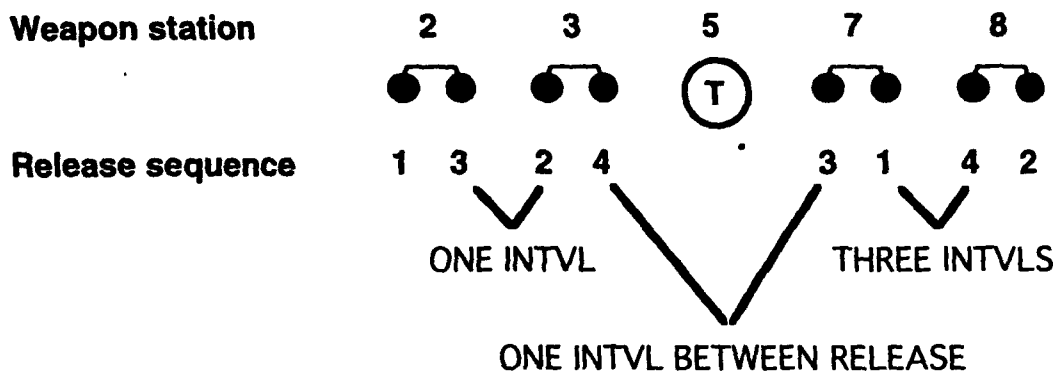
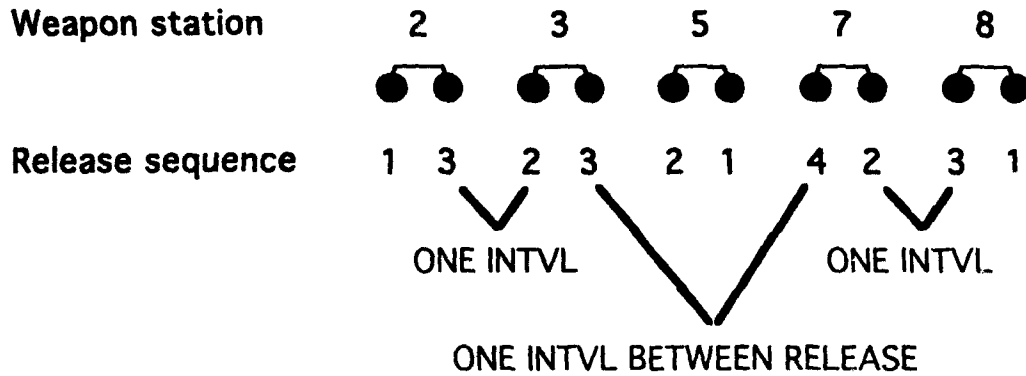


Figure 3

COMPARISON OF RELEASE SEQUENCE BETWEEN STATION
PRIORITY FIVE AND SEVEN DURING RIPPLE SALVO RELEASE

Station priority five (Quantity=10, Multiple=3)



Station priority seven (Quantity=10, Multiple=3)

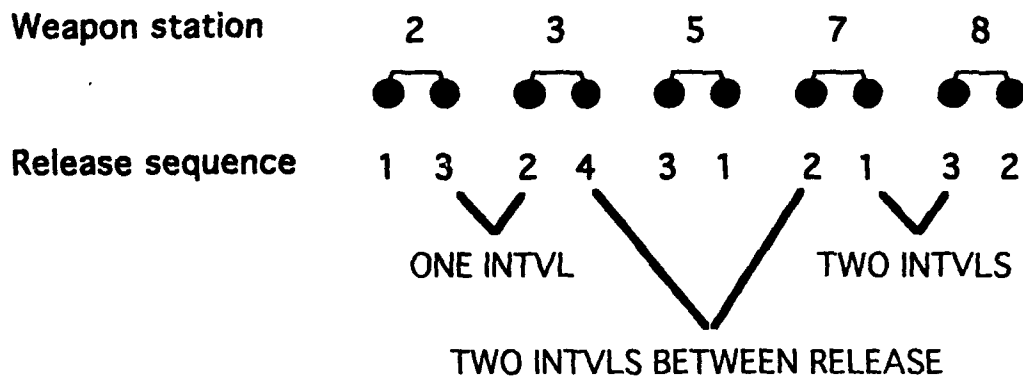


Figure 4

COMPARISON OF RELEASE SEQUENCE BETWEEN STATION PRIORITY FIVE AND SEVEN DURING RIPPLE SALVO RELEASE (QTY=10, MULT=3)

METHOD OF TEST

The evaluation consisted of ripple salvo releases of nine different weapon configurations: MK 82 General Purpose Bombs (GPB) with BSU-33A/B conical, MK-15 Mod 6 (high and low drag) and BSU-86/B (high and low drag) tail fins; MK 83 GPB with conical and BSU-85/B (high and low drag) tail fins; and MK 20 Rockeye. The MK 82 and MK 20 Rockeye were loaded on CVER on aircraft stations 2,3,5,7,8 and were released using a Quantity = 10, Multiple = 3. The MK 83 were loaded on CVER on aircraft stations 2,3,7,8 with a fuel tank on station 5 and were released using a Quantity = 8, Multiple = 2. The ripple salvo configurations tested represented the worst case release parameters in terms of minimum intervals represented by the three conditions that are associated with the highest possibility of bomb to bomb collision occurrence. The release parameters were representative of current F/A-18 Tactical Manual (TACMAN) limitations (airspeed, dive angle and MRI) for ripple single releases. All weapons were released at MRI for safe separation. Onboard high speed cameras provided qualitative data of the separation characteristics.

