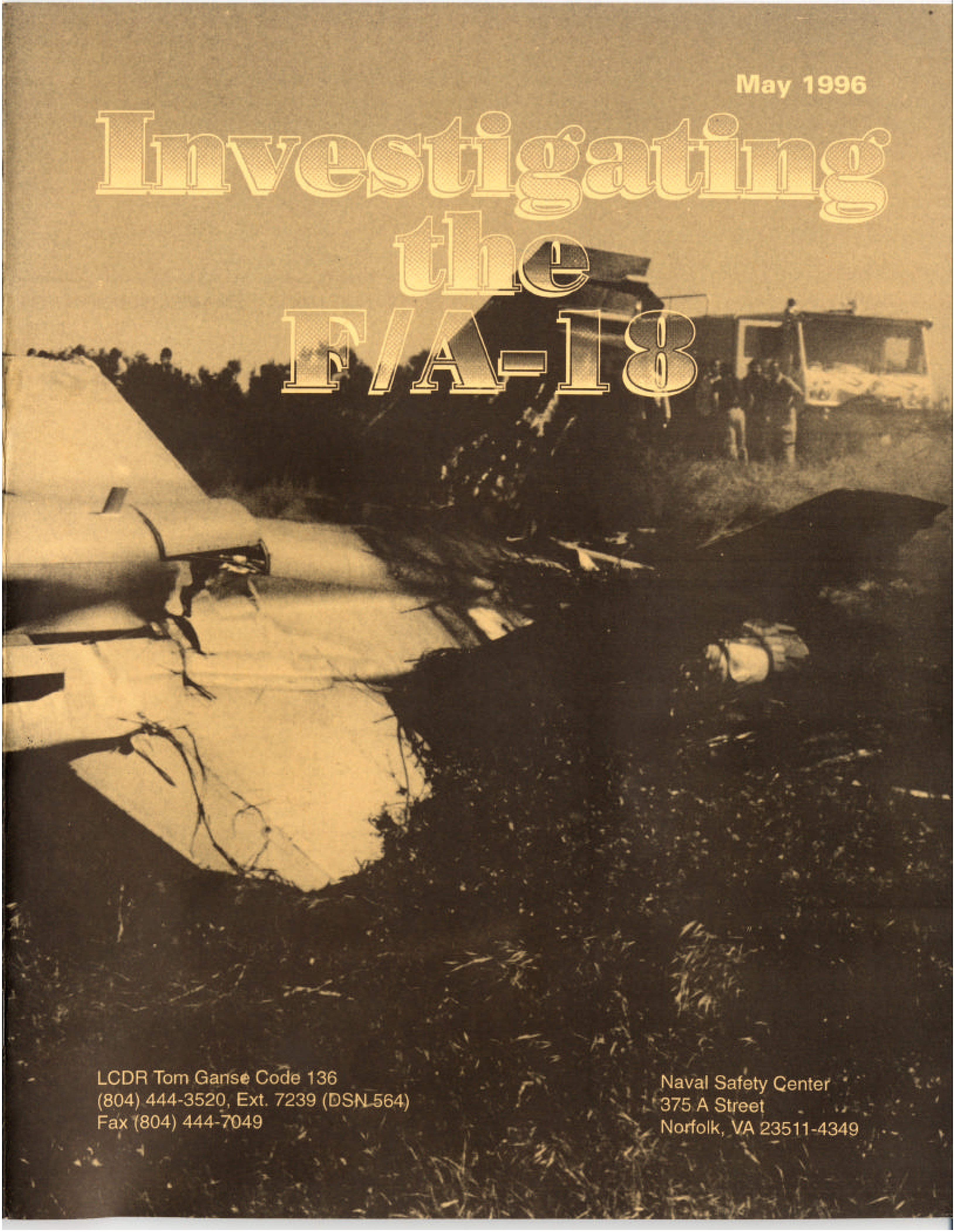
May 1996

Investigating the F/A-18



LCDR Tom Ganse Code 136
(804) 444-3520, Ext. 7239 (DSN 564)
Fax (804) 444-7049

Naval Safety Center
375 A Street
Norfolk, VA 23511-4349

FOREWORD

A few hours ago you were enjoying a good workout when you were so rudely interrupted: A plane is down, your squadronmate is now just a memory and you are on the aircraft mishap board (AMB). It's your job to find out what went wrong. By way of the Mishap Investigation Report (MIR), you will be asked to tell a story. Why did this plane crash? Were all the systems functioning properly? What was the pilot doing? Inquiring minds want to know!

Every AMB will have an Aviation Safety Officer (ASO) School graduate who has been exposed to fundamental investigative techniques and available resources. Perhaps even more comforting, a formally trained and field-experienced mishap investigator from the Naval Safety Center will normally be dispatched for a Class A mishap. Under exceptional circumstances, Safety Center investigators may be available for other mishaps. These people are your primary resources and, even though they may not have the airframe technical expertise or know all the answers, they should be able to exploit the necessary resources.

Our "electric" airplane can make mishap investigations very simple, or very difficult. If you have a survivor or reliable witnesses, the plane is equipped with a deployable flight incident recorder set (DFIRS), or the DSU/MSDRS and MC1 data can be retrieved, your investigation should be quick and simple. On the other hand, if you have no survivors, witnesses, or retrievable electronic data, you've got your work cut out for you. Fortunately, there are still places to look for good old- fashioned physical evidence.

This document was developed to make your task simpler and more logical. It is intended to provide a reference to help you find pieces of your mishap story. A deliberate decision was made to avoid general mishap philosophies such as crash kit inventories, AMB member responsibilities, sequence of events, etc.

ACKNOWLEDGEMENT

This document is the result of the insight, experience, corporate knowledge and cooperation of numerous engineers from Naval Aviation Depots, prime contractors and vendors; the professionals at McDonnell Douglas Product Safety and Investigations; and the composite knowledge gained by my predecessors and co-workers at the Naval Safety Center Aircraft Investigations Branch. Although space constraints prohibit mentioning each personally, I would like to express my deepest gratitude for each of their contributions.

LCdr. Tom Ganse, U. S. Navy

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ACRONYMS

ADC .... Air Data Computer
AFC .... Airframes Change
AMB .... Aircraft Mishap Board
CP .... Chip Pair
CSFDR .... Crash Survivable Flight Data Recorder
DFIRS .... Deployable Flight Incident Recording System
DSU .... Data Storage Unit
ECAMS .... Enhanced Comprehensive Asset Management System
FCES .... Flight Control Electrical Set
FIRAMS .... Flight Incident Recording and Monitoring System
HUD .... Head-Up Display
ILS .... Instrument Landing System
INS .... Inertial Navigation System
IPB .... Illustrated Parts Breakdown
LVDT .... Linear Variable Differential Transformer
MC .... Mission Computer
MIR .... Mishap Investigation Report
MSDRS .... Maintenance Signal Data Recording System
MSP .... Maintenance Status Panel
MU .... Memory Unit
NADEP .... Naval Aviation Depot
OFP .... Operational Flight Program
PLA .... Power Lever Angle
SOP .... Standard Operating Procedure
UFC .... Upfront Control
VTR .... Video Tape Recorder

REFERENCES

U.S. Navy.

- *NAVAIR A1-F18AC-NFM-000, F/A-18A/B/C/D NATOPS Flight Manual.*
- *NAVAIR 00-80T-116-1. Technical Manual Safety Investigation, Volume I, "Mishap Investigation".*
- *NAVAIR 00-80T-116-2. Technical Manual Safety Investigation, Volume II, "Investigative Techniques".*

U.S. Naval Postgraduate School, Aviation Safety Programs.

- *Aircraft Mishap Investigation.*

McDonnell Douglas Aircraft Products.

- *DSU or DFIRS?.*
- *Available Mishap Data from McDonnell Aircraft Products.*
- *F/A-18 C/D Deployable Flight Incident Recorder Set*

SOURCES OF INFORMATION

NON-VOLATILE MEMORY. Some consider the "glass cockpit" to be the scourge of mishap investigations. Yet, the digital technology that makes glass cockpits possible also creates a complete electronic record of aircraft and flight parameters. The problem arises when the electrons stop flowing. Fortunately, the F/A-18 is equipped with several sources of non-volatile memory. These will become your best friends if they can be recovered undamaged. Figure 1 provides a matrix of potential capabilities for specific aircraft.

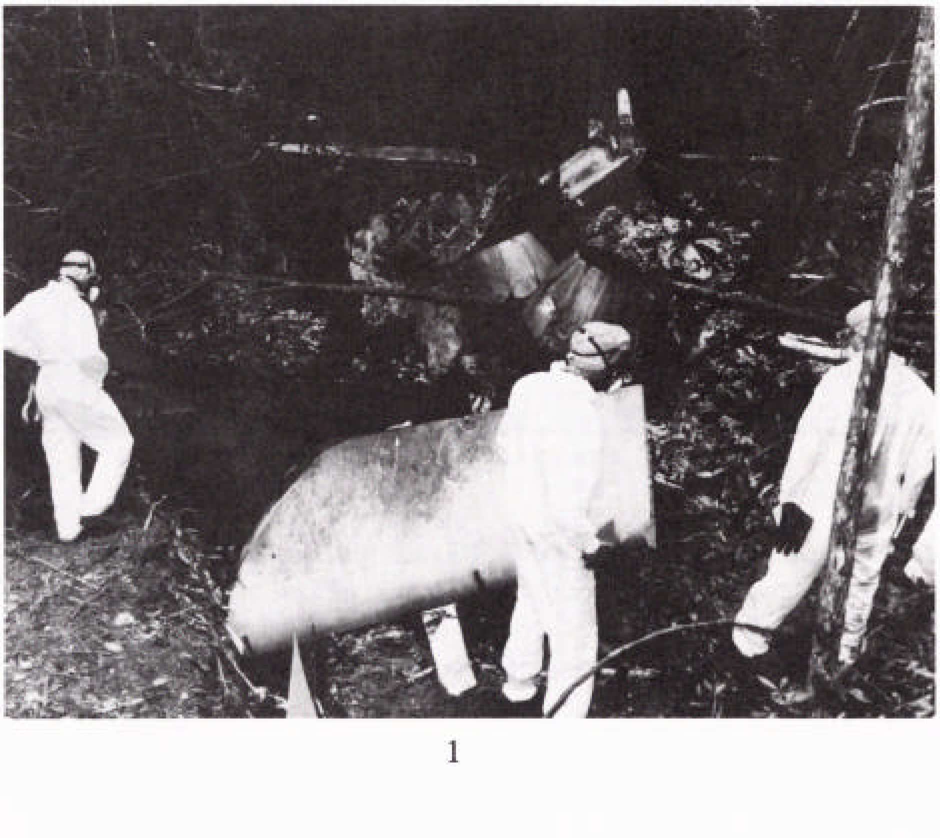
The mission computers process all information and maintain a five-second "history" buffer. Raw data is received, sorted, then filed under "addresses." You must have the correct address to access the desired data. The Naval Safety Center maintains an accurate list of addresses and corresponding parameters. The various recorders available "interrogate" some of these addresses, but do not necessarily record all of the data processed by the MCs, nor do they record some or all of the parameters at all times. An accurate working knowledge of the various recorders' limitations is required for meaningful data extraction.

NOTE

Do not attempt to access or download any electronic records from any source until competent authority has certified grounding and continuity. Failure to comply with this guidance may result in complete loss of data.

NOTE

Non-volatile memory components should be placed in de-ionized water if recovered from salt water. If de-ionized water is not available, distilled water is the next best choice, followed by fresh water, then finally, the water the component was recovered from.



