To the Graduate Council;

I am submitting herewith a thesis written by Joseph Carl Bouchard entitled "GBU-24B/B Store Certification Test Program for the F/A-18 and A-6E Airplanes". I have examined the final copy of this thesis for content and form and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Aviation Systems.

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GBU-24B/B STORE CERTIFICATION TEST PROGRAM FOR THE F/A-18 AND A-6 AIRPLANES

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee Space Institute, Tullahoma

Joseph Carl Bouchard

May 1994

DEDICATION

This thesis is dedicated to my wife,

Kristine Marie Bouchard,

who sees the bright side of everything.

ACKNOWLEDGMENTS

I would like to thank my major professor, Dr. R. D. Kimberlin, and Mr. Robert Richards, for their guidance and accommodation during my postgraduate studies. I would also like to thank Mrs. Bertie Birch, who was the lead project engineer for the GBU-24B/B certification program at Naval Air Warfare Center, Patuxent River, Maryland, and who's technical expertise and organizational skills aided in greatly enhancing the war fighting capability of the United States Navy.

ABSTRACT

This study was an in-depth look at the U. S. Navy's weapon modification and certification process of a United States Air Force weapon, namely the GBU-24A/B Low Level Laser Guided Bomb, for use on the F/A-18 and A-6E aircraft. The modified version of the weapon was designated GBU-24B/B. The major portion of this study concentrated on the scope and methodology of the flight test portion of the modified weapon's certification process. The examination also included a review of the analysis and ground tests performed in order to correctly modify the weapon. Finally, results of the certification process were presented.

It was concluded that the modified GBU-24B/B was compatible with both the F/A-18 and A-6E aircraft throughout the required flight envelope and that the modular design of the GBU-24A/B lent itself well to modification. Recommendations for improved compatibility between USAF and Navy aircraft in the area of weapon system design were presented. Finally, methods by which to reduce the amount of redundant testing between the services were suggested.

PREFACE

Within the U. S. military services, aircraft weapons and weapon suspension equipment have traditionally been designed by the contractor to meet the specifications set forth by the government. Historically, the service (e.g. USAF, USA, USN) which was paying for the program was responsible for generating the specification.

As the F/A-18 aircraft project officer assigned to the GBU-24B/B modification program at Patuxent River, the author was responsible for designing and supervising the ground and flight test of the weapon on the F/A-18 aircraft. As a test pilot, the author flew a majority of the test points and was a primary author of the report from which this thesis is adapted.

From meetings during this program, the author was able to learn, first hand, the differences between USAF and USN aircraft systems which make seemingly redundant testing necessary. However, it is the author's opinion that much of this flight testing could be eliminated if there was more commonality between U. S. aircraft systems, particularly in the area of weapon suspension equipment.

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GLOSSARY

Asymmetric Load	Situation when one wing of an aircraft is loaded with substantially more weight than the other wing.
AERO-7A	Designation for A-6E aircraft wing pylon.
AOA, α	Angle of Attack in degrees or units.
AOC	Active Oscillation Controller. F/A-18 FCC logic designed to dampen aircraft aerodynamic oscillations.
BFD	Battery Firing Device
BLU	Bomb, Live Unit
BRU	Bomb Release Unit
BRU-32A/A	F/A-18 single store, pylon mounted bomb rack
BuNo	Bureau Number
CCU	Combustible Cartridge Unit
CG	Center of Gravity
CVS	Carrier Suitability
FCC	Flight Control Computer
FMU-143	GBU-24 electric tail fuze
FOUO	For Official Use Only
FTEG	Flight Test and Engineering Group
FZU-32B/B	GBU-24 fuze initiator.
G, g	Measure of normal, lateral or longitudinal acceleration. Assume normal acceleration if not specified.
GAC	Grumman Aerospace Corporation
Gag rod	Electro-mechanical break in fuze arming train. Aligns arming train when arming wire retracted from it.
GBU	Guided Bomb Unit

GBU-24A/B	USAF Paveway III LLLGB with BLU-109 warhead
GBU-24B/B	USN Paveway III LLLGB with BLU-109 warhead
GCU	Guidance and Control Unit
IMN	Indicated Mach number.
Irreversible	No force feedback provided to flight controls by flight control surfaces.
KCAS	Knots Calibrated Airspeed
KIAS	Knots Indicated Airspeed
LCO	F/A-18 aircraft oscillatory mode known as Limit Cycle Oscillation.
LGB	Laser Guided Bomb
LLLGB	Low Level Laser Guided Bomb
Lug	Used to suspend weapon to bomb rack hooks
MDA	McDonnell Douglas Aerospace
MIL-STD-1553	"Military Standard Digital Time Division, Command/Response Multiplex Data Bus". Military specification which defines design requirements for aircraft data buses.
MK	Mark
MSL	Mean Sea Level
NATOPS	Naval Aviation Training and Operating Procedures Standardization Program
NAVAIRSYSCOM	Naval Air Systems Command
Navy	United States Navy
NAWCAD	Naval Air Warfare Center Aircraft Division
OFP	Operational Flight Program
OFP 89A	Numerical Designation for Operational Flight Program used for this test.
PBX	Plastic-bonded explosive, Polymer-bound explosive

PBXN-109	Explosive fill used in GBU-24B/B
RPO	Rolling Pull Out
SMS	Stores Management System. Controls inventory and release of weapons from F/A-18 aircraft.
Store	Anything designed to be suspended from an aircraft. Examples include weapons and fuel tanks.
SUU-63/A	Designation for F/A-18 aircraft wing pylon.
Sway brace	Interface between store and store suspension equipment which acts to absorb inflight maneuvering loads of the store.
Symmetric g	Normal acceleration (Nz) placed on the aircraft when full lateral stick input is not present.
Symmetric load	Situation when both wings of an aircraft are loaded similarly in both type and weight of stores.
TI	Texas Instruments, Inc.
TM	Telemetry
Unsymmetric g	Normal acceleration placed on the aircraft when full lateral stick input is present.
USAF	United States Air Force
USN	United States Navy
WUT	Wind Up Turn
ZRF	Zero Retention Force

INTRODUCTION

Laser guided weapons have seen widespread use by the USAF, and to a lesser extent by the Navy, beginning with the Vietnam Conflict. This type of weapon has seen great improvements in several areas of in the last twenty-five to thirty years. The newest class of laser guided bombs (LGB), of which the GBU-24 is one, is the Paveway III class. Improvements of the Paveway III over the Paveway I and Paveway II classes include improved guidance and range. Several weapon trajectory shaping profiles are also now available in the Paveway III, in order to optimize the impact angle of the weapon for better penetration and destructive capability against vertical and horizontal targets (6). Another important difference between the Paveway III and its predecessors is that the former will execute its midcourse trajectory regardless of whether or not laser energy is present. The older weapons will fall ballistically until acquiring laser energy. This difference is important because it makes being able to deliver the Paveway III with the guidance unit disabled necessary if a ballistic delivery is required.

The employment of an LGB or low-level LGB (LLLGB) is relatively simple with proper training. A target is designated by either a ground based or airborne laser designator. After release from an aircraft, the weapon searches for the laser energy and homes in on it after acquisition. The target must remain illuminated by the laser energy until weapon impact. It is generally acknowledged that it is easier for the delivery aircraft to designate its own target rather than rely on designation from ground troops (24).

The historically different missions of the USAF and the Navy have, until recently, dictated that the USAF utilize self designation while the Navy utilize ground designations. In fact, until recently, only the Navy's A-6E Intruder aircraft was capable of performing airborne laser designations. It is the author's view that the inability of most Navy platforms to perform airborne laser designations on targets has kept laser guided bomb

from being the weapon of choice for many war fighting scenarios. The Navy's interest in using laser guided bombs has recently increased and a laser designator has been incorporated into F/A-18 Hornet.

The GBU-24A/B was a 2400 pound LLLGB manufactured for the United States Air Force (USAF) by Texas Instruments, Inc. (TI). It was designed to penetrate and destroy hardened targets. USAF tactical aircraft utilized the weapon's penetration capability with great success against hardened targets in Iraq during operation Desert Storm. The Navy had no similar weapon capability.

Following the war, the Navy realized the need for the same type of hardened target penetration capability for its F/A-18 and A-6E aircraft. A time frame of no longer than two years from initial development of a suitable weapon to Initial Operational Capability (IOC) was chosen. Because of this time constraint and the GBU-24A/B's proven capability, the Navy chose to procure the GBU-24A/B and certify it for fleet use, rather than developing an entirely new weapon. Because of the different operational environments of the USAF and Navy as well as differences in delivery platforms, the GBU-24A/B would have to be modified substantially and flight tested for aircraft compatibility. Because the USAF version of the weapon had already been successfully tested for effectiveness, that testing could be eliminated from the Navy's effort. The modified weapon was designated the GBU-24B/B.

The Flight Test and Engineering Group (FTEG), Naval Air Warfare Center Aircraft Division, Patuxent River, was tasked to design and execute a test program to evaluate weapon modifications and compatibility between the GBU-24B/B and F/A-18 and A-6E aircraft(19). Both ground and flight tests were performed. FTEG is the Navy's developmental branch of aircraft flight test.

GBU-24A/B WEAPON DESCRIPTION

Although the GBU-24A/B was not used as a test asset, it is described here for comparison with the GBU-24B/B. The arrangement of the individual GBU-24A/B components is depicted figure B.1. It is also depicted below, loaded on an F/A-18 aircraft wing pylon during a fit test in 1991.

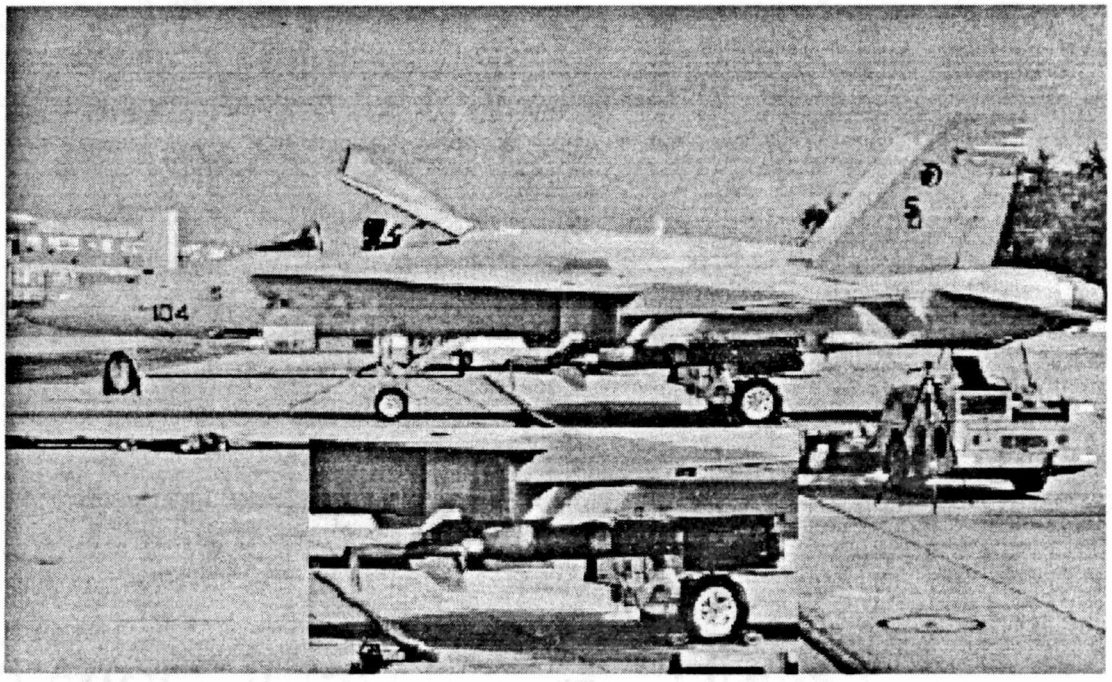

Figure 1

GBU-24 A/B LOADED ON F/A-18 AIRCRAFT

The design of the weapon was fairly modular, lending itself well to the modification of some components without major redesign. Major weapon components included the BLU-109 bomb body, the Guidance and Control Unit (GCU), the tail fin and hardback assemblies, a fuze initiator and an electric tail fuze.

The BLU-109 bomb case was composed of extruded 4340 steel alloy with approximately 1.125 inch thick side walls in order to better penetrate hardened targets. Only 30% of the BLU-109's assembled weight was composed of the explosive fill, Tritonal.

The WGU-39 guidance and control unit (GCU) was designed to guide the GBU-24A/B during weapon free flight. It consisted of four canards, a seeker assembly, an adapter assembly, and a power supply. Several post release flight profiles were available. The profile flown by the weapon was dependent on preflight selection and real-time release parameters. The GCU canards were designed to be active after release in order to proportionally guide the weapon to its target based on laser energy information the seeker head received. The power supply consisted of two thermal batteries and a pneumatic generator which were activated by withdrawal of a firing pin from the battery firing device (BFD) via an arming lanyard. If the firing pin was not pulled, the weapon would be delivered ballistically.

The tail fin assembly was designed for exceptional glide range . The tail fins were designed to spring open to 20 degrees immediately following release from the aircraft, then gradually reach full span during the next several seconds. Deployment of the fins was also required to maintain directional stability.

The hardback assembly was designed to provide proper interface between the BLU-109 and various USAF bomb racks and to house the FZU-32B/B fuze initiator. It was also designed to maintain BLU-109 integrity during target penetration by reducing the size of the attach points that would be necessary if the bomb body had suspension lug sleeves drilled directly into it. The hardback assembly consisted of two lug sleeves, a hardback, four hardback screws, two MK 3 Mod 0 suspension lugs, and FZU-32B/B extender. Each lug sleeve was attached directly to the BLU-109 bomb body by four hardened steel bolts. The lug sleeves provided an interface for bomb lugs. In addition, the hardback was

attached to the lug sleeves with two screws per lug sleeve. The hardback was constructed of a single piece cast of A356-T6 aluminum alloy which was reinforced by a series of integral ribs and blocks. The USAF version of the hardback was rounded to approximate a MK 84 general purpose bomb.

The GBU-24 series weapon was designed to be used with the FZU-32B/B bomb fuze initiator, a bomb fuze cable, fuze arming lanyard, and FMU-143 electric bomb fuze. The FZU-32B/B was a miniature ram air turbine powered generator designed to charge the electric bomb fuze. The FZU-32B/B turbine was spring loaded beneath an aluminum pull top, which was configured with a single steel lanyard rope arming lanyard. Magnetic attraction between the FZU-32B/B rotor and case was designed to prevent the generator from turning until a threshold airspeed of 260 KCAS was reached. The FMU-143 electric bomb fuze was developed for use with the FZU-32B/B bomb fuze initiator. A single steel rope arming lanyard terminated by a small safety clip was installed in the FMU-143 gag rod to provide mechanical weapon safing capability. The FMU-143/B was configured with an external control for selection of arming delay time during weapon buildup.

A general description of the GBU-24 series weapon may be found in the GBU-24A/B Aircrew Weapons Delivery Manuals (-34) Source Data (27).

NAVY SPECIFICATIONS

Because of the close proximity between aircraft on a flight deck, the Navy sets stricter standards than the USAF with regard to a weapon's resistance to accidental detonation from excessive heat. For this reason, the explosive fill of the BLU-109/B was replaced with PBXN-109 explosive fill, which is a less sensitive munition than Tritonal. For the same reason, a thermal protective coating, composed of fiberglass resin, was applied to the outside of the bomb body. The booster of the FMU-143 electric tail fuze was also modified in order to be compatible with the PBXN-109 explosive fill.(12,13)

COMPATIBILITY REDESIGNS

When a GBU-24 with the original hardback was fitted on the F/A-18 and A-6E aircraft, two problems were identified. First, there was insufficient clearance between the weapon and the F/A-18 pylon. Second, the sway brace pads of the F/A-18's BRU-32A/A bomb rack did not make the required contact with the hardback of two square inches per pad to allow proper sway bracing (MIL-STD-8591G). This meant that the weapon would not be suspended properly in flight, resulting in possible structural damage to the rack. In addition, when static ejection tests were performed with the unmodified version of the hardback from the A-6E's AERO-7A bomb rack, the hard back failed structurally because it was not reinforced in the area where the AERO-7A ejector foot made contact with it. Because of these problems, the hardback needed to be modified. These modifications consisted of external facets for compatibility with the BRU-32A/A and AERO-7A bomb rack sway brace assemblies and reinforcement under the BRU-32A/A and AERO-7A

ejector feet(3). Figures B.2 and B.3 depict the unmodified hardback on the BRU-32A/A bomb rack and after the static ejection test. Figures B.4 and B.5 show the modified version.

No modifications to the guidance control unit or tail fin assembly were deemed necessary for Navy operational use prior to flight test.

FLIGHT TESTS

CONCEPTUAL DEVELOPMENT

GENERAL

The scope of these tests was driven by operational capability requirements placed on the weapon based on the recommendations of the Naval Strike Warfare Center. However, limited test assets, funding and time to required IOC dictated that not all weapon stations of both aircraft be tested for carriage and release of the GBU-24B/B. A compromise between operational requirements and administrative constraints was reached prior to flight test, which, if successful, would provide satisfactory near-term capability for a realistic cost. Both the F/A-18 and A-6E communities were given the option of carriage on and separation from either inboard or outboard wing stations only. Because of the weapon's mass, the best option from a structural loads, flying qualities and Limit Cycle Oscillation (LCO) standpoint was to test the inboard stations of both aircraft; stations 3 and 7 for the F/A-18 and stations 2 and 4 for the A-6E. However, the standard fleet configuration of the F/A-18 included external fuel tanks on the inboard stations. The outboard stations did not include external fuel tank plumbing. Due to these reasons, it was decided to test the inboard stations on A-6E aircraft and the outboard stations (2 and 8) of the F/A-18 aircraft. Mandatory flight tests would include the following: structural loads testing, separation testing, and catapult testing. The structural loads survey and catapult tests would have to be performed because of the weapons weight and because of the large structural load placed on an aircraft during shipboard catapult launches. However, because it was determined that the weapon's size and weight precluded shipboard arrested landings, field flared landing tests would be substituted for arrested landing testing. No multiple

releases would be tested due to test asset availability and because of lack of time. The separation evaluation would only test arming function and safe separation from the aircraft and not the guidance or performance of the weapon. This had already been performed by the USAF. However, releases of weapons with other stores on an adjacent pylon would need to be performed in order to clear mixed store loadings for the fleet. Figure B.2a shows the hardback loaded on a BRU-32A/A and shows the different positions of the BRU-32A/A and AERO-7A sway brace pads. Figure B.2b shows the deformed hardback after static ejection from an AERO-7A bomb rack.

The decision to test the GBU-24B/B on stations 2 and 8 of the F/A-18 also necessitated that flutter and asymmetric flying qualities evaluations be conducted. The scope of these tests will not be discussed in detail in this paper.