RESULTS

MK 80 series low drag and MK 20 Rockeye.

The major concern for these weapon releases was the crossover of weapons released from the inboard CVER stations loaded on aircraft stations 3 and 7, which had previously resulted in bomb-to-bomb (BTB) collision when station 5 was the priority station. Flight tests with VERs loaded on stations 3 and 7 were curtailed after initial ripple salvo releases resulted in BTB collisions. Figure 5, (Rockeye release configuration; Quantity = 4, Multiple = 2) shows the results of simultaneous releases from VER on stations 3 and 7, in which the the two inboard weapons crossed beneath the aircraft and collided 1.35 sec after release. Figure 6, (Rockeye release configuration; Quantity = 10, Multiple = 3) shows the same weapons being released except using priority station seven, which eliminated the simultaneous releases of adjacent stations thereby allowing a ripple salvo release to occur without BTB collisions. The use of priority station seven for a ripple salvo release of MK 80 series low drag and MK 20 Rockeye loaded on CVERs on stations 3 and 7 was successful.

Figure 5
MK 20 ROCKEYE RELEASED UTILIZING PRIORITY STATION FIVE

Figure 6
MK 20 ROCKEYE RELEASED UTILIZING PRIORITY STATION SEVEN

MK 80 series high drag

(1) MK 82 GPB with MK 15 Mod 6 (high drag) tail fins. The major concern was the drafting of weapons upon release, which had previously resulted in BTB collisions. The flight test film data, figure 7, indicated that the weapons were stabilized and did not draft into one another.

(2) MK 82 GPB with BSU-86/B (high drag) tail fin. The last MK82/BSU-86 weapon released from the aircraft failed mechanically and remained in the low drag configuration. As the last weapon off, it had negligible affect on the first nine weapons released in groups of three in terms of drafting effects. Previous concerns with drafting of the weapons upon release, leading to bomb-to-bomb collisions did not occur. The flight test data indicates that the weapons were stabilized in relation to one another.

(3) MK 83 GPB with BSU-85/B (high drag) tail fins. This test point as repeated twice, in order to define an abnormality which was seen with one of the BSU-85 (ballute) tail fins. During both releases a ballute appeared to inflate abnormally. The repeatability of this occurrence point to the affects of the weapons drafting. Although all the weapons initially were released satisfactorily from the aircraft, approximately 2 seconds after weapon release bomb-to-bomb collision did occur. The effects of drafting allowed one weapon to fall faster than the other weapons released, thereby over taking them and colliding.

Figure 7
MK 82 WITH MK-15 MOD 6 (HIGH DRAG) TAIL FINS

CONCLUSIONS

Based on the initial satisfactory results from this flight test program, further investigation into changing the F/A-18 priority weapon station from station five to seven is warranted. The scenarios in which simultaneous releases from adjacent weapons stations and station 3 and 7 inboard on VERs or CVERs were eliminated more often when priority station seven is used than any other priority station could provide. The MK 80 series and MK 20 Rockeye weapons released in the low drag configuration from station 3 and 7 on the inboard VER/CVER station have the tendency to cross over underneath the aircraft, but did not collide. The elimination of simultaneous releases provides the opportunity for successful ripple salvo releases of low drag ordnance to occur when VER/CVER are loaded on station 3 and 7. The test cases in which high drag MK 82 with MK-15 Mod 6 (Snakeye) tail fins and BSU-86/B tail fins were released, the change in the release intervals between adjacent stations provided by using priority station seven minimized the weapons' tendency to draft on one another, resulting in successful ripple salvo releases. The ripple salvo release of the high drag MK 83 with BSU-85/B tail fins revealed post release abnormalities, the results of weapon drafting in which one ballute improperly inflated, resulting in bomb-to-bomb collisions after an initially clean separation. High drag weapons have the tendency to draft on one another. Changing the priority station to station seven increases the intervals between adjacent station releases, this in combination with a small increase in the MK83/BSU-85 (high drag) MRI may result in satisfactory separation.

The results of this preliminary evaluation as to the feasibility of increasing the multiple release capability of the F/A-18 by using priority station seven was conclusive on eight of the nine weapon configurations tested. The potential for ripple salvo releases to be performed when VER/CVER are loaded on the inboard wing station now exist. Overall, the incorporation of this simple change to the philosophy in how the release sequence of weapons should be performed, would provide the Hornet an increased weapon loadout capability, removing the many loading restrictions from the TACMAN and replace them with the following:

Proposed Restrictions for Multiple Release

1. With CVER loaded on stations 3 and 7;

a) Download symmetrically

OR

b) One additional CVER loaded (Qty = 8,7,6)

The following releases are proposed with priority station 7:

Qty = 10,9	Mult = 2,3
Qty = 8,7,5	Mult = 2
Qty = 6,4	Mult = 1

** For Qty = 8, if CVER loaded on stations 3, 5, and 7 select priority station 3.

2. With CVER downloaded from either station 3 or 7;

The following releases are proposed with priority station 7:

Qty = 9,7,6	Mult = 2,3
Qty = 5,4	Mult = 2

** When station 7 is empty or loaded with a mixed store, select priority station 3

3. With CVER downloaded from stations 3 and 7, all weapon release sequences are authorized in accordance with F/A-18 TACMAN figure 1-3.