ELECTRONIC DATA STORAGE/RETRIEVAL CAPABILITIES

	COMPUTER	OFP	MC-1/MC-2	MSDRS	FIRAMS	DSU/MU	CSFDR	DFIRS	NO. OF A/C	REMARKS
A 161353-163175 B 161354-163123	XN-6	92A	YES	YES	NO	NO	NOT YET	NO	364(A) 37(B)	NO. OF A/C INCLUDES STRICKEN BUNOS CSFDR FUNDED FOR FY97 F/A-18C/Ds RETROFITTEED WITH XN-8 COMPUTERS WILL RUN 09C OFP
C163247-163509 D163434-163778	XN-6	91C	YES	NO	YES	YES	NOT YET	NO	137(C) 31(D)	
C163985-164278 D163986-164279	XN-6	91C	YES	NO	YES	YES	NOT YET	NO	118(C) 50(D)	
C164627-164691 D164649-164692	XN-6/ XN-8	91C/ 09C	YES	NO	YES	YES	NO	MAYBE	46(C) 20(D)	AFC-128 (DFIRS RETROFIT FOR LOT 14 AND REMAINING LOT 15) IS IN PROGRESS. THESE BUNOS MAY OR MAY NOT HAVE COMPLETED THE AFC.
C164693-164724 D164694-164723	XN-6/ XN-8	91C/ 09C	YES	NO	YES	YES	NO	MAYBE	24(C) 8(D)	AIRCRAFT EQUIPPED WITH XN-8 COMPUTERS RUNNING 09-C DO NOT RETAIN THE 5 SECOND BUFFER OF INFORMATION IN THE MISSION COMPUTER
C164725-164912 D164726-164901	XN-8	09C	YES	NO	YES	YES	NO	YES	46(C) 18(D)	
C164946 + D164945 +	XN-8	09C	YES	NO	YES	YES	NO	YES	34+(C) 14+(D)	NUMBER OF AIRCRAFT INCLUDES THRU LOT 17

Figure 1. Data Retrieval Matrix

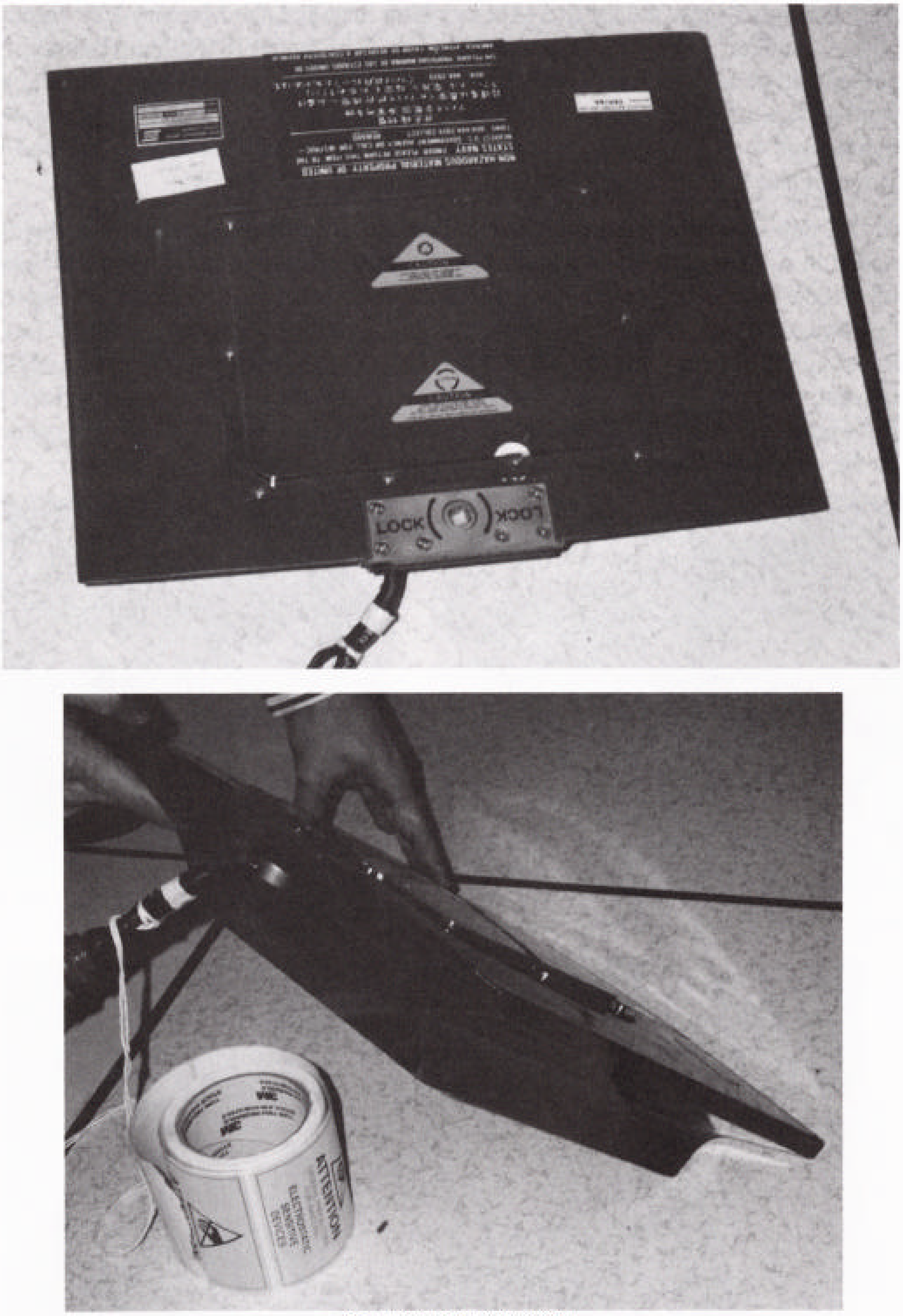


Figure 2. DFIRS Airfoil

Deployable Flight Incident Recording Set (DFIRS). Figure 2 pictures the DFIRS. It is the most complete and crash-survivable system, and can be thought of as deployable *super* ECAMS data. This international orange container is marked with reflectorized tape and measures approximately 16" X 13" X 3". It is equipped with an emergency locator transmitter (ELT) and is buoyant, fire resistant and crash hardened.

Figures 3 through 5 show the DFIRS Memory Unit installed, the Memory Unit removed from the heat-resistant blanket, and the location and appearance of the DFIRS lithium battery. This battery is considered hazardous material and must be removed before packaging and shipping. The ELT is located underneath, and appears identical to, the memory unit. The only difference between the Memory unit and the ELT is a coaxial cable on the ELT. The ELT should be disabled as soon as possible by cutting the power cord. See Appendix A - Handling the DFIRS.

The DFIRS deploys upon ejection or impact exceeding 20 Gs. The expected deployment envelope is provided in Appendix B. DFIRS maintains the most complete record of aircraft event history, including all critical parameters recorded by ECAMS. Unfortunately, it is limited to the last 30 minutes of electrical power. The Naval Safety Center can produce a hardcopy printout and a computer generated video display from this data if the memory module can be retrieved undamaged. DFIRS is currently installed in later Lot 15 aircraft and all Lot 16 and subsequent aircraft (BUNO 164725+). The ongoing retrofit into Lot 14 and 15 aircraft (BUNO 164627 - 164724) should be complete by the end of 1996.


Figure 3. DFIRS Memory Unit (installed)

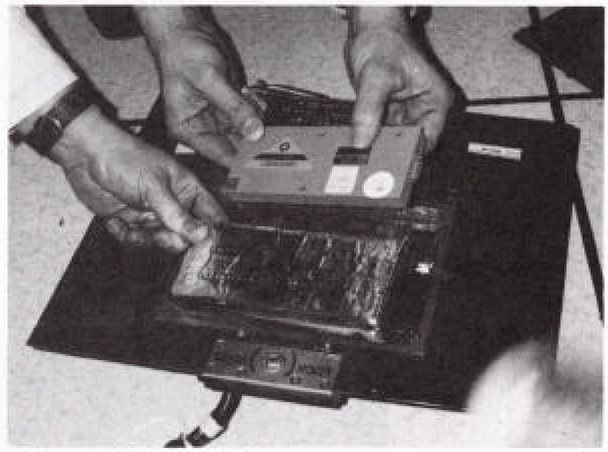


Figure 4. Memory Unit removed from heat blanket


Figure 5. DFIRS battery (unwrapped) shown above installed battery

```
                                                    09-Jun-95      11:34 AM       FILE NAME:  163492.136         PAGE:  1

F I R   D A T A     P A S S   1                   TAIL NO.=163492    FLIGHT NO.= 1    DSU DATE = 05/12
--------------------------------------------------------------------------------------------------------------------------
    TIME     :RADAR : IND  :    PLA     : BARO : ROLL :PITCH  : YAW  : HUD  : NORM : LAT.   : LONG : LAT  : RUD. :    HIGH     :  EGT  :
             : ALT  : AIR  :    DEG     : ALT  : RATE : RATE  : RATE :A-O-A : ACC  :ACCEL.  : STK  : STK  :PEDAL :    PRESS    : LT RT :
HH:MM:SS.FF:        :SPEED : LT      RT :      :      :       :      :FORCE :      :        : POS  :FORCE :FORCE :    ROTOR    :       :
             :      :      :            :      :      :       :      :      :  G   :        :      :      :      :     RPM     :       :
             :      :      :            :      :      :       :      :      :      :        :      :      :      : LT       RT :       :
             :      :      :            :      :      :       :      :      :      :        :      :      :      :             :       :
             :1KRRAL:1AIASP:   1CAPLL   :1ABCAL:1CARRT:1CAPRT :1CAYRT:UBAOAD:NHACN :NHACLT  : ICAPS:ICARSF:ICARP :    1EXNHL   :1EEGTL :
--------------------------------------------------------------------------------------------------------------------------
```

```
                                           09-Jun-95            11:34 AM       FILE NAME:  163492.136         PAGE:  1

F I R   D A T A     P A S S   2                   TAIL NO.=163492   FLIGHT NO.= 1   DSU DATE = 05/12
--------------------------------------------------------------------------------------------------------------------------
    TIME     :    LOW     :   MAIN    : FUEL :PRESS : A/C  : A/C  : A/C  :    STAB     :   TRAIL    :  G     :  OUTBD    :  RUDDER    :
             :   PRESS    :   FUEL    : QTY  : ALT  :PITCH :OUTER : MAG  :    POS      :   EDGE     :LIMIT   :  LEAD     :   POS      :
HH:MM:SS.FF:     ROTOR    :   FLOW    :TOTAL :      :      : ROLL : HDG  : LT       RT :   FLAP     :VALUE   :  EDGE     :            :
             :    RPM     : LT     RT :TOTAL :      :      :      :      :             :    POS     :        :  FLAP     : LT      RT:
             :            :           :      :      :      :      :      :             : LT      RT:        :   POS     :            :
             :            :           :      :      :      :      :      :             :            :        : LT     RT :            :
             :   1EXNLL   :  1EMEFL   :1EFQTT:1APRAL:1NPTCH:1NOROL:1HACMH:   1CALSP    :   1CALTP   :NZRE1   :  1CALLO   :  1CALRP    :
--------------------------------------------------------------------------------------------------------------------------
```

```
                                           09-Jun-95            11:34 AM       FILE NAME:  163492.136         PAGE:  1

F I R   D A T A     P A S S   3                   TAIL NO.=163492   FLIGHT NO.= 1   DSU DATE = 05/12
--------------------------------------------------------------------------------------------------------------------------
    TIME     :    AIL     :   INBD    :
             :    POS     :   LEAD    :
HH:MM:SS.FF:              :   EDGE    :
             : LT      RT :   FLAP    :
             :            :    POS    :
             :            : LT     RT :
             :   1CALAP   :  1CAILF   :
--------------------------------------------------------------------------------------------------------------------------
```

Figure 6. ECAMS Header Strips w/Parameters, Passes 1, 2 and 3

Enhanced Comprehensive Asset Management System (ECAMS). Information processed in ECAMS is also contained in DFIRS if the aircraft is so equipped, but will cover the entire flight. Previous flights are also available if the DSU was not downloaded. This information must be obtained from the DSU in Lot 10 and up aircraft (BUNO 163427+). The MSDRS tape on Lot 9 and previous aircraft contains very similar data and is discussed below. An undamaged DSU can be read locally. Damaged recorders require NADEP or contractor assistance. Full flight-incident data generates one line of information for each second of data, or about 3,600 lines/hour. Sample header strips and associated pass parameters for ECAMS printouts are shown in Figure 6. The NAVAIRTESTCEN at Pax River has a limited capability to create a computer-generated video from ECAMS data.