DESCRIPTION OF TEST AIRCRAFT

F/A-18 AIRCRAFT

General

The F/A-18 Hornet was a carrier or land-based, single seat, fly-by-wire, supersonic fighter/attack aircraft built by McDonnell Douglas Aerospace (MDA). It was powered by two General Electric F404-GE-400 turbofan engines with afterburner. Pilot flight controls were conventional in appearance. However, two digital flight control computers (FCCs) were incorporated to receive flight control inputs from the pilot, then transmit the desired input to hydraulically actuated control surfaces. The FCCs then used rate gyro and air data feedback loops to modify control surface deflections. This computer interface was transparent to the pilot. Flight controls were irreversible.

The aircraft had all-weather intercept and ground attack capability. It was capable of being configured with nine external weapon stations, five of which were capable of carrying and releasing air-to-ground ordnance. These five stations incorporated BRU-32A/A bomb racks configured with two gas powered ejector feet each for normal release. The aircraft used an integrated Stores Management System (SMS) computer with a MIL-STD-1553 data bus for armament system control. The SMS software load used during these tests was Operational Flight Program (OFP) 89A. The armament system incorporated a weapon insertion panel located behind one of the aircraft fuselage doors. The pilot used this panel to enter weapon codes, which identified the weapon or other store being carried on each weapon station. The SMS used this code to determine the type of weapon being carried, as well as which types of fuzing options to make available to the pilot once in flight. No store code for the GBU-24B/B was incorporated into OFP 89A. Therefore, a MK 84 thermal coated general purpose bomb store code was used for separation tests. This code was used because it provided selectable mechanical nose and or tail fuzing to the pilot. This code also allowed enabling of FCC active oscillation controller (AOC) logic. This logic was essentially a means by which automatic aileron inputs were used to combat an aircraft oscillatory mode known as Limit Cycle Oscillation (LCO), which typically occurs when carrying heavy stores with wing tip missiles loaded. A more detailed description of the aircraft may be found in the F/A-18 NATOPS Flight Manual(2).

BRU-32A/A Bomb Rack

The BRU-32A/A bomb rack was attached to the underside of each F/A-18 SUU-63/A wing pylon. It was designed to permit carriage and release of one external store. The BRU-32A/A rack was configured with two separate pairs of suspension hooks, one pair each for 14 and 30 in. suspension. The BRU-32A/A also incorporated two ejector feet and

an automatic sway bracing mechanism. Two CCU-45/B impulse cartridges were designed to simultaneously provide breech pressure to open all suspension hooks and residual pressure to the ejector feet which, in turn, imparted an initial downward ejection velocity on the store at release. The BRU-32A/A was configured with two zero retention force (ZRF) arming unit (AU) solenoids which, when de-energized were designed to release the GBU-24B/B arming lanyards with zero force, thereby safing the weapon. These electrically actuated AU solenoids were incorporated for pilot selectable operation of arming lanyards and were representative production BRU-32A/A bomb racks. The BRU-32A/A was also configured with four positive arming latches designed to retain arming wires without pilot option.

A-6E AIRCRAFT

General

The A-6E aircraft was a Vietnam era aircraft still in service at the time of this writing. It was a carrier or land-based, two-place, all weather attack aircraft built by Grumman Aerospace Corporation (GAC). It was powered by two non-afterburning Pratt & Whitney J-52-P8 turbojet engines rated at 9,700 lb sea level static thrust each. The flight test aircraft was equipped with composite replacement wings. The A-6E was capable of being configured with five external weapons pylons for carriage of air-to-ground ordnance. Store codes could be inserted into an armament control system in the same manner as in the F/A-18 except that the weapon insertion panel was located inside the cockpit. A more complete description of the aircraft may be found in the A-6E NATOPS Flight Manual(5). The aircraft is depicted in figure 2.

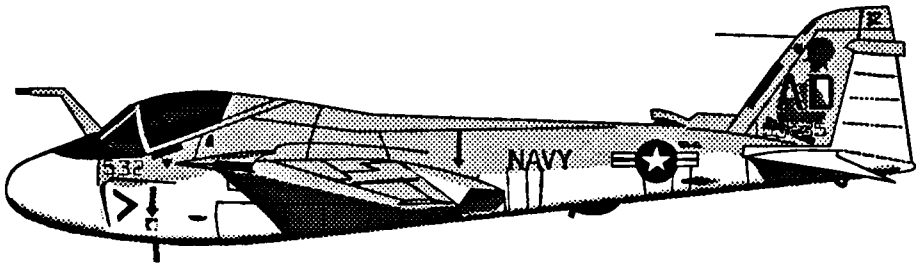

Figure 2

A-6E INTRUDER AIRCRAFT

AERO-7A Bomb Rack

The AERO-7A bomb rack was designed to provide an interface between an A-6E wing pylon and externally carried stores. The AERO-7A rack was configured with four pair of suspension hooks, two pair each for 14 and 30 in. suspension. This rack incorporated a single ejector foot vice the two ejector feet of the BRU-32A/A. Two electrically actuated AU solenoids provided for mechanical extraction of arming lanyards. The AERO-7A bomb rack was used during arming lanyard integrity testing and weapon separation testing.

DESCRIPTION OF TEST EQUIPMENT

AIRCRAFT INSTRUMENTATION

The aircraft instrumentation package consisted of an onboard magnetic tape recording (MTR) system and a telemetry (TM) system. Through these systems, production aircraft parameters, as well as instrumented aircraft and weapon parameters could be recorded inflight and transmitted real-time to engineers on the ground. In addition, aircraft mounted cameras with high speed film were used to record weapon releases.

Instrumentation parameter lists are presented in table A.I and A.II. Camera locations are presented in figures B.6 and B.7.

F/A-18 INSTRUMENTED PYLON

The SUU-63/A instrumented wing pylon was a standard F/A-18 pylon modified by MDA for structural flight tests. The instrumented pylon was used to evaluate forces exerted by the weapon into the pylon during structural loads survey flight tests. No structural modifications were made to the instrumented pylon. It was configured with strain gauges which were designed to provide accurate orthogonal force and moment data during structural loads survey flight tests. The forces and moments would be analyzed to determine store generated wing loads. The instrumented pylon was representative of production pylons for the purposes of these tests.

A-6E BALANCE BEAM

The A-6E balance beam was an instrumented force balance fabricated for the U.S. Navy by GAC. It was installed in place of the AERO-7A rack on the A-6E test aircraft during structural loads survey testing. The weight of the beam was approximately 160 lbs, comparable to the weight of the AERO-7A. The A-6E balance beam was configured with strain gauges which, like the instrumented SUU-63/A, were designed to provide accurate orthogonal force and moment data during structural loads survey flight tests. The forces and moments would be analyzed to determine store generated wing loads. Balance beam hook location and sway braces were identical to those of the AERO-7A. The A-6E balance beam was representative of production AERO-7A bomb racks for the purposes of structural loads survey tests.

TEST WEAPONS

General

The BLU-109 bomb bodies used during this test program contained filler E, a non-explosive but mass representative fill, which would eliminate the risk of detonation during separation testing in the event of a bomb to aircraft collision. Mass properties for a typical weapon are presented in table I, below.

Table I
MASS PROPERTIES GBU-24B/B

Wt. (lbs.)	2353
CG (in aft of fwd lug)	12.95
Iyy Pitch (Slug ft^2)	602
Ixx Roll (Slug ft^2)	31
Izz Yaw (Slug ft^2)	602

The inert bomb bodies used for this program were representative of live bomb bodies for the purposes of these tests.

For carrier suitability tests, a production representative WGU-39 GCU was used. For all other tests, inert WGU-12s were used. Both were compatible with the GBU-24B/B and differed only internally. Because the GCU was inert, GCU canards remained spring centered at neutral, which was representative of the operation of production GCUs during the first two seconds after weapon release. The GCU was attached to the front of the

BLU-109 bomb by a forward adapter assembly. The inert WGU-12 was representative of the WGU-39 for the separation and structural loads survey flight tests.

Six electrically functional, inert FMU-143 fuzes were used during separation tests to evaluate FZU-32B/B function. Post release FZU-32B/B generated voltage was telemetered to ground station to evaluate specification compliance. Inert fuze mass models were used for all other tests to evaluate arming lanyard function. All fuzing components were representative of production fuzing components for the purposes of these tests.

For both aircraft, the FZU-32B/B and the tail fin assembly were positively armed (attached to positive arming latches), while the GCU and FMU-143 were pilot selectable via arming lanyard routing to AU solenoids. This was to allow the pilot to release the weapon in any combination of simulated guided or ballistic, and simulated armed or safe modes, in order to test arming wire function. Arming lanyard configurations are depicted in figure B.8 and B.9.

Weapon First Motion Photo Flash

The weapon first motion photo flash was contained in an 8-in. long, 1.875-in. diameter cylindrical flash bulb holder and was used to assist in annotating first store movement during separation testing on film. This was later used as a start point to generate ballistic tables. The flash was electrically connected to the respective bomb rack electrical fuzing hook open micro-switch. The flash operated when the bomb rack hook opened during weapon release. The flash was recorded by onboard and Inter Range Instrumentation Group (IRIG) time correlated ground cameras.

Weapon Telemetry Package

A self-contained telemetry system, depicted in figures B.11 and B.12, was installed in six GBU-24B/B weapons used during separation testing. Electrically functional, inert FMU-143B/B fuzes were used with the TM units. The system was isolated and required no interface with the aircraft systems. Total TM package weight was six pounds and had negligible affect on weapon mass properties. The TM system enabled evaluation of the arming lanyard and fuze system by transmitted FZU-32B/B output voltage during weapon trajectory. The TM unit measured the voltage at the FMU-143 face plate connector. Externally mounted instrumentation was used during carrier suitability and structural loads survey tests, as presented in figure B.10.

METHODOLOGY

GENERAL

The F/A-18/GBU24B/B evaluation consisted of seven catapult launches, 16 flared field landings, seven structural loads survey flights and 11 separation flights for 19.7 hours. The test loadings for carrier suitability and structural loads survey flights are shown in table A.III. The conditions for catapult launches are shown in table A.IV. The matrices for the structural loads survey flight tests are presented in table A.V. Flared field landing data were collected during touch and go and full stop landings in conjunction with catapult launch and structural loads survey tests. Seventeen weapon releases were conducted under the loadings and conditions described in table A.VI. No multiple weapons releases were conducted. The flight tests were conducted within the limits of the NATOPS Flight Manual (8). The test envelope is presented in table II.

Table II

F/A-18 AIRCRAFT FLIGHT TEST ENVELOPE

Parameter	Structural Loads Survey	Separation
Airspeed (KCAS)	620 (max)	450 to 643
Mach	0.70 to 1.21	0.74 to 1.28
Altitude (FT MSL)	SFC to 35000	6000 to 18240
Normal Acceleration N_Z (g)	Symmetric(1): -2.7 to +7.5 Unsymmetric(2):+1.0 to +6.1	Symmetric: +0.5 to +1.0
Flight Path Angle (deg)	+45 to -60	0 to -61

Notes:
(1) Symmetric g - normal acceleration (Nz) placed on the aircraft when full lateral stick input is not present.
(2) Unsymmetric g - normal acceleration placed on the aircraft when full lateral stick input is present.

The A-6E/GBU-24B/B evaluation consisted of five flared field landings, five structural loads survey flights, one captive arming lanyard evaluation flight, and seven separation flights for 14.0 hours. Flared field landing loads data were collected at the end of each structural loads survey flight. The test loadings for the structural loads survey and captive carriage arming lanyard evaluations are shown in table A.VII. The matrix for the structural loads survey flight tests is presented in table A.VIII. The captive carriage arming lanyard evaluation matrix is presented in table A.IX. Twelve weapon releases were conducted under the loadings and conditions presented in table A.X. Since it had previously been determined that the dynamic structural loads during catapult launches on an A-6E aircraft would be less than those of the F/A-18 relative to the strength of the pylon, only F/A-18 catapults were necessary. The flight tests were conducted within the limits of the NATOPS Flight Manual(5). Test envelope is presented in table III.

Table III

A-6E AIRCRAFT FLIGHT TEST ENVELOPE

Parameter	Structural Loads Survey	Separation
Airspeed (KIAS)	504 (max)	452 to 527
Mach (IMN)	0.50 to 0.9	.74
Altitude (FT MSL)	SFC to 29000	5300 to 7500
Normal Acceleration -N_Z (G)	Symmetric: -2.4 to +6.8 Unsymmetric: +1.64 to +4.9	+0.5 to +1.1
Flight Path Angle (DEG)	Not Recorded	0 to -47

Notes:

(1) Symmetric g - normal acceleration (Nz) placed on the aircraft when full lateral stick input is not present.

(2) Unsymmetric g - normal acceleration placed on the aircraft when full lateral stick input is present.

F/A-18 CATAPULT LAUNCHES

Catapult tests were conducted at Patuxent River's catapult launch site. An instrumented GBU-24B/B was loaded on station 8, which consisted of the instrumented pylon and BRU-32A/A. The goal of these tests was to simulate the maximum loads which would be exerted on the GBU-24B/B and the weapon-aircraft interface during shipboard launches. Test buildup consisted of increasing the longitudinal acceleration exerted on the aircraft during the catapult stroke until the maximum longitudinal acceleration limit of the aircraft was reached on the last catapult launch. Off-center catapult launches were also conducted, as described in the Carrier Suitability Testing Manual(23). Prior to the first catapult launch, a field takeoff into the pattern was conducted for pilot familiarization of asymmetric handling qualities in the takeoff and power approach configurations. Visual inspections of the aircraft and GBU-24B/B were conducted prior to each catapult launch. Structural load parameters were telemetered to an engineering ground station and were

monitored and analyzed by the test team. A detailed instrumentation parameter list is provided in table A.1 and A.2. Each catapult event was also recorded on videotape. The GBU-24B/B GCU was functionally checked for normal operations after completion of the catapult launch tests.

STRUCTURAL LOADS SURVEYS

Flight maneuvers were performed in accordance with the procedures outlined in MIL-STD-8861B(AS), Aircraft Strength and Rigidity Flight Loads(11) and Fixed Wing Performance Manual, USNTPS-FTM-104(28). Specific aircraft test maneuvers are explained in detail in appendix C. Test matrices were designed to provide build-up in Mach, dynamic pressure and normal acceleration for both symmetric and unsymmetric maneuvers. Because the maximum G available varied structurally with gross weight for both airplanes, fuel and other external stores were reduced until the maximum placard G was available. An instrumented GBU-24B/B was loaded on an instrumented SUU-63/A pylon for the F/A-18 and balance beam for the A-6E. Structural load parameters were telemetered to an engineering ground station and were monitored and analyzed by the test team. This enabled engineers on the ground to quickly determine if limits were being approached and to stop testing, if necessary. Structural loads survey flight test limits were two-thirds ultimate load for measured parameters and one-half ultimate load for calculated parameters. The weapon and aircraft were visually examined for structural anomalies after each flight. In addition, GBU-24B/B arming lanyards were inspected after each F/A-18 flight. The A-6E balance beam did not incorporate AU solenoids and positive arming latches; therefore, the tail fin release arming lanyard was routed to the outboard aft sway brace during the structural loads survey flight test. A dedicated captive carriage flight to

evaluate arming lanyard integrity was performed on the A-6E using an AERO-7A bomb rack.

SEPARATION

Separation characteristics, ballistic trajectories and arming lanyard operation in both armed and safe mode were evaluated. All tests were conducted per MIL-STD-1763A, Aircraft/Store Certification Procedures, and NATCINST 8600.1A(9), Standardized Armament Test Manual(15). Weapon separation characteristics were recorded by aircraft mounted high-speed 16 mm cameras and ground cameras operating at 200 frames per second. Preflight visual inspections were made of the weapons and aircraft to ensure proper weapon loading and arming lanyard routing. A post flight inspection of the aircraft was conducted to verify that there were no store to aircraft collisions and that the arming wires and AU solenoids operated properly. Aircraft parameters were telemetered to the ground station during release. Arming lanyard operation was recorded by the onboard cameras and inferred by post flight inspection of AU solenoids and arming latches. The arming lanyard rigging and routing were evaluated during separation from the A-6E aircraft as depicted in figure B.7. The F/A-18 arming lanyard rigging was modified during flight test due to arming lanyard problems. The two riggings are depicted in figures B.7 and B.8. A self-contained telemetry system was installed in six weapons used for separation tests. External fuel tanks were used for both the F/A-18 and the A-6E as worst case adjacent stores during loads and separation testing

TEST LOADINGS

Test loadings for A-6E and F/A-18 flight tests are presented in tables A.III and A.VII. Loading considerations included previous analysis of captive airloads and known aircraft performance characteristics.

RESULTS

F/A-18 CATAPULT LAUNCHES AND FLARED LANDINGS

The suitability of the GBU-24B/B was evaluated for shipboard catapult launch operations and flared landings. No anomalies with the GBU-24B/B, arming lanyards, or F/A-18 aircraft were noted during post event visual inspection. The GBU-24B/B was satisfactory for shipboard catapult launch operations and flared landings to the limits of the F/A-18 aircraft. It was recommended that the GBU-24B/B be cleared for shipboard catapult launches and flared landings to the limits of the F/A-18 and A-6E aircraft.

F/A-18 STRUCTURAL LOADS SURVEY

General

The structural adequacy of the F/A-18 wing pylon, BRU-32A/A bomb rack, and GBU-24B/B was quantitatively evaluated during level sideslips, 1-g level rolls, wind up turns (WUT), rolling pull outs (RPO) and negative-g pushover structural loads survey maneuvers. Test maneuvers and conditions are presented in table A.V. Flight maneuvers are explained in appendix C. Level sideslips, 1-g level rolls, wind up turns, and negative-

g pushovers produced loads which did not approach any established limits for the pylon, rack, or weapon. It was determined that the structural adequacy of the F/A-18 wing pylon, BRU-32A/A bomb rack, and GBU-24B/B during level sideslips, 1-g rolls, wind up turns, and negative-g pushovers was satisfactory.