The above generalized downloading rules for developing the weapon load configurations were established to ensure a fixed set of load configuration possibilities regardless of weapon type. Follow-on testing may expand the various load configurations tailored to specific weapon types. For the purposes of this preliminary evaluation, a fixed number of load configurations were analyzed. The results indicate that incorporation of this new release sequence into the F/A-18 OFP can be easily performed and in time for the base line OFP to be used in the F/A-18E/F. The ability to carry VER/CVER on the F/A-18 inboard weapon station will enhance its weapons loadout capability. In the meantime, simply stepping to station seven on the stores page will allow the Hornet pilot today to have a ripple salvo capability when carrying VER/CVERs on stations 3 and 7.

LESSONS LEARNED

After more than 10 years of service in the fleet, the F/A-18 Hornet is still expanding its ordnance capability. This preliminary evaluation into resolving a limitation to its weapon loadout capability has been one of challenging the conventional thought of the traditional release sequence. An innovative, yet simple switch in the aircraft's release sequence could yield a 66% increase in the allowable weapon loads that would be released in a ripple salvo delivery.

The fact that low drag weapons released from the F/A-18 tend to cross beneath the Hornet when released from stations 3 and 7 will also be present on the F/A-18E/F, since the distance between wing stations 4 and 8 on the F/A-18E/F will be the same as on the current Hornet's wing stations 3 and 7. High drag weapons released will still have the tendency to draft on one another, unless the weapon's fins are redesigned or the weapon's MRI is dramatically increased. Utilizing this new releases philosophy should work in resolving the potential ripple salvo restrictions on the F/A-18E/F. The priority station should then be, Station eight, with the station sequence being stations 8, 6, 2, 10, 3, 9 & 4.

The application of this test plan can be easily added to the current F/A-18 aircraft's Operational Flight Program (OFP). Subsequently, the basis of the current modified OFP can be incorporated into the F/A-18E/F OFP. By using this new release sequence for the F/A-18E/F OFP, CVERS will be able to be carried on both of the aircraft's inboard wing stations and further increase its weapon load out capability.

Innovative and challenging thinking by the test pilot and his close ties to the fleet assisted in bringing this limitation to the attention of the developer. This fleet input validates the Navy's philosophy of rotating its test pilots back to the fleet. This philosophy allows the fleet's needs to be understood and met by the test community.

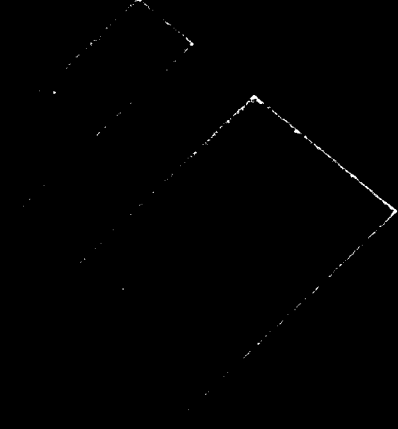


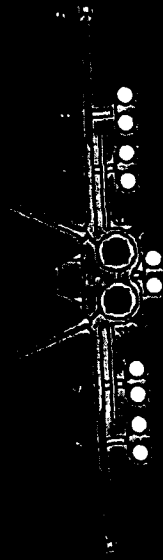
Background

■ Restrictions on performing Ripple Salvo releases when loaded on VER/CVER inboard stations

■ Ripple Salvo

- Quantity > Multiple
- Multiple > 1



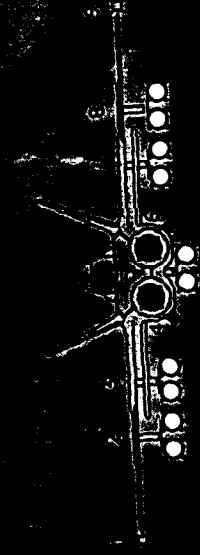


- Air-to-Ground delivery restricted to Ripple Single when VER/CVER loaded on stations 3 & 7 due to separation problems:
 - Between Sta 3 & 7
 - Between Sta 5 port & 3 inboard
 - Between Sta 5 stbd & 7 inboard



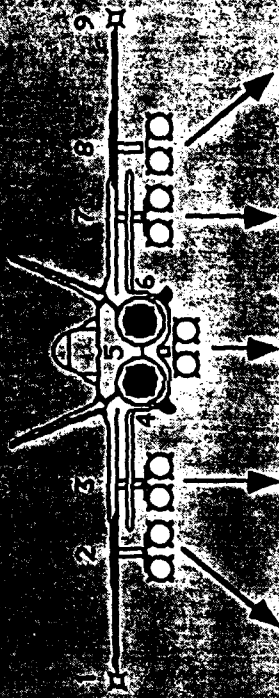
Purpose

- In-depth analysis of the F/A-18 release sequence was conducted
 - Increase in MRI - Unacceptable
 - Change order of release
- Re-ordering to reduce potential of collisions
 - OFP has "STEP" function