Maintenance Signal Data Recording System (MSDRS). This removable cassette, pictured in Figure 7, is used by Lot 9 and earlier aircraft (BUNO 161353 - 163175). The gray metal case measures approximately 3" X 3" X 1.5" and has a yellow stripe painted around it. It is not crash hardened, and does not contain all of the information the DSU does. Figure 8 shows the MSDRS installed behind Door 14R. Figure 9 shows recorded parameters. An undamaged MSDRS tape can be read locally.

Figure 7. MSDRS Cassette

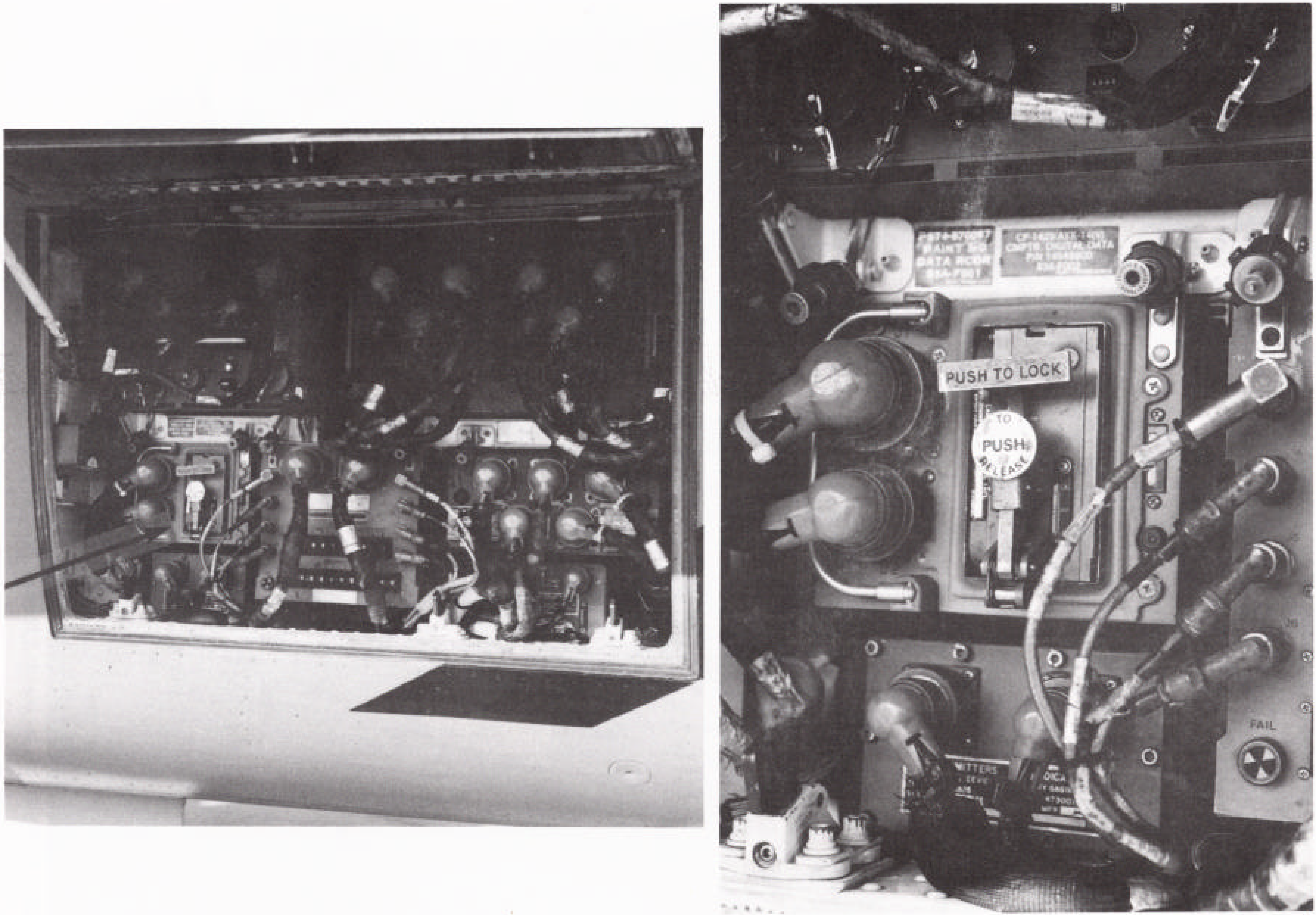


Figure 8. MSDRS Cassette Installed Behind Door 14R

```
                                              09-Jun-95        11:34 AM        FILE NAME:  161927.136          PAGE:  1
F I R   D A T A    P A S S   1                TAIL NO.=161927    FLIGHT NO.= 2    DSU DATE = 05/12
----------------------------------------------------------------------------------------------------------------------------------
    TIME    :RADAR : IND  :     PLA     : BARO : ROLL :PITCH  : YAW  : HUD  : NORM : LAT.   : LONG : LAT  : RUD.  :    HIGH    :  EGT  :
            : ALT  : AIR  :     DEG     : ALT  : RATE : RATE  : RATE :A-O-A : ACC  :ACCEL.  : STK  : STK  :PEDAL  :    PRESS   : LT RT :
HH:MM:SS.FF:       :SPEED : LT       RT :      :      :       :      :FORCE :      :        : POS  :FORCE :FORCE  :    ROTOR   :       :
            :      :      :             :      :      :       :      :      :  G   :        :      :      :       :     RPM    :       :
            :      :      :             :      :      :       :      :      :      :        :      :      :       : LT      RT :       :
            :      :      :             :      :      :       :      :      :      :        :      :      :       :            :       :
            :1KRRAL:1AIASP:   1CAPLL    :1ABCAL:1CARRT:1CAPRT :1CAYRT:UBAOAD:NHACN :NHACLT  : ICAPS:ICARSF:ICARP  :   1EXNHL   :1EEGTL :
----------------------------------------------------------------------------------------------------------------------------------
```

```
                                         09-Jun-95          11:34 AM        FILE NAME:  161927.136          PAGE:  1
F I R   D A T A    P A S S   2           TAIL NO.=161927   FLIGHT NO.= 2   DSU DATE = 05/12
----------------------------------------------------------------------------------------------------------------------------------
    TIME    :    LOW     :   MAIN     : FUEL  :PRESS : A/C  : A/C   : A/C  :    STAB     :   TRAIL     :  G     :   OUTBD     :  RUDDER    :
            :   PRESS    :   FUEL     : QTY   : ALT  :PITCH :OUTER  : MAG  :    POS      :   EDGE      :LIMIT   :   LEAD      :    POS     :
HH:MM:SS.FF:   ROTOR    :   FLOW     :TOTAL  :      :      : ROLL  : HDG  : LT       RT :   FLAP      :VALUE   :   EDGE      :            :
            :    RPM     : LT     RT  :TOTAL  :      :      :       :      :             :    POS      :        :   FLAP      : LT      RT :
            :            :            :       :      :      :       :      :             : LT       RT :        :    POS      :            :
            :            :            :       :      :      :       :      :             :             :        : LT      RT  :            :
            :   1EXNLL   :  1EMEFL    :1EFQTT:1APRAL:1NPTCH:1NOROL:1HACMH:   1CALSP    :   1CALTP    :NZRE1   :   1CALLO    :   1CALRP   :
----------------------------------------------------------------------------------------------------------------------------------
```

```
                                         09-Jun-95          11:34 AM        FILE NAME:  161927.136          PAGE:  1
F I R   D A T A    P A S S   3           TAIL NO.=161927   FLIGHT NO.= 2   DSU DATE = 05/12
----------------------------------------------------------------------------------------------------------------------------------
    TIME    :    AIL     :   INBD     :
            :    POS     :   LEAD     :
HH:MM:SS.FF:            :   EDGE     :
            : LT      RT :   FLAP     :
            :            :    POS     :
            :            : LT     RT  :
            :   1CALAP   :  1CAILF    :
----------------------------------------------------------------------------------------------------------------------------------
```

Figure 9. MSDRS Header Strips w/Parameters, Passes 1, 2 and 3

Data Storage Unit (DSU). The DSU is also known as the **Memory Unit (or MU).** Figures 10 and 11 depict the DSU, not installed and installed, respectively. It is designed to provide ECAMS data on aircraft BUNOs 163427 and up. A memory card holds 32 gold-colored chips arranged as 16 pairs. These chip pairs hold the non-volatile memory and are numbered CP1 through CP16, High and Low. Figure 12 shows the memory card, front and back, at approximately 75 percent actual size. Figure 13 is a legend showing chip pair locations.

The DSU, or what remains of it, ***must*** be wrapped immediately with electrostatic shielding material and bagged. Do not allow this to become a "show and tell" item! The more it is handled, the greater the risk of losing chips. A lot of data can be obtained even if some chips are lost or unreadable. In this case, the data is like a picture-puzzle; each missing chip will have some random pieces of that puzzle, so the more chips you lose, the harder it is to recognize the picture. Data usually is not retrievable if the chip is cracked or broken. Your Safety Center investigator will over-see any reconstruction and data retrieval attempts if the DSU is damaged. Figure 6 lists parameters available from the DSU.