RPO Maneuvers with Asymmetric Fuel Tank Loading

The structural adequacy of the F/A-18 wing pylon, BRU-32A/A bomb rack, and GBU-24B/B was quantitatively evaluated during RPO structural loads survey maneuvers with loading B of table A.III. This loading included a general purpose bomb(GPB) on station 2, a fuel tank on station 7, and the GBU-24B/B on station 8. Test maneuvers and conditions are presented in event 2 of table A.V. Loading B was used because flight tests with previous weapons had demonstrated that higher air loads existed on a weapon when it was hung adjacent to a fuel tank, resulting in higher structural loads. A fuel tank was not hung on the opposite wing in order to reduce weight and increase G available during the maneuver. Lateral asymmetry during this test was approximately 8,300 ft-lb right wing down. The aircraft loading apparently produced large drag asymmetry at high dynamic pressure due to the fuel tank on aircraft station 7 with no tank or pylon on aircraft station 3. Asymmetry was more pronounced with increasing normal acceleration. When setting up for RPO maneuvers by increasing g in a constant altitude, banked turn, a continuously increasing amount of lateral stick displacement from neutral was necessary with increasing g to maintain desired bank angle. This was apparently caused by an increasing load imbalance between the left and right side of the aircraft as g increased. Increased lateral control power in the opposite direction was therefore available to the pilot, due to the non-neutral stick position at the start of the maneuver. RPOs performed during event 8 at 0.8 to 0.9 Mach and greater than approximately 4 g produced 168 deg/sec roll rates and 3.5 g

lateral acceleration on the store. High roll rates or lateral accelerations were not encountered during 1.0 g full stick rolls in loading B and C nor RPOs in loadings C. High lateral accelerations were caused by applying full opposite lateral control input at the end of the high roll rate maneuver. The impact of high roll rates and lateral accelerations on static and fatigue strength of uninstrumented aircraft structural members was not known due to instrumentation limitations. The excessive roll rate and resulting lateral acceleration on the store experienced during full stick deflection RPOs with asymmetric fuel tank loading was a minor deficiency. It was recommended that abrupt lateral control inputs be limited to less than one half stick when aircraft normal accelerations are greater than 1 g, drop tanks are not loaded symmetrically, and 2,000 lb class stores are loaded on stations 2 or 8. It was also recommended that structural testing be conducted using an aircraft with a fully instrumented and calibrated wing to determine the impact on the aircraft static and fatigue strength resulting from carriage of heavy stores on stations two and eight with fuel tanks loaded asymmetrically.

Rolling Pull Out Maneuvers with Symmetric Fuel Tank Loadings

The structural adequacy of the F/A-18 wing pylon, BRU-32A/A bomb rack, and GBU-24B/B was quantitatively evaluated during high-g RPO structural loads survey maneuvers with loading C, which included a fuel tank on both stations 3 and 7, and the GBU-24B/B on station 8. Test maneuvers and conditions are presented in event table A.V. The test loading was changed from B to C after problems in the previous paragraph were identified. During the 5.3 g entry at 0.85 IMN and 5000 FT MSL, a load equal to 100% of the test limit was observed on the pylon forward hook. During the 5.3g entry at 0.9 IMN and 5000 FT MSL, a load equal to 102% of test limit was produced on the pylon aft attach fitting. During these maneuvers, these limit loads occurred at aircraft normal accelerations

lower than the 6.0 g NATOPS limit by 0.7 g. The design strength of the pylon forward hook and aft attach fitting at the above test conditions was inadequate for carriage of the GBU-24B/B to the NATOPS limits of the aircraft. During high g, unsymmetrical maneuvering with a GBU-24B/B loaded on pylon stations 2 or 8, it would be possible for the F/A-18 pilot to inadvertently over stress the pylon, reducing its structural design margin and possibly shortening its fatigue life. The incompatibility between the design strength of the SUU-63/A pylon and the GBU-24B/B loaded on aircraft stations 2 or 8 during high g RPOs at 0.85 Mach or greater at 5,000 FT MSL or less was a minor deficiency. It was recommended that an unsymmetrical maneuvering limit of 5.0 g be placed upon the F/A-18 when carrying the GBU-24B/B to preclude exceeding pylon forward hook and aft attach fitting structural limits.

F/A-18 Arming Lanyard Integrity

The GBU-24B/B arming lanyards were evaluated for proper retention in the F/A-18 aircraft AU solenoids and GBU-24B/B during structural loads survey flights. Arming lanyards were routed as presented in figure B.8. Test maneuvers and conditions are presented in table A.V. Post flight visual inspection indicated all arming lanyards were retained by the AU solenoids and GBU-24B/B. It was determined that, the GBU-24B/B arming lanyard routing shown in figure B.8, was satisfactory for retention in bomb rack AU solenoids and GBU-24B/B during carriage on the F/A-18 aircraft.

F/A-18 SEPARATION

The GBU-24B/B was evaluated for separation characteristics during 17 releases from the F/A-18 aircraft. Release loadings are shown in appendix A.VI. GBU-24B/B releases

were generally characterized by counterclockwise roll after ejection and positive movement away from the release aircraft as shown in the film sequences of flights 8 and 9 presented in figures B.13 and B.14. All weapons demonstrated positive stability after tail fin extension. Weapons demonstrated a slight hesitation 4 to 5 feet below the aircraft. Hesitation was most severe during flight 7. Weapon releases subsequent to flight 7 were characterized by decreased hesitation. Weapons released adjacent to a 330 gal fuel tank yawed such that the GBU-24B/B tail fin translated towards the tank, to within approximately 6 in. Since all flights were conducted with the GBU-24B/B loaded on aircraft station 2 and the fuel tank on aircraft station 3, the GBU-24B/B tail fin rolled away from the fuel tank. Flight 11 was added to the matrix to evaluate tail clearance when the tail fin would roll toward the fuel tank. GBU-24B/B release from aircraft station 8 with a fuel tank on aircraft station 7 was characterized by decreased counterclockwise roll rate and yaw rate which resulted in similar tail fin to tank clearance demonstrated during previous flights. It was determined that GBU-24B/B separation characteristics from the F/A-18 weapon stations 2 and 8 were satisfactory with and without 330 gal fuel tanks loaded on weapon stations 3 and 7. It was recommended that the F/A-18 aircraft be authorized for single releases of GBU-24B/B from aircraft stations 2 and 8 to the limits of table IV with mix store loadings per the F/A-18 Tactical Manual for similar types of stores.

Table IV

RECOMMENDED F/A-18 GBU-24B/B RELEASE LIMITS

Weapons Station									Release Conditions			Remarks
1	2	3	4	5	6	7	8	9	SPEED (KCAS)	DIVE (Deg)	ACCEL 7.2.10.	
	X						X		Confid-ential number.	60°	+0.5 to +1.0	A confidential list of authorized adjacent stores was recommended.

F/A-18 ARMING LANYARD FUNCTION

FZU-32B/B and Tail Fin Release Latch Functional Utility

The FZU-32B/B bomb fuze initiator pull top and BSU-84/B tail fin release latch were evaluated for proper operation and functional utility during 17 releases from the F/A-18 aircraft. Arming lanyards were routed as presented in figures B.8 and B.9. Aircraft release conditions are presented in table A.VI. The FZU-32B/B pull top and wing release latch were both attached by arming wires to positive arming latches, precluding inflight selection by the pilot. Both functioned properly during all releases. It was determined that the operation and functional utility of the FZU-32B/B pull top and tail fin arming lanyards were satisfactory during releases from the BRU-32A/A bomb rack.

GCU Functional Utility

a. Guided Releases

The GCU arming lanyard was evaluated for proper operation and functional utility during nine simulated guided releases from an F/A-18. The GCU arming lanyard was routed to the forward AU solenoid as depicted in figures B.8 and B.9. This was done so that the pilot would have the option of dropping the weapon ballistically (unguided) in the event that a laser designation was not available on the target. Arming lanyard function was determined by review of onboard high-speed film and post flight inspection of AU solenoids. A summary of arming lanyard results is presented in table A.VIII. The GCU arming lanyard

properly activated the GCU during all simulated guided releases. It was determined that the operation of the GCU arming lanyard was satisfactory.

b. Unguided Releases

The GCU arming lanyard was evaluated for proper operation and functional utility during eight simulated unguided releases from an F/A-18. The GCU unintentionally activated during two of eight simulated, unguided trajectory releases. Both failures occurred at airspeeds greater than 550 KCAS when the MAU-166 swivel which attaches the GCU arming lanyard to the forward AU solenoid, became entangled with the bomb rack or the FZU-32B/B arming lanyard after MAU-166 release from the forward ZRF AU solenoid. This would result in off target hits and excessive collateral damage due to mid course trajectory adjustments during guided flight which deviated from the ballistic profile. The inability to reliably release the GBU-24B/B in an unguided trajectory at airspeeds greater than 550 KCAS was a major deficiency. However, unguided release was viewed as a backup delivery mode. Therefore, modification of the arming wire routing to correct this problem was not performed in this test program.

FMU-143 Electric Bomb Fuze Arming Lanyard

a. Safe Releases

FMU-143 electric bomb fuze arming lanyard routings were evaluated for proper operation and functional utility during eight simulated safe releases from an F/A-18 aircraft. The FMU-143 arming lanyard was routed to the aft ZRF AU solenoid to permit the pilot the option of jettisoning the weapon in a safe mode in the event of an emergency. This is

depicted in figures B.8 and B.9. Arming lanyard function was determined by review of onboard high-speed film and post flight inspection of AU solenoids. A summary of arming lanyard results is presented in table A.VIII. Post flight inspection and review of onboard film indicated the arming lanyard swivel properly withdrew from the ZRF AU solenoid during safe weapon release using arming lanyard routing presented in figure B.8. However, further analysis of onboard film indicated that, upon release, the swivel accelerated aft until reaching the end of the arming lanyard resulting in a rapid jerk on the arming lanyard which may have exceeded the FMU-143 gag rod safety clip retention force, resulting in unintentional safety clip withdrawal from the gag rod, which armed the weapon. An 18 inch long fuze safe-jettison-lanyard was developed using 1/16 in. lanyard rope and added to the arming lanyard as shown in figure B.9. Two additional safe releases were conducted using 1/16 in. fuze safe-jettison-lanyard. During the second safe release, the aft bomb rack hook cut the 1/16 in. fuze safe-jettison-lanyard resulting in the safety clip withdrawing from the fuze gag rod. Subsequent fuze safe-jettison-lanyards were manufactured using 3/32 in. lanyard rope. During the final two safe releases, the aft bomb rack hook did not cut the fuze safe-jettison-lanyard resulting in the safety clip remaining in the fuze gag rod. It was determined that the arming lanyard routing with the fuze safe-jettison-lanyard constructed with 3/32 in. lanyard rope as presented in figure B.9, was satisfactory for safe release of the GBU-24B/B weapon from the F/A-18 aircraft. It was recommended that the arming lanyard routing presented in figure B.9 be authorized for fleet operations for safe releases of the GBU-24B/B weapon from the F/A-18 aircraft.

b. Armed Releases

FMU-143 electric bomb fuze arming lanyard routings were evaluated for proper operation and functional utility during eight armed releases from an F/A-18 aircraft. Two

FMU-143 arming lanyard routings for F/A-18 are presented in figures B.8 and B.9. Arming lanyard function was determined by review of onboard high-speed film and post flight inspection of AU solenoids. A summary of arming lanyard results is presented in table A.VIII. The FMU-143 gag rod safety clip was properly withdrawn by both arming lanyard configurations during all armed releases. It was determined that the FMU-143 electric bomb fuze arming lanyard routings depicted in figures B.8 and B.9 were satisfactory for armed weapon releases from the F/A-18 aircraft. Due to the deficiency identified in the previous paragraph, it was recommended that the arming lanyard routing presented in figure B.9 be authorized for fleet operations for armed releases of the GBU-24B/B weapon from the F/A-18 aircraft.

A-6E STRUCTURAL LOADS SURVEY

The structural integrity of the A-6E wing, pylon, AERO-7A bomb rack, and GBU-24B/B was quantitatively evaluated during structural loads survey flight tests with GBU-24B/B loaded on an instrumented force balance beam on aircraft station 2. Specific test events and conditions are presented in table A.IX. Test loadings are presented in table A.VII. Measured and calculated parameters are presented in table A.II. The port forward rack sway brace reached 54% of limit load during event 6, a level roll at 0.85 IMN/5K ft. Highest pylon wing interface load reached was 55% of test limit at the right aft lug during event 6, a level roll at 0.9 IMN/5K feet. All other loads were of a lower percentage of the parameter limit load. Addition of the AERO-1D fuel tank adjacent to the GBU-24B/B increased the inboard side force on the GBU-24B/B and apparently resulted in a net decrease in the outboard side loads during rolling maneuvers. Loads were generally lower with the AERO-1D fuel tank loaded adjacent to the GBU-24B/B. It was determined that the

structural load characteristics of the A-6E wing, pylon, AERO-7A bomb rack, and GBU-24B/B were satisfactory to the limits of the basic aircraft (LBA). It was recommended that the GBU-24B/B be authorized for carriage on A-6E wing stations 2 and 4 to LBA.

A-6E SEPARATION

The separation characteristics of the GBU-24B/B from A-6E stations 2 and 4 were qualitatively evaluated during 12 weapon releases. The test matrix is presented in table A.X. All weapons exhibited positive movement away from the release aircraft at all times. All weapons demonstrated positive stability after tail fin extension. End point releases of the GBU-24B/B with and without an adjacent AERO-1D fuel tank, flights 6/2 and 7/1, are depicted in figures B.13 and B.14, and were characterized by a slight deceleration 4 to 5 ft below the aircraft weapon station. However, weapon separation distance continually increased and posed no safety of flight concerns. It was determined that separation characteristics of the GBU-24B/B from A-6E stations 2 and 4 were satisfactory to the loadings and limits of table A.X. It was recommended that the A-6E aircraft be authorized to release the GBU-24B/B from aircraft stations 2 and 4 to the limits of table V.

Table V

RECOMMENDED A-6E GBU-24B/B RELEASE LIMITS

Weapon Stations					Release Conditions			Remarks
1	2	3	4	5	SPEED (KIAS)	DIVE (Deg)	N_Z (g)	
	■		■		FOUO	45	+0.7 to +1.0	none.

A-6E ARMING LANYARD INTEGRITY

The GBU-24B/B arming lanyards were evaluated for proper retention in the A-6E aircraft AU solenoids and GBU-24B/B during a captive carriage arming lanyard evaluation flight. Arming lanyards were routed as presented in figure B.8. The maneuvers and loading are shown in tables A.XI and A.VII. Post flight visual inspection indicated all arming lanyards were retained by the AU solenoids and GBU-24B/B. It was determined that the GBU-24B/B arming lanyard routing shown in figure B.8 was satisfactory for retention in bomb rack AU solenoids and GBU-24B/B during carriage on the A-6E aircraft.

A-6E ARMING LANYARD FUNCTION

FZU-32B/B and Wing Release Latch Functional Utility

The FZU-32B/B bomb fuze initiator pull top and BSU-84/B wing release latch were evaluated for proper operation and functional utility during 12 releases from the A-6E aircraft. Arming lanyards were routed to positive arming latches as presented in figure B.8. Aircraft release conditions are presented in table A.X. The FZU-32B/B pull top and wing release latch were both attached by arming wires to positive arming latches, precluding inflight selection by the pilot. Both functioned properly during all releases. It was determined that the operation and functional utility of the FZU-32B/B pull top and BSU-84/B arming lanyards were satisfactory.

GCU Functional Utility

a. Guided Releases

The GCU arming lanyard was evaluated for proper operation and functional utility during nine simulated guided releases from an A-6E aircraft. The GCU arming lanyard routing is presented in figure B.8. Arming lanyard function was determined by review of onboard high-speed film and post flight inspection of AU solenoids. A summary of arming lanyard results was presented in table A.XII. The GCU arming lanyard properly activated the GCU during all simulated guided releases. It was determined that the operation of the GCU arming lanyard was satisfactory during simulated guided releases from the AERO-7A bomb rack.

b. Unguided Releases

The GCU arming lanyard was evaluated for proper operation and functional utility during eight simulated unguided releases from an A-6E aircraft. The GCU arming lanyard routing is presented in figure B.8. Arming lanyard function was determined by review of onboard high-speed film and post flight inspection of AU solenoids. A summary of arming lanyard results is presented in table A.XII. The GCU unintentionally activated during three of nine simulated unguided releases. Cause of the simulated unguided release failures could not be directly attributed to a single factor. It was determined that during high-speed unguided releases, a significant percentage of weapon GCUs would activate, resulting in off target hits and excessive collateral damage due to mid course trajectory adjustments similar to those discussed with the F/A-18. The inability to reliably release the GBU-24B/B in an unguided trajectory from the A-6E aircraft was a major deficiency. As with the F/A-

18, an unguided delivery was considered as a backup mode in the event that laser energy was not available. It was not corrected in this test program.

FMU-143 Electric Bomb Fuze Arming Lanyard

a. Safe Releases

FMU-143 electric bomb fuze arming lanyard routings were evaluated for proper operation and functional utility during seven safe releases from an A-6E aircraft. The FMU-143 arming lanyard was routed to the aft AU solenoid as depicted in figure B.8. Arming lanyard function was determined by review of onboard high-speed film and post flight inspection of AU solenoids. A summary of arming lanyard results is presented in table A.XII. Review of onboard film indicated the gag rod safety clip was unintentionally withdrawn from the FMU-143 gag rod for four of the seven safe releases. Initial assessment attributed these failures to non-ZRF design of the AU solenoids. Since the FMU-143 electric bomb fuze in the GBU-24B/B was dependent upon non-ZRF AU solenoids for safe jettison, the failure rates would be similar to failure rates of conventional ordnance with mechanical bomb fuzes on AERO-7A bomb racks. Subsequent F/A-18 releases from a BRU-32A/A equipped with ZRF solenoids revealed an arming lanyard design deficiency which resulted in fuze arming after successful arming lanyard release from the solenoid. This failure mode was independent of the suspension equipment used to carry the GBU-24B/B and may have been the cause of some failures on the A-6E aircraft. The fuze safe-jettison-lanyard, depicted in figure B.9, eliminated this failure mode during F/A-18 testing but could not be evaluated on the AERO-7A due to limited test assets. Based on analysis of the F/A-18 fuze safe-jettison-lanyard test results, it was determined that the fuze safe-jettison-lanyard should be added to the A-6E arming lanyard configuration

without flight tests as presented in figure B.9. It was determined that the arming lanyard routing with the fuze safe-jettison-lanyard would be satisfactory for preventing armed releases due to arming lanyard dynamics; however, the reliability of safe jettison for the GBU-24B/B would be similar to that of mechanically fuzed bombs which use AERO-7A AU solenoids for safe jettison. It was recommended that the arming lanyard configuration presented in figure B.9 be authorized for fleet operations for safe releases of the GBU-24B/B from the A-6E aircraft.

b. Armed Releases

The FMU-143 electric bomb fuze arming lanyard routings were evaluated for proper operation and functional utility during five armed releases from an A-6E aircraft. The FMU-143 arming lanyard routing for the A-6E is presented in figure B.8. The FMU-143 gag rod safety clip was properly withdrawn by both arming lanyard configurations during all armed releases. The fuze safe-jettison-lanyard installed during F/A-18 testing could not be evaluated with the A-6E due to limited test assets. Based on F/A-18 test results, however, it was determined that the fuze safe-jettison-lanyard would be added to the A-6E arming lanyard configuration without flight test as presented in figure B.9. It was determined that the FMU-143 electric bomb fuze arming lanyard routing depicted in figure B.9 would be satisfactory for armed releases. It was recommended that the arming lanyard presented in figure B.9 be authorized for fleet operations for armed releases of the GBU-24B/B from the A-6E aircraft.

GBU-24B/B WEAPON INTEGRITY

General

The GBU-24B/B was evaluated for structural integrity during all captive carriage flight tests. Preflight and postflight inspections were conducted during all GBU-24B/B flight tests. No anomalies or deficiencies were identified with the GBU-24B/B except for those noted below.