- Analysis of weapon stations to determine least chance of bomb-to-bomb collisions
- Three conditions of simultaneous releases:
 - A) Sta 2 inboard & Sta 3 outboard or Sta 8 inboard & Sta 7 outboard
 - B) Sta 3 inboard & Sta 5 port or Sta 7 inboard & Sta 5 stbd
 - C) Sta 3 & Sta 7 inboard

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PARENT

2	4	1	5	3
2/7	4/9	6/1	10/5	8/3

CVER

PRIORITY STATION 5

PARENT

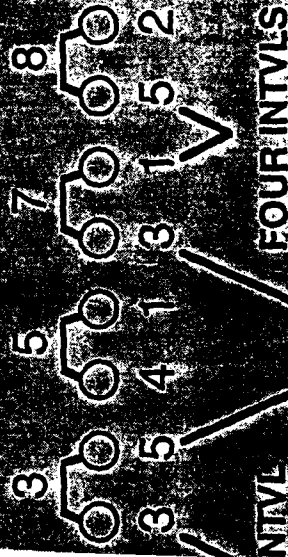
3	5	2	1	4
3/8	5/10	7/2	6/1	9/4

CVER

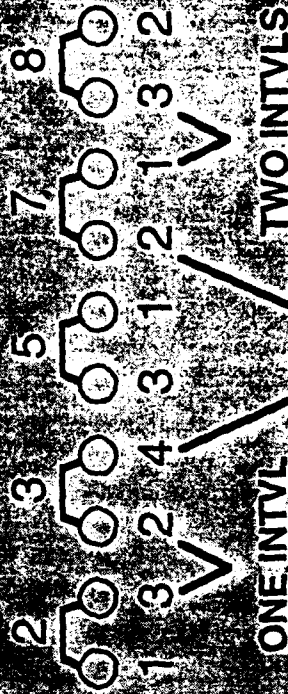
PRIORITY STATION 7

STATION PRIORITY SEVEN

QTY = 10, MULT = 2



QTY = 10, MULT = 3



FOUR INTVL

ONE INTVL

TWO INTVL