Figure 10. Data Storage Unit

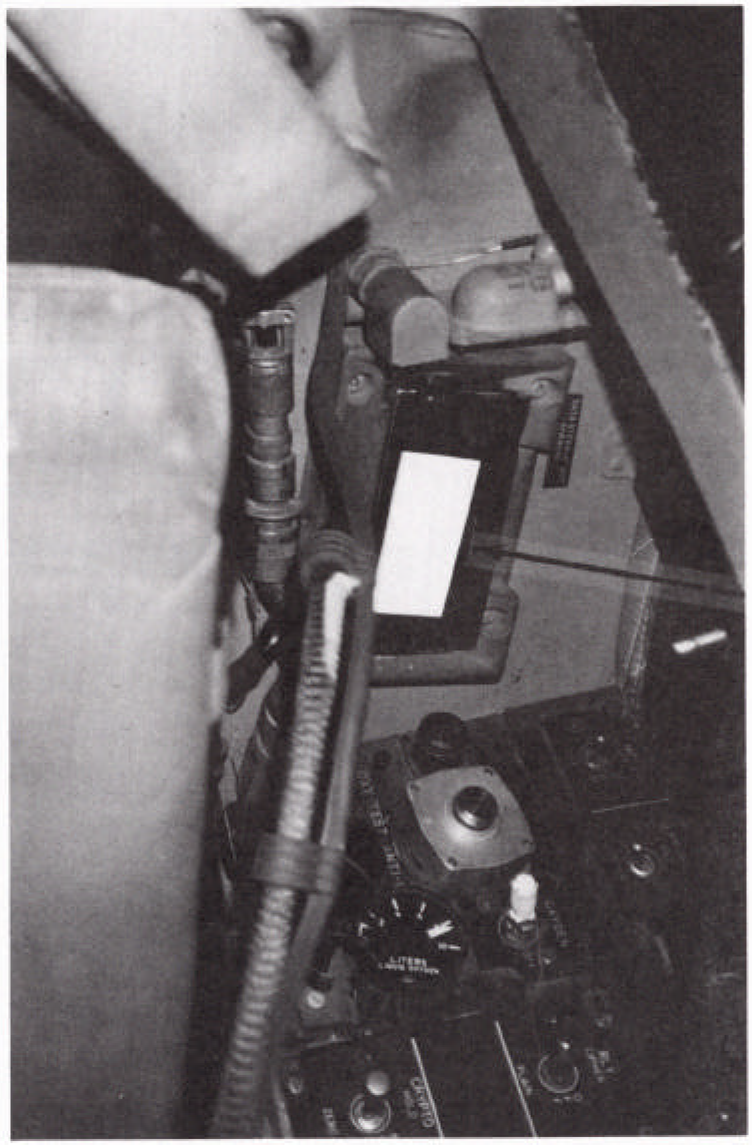
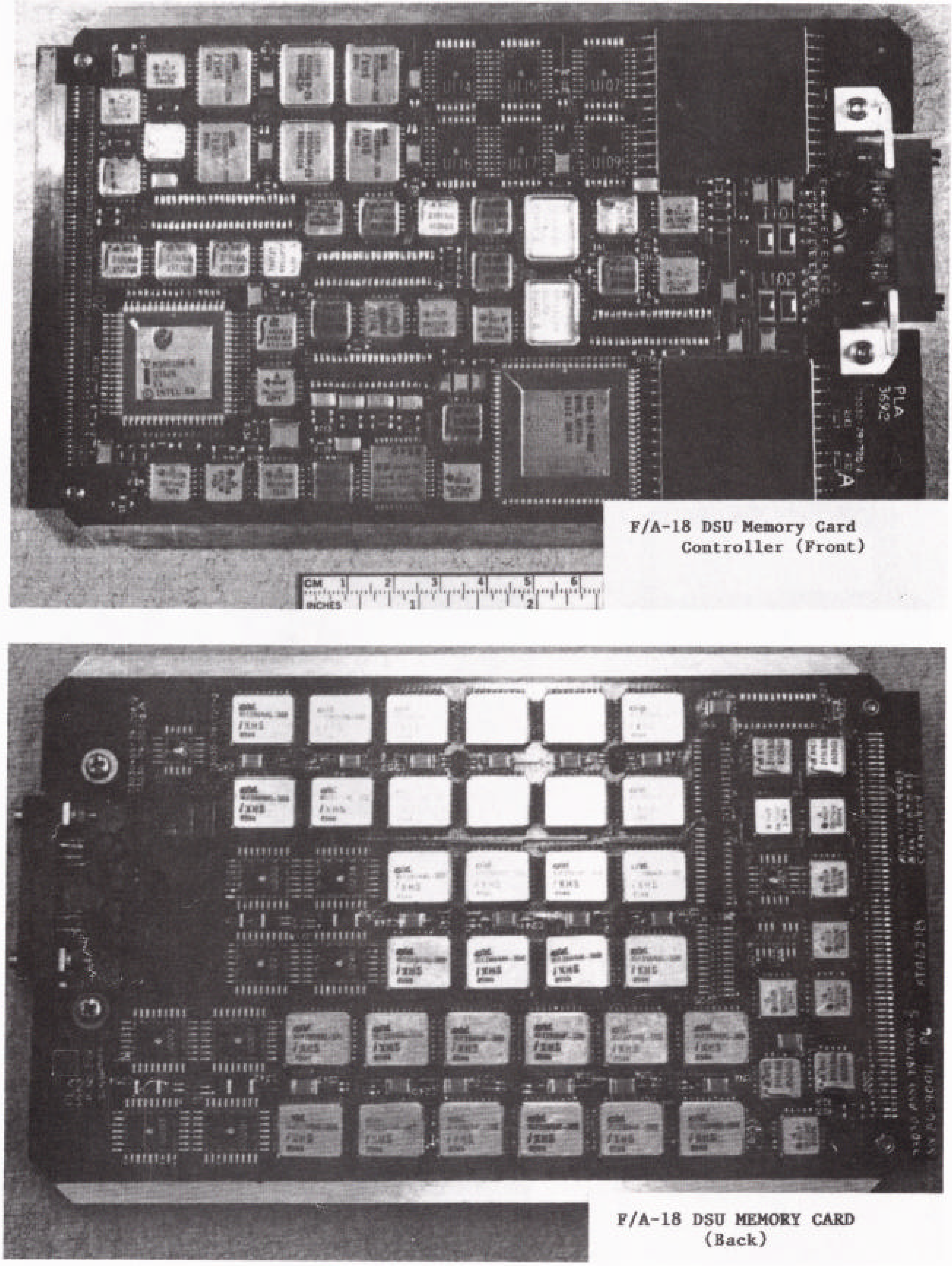


Figure 11. DSU Installed, Lefthand Side of Cockpit Aft Bulkhead



F/A-18 DSU Memory Card Controller (Front)

F/A-18 DSU MEMORY CARD (Back)

Figure 12. DSU Memory Card, Front and Back

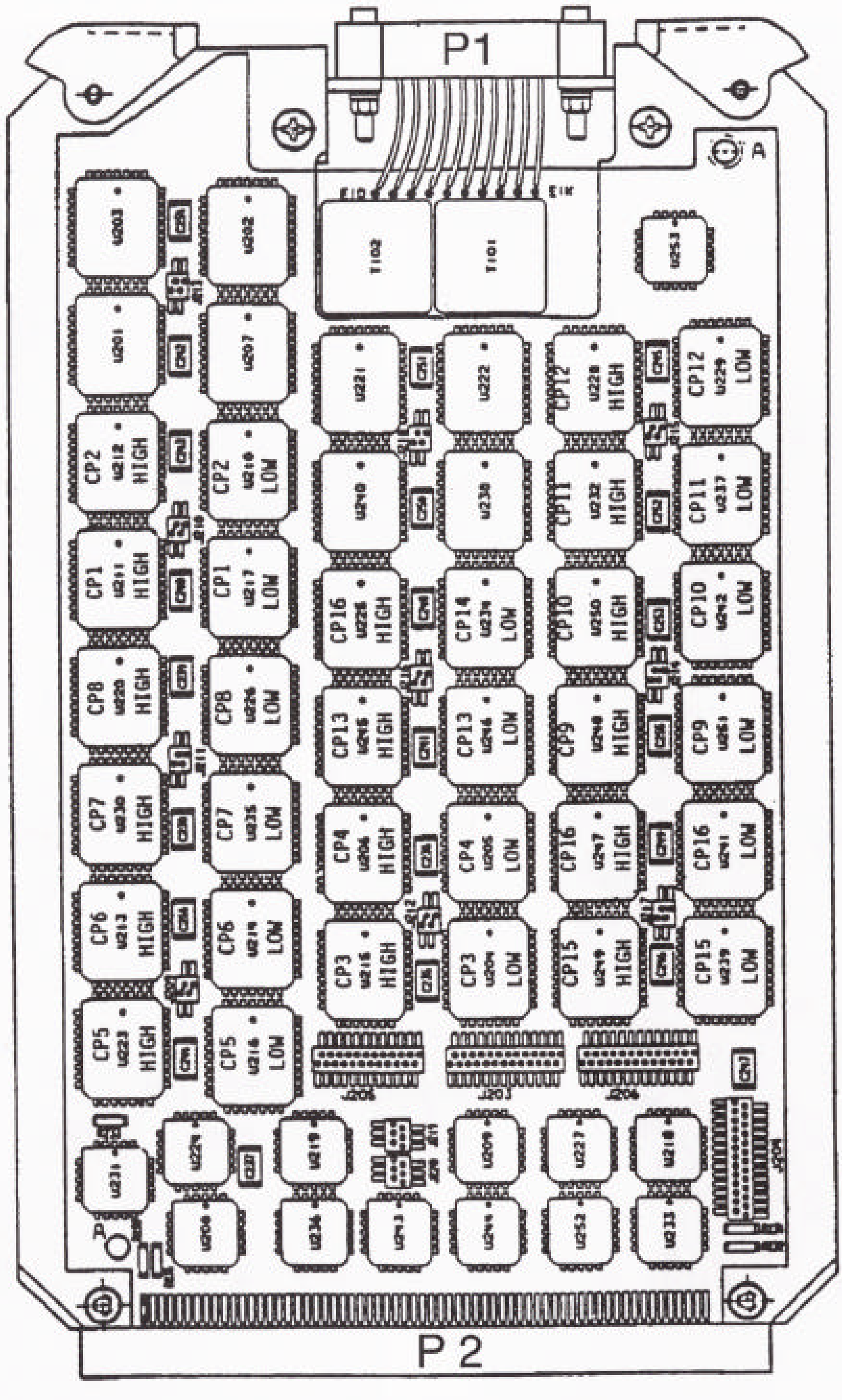


Figure 13. DSU Memory Card Chip Pair Locations (actual size)

Mission Computers. Both MC1 and MC2 may provide a snapshot of data at power loss, including control surface positions, flight performance parameters, flight control system status, maintenance codes, warnings and cautions displayed on HUD or DDIs, master caution light status, and HUD and DDI displays at power loss. This information is stored in a five-second buffer. It may complete or confirm information from DFIRS, ECAMS, or MSDRS. Figure 14 shows a mission computer. Figure 15 provides examples of reconstructed displays created from extracted data. Reconstructed displays cannot be generated from OFP 09C.

MC1 contains the most complete data since it contains navigation and status data. MC2 contains primarily tactical data. Both MCs record status data, therefore, it may be retrieved from MC2 if MC1 is unusable. Table 1 lists MC1 parametric data. Table 2 shows status data. If the MCs were fragmented but readable core modules are recovered, the modules can be matched to their respective MCs by using the addresses in Table 3

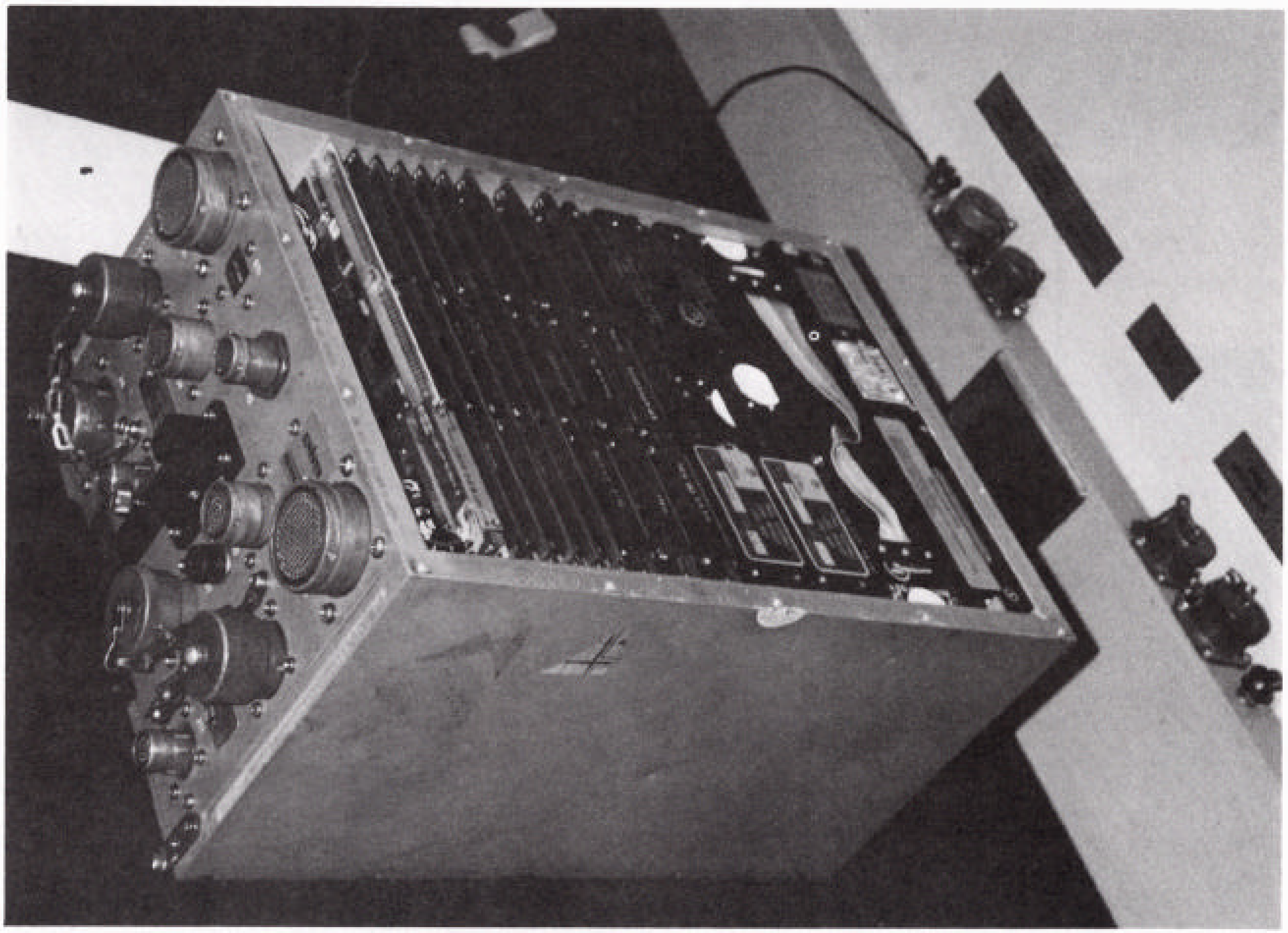


Figure 14. Mission Computer (top cover removed)

Flight-incident recording begins when both throttles are advanced past 90 percent PLA or groundspeed exceeds 50 knots, and stops 15 seconds after weight-on-wheels with both throttles less than 90 percent PLA and groundspeed below 50 knots. Recording is continuous anytime the aircraft shows weight-off-wheels. One hundred percent retrieval may not be possible since many of the parameters are only sampled once every five seconds, and not all on the same schedule.