GCU Rotation

The GCU was evaluated for structural integrity during structural loads survey flight tests. Upon completion of event 5 of table A.V, the GCU had loosened from the BLU-109 bomb body. At the completion of event 5, the test weapon had accumulated a total of 9.0 flight hour during six flights which included eight flared field landings. The forward adapter assembly provided the mechanical interface between the GCU and the bomb body. The assembly consisted of a forward adapter, retainer bolt, adapter spacer, and clamp ring with set screw, as depicted in figure B.15. It was determined that the failure to remain tightly attached was due to the retainer bolt loosening from the nose of the BLU-109. Close inspection of the BLU-109 revealed that some of the thermal protection coating had dripped onto the interface surface between the BLU-109A/B and the forward adapter spacer during application, preventing the spacer from making uniform contact with the bomb. This is evidenced in figures B.16. After weapon assembly, the high compression force exerted by the retainer bolt caused the thermal coat to deform and relieve the bolt torque. Disassembly of several weapons confirmed that approximately two thirds of the original 600 ft-lb torque had been lost in a matter of days since assembly. The thermal protective coating was

modified by removing the excess material and beveling the forward edge of the coating. After this modification and 4.3 flight hours, break torque measurements confirmed that the forward adapter bolts and clamp ring retained all of the original torque. The unmodified weapon was unacceptable for long test missions due to loosening of the GCU. It was determined that during long strike missions, the GBU-24B/B GCU would rotate loose, resulting in unreliable weapon performance. The excess thermal protection dripped onto the interface surface between the BLU-109A/B and the forward adapter spacer during application was a major deficiency which was corrected in subsequent bomb bodies being procured for the fleet. It was recommended that the production BLU-109A/B be inspected after thermal protection application to ensure that there was no thermal protective coating on the interface surface.

Loosened Hardback Screws

The hardback screws were evaluated for structural integrity during loads and captive carriage flight tests on both the F/A-18 and A-6E aircraft. The GBU-24B/B was configured with a cast A356-T6 aluminum alloy hardback adapter which was designed to provide a physical interface between the BLU-109 bomb body and the bomb rack ejector feet and sway bracing mechanisms. This was discussed in the weapon description section. The hardback was attached to the lug sleeve adapters by four hex head attachment screws torqued to 70 ±5 in-lb. During F/A-18 loads survey flight tests, it was discovered that three of four hardback attachment screws had loosened and partially backed out of the lug sleeve adapters. The test weapon had accumulated 4.5 hours of flight time since initial assembly which included the complete carrier suitability evaluation discussed previously. The hardback screws were reinstalled using grade D thread locking compound, and the test weapon completed the loads survey test matrix, an additional three flights and 4 flight

hours, without reoccurrence. Subsequent asymmetric flying qualities and flutter flight tests were flown without thread lock compound installed to permit further investigation of this phenomena. During F/A-18 flutter testing, two hardback screws were again found loosened. The flutter aircraft was configured with two GBU-24B/Bs which had each accumulated 14.3 hours during seven flights. Post flight inspection revealed that the forward outboard and aft inboard screws on the station 8 weapon had partially backed out of their respective lug sleeves. Additionally, all other hardback screws had a break torque force of less than 25 in-lb. The hardback screws were inspected and reinstalled at the designed torque. After a single flight of 2.3 hour duration, the average hardback screw break torque was 57 in-lb. The following flight included low altitude, high dynamic pressure test points and supersonic dive maneuvers and resulted in a post flight average hardback screw break torque of 34 in-lb. The hardback screws did not loosen during the A-6E flight tests. The loss of torque may have been caused by the action of the BRU-32A/A sway bracing mechanism, which may be the reason the phenomenon did not manifest itself during A-6E testing. It was determined that the retention torque value of the hardback screws was not sufficient for long strike missions and that the screws should be redesigned or installation procedures modified to include thread lock compound.

CONCLUSIONS

This program began as an effort by the Navy to provide itself with an air-to-ground weapon capability against hardened targets. At the same time, the Navy wanted to reduce design costs and development time by procuring an existing U. S. Air Force weapon, the GBU-24A/B. Unfortunately, this idea was simplistic and overlooked some basic differences between the aircraft for which the weapon was designed and the aircraft for which it was not. It also overlooked basic differences in Navy and Air Force criteria for weapon design. The key difference between the aircraft, which was not originally planned for, was the bomb rack. The lack of a standardized design meant that the GBU-24A/B hardback would have to be modified for the Navy. As of this writing, there is still no joint standard for weapon suspension design. In fact, no standardization exists within the Navy, itself. The Navy's stringent criteria in the area of weapon sensitivity to heat resulted in modifications to both the BLU-109 bomb body and the FMU-143 fuze before aircraft compatibility testing was even begun. Because of these modifications to the basic weapon, the two services will not have the ability to share weapon inventories, which will complicate supply and logistics systems.

Several deficiencies were identified during inflight loads and asymmetric flying qualities testing. These deficiencies resulted in maneuvering limitations being placed on the F/A-18 when carrying the weapon and were mainly due to the weapon's weight. Had the weapon been a fraction lighter, these restrictions might not have been necessary. The weapon would have also been recoverable aboard ship. Therefore, had the Navy been a contributor to the original design process, these restrictions probably could have been avoided.

Because of the modular design of the GBU-24A/B, the Navy test team was able to successfully modify the weapon and recommend an acceptable flight envelope for its

carriage and separation. Fortunately, the Navy was able to save substantial design costs by procuring this weapon. However, a majority of the ground and flight tests necessary with a new weapon were necessary with the GBU-24B/B. Therefore, little test money or time was saved.

The author's recommendation is that the services should work together in order to save money during the design phase, rather than working separately and relying on modification. It may seem obvious, but joint service efforts have, until recently, been perceived as too difficult to coordinate. Only in the past few years, because of shrinking budgets, have the Navy and Air Force begun to cooperate on major weapon programs. If joint research, development, test and evaluation (RDT&E) teams work together toward development of common weapons and weapon systems, the probability of success with programs like the one described in this paper would be substantially increased.

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APPENDIX A: TABLES

Table A.I

PARAMETERS AND LIMITS FOR GBU-24B/B FLIGHT TESTS ON THE F/A-18 AIRCRAFT

Description/location	Units	Limit	Type(1)
Longitudinal acceleration, GBU-24, cg, starboard side	G	None	MP
Lateral acceleration, GBU-24, cg, starboard side	G	None	MP
Lateral acceleration, GBU-24, nose, starboard side	G	None	MP
Vertical acceleration, GBU-24, cg, starboard side	G	None	MP
Vertical acceleration, GBU-24, cg, port side	G	None	MP
Vertical acceleration, GBU-24, nose, starboard side	G	None	MP
Vertical acceleration, GBU-24, cg	G	None	CP
GBU-24 roll acceleration	rad/sec^2	None	CP
GBU-24 pitch acceleration	rad/sec^2	None	CP
GBU-24 yaw acceleration	rad/sec^2	None	CP
Forward port swaybrace load	lbf	32K	MP
Forward starboard swaybrace load	lbf	32K	MP
Aft port swaybrace load	lbf	32K	MP
Aft starboard swaybrace load	lbf	32K	MP
GBU-24 forward lug vertical load (positive force is up)	lbf	34K	MP
GBU-24 aft lug vertical load	lbf	34K	MP
Instrumented pylon	mV/V	None	MP
Instrumented pylon	mV/V	None	MP
Instrumented pylon	mV/V	None	MP
Instrumented pylon	mV/V	None	MP
Instrumented pylon	mV/V	None	MP
Instrumented pylon	mV/V	None	MP
Instrumented pylon #41, hook vertical load	kips	None	CP
Instrumented pylon #41, post RM	in-kips	None	CP
Instrumented pylon #41, post YM	in-kips	None	CP
Instrumented pylon #41, preload	kips	None	CP
Instrumented pylon #41, aft vertical load	kips	None	CP

Table A.I (cont'd)

Description/location	Units	Limits	Type(1)
Instrumented pylon #41, PM	in-kips	None	CP
Instrumented pylon #41, side load	kips	None	CP
Instrumented pylon #41, total vertical load	kips	None	CP
BRU-32 forward connecting link load	lbf	9K	MP
BRU-32 aft connecting link load	lbf	9K	MP
Aircraft rudder input position or force	lbf	None	MP
Aircraft longitudinal stick position	inches	None	MP
Aircraft lateral stick position	inches	None	MP
Aircraft port rudder control surface position	degrees	None	MP
Aircraft starboard rudder control surface position	degrees	None	MP
Aircraft port stabilizer control surface position	degrees	None	MP
Aircraft starboard stabilizer control surface position	degrees	None	MP
Aircraft port aileron position	degrees	None	MP
Aircraft starboard aileron position	degrees	None	MP
Impact pressure	inches Hg	None	MP
Aircraft roll rate	deg/sec	None	MP
Aircraft pitch rate	deg/sec	None	MP
Aircraft yaw rate	deg/sec	None	MP
Aircraft angle of attack (positive is nose up)	degrees	None	MP
Aircraft angle of sideslip (positive is nose port)	degrees	None	MP
Aircraft sink rate	fps	None	MP
Aircraft airspeed	KIAS	635	MP
Aircraft altitude	ft	None	MP
Aircraft mach number	IMN	1.3	MP
Aircraft cg longitudinal acceleration	G	None	MP
Aircraft cg lateral acceleration	G	None	MP
Aircraft cg vertical acceleration	G	-3.0 to +7.5	MP

Notes: (1) CP-calculated parameter, MP-measured parameter

Table A.II
PARAMETERS AND LIMITS FOR GBU-24B/B FLIGHT TESTS ON THE A-6E AIRCRAFT

Description/location	Units	Limit	Type(1)
Longitudinal acceleration, GBU-24, cg, starboard side (positive in aft direction)	G	None	MP
Lateral acceleration, GBU-24, cg, starboard side (positive in starboard direction)	G	None	MP
Lateral acceleration, GBU-24, nose, starboard side	G	None	MP
Vertical acceleration, GBU-24, cg, starboard side (positive in up direction)	G	None	MP
Vertical acceleration, GBU-24, cg, port side	G	None	MP
Vertical acceleration, GBU-24, nose, starboard side	G	None	MP
Vertical acceleration, GBU-24, cg	G	None	CP
GBU-24 roll acceleration	rad/sec^2	None	CP
GBU-24 pitch acceleration	rad/sec^2	None	CP
GBU-24 yaw acceleration	rad/sec^2	None	CP
Balance beam forward port swaybrace load (positive force is down)	lbf	9.3K	MP
Balance beam forward starboard swaybrace load	lbf	9.3K	MP
Balance beam aft port swaybrace load	lbf	9.3K	MP
Balance beam aft starboard swaybrace load	lbf	9.3K	MP
GBU-24 forward lug vertical load or balance beam forward hook vertical load (positve force is up)	lbf	28K	MP
GBU-24 aft lug vertical load or balance beam aft hook vertical load	lbf	28K	MP
Balance beam longitudinal force, corrected	lbf	18K	CP
Balance beam lateral force, corrected	lbf	8K	CP
Balance beam roll moment	in-lbf	124K	MP
Balance beam pitch moment, corrected	in-lbf	584K	CP
Balance beam yaw moment, corrected	in-lbf	260K	CP
Pylon to wing, forward outboard vertical load	lbf	25K ver/41K lat	CP
Pylon to wing, forward inboard vertical load	lbf	25K ver/41K lat	CP
Pylon to wing, aft outboard vertical load	lbf	25K ver/41K lat	CP
Pylon to wing, aft inboard vertical load	lbf	25K ver/41K lat	CP

Table A.II (cont'd)

Description/location	Units	Limits	Type(1)
Pylon to rack, forward outboard vertical load	lbf	33K ver/28K lat	CP
Pylon to rack, forward inboard vertical load	lbf	33K ver/28K lat	CP
Pylon to rack, aft outboard vertical load	lbf	33K ver/28K lat	CP
Pylon to rack, aft inboard vertical load	lbf	33K ver/28K lat	CP
Aircraft rudder pedal position	inches	None	MP
Aircraft longitudinal stick position	degrees	None	MP
Aircraft lateral stick position	degrees	None	MP
Aircraft port flaperon control surface position	degrees	None	MP
Aircraft starboard flaperon control surface position	degrees	None	MP
Aircraft rudder control surface position	degrees	+/-40 (clean)	MP
Impact pressure	psi	None	CP
Aircraft roll rate	deg/sec	None	MP
Aircraft pitch rate	deg/sec	None	MP
Aircraft yaw rate	deg/sec	None	MP
Aircraft heading	degrees	None	MP
Aircraft sink rate	fps	None	MP
Aircraft angle of attack (positive is nose up)	degrees	None	MP
Aircraft airspeed	KIAS	None	MP
Aircraft altitude	ft	None	MP
Aircraft mach number	IMN	None	CP
Aircraft cg longitudinal acceleration	G	None	MP
Aircraft cg lateral acceleration	G	None	MP
Aircraft cg vertical acceleration	G	-2.4 to +6.5	MP
Balance beam axial force	μ strain	None	MP
Balance beam lateral force	μ strain	None	MP
Balance beam pitch moment	μ strain	None	MP
Balance beam yaw moment	μ strain	None	MP
Balance beam roll moment	μ strain	None	MP
Balance beam lateral force #2	μ strain	None	MP

Notes: (1) CP-calculated parameter, MP-measured parameter

Table A.III

F/A-18 CVS AND STRUCTURAL LOADS SURVEY FLIGHT TEST LOADINGS

Loading	Description	Test
A	Sta 1, 3, 4, 6, 7, & 9: Empty Sta 2: MK 82 CFA/Pylon/Bomb Rack Sta 5: TM Pod/Pylon/Bomb Rack Sta 8: GBU-24B/B/Instrumented Pylon/Bomb Rack	Carrier Suitability
B	Sta 1 and 9: Empty Sta 2: Pylon/MK 84 CFA Sta 3: No pylon Sta 4, 5, and 6: No pylon Sta 7: Pylon/330 gal fuel tank Sta 8: GBU-24B/B on instrumented pylon	Structural Load Survey
C	Sta 1 and 9: Empty Sta 2: Pylon/MK 84 CFA Sta 3: Pylon/330 gal fuel tank Sta 4, 5, & 6: No pylon Sta 7: Pylon/330 gal fuel tank Sta 8: GBU-24B/B on instrumented pylon	Structural Load Survey

Table A.IV

F/A-18 CONDITIONS FOR CATAPULT LAUNCH EVENTS

Event	Type	CSV Setting	Gross Weight (lb)	Catapult Endspeed (kt)	Longitudinal Acceleration (g)	Offcenter Spot (deg)
1	BU	222	37,100	145	4.2	0
2	BU	224	35,500	149	4.3	0
3	BU	240	34,900	154	4.5	0
4	BU	278	33,600	164	5.2	6 Right
5	Mg	310	32,600	171	5.6	0
6	Mg	320	35,100	168	5.5	6 Left
7	Mg	320	34,100	172	5.7	6 Right

LEGEND:

BU-Buildup

Mg-Maximum longitudinal acceleration launch

Table A.Y

F/A-18 STRUCTURAL LOADS SURVEY FLIGHT TEST MATRIX

Event No.	Altitude (ft MSL)	Loading[1]	Mach Steps	Test	Remarks
1	15,000	B	0.80, 0.90, 0.95	Right Level Sideslip Left Level Sideslip Right 1/2 LateralStick 360° Roll Right 1/2 LateralStick 360° Roll Right Full LateralStick 360° Roll Left Full Lateral Stick 360° Roll	
2	15,000	B	0.80, 0.90, 0.95	4.0 g Right Wind Up Turn N_{zmax} Right Wind Up Turn 4.0 g Left Wind Up Turn N_{zmax} Left Wind Up Turn Negative N_{zmax} Pushover 4.0 g Right Wind Turn N_{zmax} Right Rolling Pull Out 4.0 g Left Wind Up Turn N_{zmax} Left Rolling Pull Out	
3	10,000	B	0.70, 0.80, 0.85, 0.90, 0.95	Right 1/2 Lateral Stick 360° Roll Right 1/2 Lateral Stick 360° Roll Right Full Lateral Stick 360° Roll Left Full Lateral Stick 360° Roll	
4	10,000	B	0.70, 0.80, 0.85, 0.90, 0.95	4.0 g Right Wind Up Turn N_{zmax} Right Rolling Pull Out 4.0 g Left Wind Up Turn N_{zmax} Left Rolling Pull Out	
5	5,000	B	0.70, 0.80, 0.85, 0.90, 0.95	Right Level Sideslip Left Level Sideslip Right 1/2 Lateral Stick 360° Roll Right 1/2 Lateral Stick 360° Roll Right Full Lateral Stick 360° Roll Left Full Lateral Stick 360° Roll	Left and right level sideslips not conducted at 0.70 and 0.80 Mach.

Table A-Y (cont'd)

Event No.	Altitude (ft MSL)	Loading[1]	Mach Steps	Test	Remarks
6	5,000	B	0.70, 0.80, 0.85, 0.90, 0.95	4.0 g Right Wind Up Turn N_{zmax} Right Wind Up Turn 4.0 g Left Wind Up Turn N_{zmax} Left Wind Up Turn Negative N_{zmax} Pushover 4.0 g Right Rolling Pull Out, N_{zmax} Right Rolling Pull Out 4.0 g Left Rolling Pull Out N_{zmax} Left Rolling Pull Out	Wind up turns and negative Nz_{max} pushover not conducted at 0.70 and 0.80 Mach. RPO's not conducted at 0.95 Mach
7	5,000	C	0.70, 0.80, 0.85, 0.90, 0.95	Right Level Sideslip Left Level Sideslip Right 1/2 Lateral Stick 360° Roll Right 1/2 Lateral Stick 360° Roll Right Full Lateral Stick 360° Roll Left Full Lateral Stick 360° Roll	Left and right level sideslips not conducted at 0.70 and 0.80 Mach.
8	5,000	C	0.70, 0.80, 0.85, 0.90, 0.95	4.0 g Right Wind Up Turn N_{zmax} Right Wind Up Turn 4.0 g Left Wind Up Turn N_{zmax} Left Wind Up Turn Negative N_{zmax} Pushover 4.0 g Right Rolling Pull Out N_{zmax} Right Rolling Pull Out 4.0 g Left Rolling Pull Out N_{zmax} Left Rolling Pull Out	Wind up turns and negative Nz_{max} pushover not conducted at 0.70 and 0.80 Mach. RPO's not conducted at 0.95 Mach
9		C	N/A	Simulated Ordnance Deliveries Run one at 7 K ft MSL 500 KCAS, 0.84 Mach, 0.7 g, 45° dive Run two at 14K ft MSL 600 KCAS, 1.10 Mach, 0.5 g, 60° dive Run three at 19K ft MSL 635 KCAS, 1.3 Mach, 0.5 g, 60° dive	

NOTES: (1) Loading defined in enclosure (2), table III.