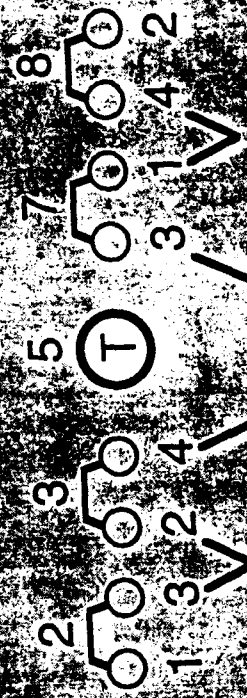
INTVL BETWEEN RELEASE

TWO INTVL BETWEEN RELEASE

STATION PRIORITY SEVEN

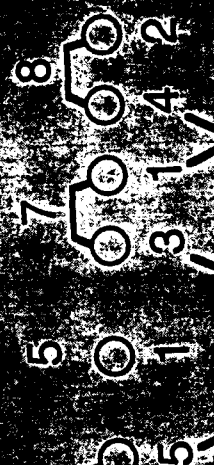
QTY = 8, MULT = 2

Y = 9, MULT = 2



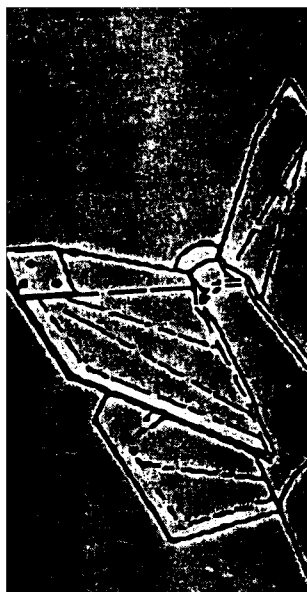
THREE INTVLS

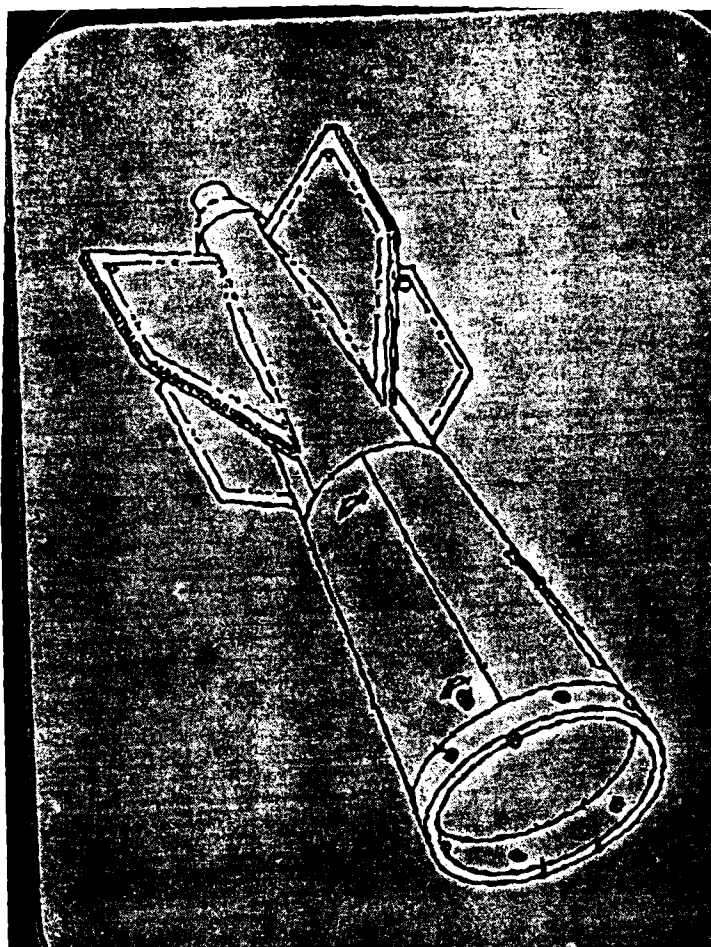
ONE INTVL BETWEEN RELEASE



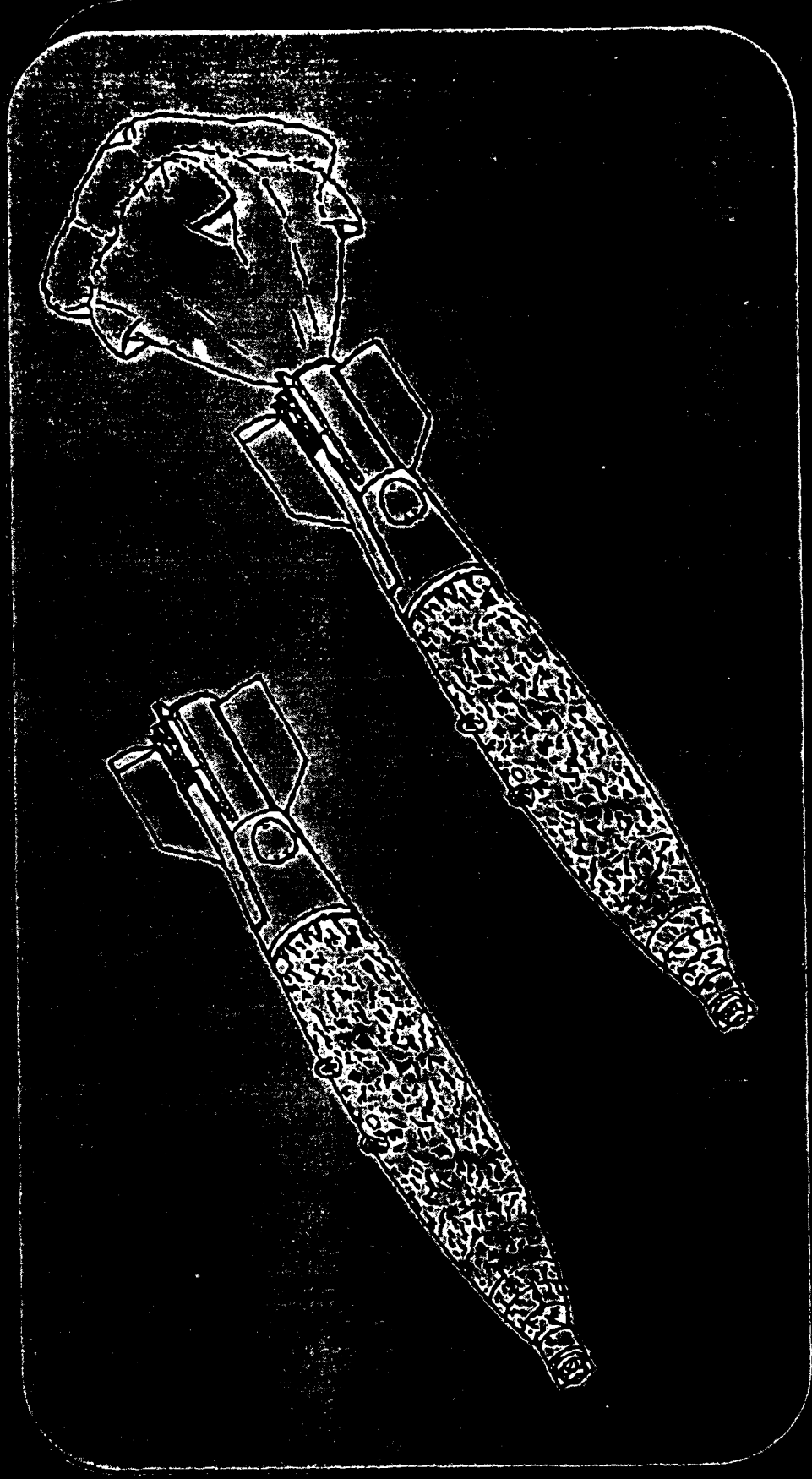