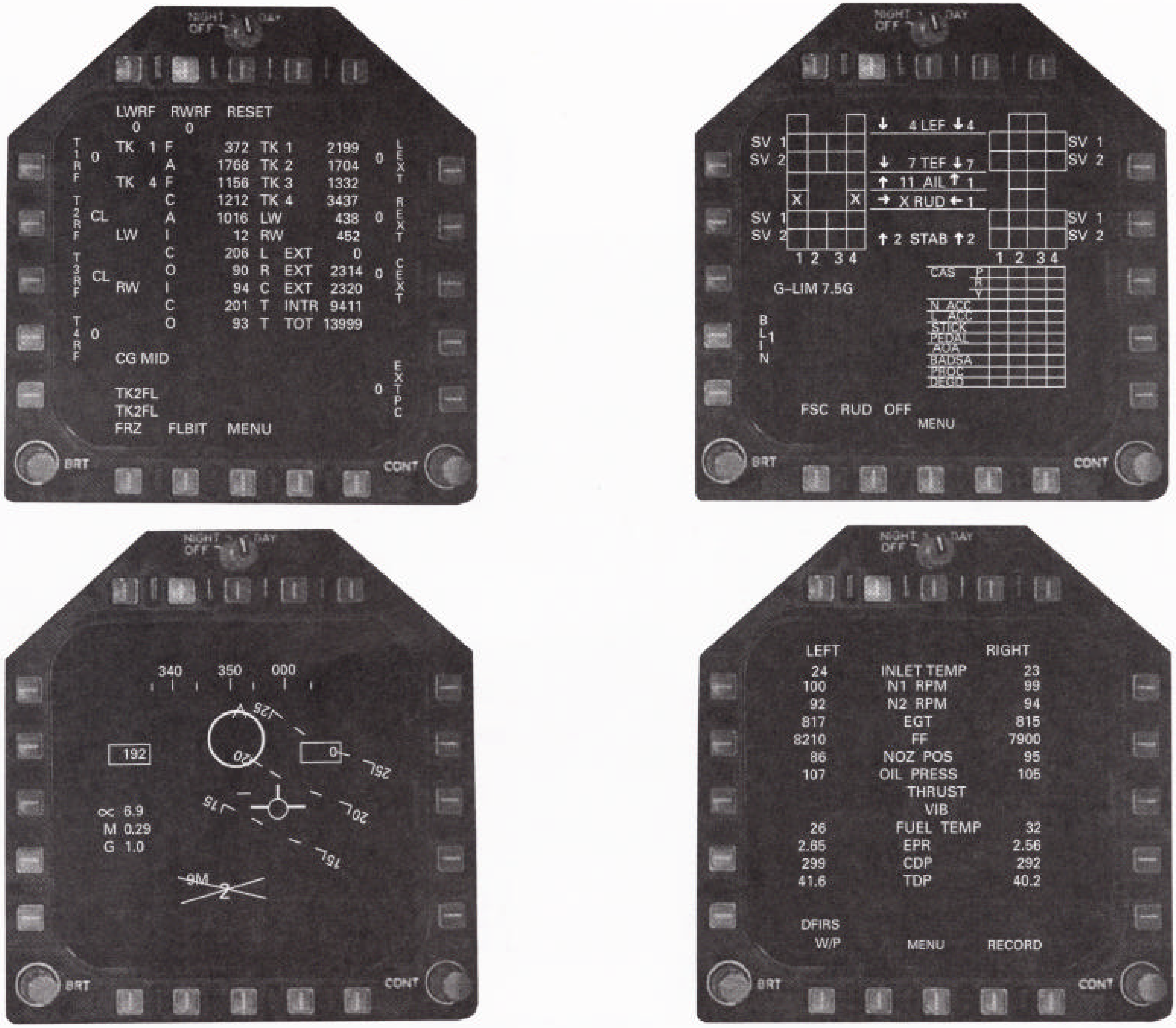


Figure 15. Sample Reconstructed Displays Created From MC Extracted Data

MC1 is located behind door 13L (Figure 16). MC2 is located behind door 14R (Figure 17). Each computer contains two core memory modules (Figure 18). Both memory modules must be recovered to retrieve all of the data from either computer since data is transferred as odd and even words to the respective modules. Success has been negligible when only one module is available. Core module bending or prolonged exposure to fire may render it useless. As a general rule, if the concavity of a bent core module exceeds 10 percent of the module's thickness, information will be irretrievable. Implosion damage caused by deep water may not be fatal, but reconstruction is a long, work-intensive evolution that will normally take three to six months.

Indicated Airspeed	Radar Altitude	Left PLA
Baro Alt (Corr offset)	Acft Roll Rate	Right PLA
Angle of Attack	Pressure Altitude	Mag Heading
Acft Pitch	Acft Outer Roll	Normal Acceleration
Acft Pitch Rate	Acft Yaw Rate	Lateral Acceleration
Lateral Stick Position	Rudder Pedal Force	Longitudinal Stick Position
Stab Position	TEF Position	Rudder Position
Outboard LEF Position	Inboard LEF Position	Aileron Position
Compressor Speed (HP/N2)	Main Fuel Flow	Exhaust Gas Temperature
Fan Speed (LP/N1)	Total Fuel Quantity	Computed Max G
ADC MUX Data	Buffered FCS Data	

Table 1. Information and Parameters Available From MC

Engine Life History	Avionics Software Configuration
BIT Data	Fuel System (C/D models)
MSP Data	Tactical Information
Fatigue Data	Engine Malfunction

Note: A detailed list of available parameters is on file at the Naval Safety Center.