Table A.VI

F/A-18/GBU-24B/B WEAPON RELEASE MATRIX

DATE	FLT/ RUN	WEAPON STATION									RELEASE CONDITION				
		1	2	3	4	5	6	7	8	9	ALT (MSL)	KCAS	MACH	ACCEL (G)	DIVE (DEG)
19 Apr 93	1	cams	■		cams		cams	○		cams	4960	449	0.73	1.0	0
30 Apr 93	2/1		■	○					⌑		4990	449	0.73	1.0	0
30 Apr 93	2/2			○					■		4970	499	0.82	1.0	0
30 Apr 93	3/1		■	○					⌑		4920	500	0.82	1.0	0
30 Apr 93	3/2			○					■		6510	501	0.84	0.8	44
1 May 93	4/1		■	○					⌑		6010	493	0.83	0.8	44
1 May 93	4/2			○					■		10610	494	0.89	0.4	58
3 May 93	5/1		■	○					⌑		11600	521	0.95	0.3	60
3 May 93	5/2			○					■		11370	522	0.95	0.6	60
7 May 93	5A			○					■		10850	536	0.96	0.3	59
8 May 93	6/1			○					■		11030	540	0.98	0.3	60

○ = tank

⌑ = weapon

■ = release weapon

Table A.VI (Continued)

F/A-18/GBU-24B/B WEAPON RELEASE MATRIX

DATE	FLT/ RUN	WEAPON STATION									RELEASE CONDITION				
		1	2	3	4	5	6	7	8	9	ALT (MSL)	KCAS	MACH	ACCEL (G)	DIVE (DEG)
8 May 93	6/2			◯					■		13600	600	1.11	0.5	59
8 May 93	7/1		■	◯					⌑		12660	592	1.08	0.5	60
8 May 93	7/2			◯					■		18050	643	1.28	0.7	59
10 May 93	7A			◯					■		18240	634	1.27	0.5	60
10 May 93	8		■	◯					GPB		15730	638	1.23	0.5	58
12 May 93	8A		GPB					◯	■		10450	555	0.99	0.0	59

◯ = fuel tank
⌑ = weapon
■ = release weapon

Table A.VII

A-6E STRUCTURAL LOADS SURVEY AND CAPTIVE CARRIAGE ARMING LANYARD EVALUATION FLIGHT TEST LOADINGS

Loading	Description	Tests
A	Sta 1, 4: Empty Sta 2: GBU-24B/B Loaded on instrumented balance beam. Sta 3: Sink Rate Pod Sta 5: MK-83 CFA	Structural Loads Survey
B	Sta 1: Empty Aero-1D Fuel Tank Sta 2: GBU-24B/B Loaded on instrumented balance beam. Sta 3: Sink Rate Pod Sta 4: Empty Sta 5: MK-83 CFA	Structural Loads Survey
C	Sta 1: MK 83 CFA Sta 2, 3, and 5: Empty Sta 4: GBU-24B/B Loaded on AERO-7A	Arming Lanyard Evaluation

Table A.VIII

F/A-18 SUMMARY OF ARMING LANYARD RESULTS

Release No.	Arming Mode (BFD/Fuze)	BFD Result	Fuze Result	Summary (BFD/Fuze)	Remarks
1	ARM/ARM	ARM	ARM	SAT/SAT	Telemetry Weapon
2/1	SAFE/SAFE	SAFE	ARM	SAT/Fail	
2/2	ARM/ARM	ARM	ARM	SAT/SAT	
3/1	SAFE/SAFE	SAFE	SAFE	SAT/SAT	
3/2	ARM/ARM	ARM	ARM	SAT/SAT	
4/1	SAFE/SAFE	SAFE	ARM	SAT/Fail	
4/2	ARM/ARM	ARM	ARM	SAT/SAT	
5/1	SAFE/SAFE	SAFE	ARM	SAT/Fail	
5/2	ARM/ARM	ARM	ARM	SAT/SAT	Telemetry Weapon
6/1	ARM/ARM	ARM	ARM	SAT/SAT	1/16 in. diameter extension lanyard
6/2	SAFE/SAFE	SAFE	SAFE	SAT/SAT	1/16 in. diameter extension lanyard
7/1	ARM/ARM	ARM	ARM	SAT/SAT	1/16 in. diameter extension lanyard
7/2	SAFE/SAFE	SAFE	ARM	SAT/Fail	1/16 in. diameter extension lanyard severed by hook
8	ARM/ARM	ARM	ARM	SAT/SAT	1/16 in. diameter extension lanyard Telemetry Weapon
9	ARM/ARM	ARM	ARM	SAT/SAT	3/32 in. diameter extension lanyard
10	SAFE/SAFE	ARM	SAFE	Fail/SAT	BFD swivel caught on sway brace arm. 3/32 in. diameter extension lanyard
11	SAFE/SAFE	ARM	SAFE	Fail/SAT	BFD swivel tangled with FZU-32 lanyard. 3/32 in. diameter extension lanyard

Table A.IX

A-6E/GBU-24B/B STRUCTURAL LOADS SURVEY FLIGHT TEST MATRIX

EVT NO.	ALTITUDE (FT MSL)	LOADING	MANEUVERS	MACH STEPS	REMARKS
1	20,000	A	L/R Level Side Slip 4g and 6.5g L/R WUT -1g Symmetric Push-over (-2.4 g @ 0.90 IMN)	Level Accel 0.5M to V_{max} 0.6, 0.7, 0.75, 0.8, 0.85, 0.90, 0.95	Directional and Symmetric Load Survey
2	5,000	A	L/R Level Side Slip 4g and 6.5g L/R WUT -1g Symmetric Push-over (-2.4 g @ 0.85 IMN)	Level Accel 0.4M to V_{max} 0.5, 0.6, 0.7, 0.75, 0.8, 0.85, 0.90	5K ft block need not be complete before proceeding to Loading B.
3	20,000	B	L/R Level Side Slip 4g and 6.5g L/R WUT -1g Symmetric Push-over (-2.4 g @ 0.90 IMN)	Level Accel 0.5M to V_{max} 0.6, 0.7, 0.75, 0.8, 0.85, 0.90, 0.95	* Block does not require completion if it is determined that loading A is more critical loading.
4	5,000	B	L/R Level Side Slip 4g and 6.5g L/R WUT -1g Symmetric Push-over (-2.4 g @ 0.85 IMN)	Level Accel 0.4M to V_{max} 0.5, 0.6, 0.7, 0.75, 0.8, 0.85, 0.90	Block does not require completion if it is determined that loading A is more critical loading.

Table A.IX (Continued)

A-6E/GBU-24B/B STRUCTURAL LOADS SURVEY FLIGHT TEST MATRIX

EVT NO.	ALTITUDE (ft MSL)	LOADING	MANEUVERS	MACH STEPS	REMARKS
5	20,000	A	L/R Full Stick Rolls L/R RPO	0.6, 0.7, 0.75, 0.8, 0.85, 0.90, 0.95	Rolling Load Survey RPO N_Z TBD (upon completion of Direcitonal/Symmetric Survey)
6	5,000	A	L/R Partial (1/2) Stick Rolls L/R Full Stick Rolls L/R RPO	0.5, 0.6, 0.7, 0.75, 0.8, 0.85, 0.90	RPO N_Z TBD (upon completion of Direcitonal/Symmetric Survey)

Table A.X

A-6E/GBU-24B/B WEAPON RELEASE MATRIX

DATE	FLT/ RUN	Weapon Station					Release Condition			
		1	2	3	4	5	ALT (FT MSL)	SPEED (KIAS)	DIVE (DEG)	ACCEL (G)
19 APR 93	1		■				5300	452	1.1	1.0
27 APR 93	2/1	○	■		⌑		5100	452	0	1.0
27 APR 93	2/2	○			■		5800	446	31	0.9
28 APR 93	3/1	○	■		⌑		5100	450	32	0.9
28 APR 93	3/2	○			■		6900	450	45	1.1
28 APR 93	4/1	○	■		⌑		6900	455	47	0.7
28 APR 93	4/2	○			■		6700	480	46	0.7
29 APR 93	5/1	○	■		⌑		7400	475	46	0.7
29 APR 93	5/2	○			■		6600	500	46	0.7
29 APR 93	6/1	○	■		⌑		8000	500	47	0.7
29 APR 93	6/2	○			■		7300	524	47	0.7
30 APR 93	7/1	○	■				7500	527	45	0.7

■ Weapon released on current run

⌑ Captive carry weapon on current run

○ Purged AERO-1D Fuel tank

Table A.XI

A-6E CAPTIVE CARRIAGE ARMING LANYARD EVALUATION TEST MATRIX

Maneuver	Altitude (K ft MSL)	Airspeed (KIAS)	Normal Acceleration (g)	Remarks/ Limitations
Level Acceleration	12000 - 5,000	250 - 570/0.85	+1.0	
Steady Heading Side Slip	5,000 - 6,000	490 - 495/0.82	+1.0	
360 deg Flaperon Rolls	Not Recorded	490 - 495/0.82	+1.0	
Wings Level Pushover	Not Recorded	490 - 495/0.85	-1.0	
Loaded Roll Reversal	4,000 - 7,000	490 - 495/0.82	+4.9	Entry at 1.6 g Delta Nz approximatel y 3.3 g
Wind-up Turn	7,000 - 6.100	LWUT - 0.85 RWUT - 0.82	+6.8	
45 deg Dive	15,000 - 4,500	300 -	0.7	
Arming Lanyard Endurance	5,000 - 6,000	490 - 495	+1.0	30 Minutes
Flared Field Landing	SL		1.0	Rate of Descent 100 - 200 FPM

Table A.XII

A-6E SUMMARY OF ARMING LANYARD RESULTS

Flt/Run No.	Station No.	Arming Mode (BFD/Fuze)	BFD Result	Fuze Result	Summary (BFD/Fuze)	Remarks
1	2	ARM/ARM	ARM	ARM	SAT/SAT	Telemetry Weapon
2/1	4	SAFE/ARM	ARM	ARM	Fail/SAT	
2/2	2	SAFE/ARM	ARM	ARM	Fail/SAT	
3/1	4	SAFE/SAFE	ARM	ARM	Fail/Fail	
3/2	2	SAFE/SAFE	SAFE	ARM	SAT/Fail	
4/1	4	ARM/ARM	ARM	ARM	SAT/SAT	Telemetry Weapon
4/2	2	SAFE/SAFE	SAFE	ARM	SAT/Fail	
5/1	4	SAFE/SAFE	SAFE	SAFE	SAT/SAT	
5/2	2	SAFE/SAFE	SAFE	ARM	SAT/Fail	
6/1	4	SAFE/SAFE	SAFE	SAFE	SAT/SAT	
6/2	2	SAFE/SAFE	No Data	SAFE	UNK/SAT	Could not determine function of arming wire from film review
7	4	ARM/ARM	ARM	No Data	SAT/UNK	Could not determine function of arming wire from film review. Telemetry Weapon