THREE INTVLS

IS BETWEEN RELEASE



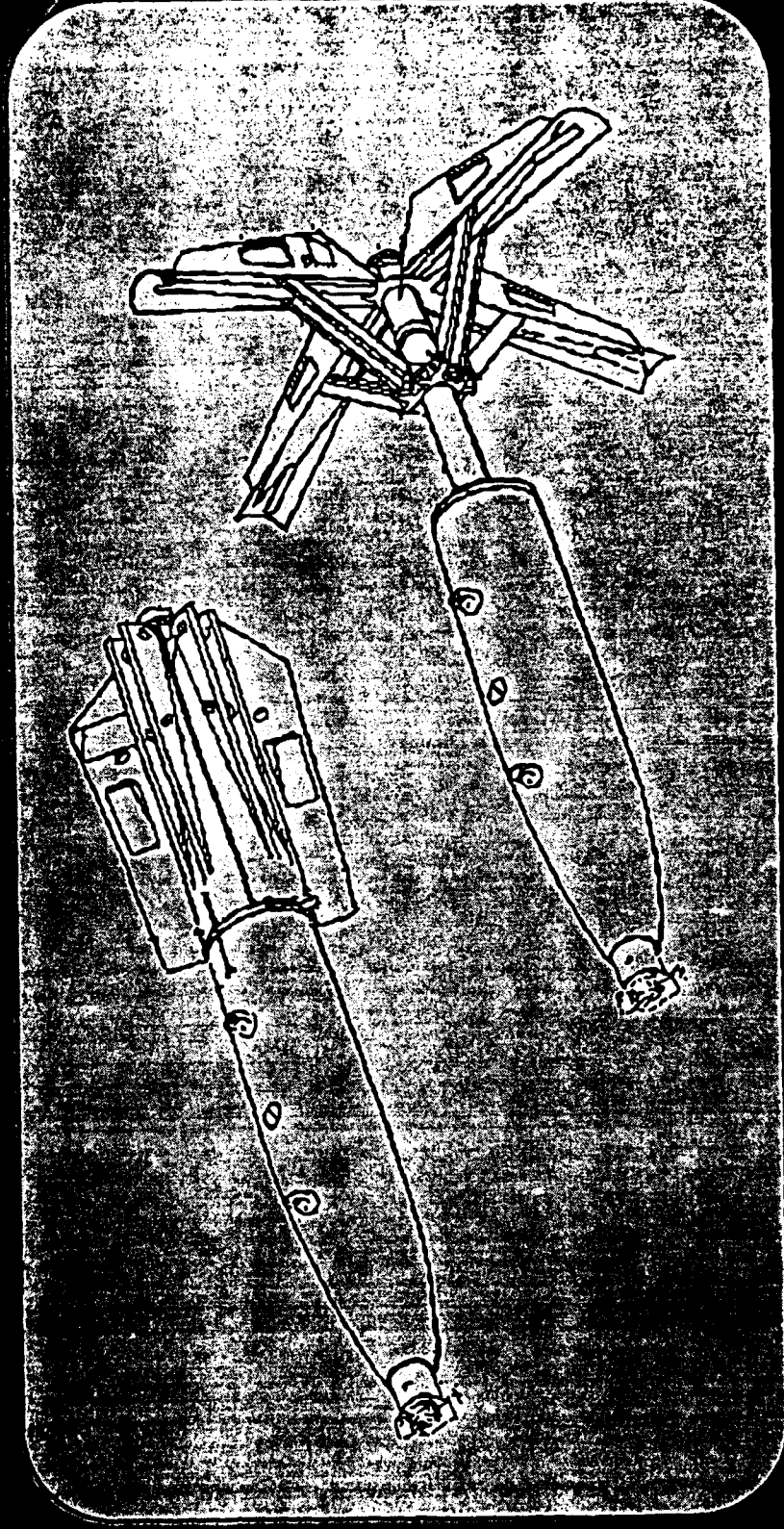


Weapons Evaluated for Ripple Salvo Releases



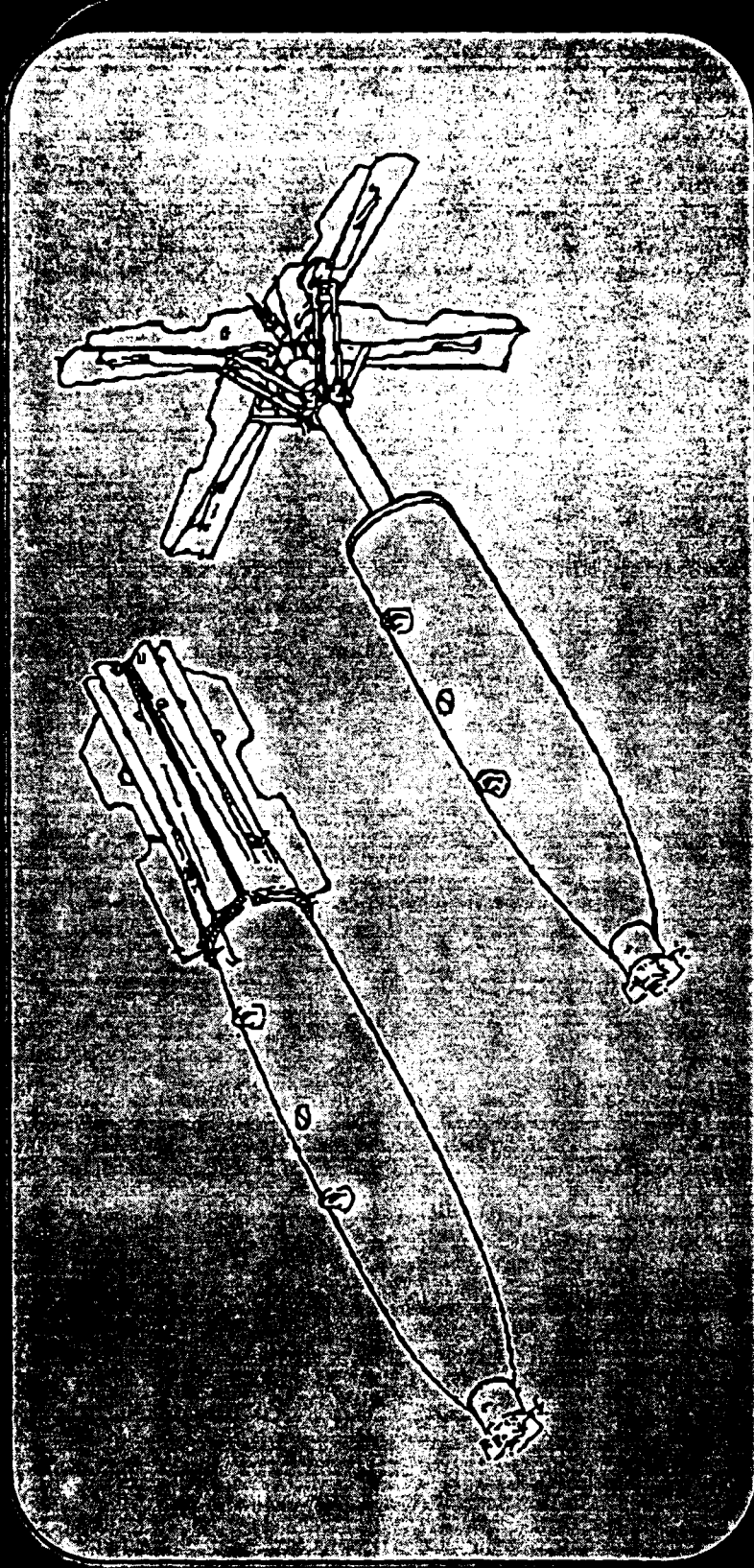
MK 83 BSU-85 (Low and High Drag)

Weapons Evaluated for Ripple Salvo Releases



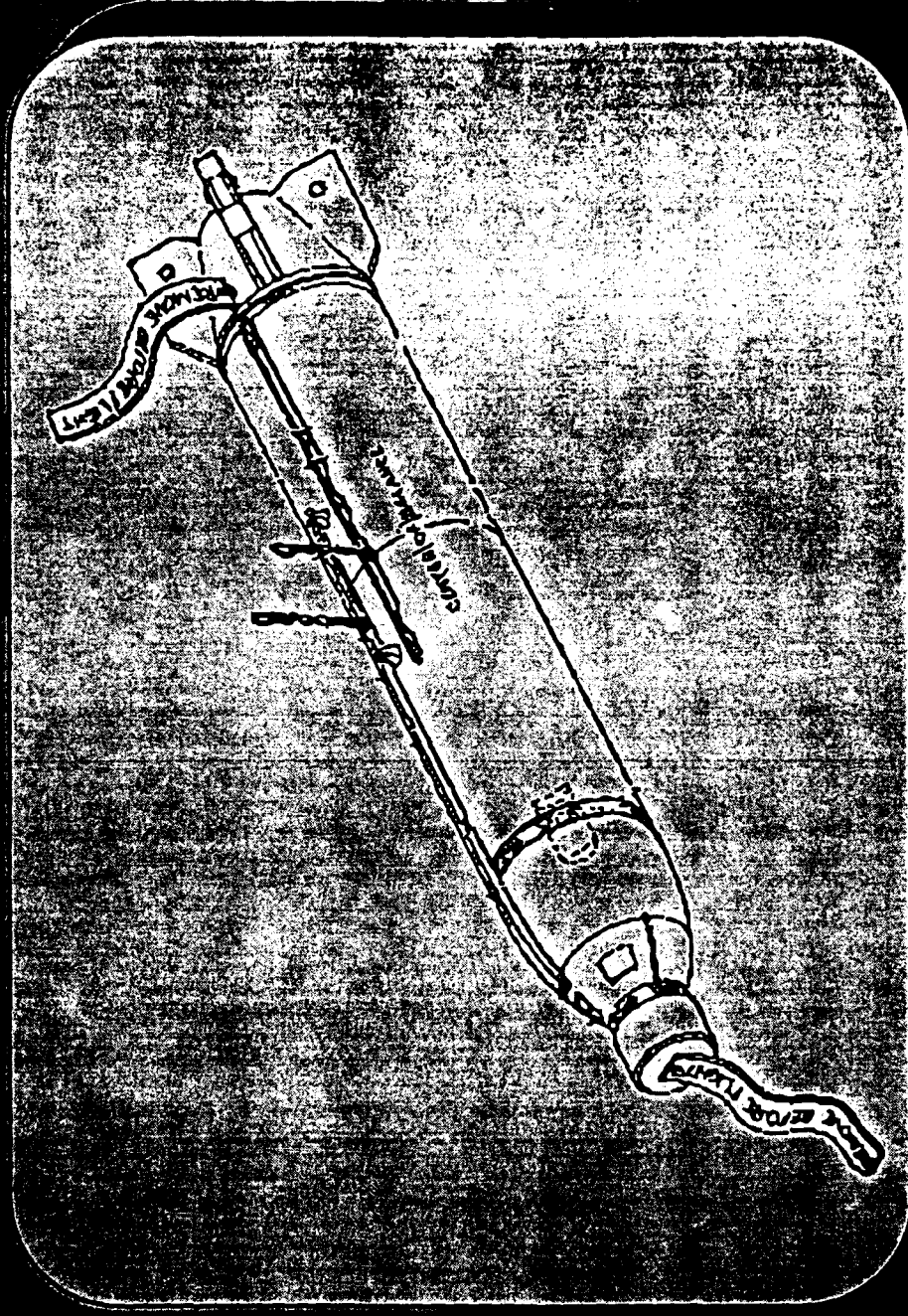
MK 82 BSU-86 (Low and High Drag)