Table 2. Status Data Available From Mission Computers

ADDRESS	VALUE	MC	MODULE
200000	003403	1	A-10
200000	023440	2	A-10
200001	136454	1	A-11
200001	023737	2	A-11

Table 3. Data Addresses for Core Module/Mission Computer Matching

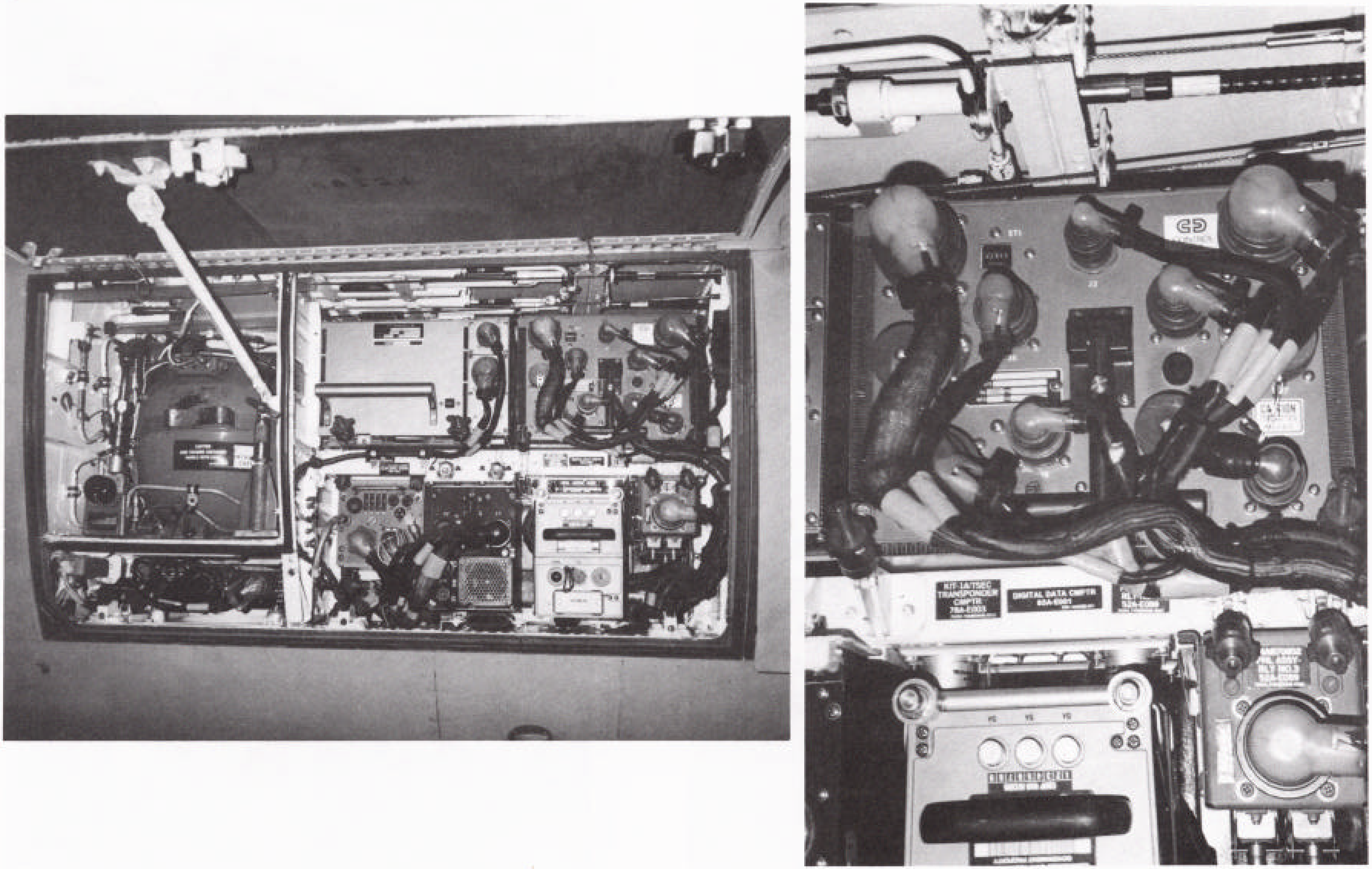


Figure 16. Mission Computer Installed as MC1 Behind Door 13L

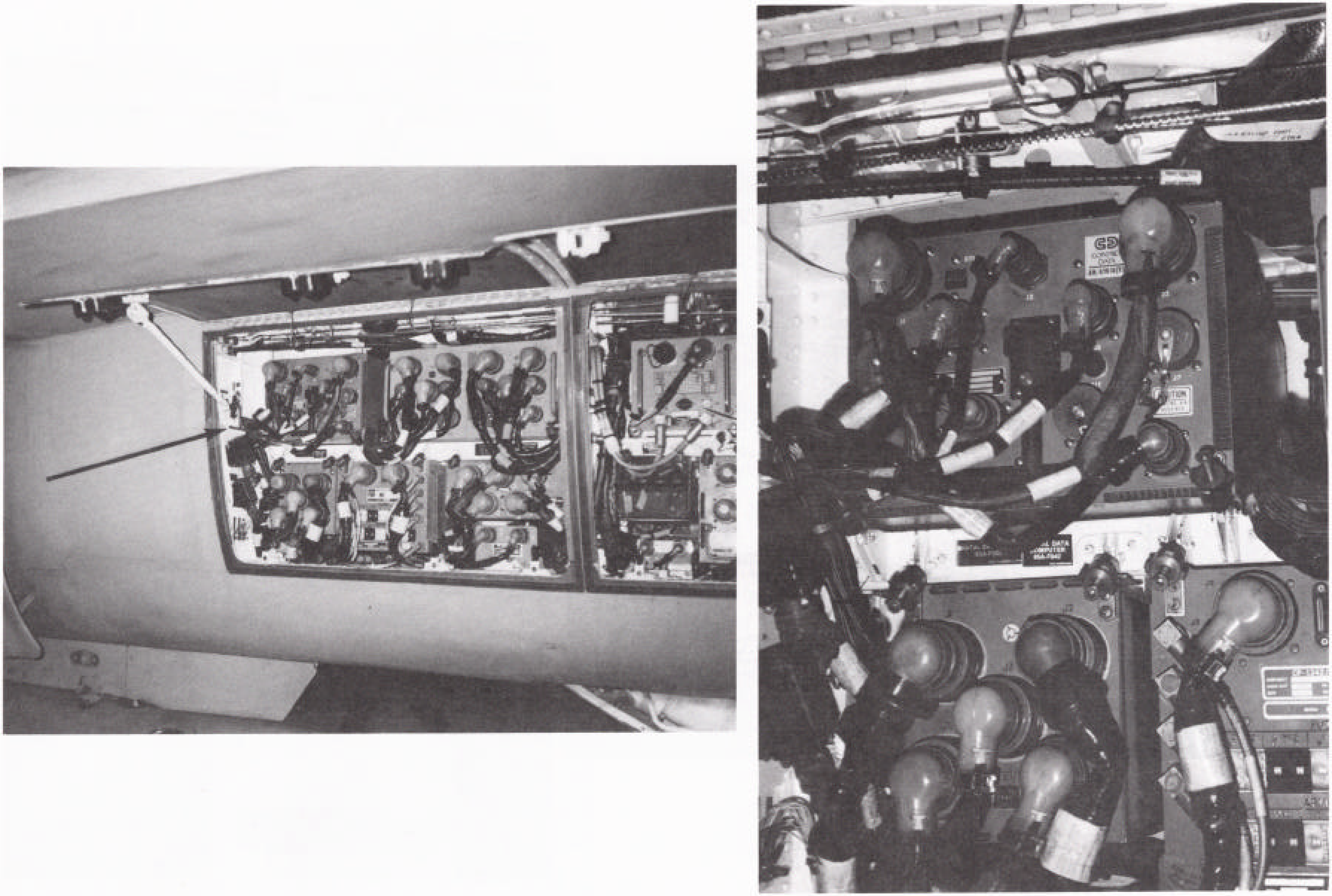


Figure 17. Mission Computer Installed as MC2 Behind Door 14R

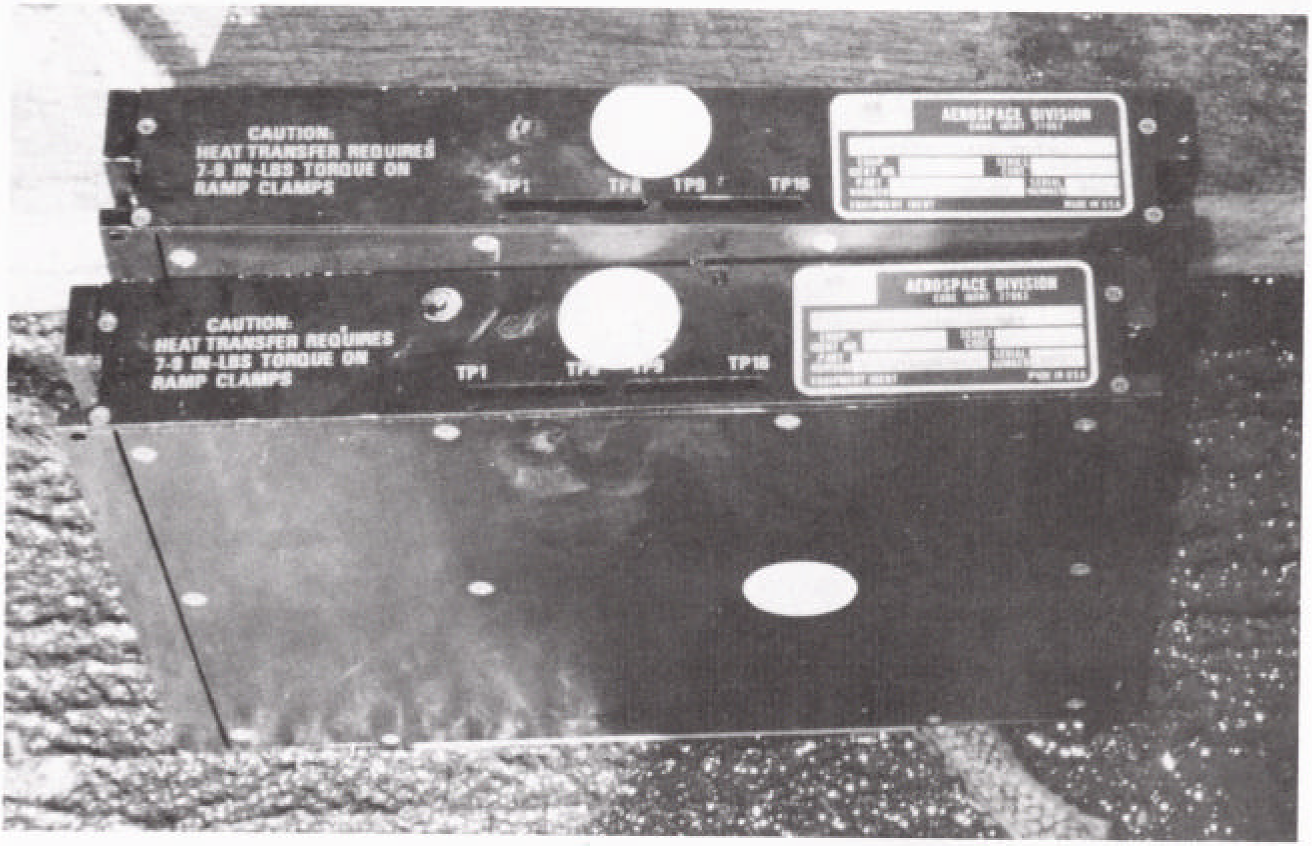


Figure 18. Mission Computer Memory Core Modules

Video Tape Recorder. The video tape recorder (VTR) records audio and video information coincident with trigger squeeze or when selected "ON" by the pilot. Figures 19 and 20 show VTRs installed in "A" or "C" models and "B" or "D" models, respectively. Figure 21 is a close-up of the recorder. The VTR is mounted behind door 14L in "B" and "D" models. The standard Navy 3/4" Beta VTR tape shown in Figure 22 holds approximately 25 minutes of information. Many squadrons direct when this tape will be carried and when information shall be recorded. The tapes are often assigned to specific pilots, therefore, they may provide information about a mishap pilot's performance or demeanor even if it was not recording at the time of the mishap. A review of the tape library and log may provide additional information about the mishap pilot in cases where pilots are assigned specific tapes.

The VTR tape is the only onboard potential source of cockpit audio. External transmissions may be recorded on ATC or Range Control tapes as well as a wingman's VTR tape. Some capabilities exist for damaged VTR tape reconstruction or enhancement. Major efforts using advanced technologies rapidly become cost-prohibitive, particularly if evidence is available from other sources.

Electronic Recreations. The Tactical Aircrew Training Systems (TACTS) and Recovery and Analysis Presentation System (RAPS) are the two most fruitful sytems for translating electronic data to animated flight recreations. Both are capable of providing video and tabular data. RAPS is the primary tool for converting DFIRS, DSU, or MSDRS data, and has been used successfully to convert ATC radar data to three-dimensional animations.