APPENDIX B: FIGURES

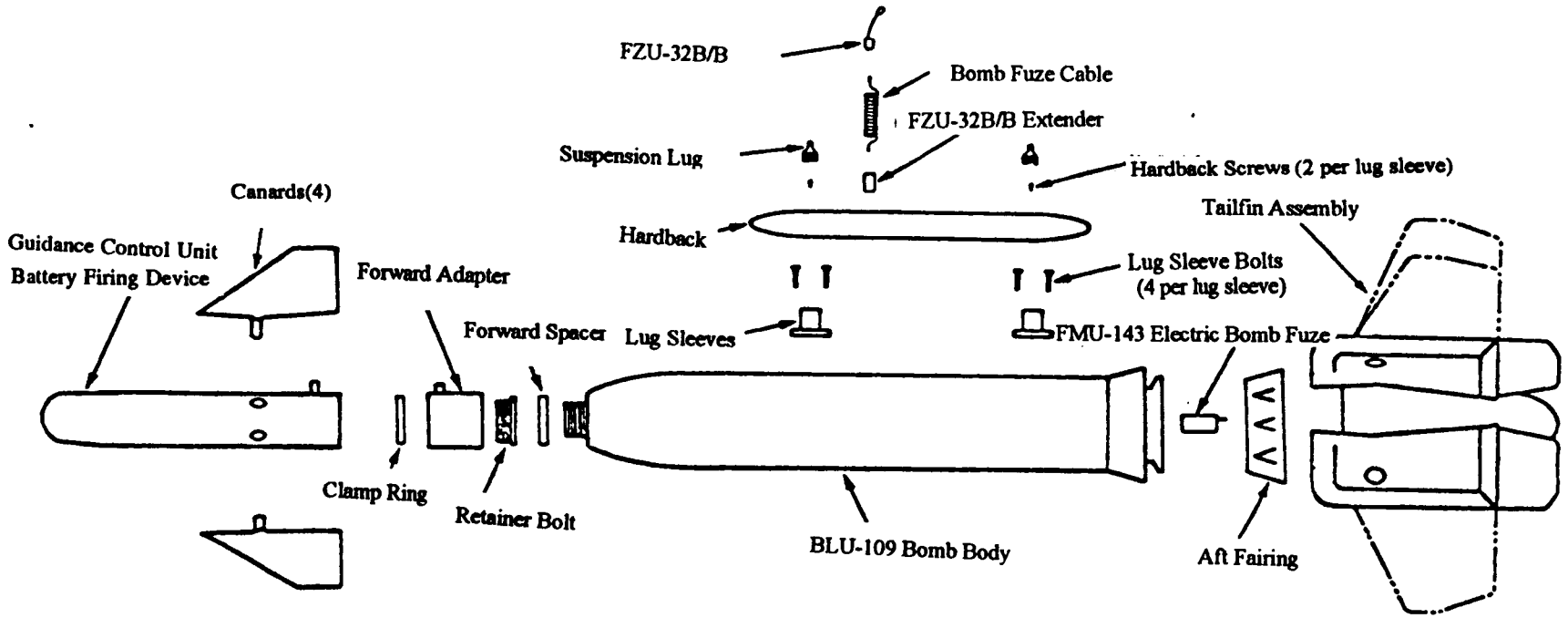


Figure B.1
GBU-24A/B GENERAL ARRANGEMENT

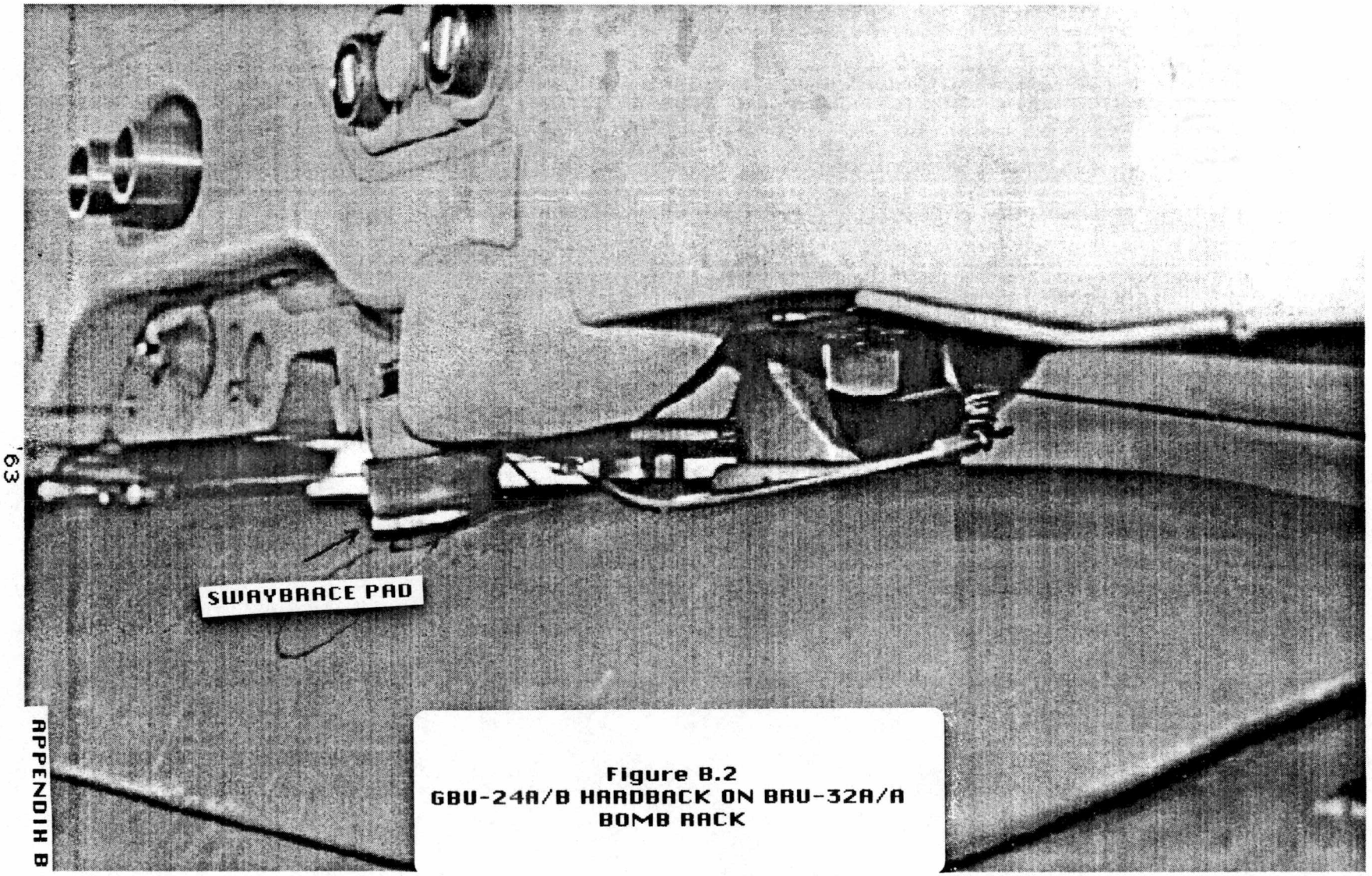


Figure B.2
GBU-24A/B HARDBACK ON BRU-32A/A
BOMB RACK

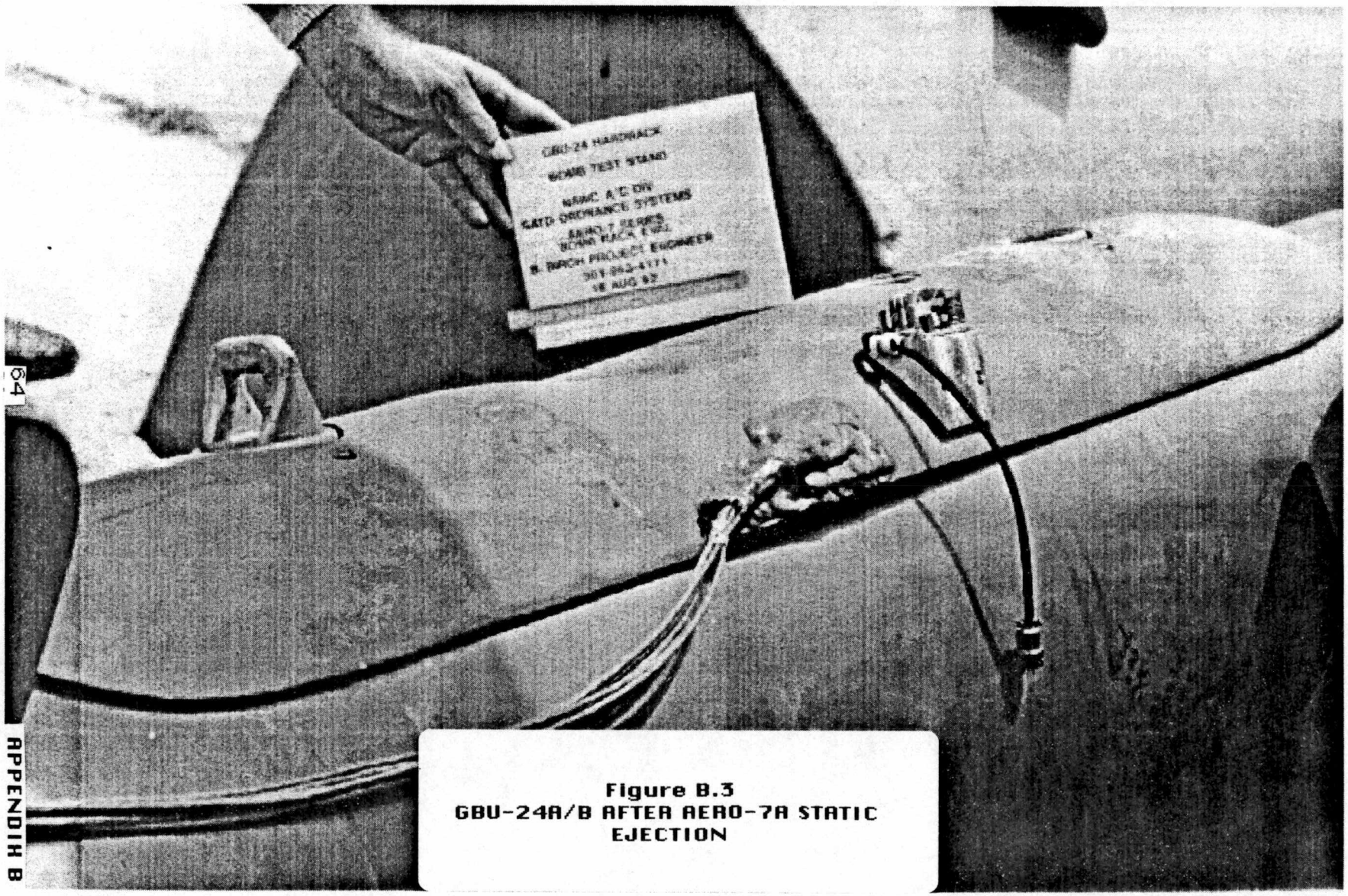


Figure B.3
GBU-24A/B AFTER AERO-7A STATIC EJECTION

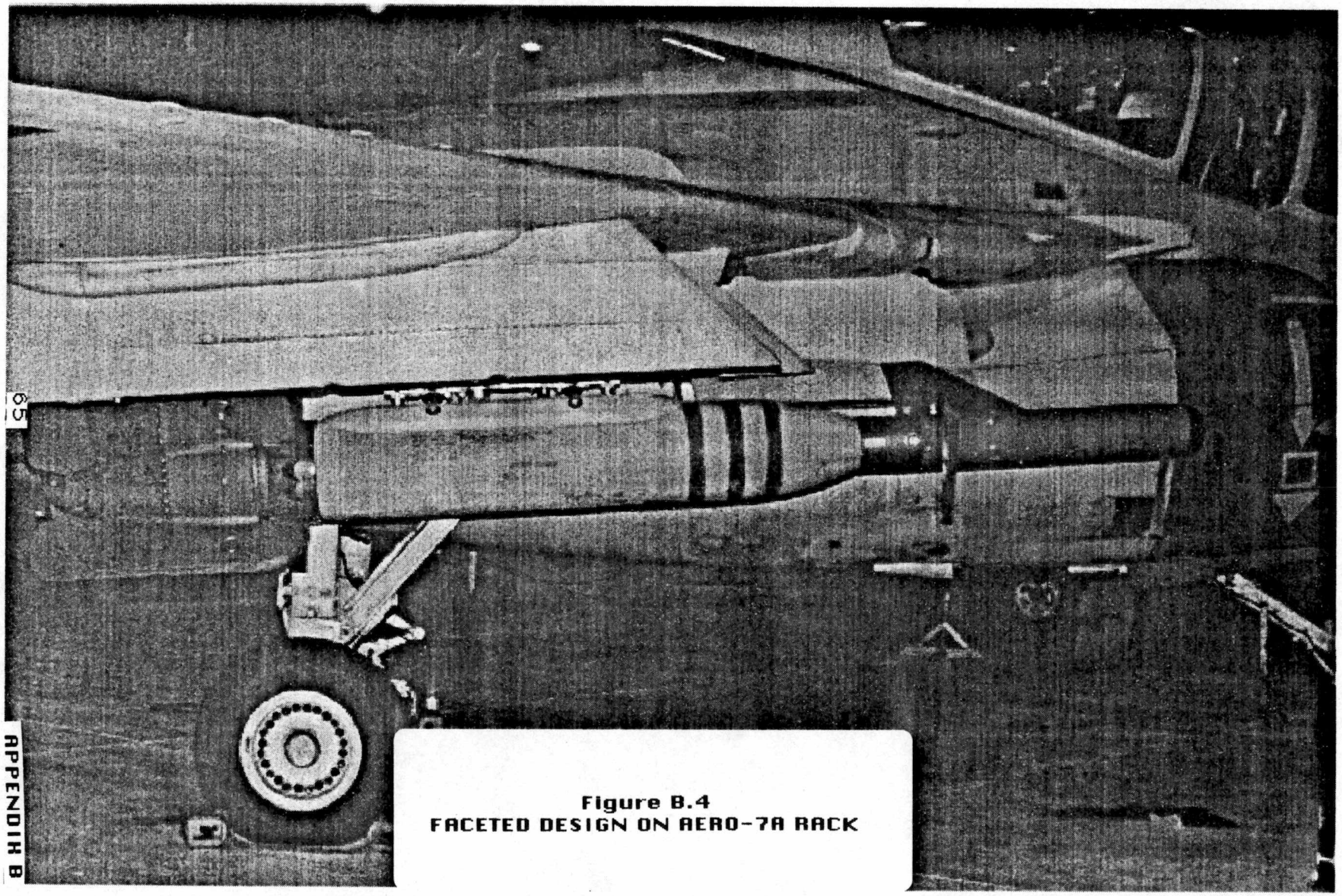


Figure B.4
FACETED DESIGN ON AERO-7A RACK

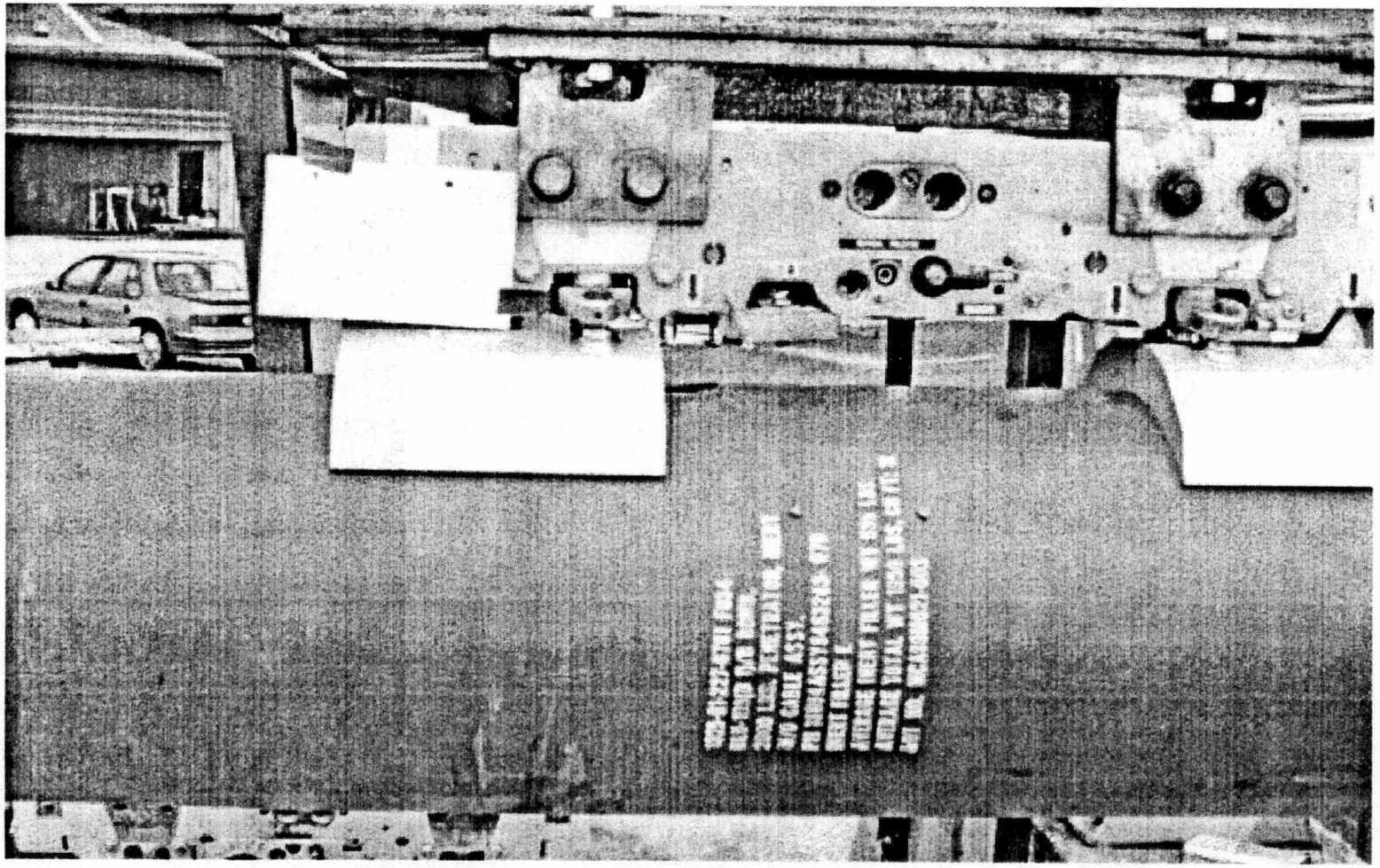


Figure B.5
FACETED HARDBACK DESIGN (PROTOTYPE) ON BRU-32A/A BOMB RACK

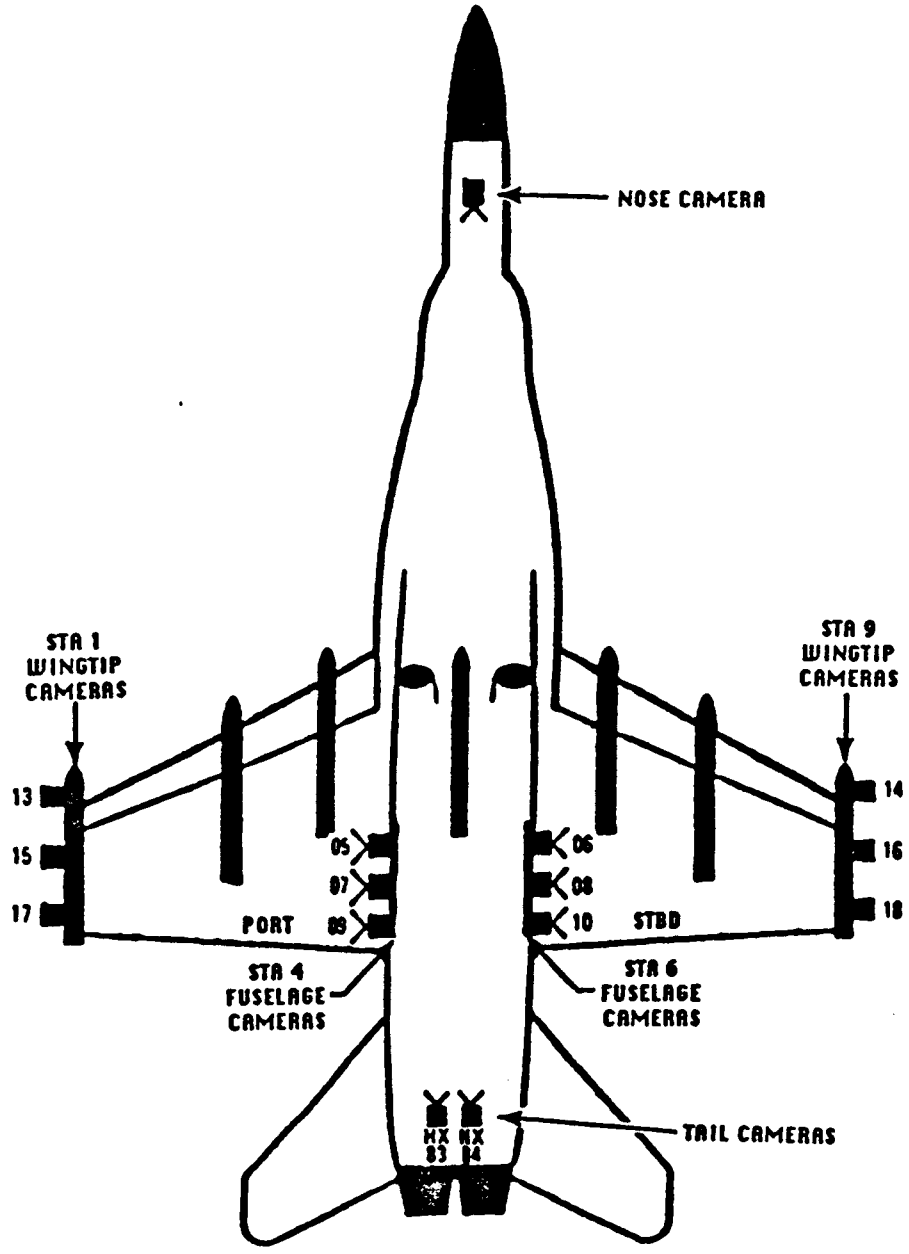


Figure B.6
F/A-18 CAMERA LOCATIONS

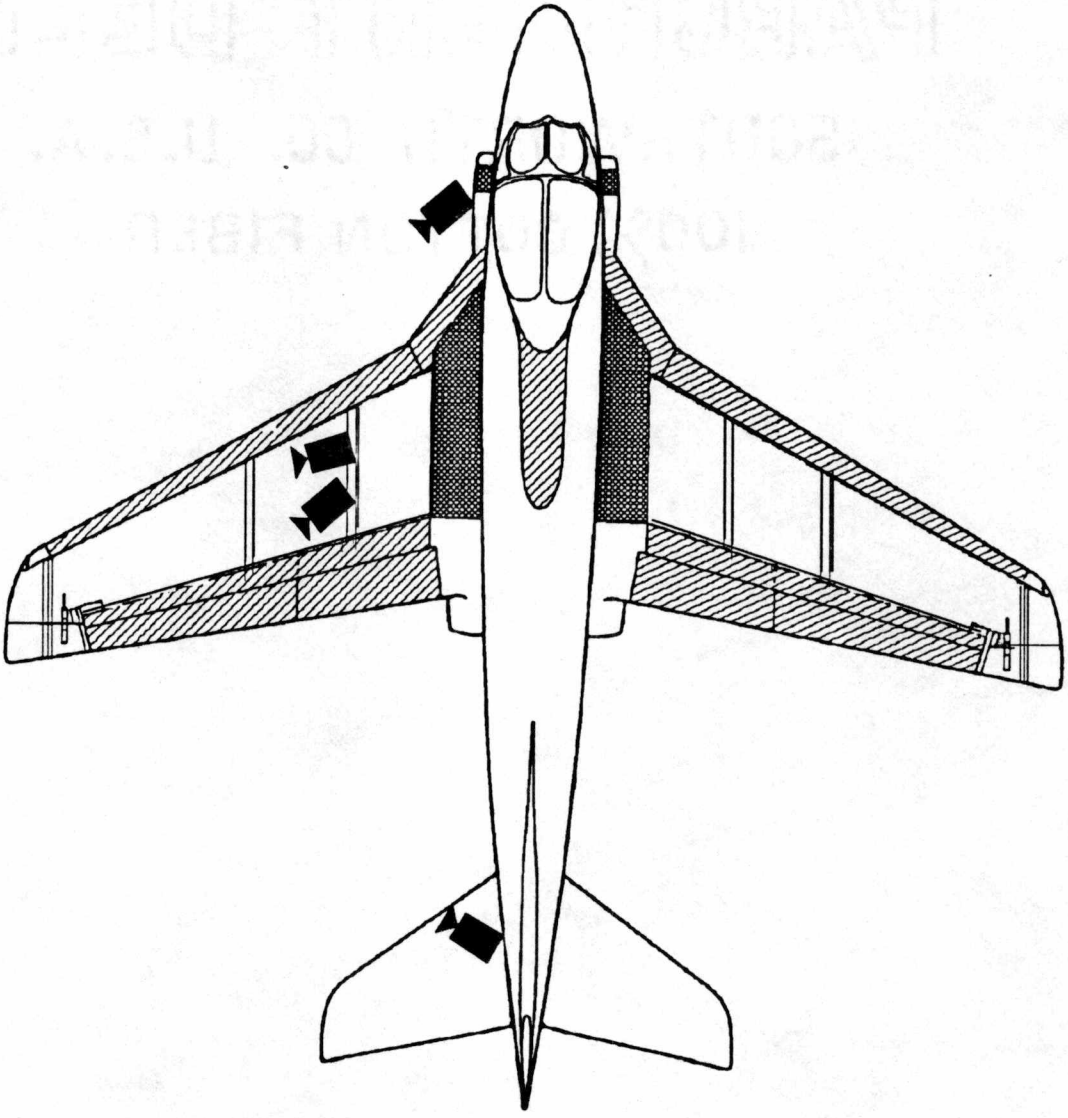
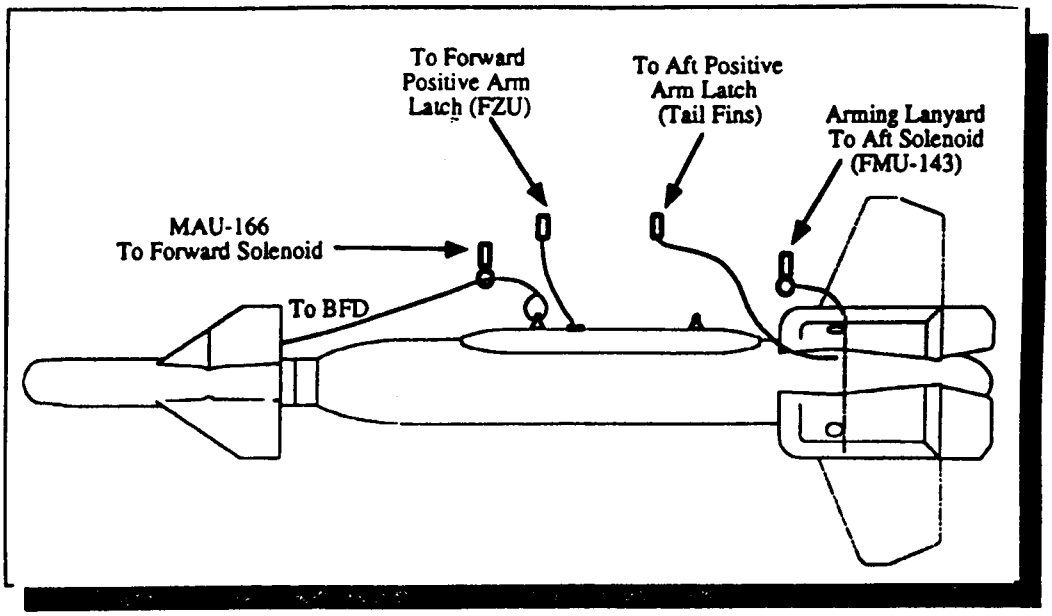
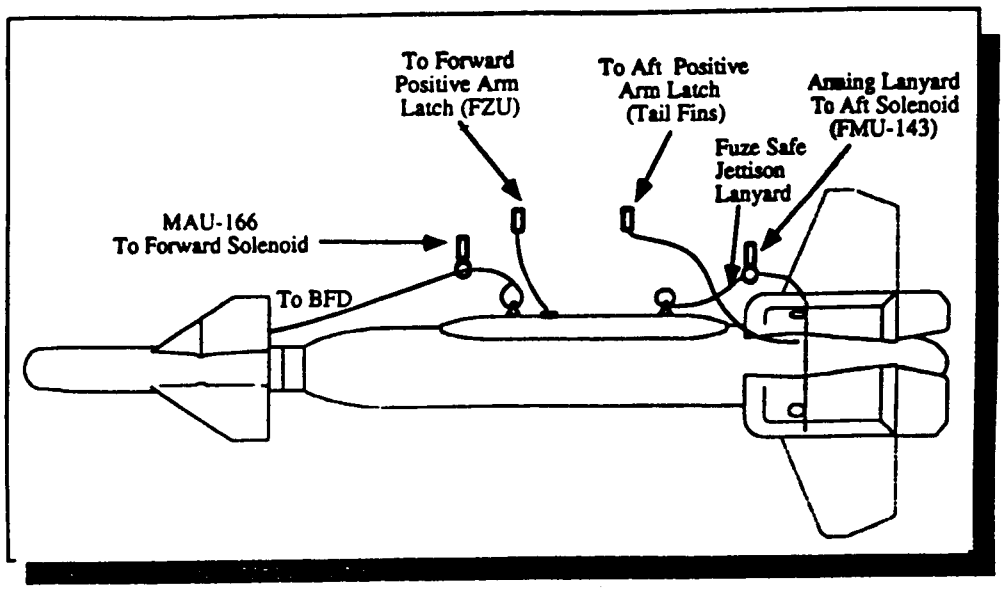