Weapons Evaluated for Ripple Salvo Releases



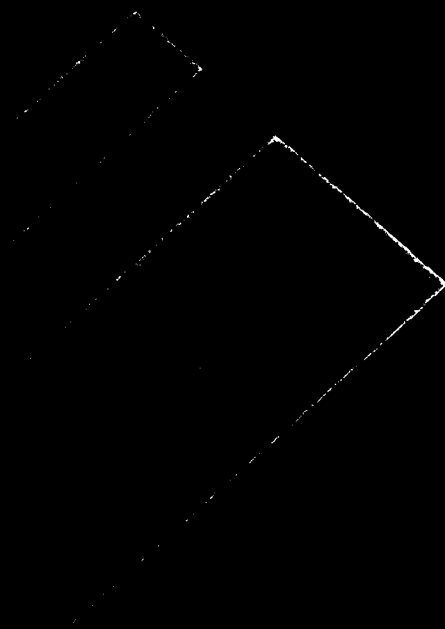
MK 82 MK-15 Mod 6 (Low and High Drag)

Weapons Evaluated for Ripple Salvo Releases



MK 20 Rockeye

VIDEO



Results

- MK 80 Series high drag
 - MK 82 (GPB) with MK-15 Mod 6 tail fin
 - MK 82 (GPB) with BSU-86 tail fin
 - » Weapons stabilized - minimal drafting
 - MK 83 (GPB) with BSU-85 tail fin
 - » Initial separation sat, drafting caused BTB @ 2 seconds after release

Conclusions

- Simultaneous releases were eliminated more often
- Change priority station with minimal increase in MRI for high drag weapons
- Ripple Salvo releases when VER/CVER loaded on stations 3 & 7 is feasible
- Simple change in procedure - increases weapon loadout capability 66%

Proposed TACMAN Restrictions for Multiple Releases

- With VER/CVER loaded on stations 3 & 7
 - Download symmetrically, or
 - One additional VER/CVER loaded (Qty = 8,7,6)
 - The following releases are proposed with priority station 7:
 - » Qty = 10,9 Mult = 2,3
 - » Qty = 8,7,5 Mult = 2
 - » Qty = 6,4 Mult = 1
 - For Qty = 8, if VER/CVER loaded on stations 3, 5 and 7 select priority station 3

Proposed TACMAN Restrictions for Multiple Releases

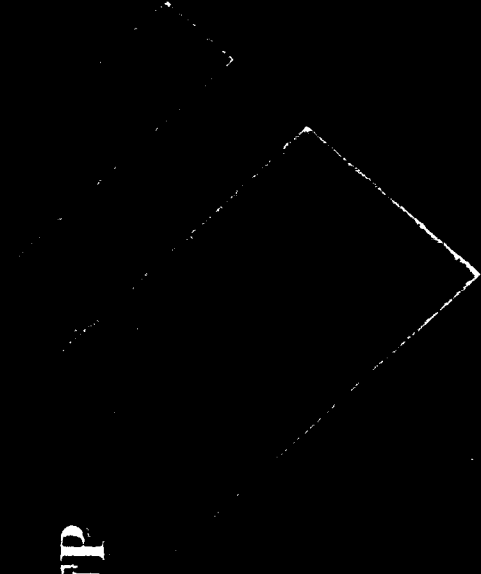
- With VER/CVER downloaded from either station 3 or 7
 - The following releases are proposed with priority station 7:
 - » Qty = 9,7,6 Mult = 2,3
 - » Qty = 5,4 Mult = 2
 - When station 7 is empty or loaded with a mixed store, select priority station 3

Proposed TACMAN Restrictions for Multiple Releases

- With VER/CVER downloaded from stations 3 & 7, all weapon release sequences are authorized in accordance with TACMAN figure 1-3

Recommendation

- Further testing is required to obtain conclusive answers to this proposal
- Stepping to station 7 on the store page will allow the Hornet pilot to have an expanded Ripple Salvo capability
- Incorporate into OFP



Lessons Learned

- F/A-18 Hornet ordnance loadout still capable of expansion
- 66% increase in allowable weapon loads
- Low drag weapons cross beneath when released from the inboard stations - This tendency will be present on the F/A-18E/F
- High drag weapons draft - Short of redesign or increasing MRI, this procedure should resolve potential Ripple Salvo restrictions of the F/A-18E/F

Application

- Easily added to the current/future F/A-18
- F/A-18A-D - Priority Station 7
Release Sequence 7-5-2-8-3
- F/A-18E/F - Priority station 8
Release Sequence 8-6-2-10-3-9-4