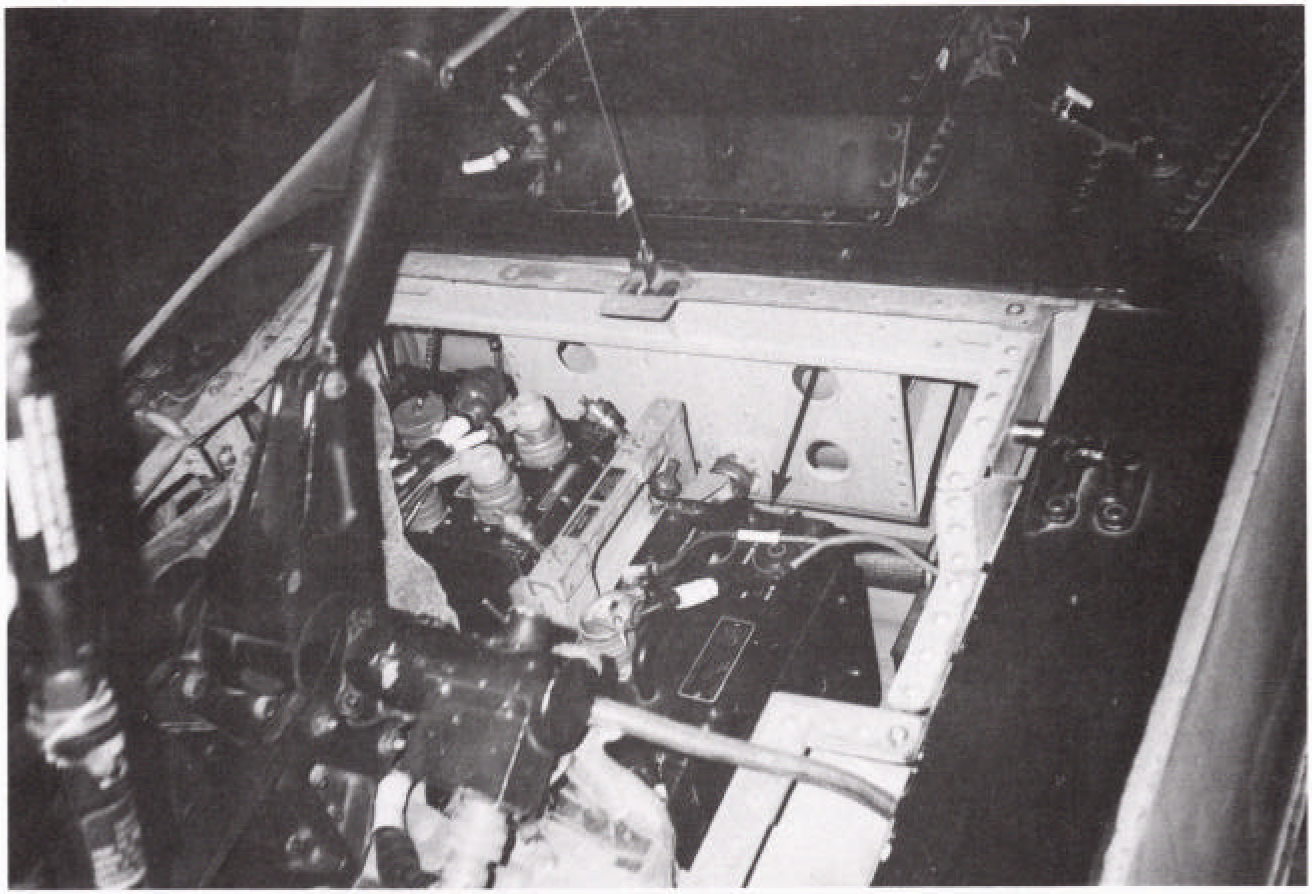


Figure 19. Video Tape Recorder Installed in A or C Model

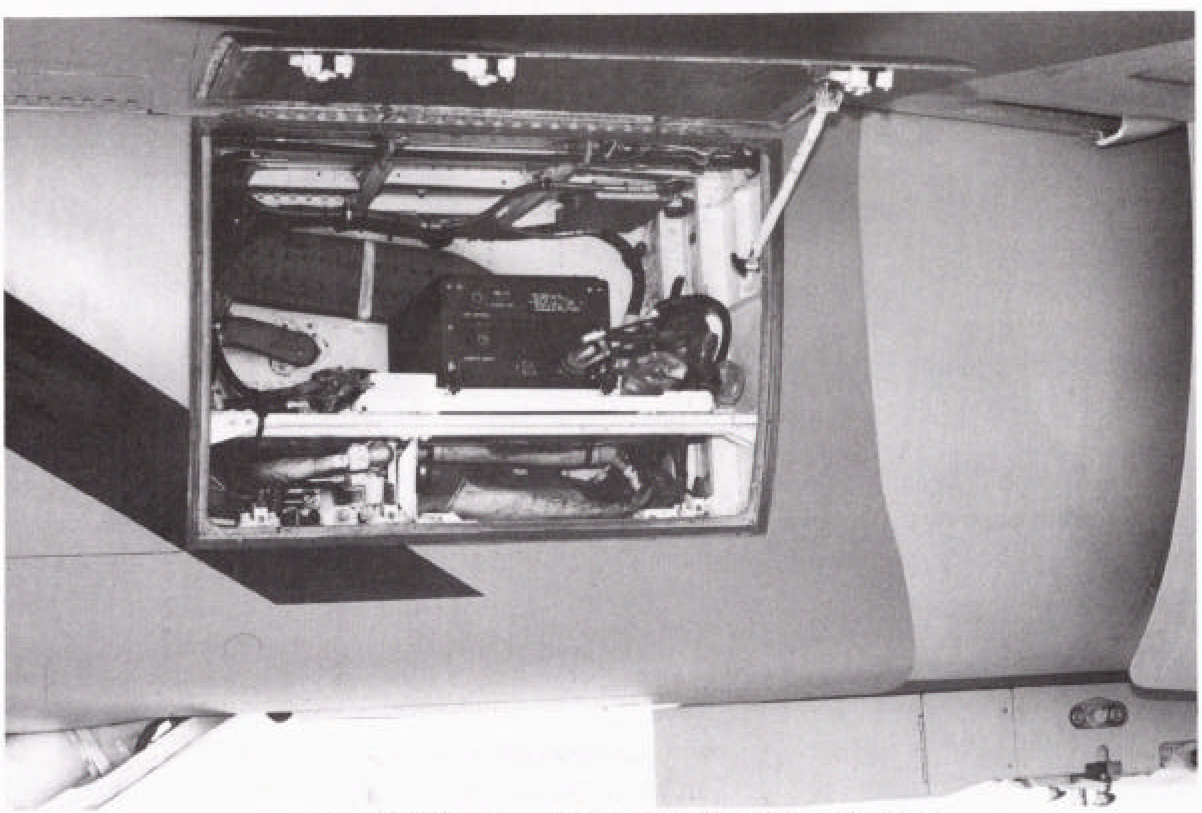


Figure 20. Video Tape Recorder Installed in B or D Model

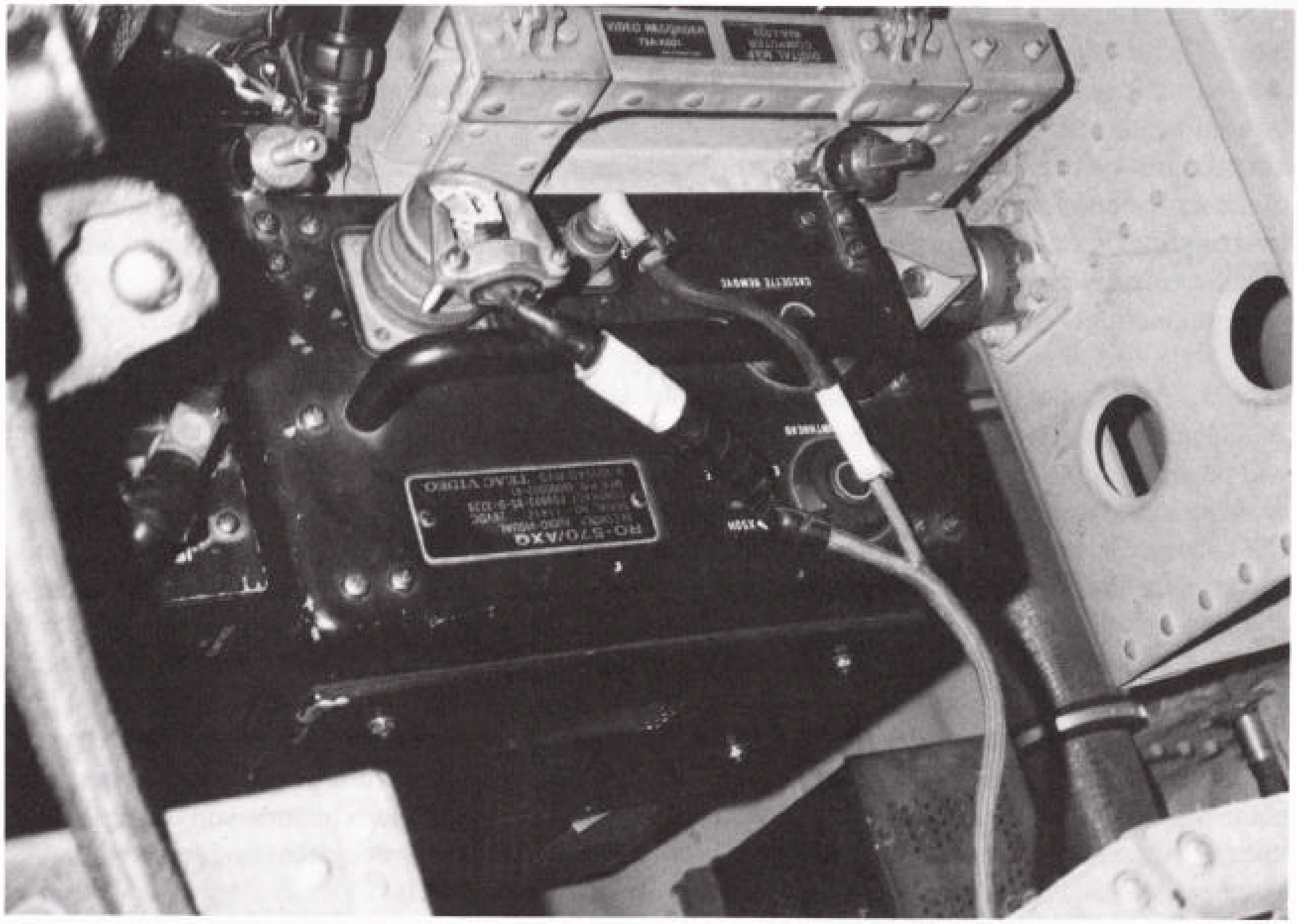


Figure 21. Video Cassette Recorder Close-up

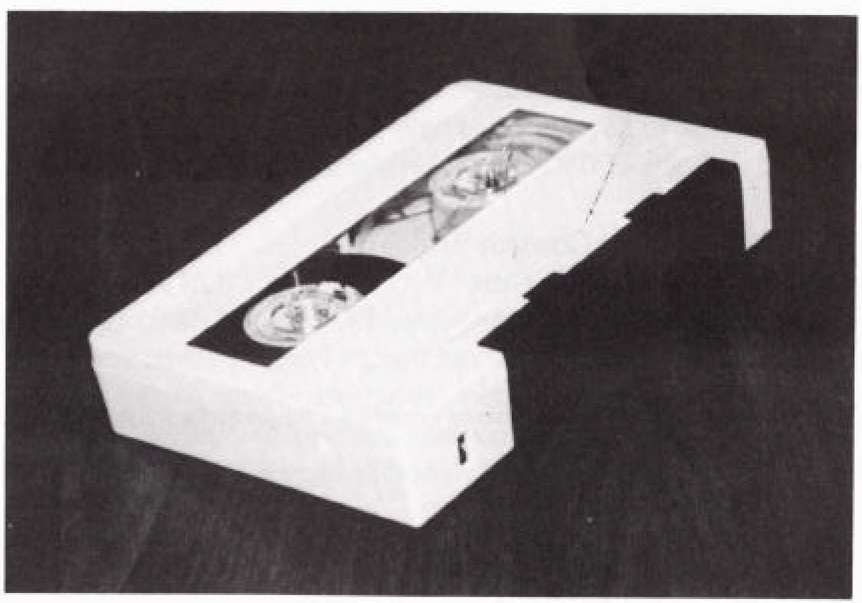


Figure 22. Standard Navy 3/4" Beta Tape Video Cassette

MECHANICAL EVIDENCE. This is the hard evidence; the meat you can sink your teeth into. It is also the only thing left if you have no survivors, witnesses, or electronic record. Invariably, you will need to have aircraft parts analyzed by trained engineers, and those results interpreted by a trained investigator, before you obtain any reliable information. Virtually every part of the aircraft must be considered "guilty until proven innocent" since anything man-made can fail. Some of the more common and more easily retrieved components are listed below. These components also tend to provide enough information to rule out major systems or direct your investigation to a more specific cause.

NOTE

Squadron support in the form of systems experts is essential at the mishap site. These people will be called on to identify components and component fragments. They must have a thorough working knowledge of, and ready access to, applicable illustrated parts breakdown (IPB) documents. IPBs should be on site if at all possible. Realize that a crash can change the shape, size and color of a component. Your chosen experts should not expect to find components that appear ready for issue.

Flight Control Actuators. Are the control surfaces all accounted for? How were they deflected at impact? Were the actuators working? Answers to these questions provide a good starting point when all you can do is scratch your head. By recovering all of the actuators, you can make an initial assessment of the health of the hydraulic system and flight control system (to include the actuators, themselves). Table 4 provides a complete list of actuators.

If the impact created witness marks, they can be correlated to actual degrees of deflection. Remember that actuator rods can and do move after initial impact, during salvage, and after handling, therefore, actual rod position is not considered reliable information. Degrees of deflection may answer the following questions: Was the aircraft maneuvering (Pilot incapacitation? Distraction?) Were the actuators working (Loss of control? Mech reversion? Compound emergency? FCES problem? Hydraulic problem?) What was the magnitude of deflection (Aircraft airspeed, AOA and G at impact?)

Leading Edge Flap Asymmetry Control Brake (2)	L/R Stabilator Actuator (2)
Leading Edge Flap Hydraulic Drive Unit (1)	L/R Aileron Actuator (2)
Leading Edge Flap Overtravel Stop (2)	L/R Rudder Actuator (2)
L/R Trailing Edge Flap Actuator (2)	

Table 4. F/A-18 Actuators Capable of Providing Control Surface Information

Other Actuators. You may want to look at other actuators such as landing gear, tailhook, and other ancillary equipment, depending on the nature of the mishap. Were they deployed when they shouldn't have been? Were they not deployed when they should have been? Do their positions match the cockpit selections or indications? Did they inadvertently deploy?

Standby Instruments. Standby instruments may provide you with aircraft attitude, airspeed, VSI and altimeter setting. You should not place a lot of confidence in these clues unless they can be corroborated with other strong evidence. Witness marks may have occurred after the initial impact. The standby gyro may have precessed. On the other hand, they may provide the first clue that there was a problem with the pitot static system. Did the ADC degrade? If so, did it degrade the INS/ platform?