Figure B.7
A-6E CAMERA LOCATIONS



ARMING LANYARD ROUTING	
Battery Firing Device (BFD)	1. Attached MAU-166 to forward solenoid. 2. Looped arming lanyard through forward suspension lug and through MAU-166 to the BFD. 3. Connected arming lanyard to BFD, laced and cut 6 in.
Fuze Initiator (FZU-32)	1. Attached arming lanyard (supplied with FZU) to forward positive arm latch.
Tail Fuze (FMU-143)	1. Guided arming lanyard (supplied with fuze) through tail fin assembly from inside. 2. Attached break link to arming lanyard and attached to aft solenoid. 3. Attached safety clip to FMU-143 fuze.
Tail Fin Release	1. Attached fin release cable to aft positive arm latch. 2. Routed fin release cable through guide then fin release latch and removed all slack. 3. Pulled all lacing tight and cut off excess cable approximately 3 to 6 in. from tail fin release latch.

Figure B.8
ARMING LANYARD ROUTING WITHOUT FUZE SAFE-JETTISON-LANYARD



ARMING LANYARD ROUTING	
Battery Firing Device (BFD)	1. Attached MAU-166 to forward solenoid. 2. Looped arming lanyard through forward suspension lug and through MAU-166 to the BFD. 3. Connected arming lanyard to BFD, laced and cut 6 in.
Fuze Initiator (FZU-32)	1. Attached arming lanyard (supplied with FZU) to forward positive arm latch.
Tail Fuze (FMU-143)	1. Guided arming lanyard (supplied with fuze) through tail fin assembly from inside. 2. Attached break link to arming lanyard. 3. Looped fuze safe jettison lanyard through aft suspension lug and attached to break link. 4. Attached break link to aft solenoid. Attached safety clip to FMU-143 fuze.
Tail Fin Release	1. Attached fin release cable to aft positive arm latch. 2. Routed fin release cable through guide then fin release latch and removed all slack. 3. Pulled all lacing tight and cut off excess cable approximately 3 to 6 in. from tail fin release latch.

Figure B.9
ARMING LANYARD ROUTING WITH FUZE SAFE-JETTISON-LANYARD

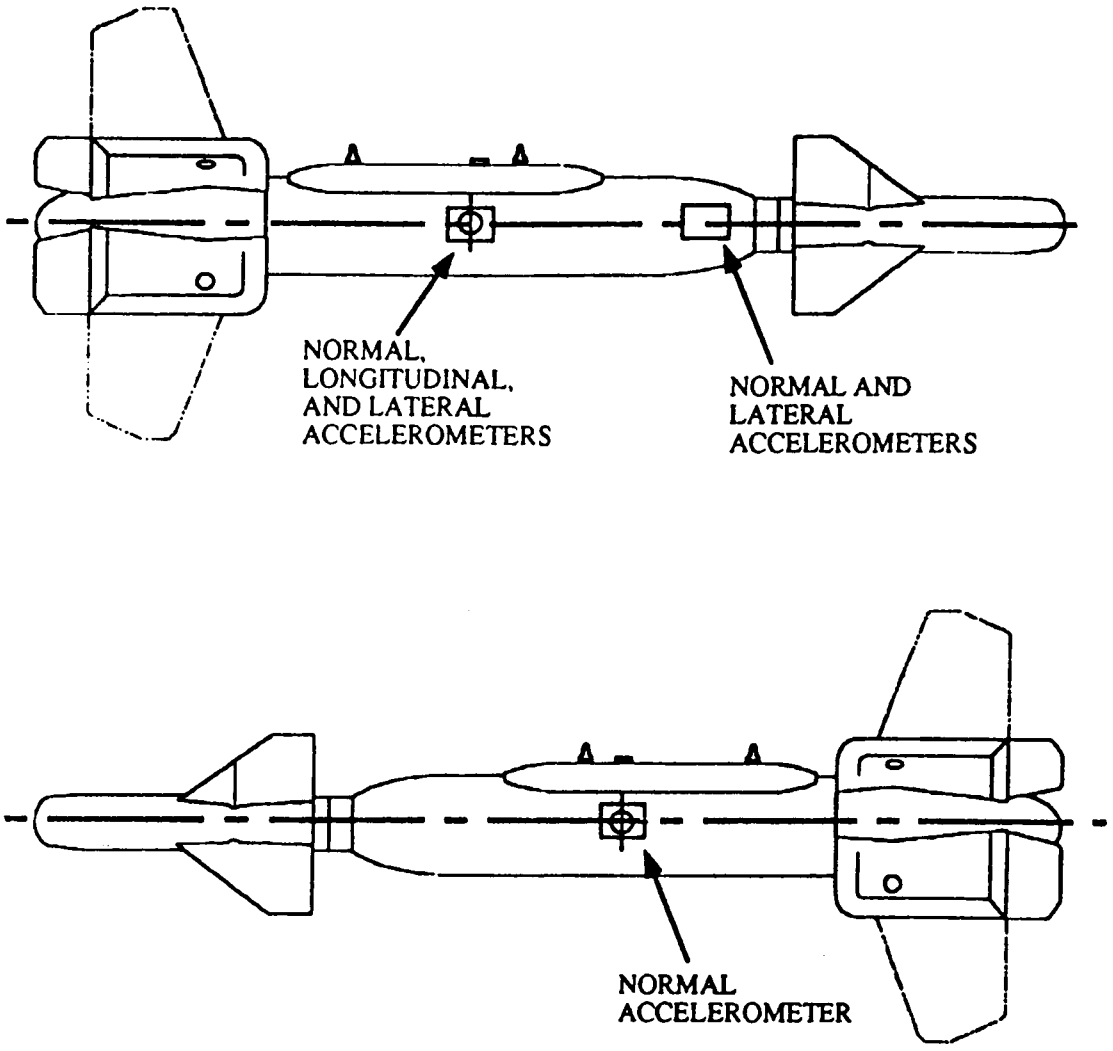


Figure B.10
CARRIER SUITABILITY AND LOADS SURVEY INSTRUMENTATION

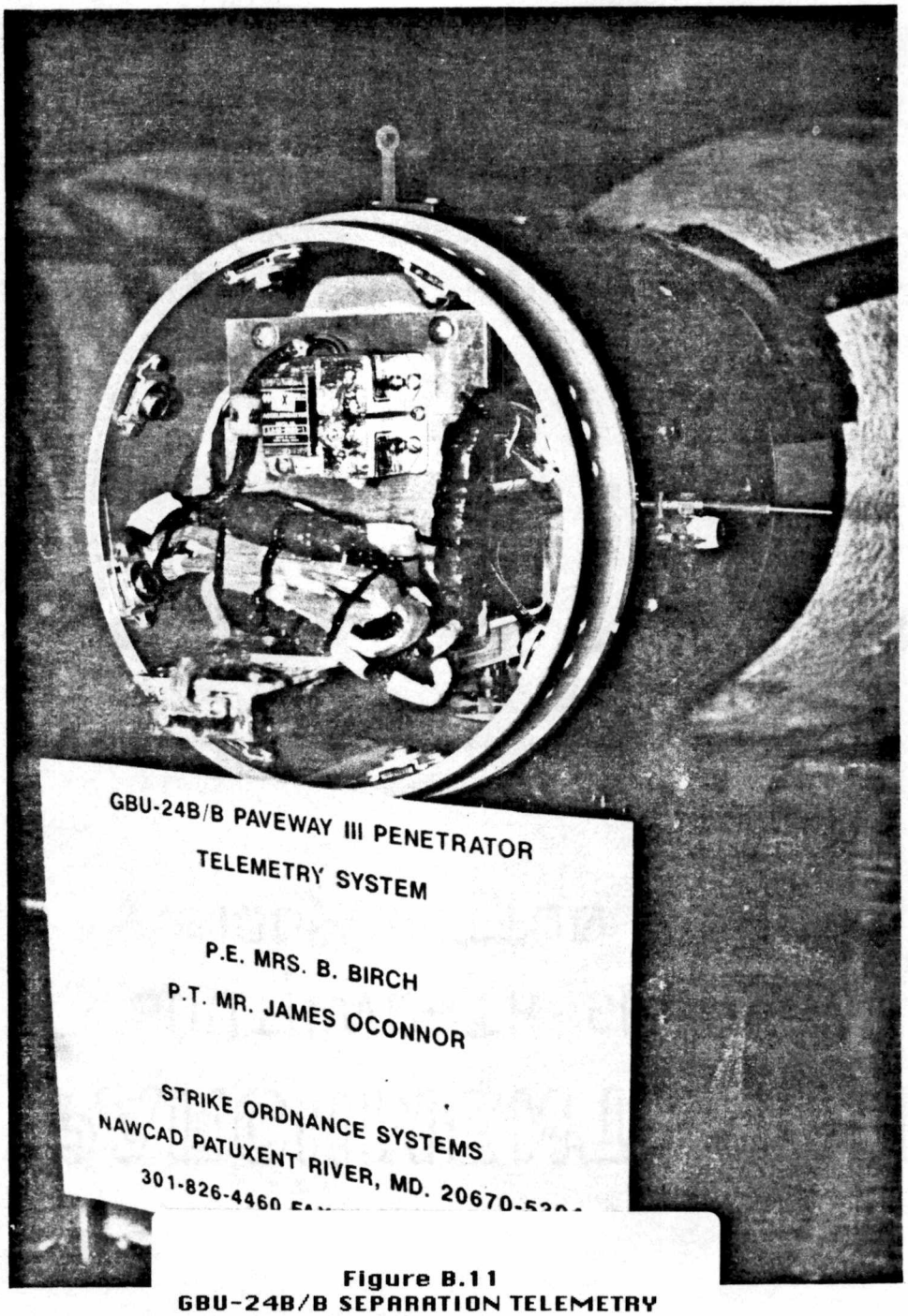


Figure B.11
GBU-24B/B SEPARATION TELEMETRY SYSTEM (INSTALLED)

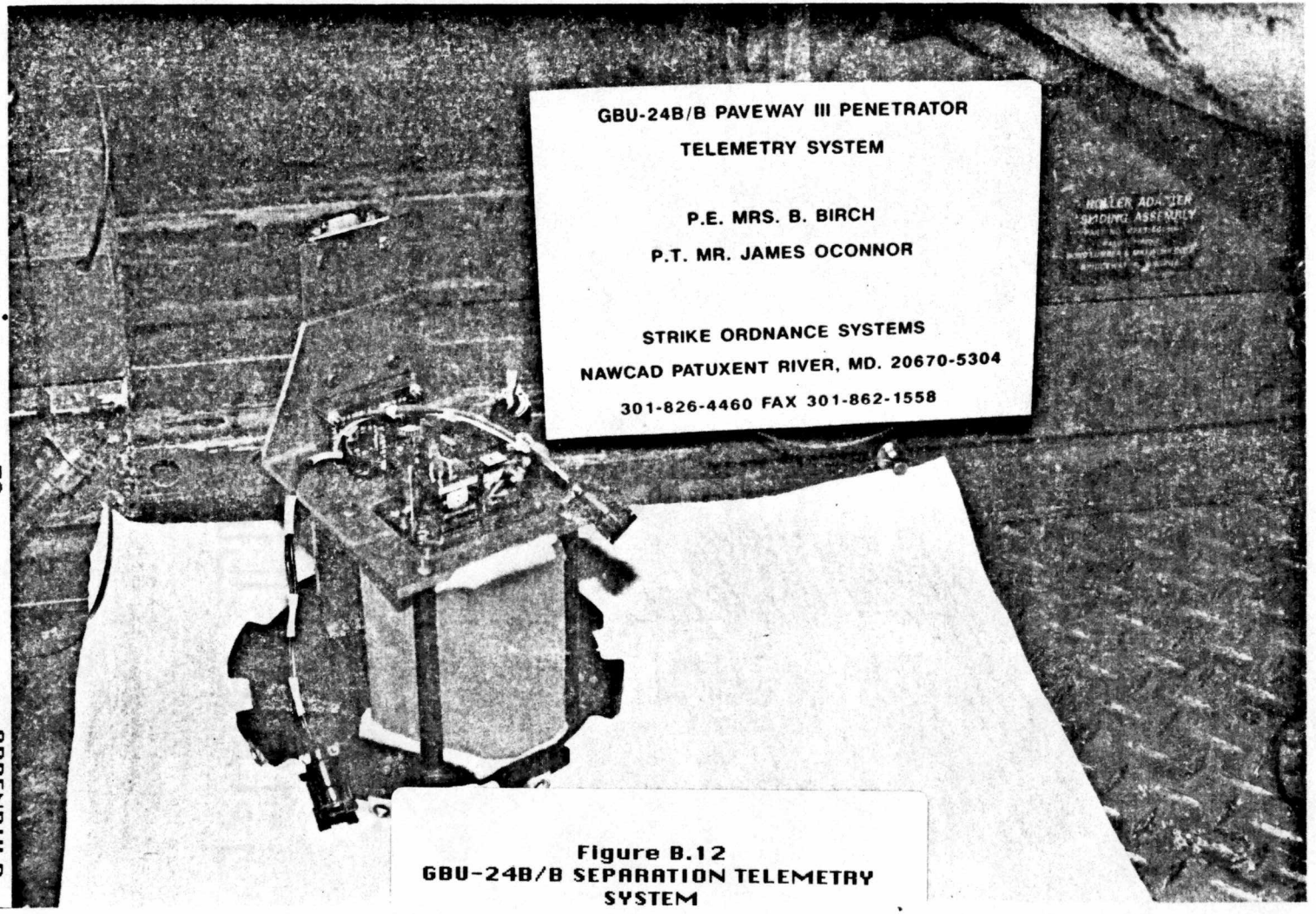
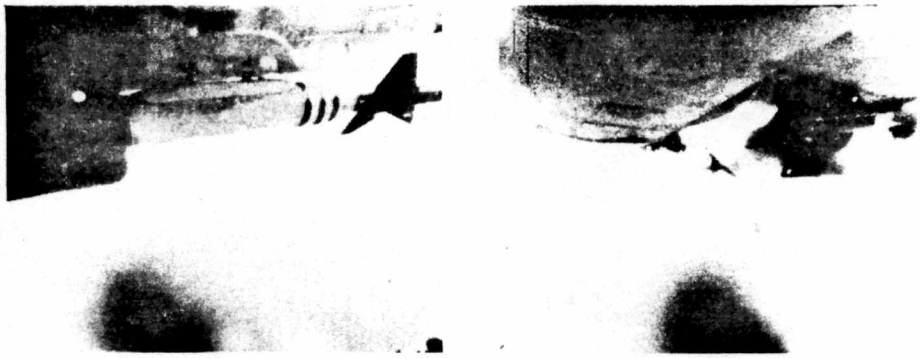


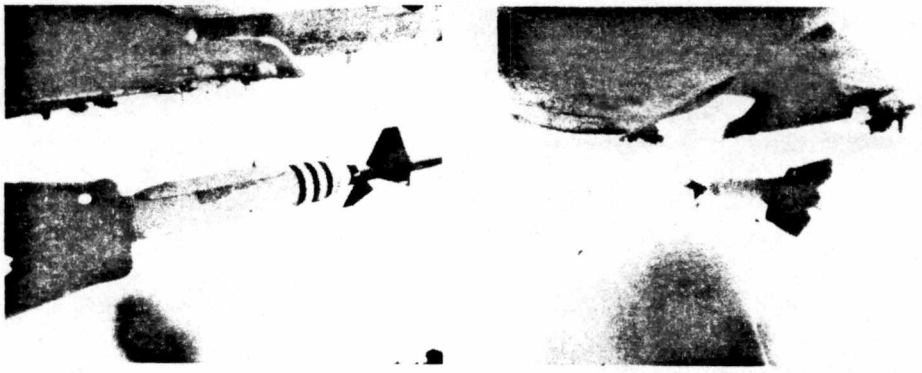
Figure B.12
GBU-24B/B SEPARATION TELEMETRY SYSTEM



t = 0



t = 100 msec



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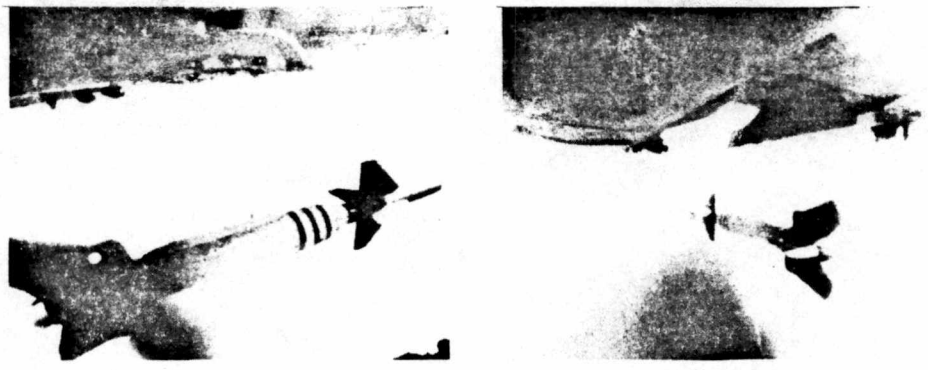
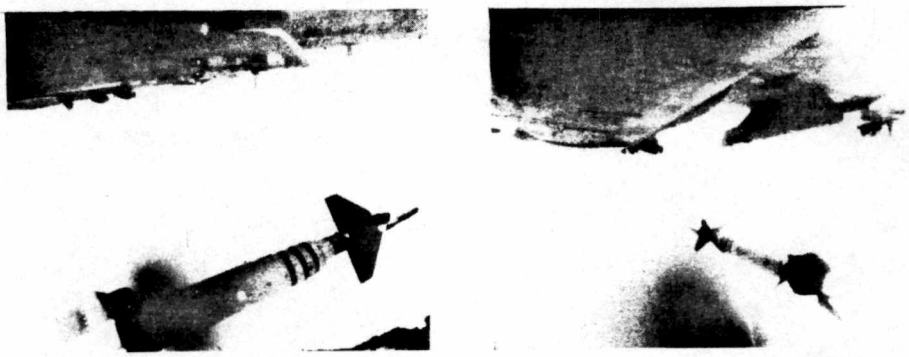


t = 300 msec

Figure B.13

F/A-18 SEPARATION FLIGHT 8



t = 400 msec



t = 500 msec

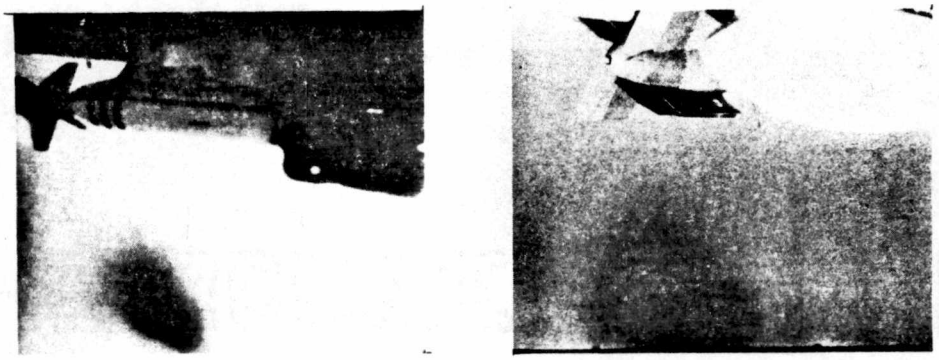


t = 600 msec

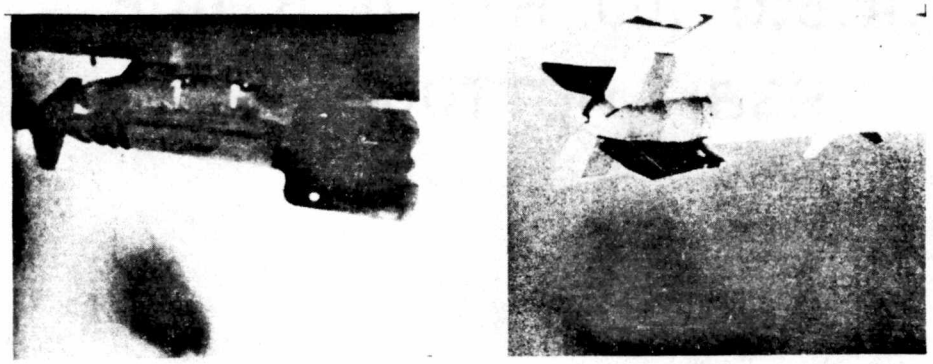


t = 700 msec

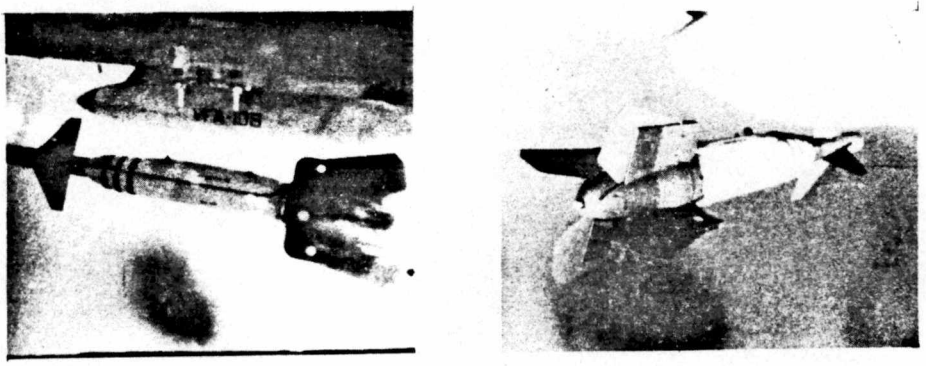
Figure B.13 (CONTD)



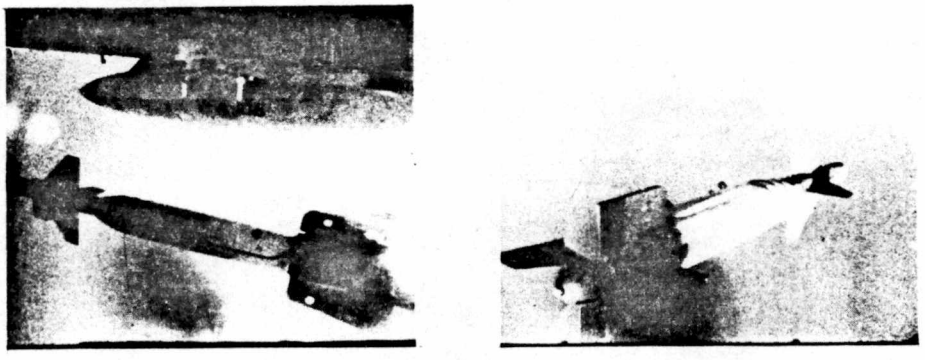
t = 0



t = 100 msec



t = 200 msec

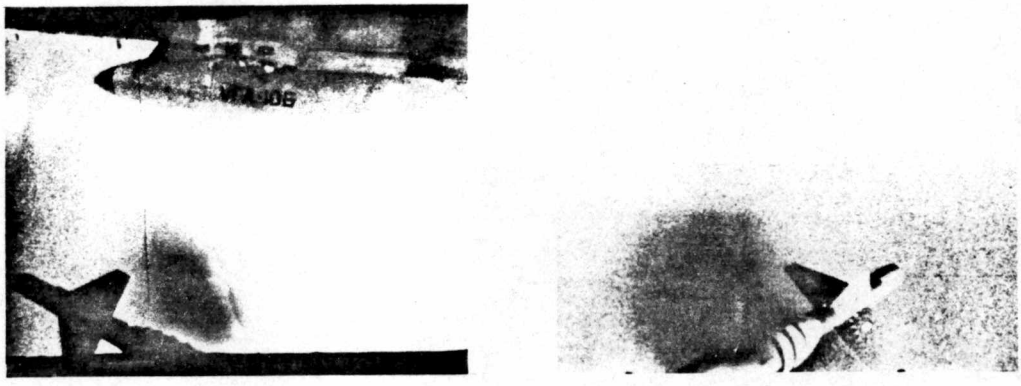


t = 300 msec

Figure B.14
F/A-18 SEPARATION FLIGHT 9



t = 400 msec



t = 500 msec

Figure B.14 (CONTD)

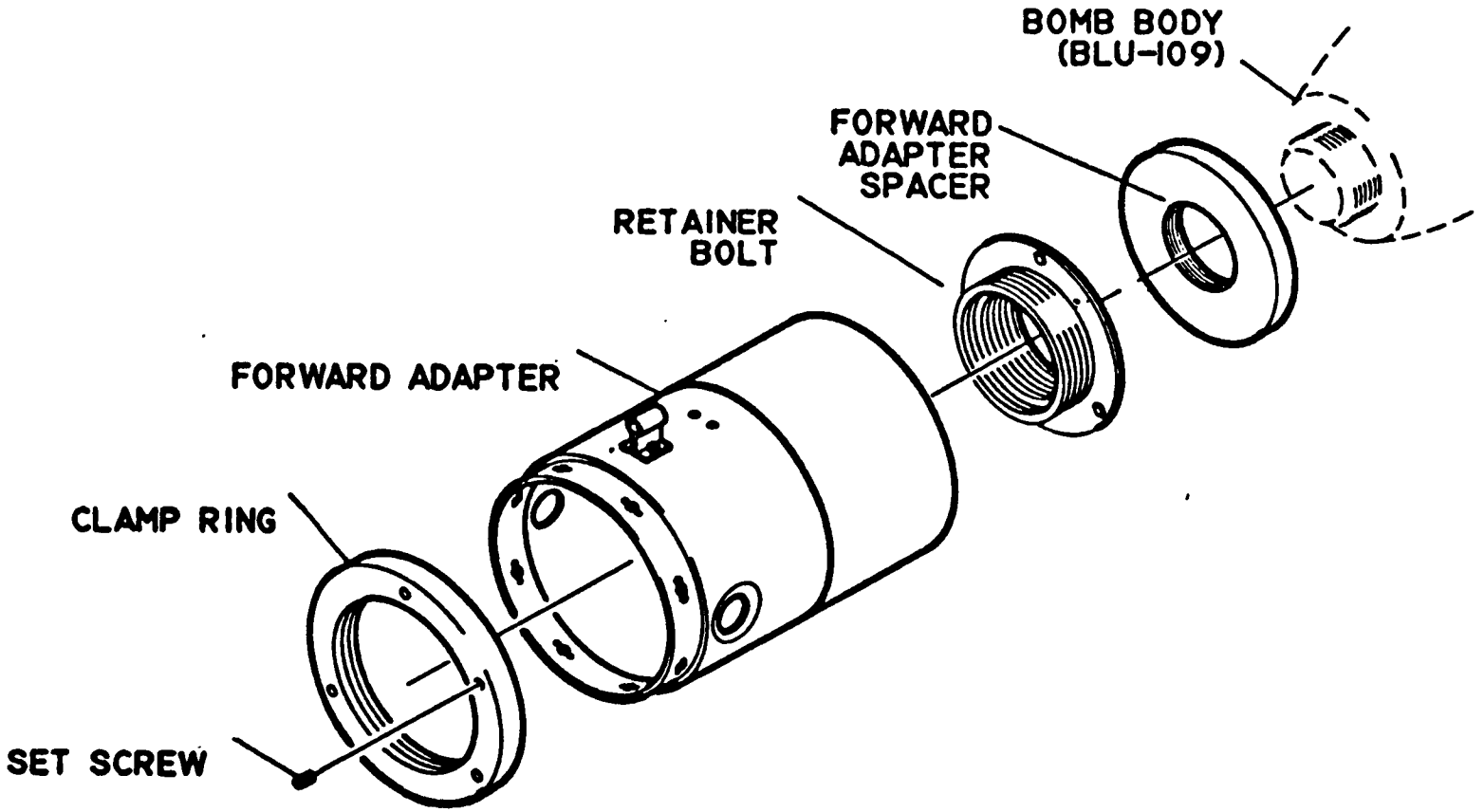


Figure B.15
GCU FORWARD ADAPTER ASSEMBLY

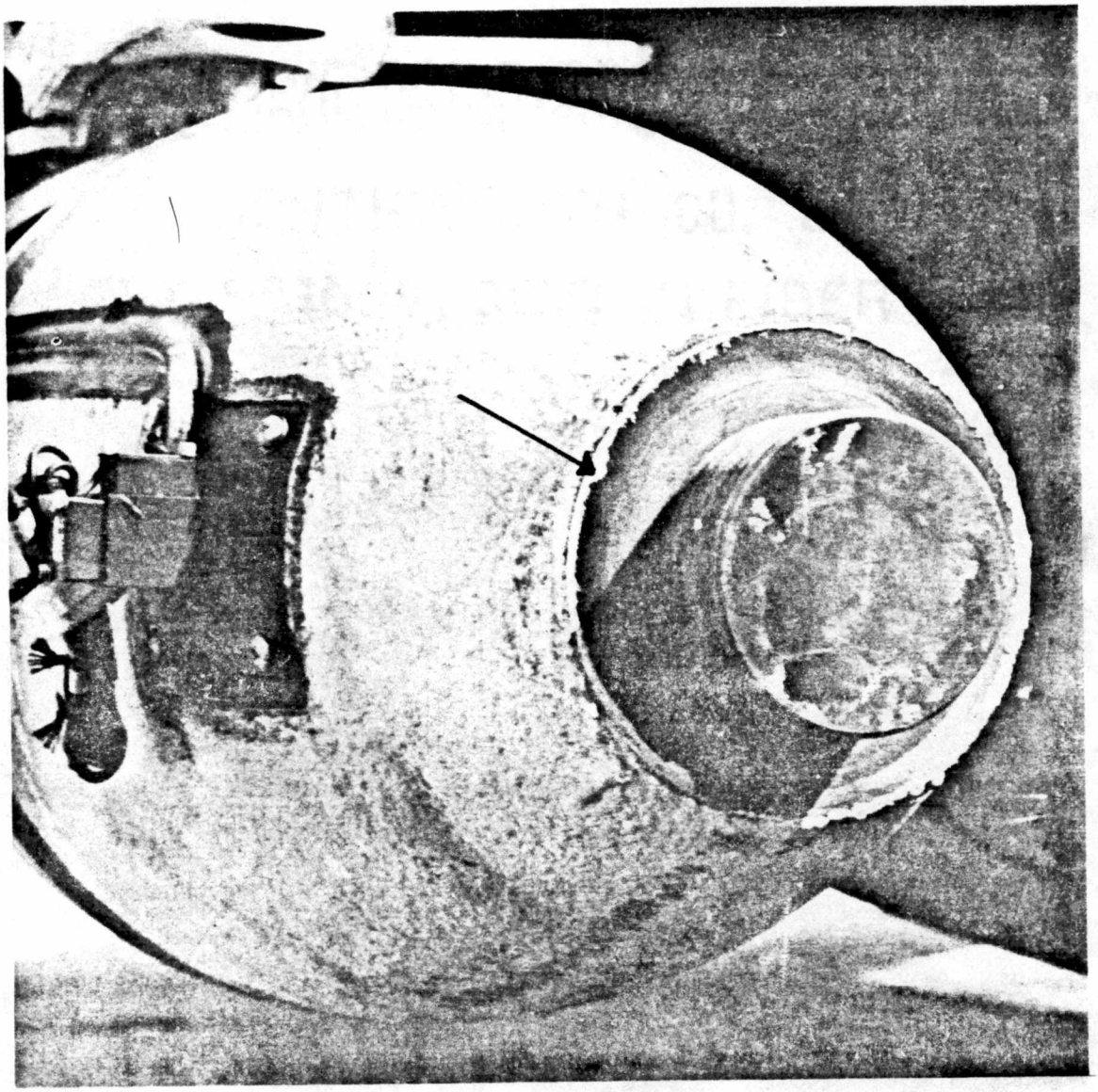


Figure B.16
THERMAL PROTECTION COATING ON INTERFACE SURFACE

APPENDIX C: STRUCTURAL FLIGHT TEST MANEUVERS

Pre-Takeoff Ambient

An ambient record will be taken in the chocks prior to takeoff and after landing. If possible, an ambient record will also be taken prior to engine start with external power on the aircraft.

Phasing Maneuver

A phasing maneuver will be flown at the beginning of each flight prior to performing any test maneuvers. The phasing maneuver may be omitted at the discretion of the on-site test team. The phasing maneuver will be flown at 0.6 Mach / 10k feet using the following procedures:

a. trimmed 1g level flight
b. -1.0g symmetric pushover
c. symmetric +3.0 g pull
d. left and right steady heading sideslip
e. left and right 1g 360° rolls

1g 360° roll

The aircraft shall be initially trimmed in 1g flight with zero degrees sideslip. During the maneuver, the directional control shall be fixed. The maneuver shall be initiated by applying the lateral stick force in 0.1 seconds and holding until a maximum applied force in

the opposite direction in 0.2 seconds will result in stopping the aircraft at 360° of roll. Longitudinal stick position shall remain constant during the maneuver.

Wind-up Turn (WUT)

The aircraft shall be initially trimmed in 1g flight. Load factor shall be increased up to the specified level by smooth application of longitudinal stick force. During the maneuver, the Mach number should be held constant, the load factor rate should not exceed 1g per second, and the longitudinal force should be increased until target N_Z, N_ZW, or 25°α is reached. A loss in altitude is acceptable if needed to maintain Mach number.

Rolling Pullout (RPO)

The aircraft shall be initially trimmed in 1g flight at specified Mach number. The aircraft shall be placed in a level turn, with sufficient bank angle to achieve target g. Full opposite stick shall then be applied (0.1sec) through a bank angle equal to two times the initial bank angle. Maximum lateral stick force shall be applied in 0.2 seconds to terminate roll at the opposite bank angle. Longitudinal stick position required to pull the specified load factor at the beginning of the maneuver shall be maintained throughout the maneuver. Rudder inputs are prohibited during these maneuvers.

VITA

Lieutenant Joseph C. Bouchard was born in Exeter, New Hampshire in 1964 where he attended Phillips Exeter Academy. He graduated from the University of Rochester in 1986 and received a commission as an Ensign in the United States Navy. Upon completion of jet flight training in 1987, he was selected to fly the F/A-18 Hornet. Since receiving his wings, he has accumulated more than 1600 flight hours in over 20 different aircraft. He has 275 arrested landings and has made deployments aboard the USS Constellation and USS Independence. He is a graduate of TOPGUN and the U.S. Naval Test Pilot School. He is currently a project officer at Strike Aircraft Test Directorate, Ordnance Systems Branch in Patuxent River, MD.