Engines. Perhaps more than any other component, engine information requires multiple sources of confirmation. In reality, just about every engine component has a story to tell. This paper is not long enough to list potential culprits if the engine was the cause of the mishap. Some of the more obvious engine and throttle linkage components that can help complete the picture include fan and high pressure compressor variable stator actuators, shafts, blades, nozzles, main fuel control, power lever control, throttle boost actuators and throttle quadrant.

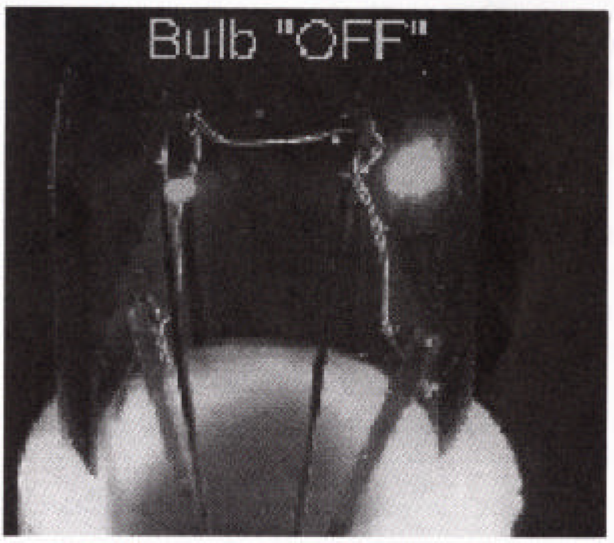
Questions you need to answer include: Were the engines operating? Were they functioning properly? Any evidence of fire outside the casing? Where was the power set? Mechanical evidence combined with reasonable estimates of airspeed, altitude, and temperature will usually yield a good estimate of engine RPM. The answers to the other questions may be found by examining the other components.

Control Stick Position. Unlike other aircraft, stick position in the F/A-18 does not equal control position. You may want to determine stick position and correlate it to control positions if aircraft control is being considered. Chances of getting witness marks from a control stick are extremely remote, therefore, your best chance of determining stick position is through the longitudinal and lateral feel trim actuators. These will need to be X-rayed to determine linear variable differential transformer (LVDT) positions. The position of the LVDTs can then be correlated to a stick position.

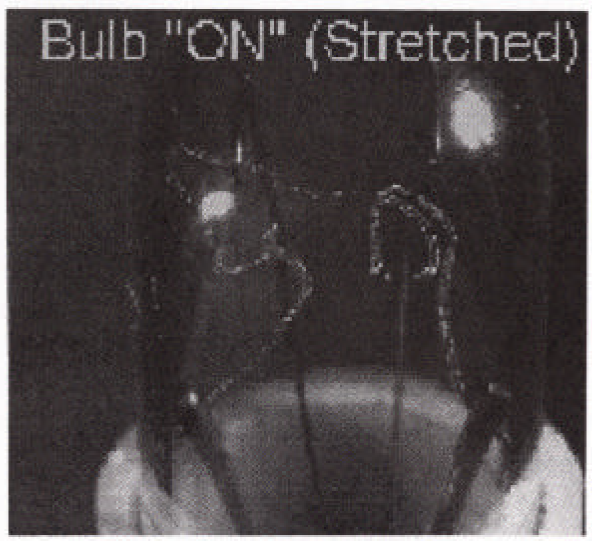
Hydraulic Components. The F/A-18 hydraulic system has spent its share of time in the limelight. There will be many mishaps where it must be ruled out before you can concentrate on other potential causes. Recovering hydraulic reservoirs, installed filters, switching valves and actuators will help you evaluate the system. Questions to answer include: Was there a leak? Was the system running hot? Was it operating in a degraded mode? Were the switching valves operating properly? The reservoir? The actuators?

Electrical Components. The health of this electric aircraft's electrical system is a vital clue. Components can be bench-tested if they are recovered undamaged. In the event of total destruction, you must find some evidence that the electrical system was functioning. A HUD tape or ATC recording may indicate radio or IFF transmission right up to impact. Filament stretching in light bulbs is a good indication of electrical power at impact. You may even be able to determine which busses were functioning. Evidence of DC power on the left or right 28V DC bus is a good indication that AC power was also available. Good sources of evidence of 28V DC power include: Anti-skid, approach indexer lights, external lights, ILS, speedbrake, internal lights, Comm 2, and video tape recorder.

Lights. Incandescent light bulbs produce light by heating a thin metal filament until it glows white hot. A filament in this condition exhibits ductile failure characteristics, therefore, if it is illuminated at impact, it will stretch and distort instead of breaking. The time it takes for filaments to change from ductile to brittle is measured in hundredths of a second. Because of this, analyzing light bulbs may provide answers to questions like: Did the aircraft have electrical power? Which busses were powered? Was a fire light on? Any other warnings, cautions, or advisories lit? Was the Master Caution light on? Be careful with this last one since a caution may exist but the master caution light may have been deselected. Master Caution light on is a good indication that a caution existed, but master caution off tells you very little. The illustrations in Figure 23 provide examples of filament analysis, which can even be accomplished at the crash site with larger bulbs.



Broken or intact filament
indicating light OFF at impact



Stretched and distorted filament
indicating light ON impact

Figure 23. Light Bulb Filament Analysis

Recent breakthroughs have made it possible to assess radar altimeter warning functions by analyzing the lights in the upfront control panel. Illumination of :**RALT** in the upper right option window is a good clue that you had electrical power and that the warning system was functioning as advertised. It is possible to determine what may have been happening in the cockpit in certain scenarios. For instance, you may conclude that the pilot was directing his attention to communications tasking if the UFC windows provide indications of radio frequency and display options. The Naval Safety Center has translational maps for converting lit bulb position to display readout.

CONCLUSION

If something is of human design, someone will be able to explain how it works (or doesn't work). Don't accept a "Beats the heck out of me" response. Temper any explanations with other evidence. Is it consistent? Is it logical? Is it feasible? A single piece of evidence should be treated with little confidence. Additional, independent corroborating evidence is required to increase confidence. Ideally, you should obtain three pieces of evidence from different sources before drawing any conclusions. For example, a shallow crater, debris scattered a mile downrange, and a standby airspeed indicator witness mark at 450 knots gives a high degree of confidence that the aircraft impacted at a shallow angle and high airspeed.

I was going to close this paper with a few rules of thumb, but deliberately decided against it. Why? Because, in the immortal words of one of the most famous investigators of all time, "It is unwise, my dear Watson, to speculate in advance of the facts. Invariably, it biases the judgement." Always remember, you are conducting an investigation, not a speculation. Good luck!

Each clue is a puzzle piece.
By itself, it is nothing.
With other pieces, it is a picture.

- Anonymous

Handling the DFIRS

1. Assess the condition of the DFIRS. If central (metal) portion is damaged - STOP. Get technical/contractor assistance.

2. If central portion is in good condition, remove DFIRS to an electrostatic discharge (ESD)/HERO safe environment, then remove coverplate.

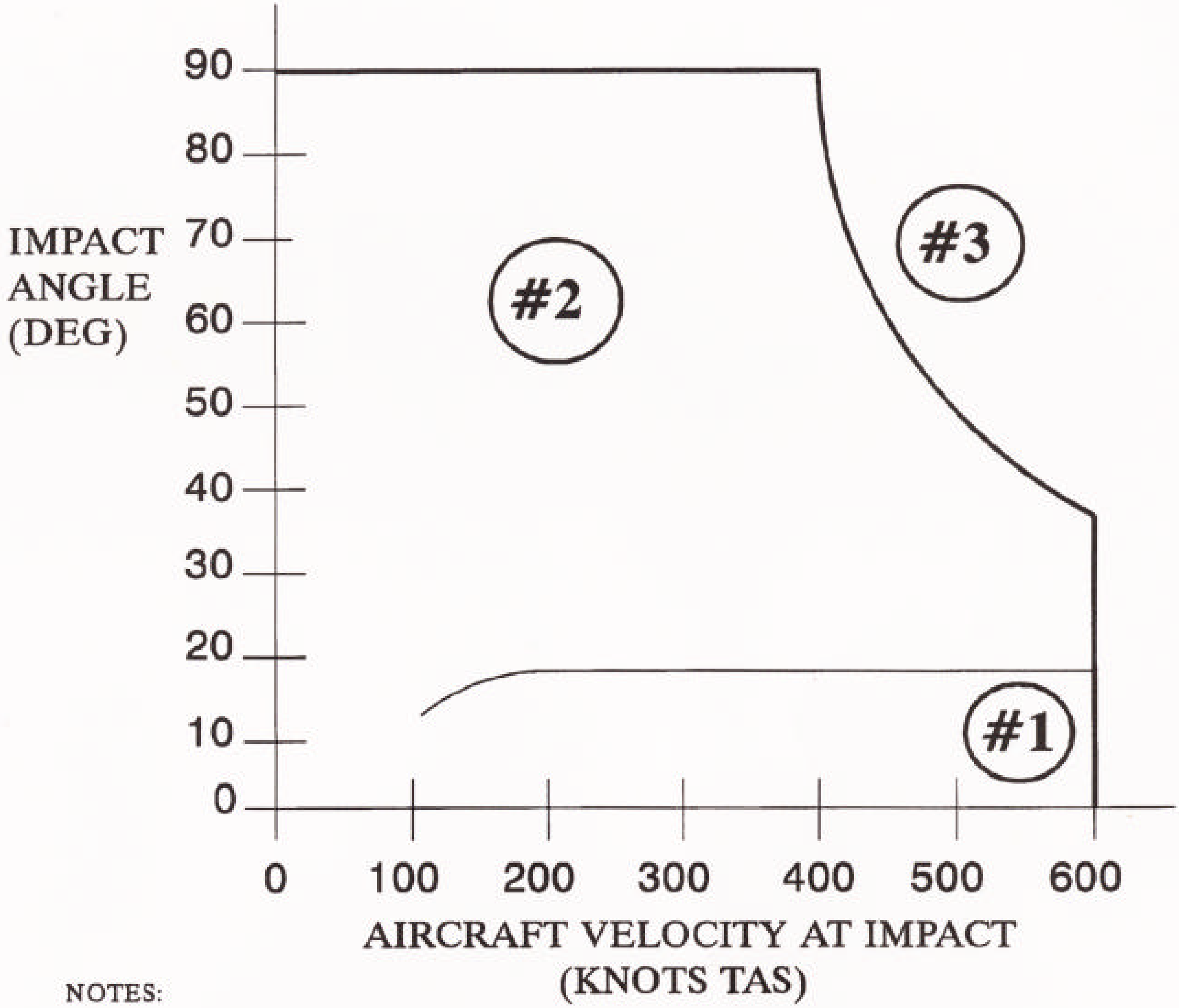
3. Under the coverplate lie three boxes wrapped in silver heat blankets, and a styrofoam filler block.

4. Remove the four components. Using ESD precautions, remove silver heat blankets. You will find two gray boxes and a lithium battery. CUT THE WIRE FROM THE BATTERY. The ELT is now disabled.

5. Compare the two gray boxes. One has wire leads and a coaxial cable connection. The other has only wire leads to a serial port-type connector. The gray box WITHOUT the coaxial cable is the memory unit. Again, use all ESD precautions. Use appropriate tools to unscrew and remove the connector from the memory unit.

6. Store memory unit in an ESD ziploc bag. Safeguard until the Safety Center Mishap Investigator arrives to take custody.

DFIRS Deployment Envelope



NOTES:

1. Projected deployment areas depicted as follows:
   #1 DFIRS likely to be deployed and recovered.
   #2 DFIRS likely to be deployed, may not be recovered.
   #3 DFIRS may not be deployed.

2. Deployment area definition based on:

   a. Aircraft upright, nose down, wings level.
   b. Flat, planar impact surface.
   c. Aircraft velocity vector coincident with longitudinal axis.

3. Impact angle is defined as the angle between the aircraft longitudinal axis and impact surface.