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W7711-007675

Defence and Civil Institute of Environmental Medicine

Contract Report
DCIEM CR 2001-034
July 2001

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Abstract

The Directorate of Aerospace Requirements (**DAR 5**) is in the process of upgrading the CF-18A to maintain its technical currency over the next 20 years. Part of this upgrade will be the inclusion of a Helmet Mounted Display (**HMD**) with a Night Vision Imaging System (**NVIS**) capability.

As the use of HMD and NVIS technologies in the CF-18A represent new ways of performing old tasks, it was determined essential to establish how this technology would be used and to document the flow of information in the cockpit.

The Defence and Civil Institute of Environmental Medicine (**DCIEM**) has undertaken an investigation of HMD and NVIS technologies in order to provide DAR with advice on human factors issues that may arise from their use in the CF-18A. The investigation will focus on the Air to Ground role of the CF-18A as this is the most likely role in North Atlantic Treaty Organization (**NATO**) and coalition activities. The Air to Ground role of the CF-18A also presents a high cognitive demand on the skills and abilities of the pilot.

This report provides a detailed description of the assumed air vehicle and presents a mission scenario based on a defined CF-18A equipment suite and the employment of the CF-18A in an operational Air to Ground environment. The results of the Human Factors (**HF**) Analysis will be used to assess the impact of HMD and NVIS technologies and the flow of information in the cockpit of the Modernized CF-18A.

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Executive Summary

This report is one of two Human Factors Engineering (**HFE**) reports being prepared for the Defence and Civil Institute of Environmental Medicine (**DCIEM**) in support of the Directorate of Aerospace Requirements (**DAR** 5) of the Department of National Defence (**DND**). The objective of the Human Factors Engineering System Analysis of CF-18A Helmet Mounted Displays (**HMDs**) is to establish a baseline of information that will be used to assess the impact of HMD and Night Vision Imaging System (**NVIS**) technologies and the flow of information in the cockpit of the Modernized CF-18A.

This report documents the findings of the HFE Analysis of the CF-18A in an Air to Ground Role in accordance with the Statement Of Work (**SOW**), Public Works and Government Services Canada (**PWGSC**) Solicitation No. W7711-007675/A.

The analysis follows the general principles and guidelines for HFE as described in MIL-HDBK-46855 "Human Engineering Program Process and Procedures". Specifically, this report addresses the objectives of the SOW to develop a detailed description of the assumed air vehicle and presents a mission analysis based on a defined CF-18A equipment suite and the employment of the CF-18A in an operational Air to Ground environment.

This Mission Analysis Report includes: a description of the assumed Air Vehicle, a Composite Mission Scenario and identifies potential Measures of Effectiveness.

For the purposes of this study, the assumed air vehicle will be the post CF-18A modernization aircraft configuration, avionics sub-systems, weapons systems and Defensive Electronic Warfare Suite (**DEWS**). The assumed air vehicle will incorporate the CF-18A Incremental Modernization Program (**IMP**) and Capital Program initiatives described in the following subsections. Although the CF-18A HMD will be an integral part of the CF-18A modernization, for the purpose of establishing an initial reference database, it will not be included as part of the assumed air vehicle.

The Composite Mission Scenario will describe a hypothetical Air to Ground mission that would be representative of a challenging engagement using modern weapons and threats consistent with the CONcept of OPerationS (**CONOPS**) for the CF-18A.

The potential Measures of Effectiveness (**MOEs**) identified will be used in assessing system design.

The results of the HFE Analysis will also include: a functional/goal decomposition, a goal allocation analysis, operational sequence diagrams, a critical goal analysis and an information flow analysis. This information will be presented in a second report, Document Number 42-014-002.

As a separate task, the results of the system analysis will be entered into **IPME** to support future modelling activities.

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Acknowledgements

The Department of National Defence (DND) entered into a contract with BAE SYSTEMS CANADA INC. (**BSC**) to conduct a Human Engineering Study of the APG-65 Radar interface in the CF-18 aircraft. Specifically, Director Science and Technology, Air (**DSTA**) sought to address Air Force requirements for a low-cost means to evaluate the integration of a new generation Head-Down Display (**HDD**) for the CF-18 aircraft. This first activity was undertaken by BSC is to conduct a traditional human engineering mission analysis to investigate and document all aspects of CF-18 employment in an operational environment. The purpose of this analysis was to develop a basis on which to document HDD requirements of the APG-65 Radar system.

The Mission Analysis Report is based upon this initial study conducted by BAE SYSTEMS CANADA INC. (BSC) and includes much of the content contained within the CF188 APG-65 RADAR HUMAN FACTORS ENGINEERING STUDY MISSION ANALYSIS REPORT published 31 May 2000 (BAE Document Number 1000-1205, Contract Serial Number W7714-9-0281).

INTRODUCTION

GENERAL

The Directorate of Aerospace Requirements (DAR 5) is in the process of upgrading the CF-18A to maintain its technical currency over the next 20 years. Part of this upgrade will be the inclusion of a Helmet Mounted Display (HMD) with a Night Vision Image System (NVIS) capability.

As the use of HMD and NVIS technologies in the CF-18A represent new ways of performing old tasks, it was determined essential to establish how this technology would be used and to document the flow of information in the cockpit.

The Defence and Civil Institute of Environmental Medicine (DCIEM) has undertaken an investigation of HMD and NVIS technologies in order to provide DAR with advice on human factors issues that may arise from their use in the CF-18A. The investigation will focus on the Air to Ground role of the CF-18A as this is the most likely role in NATO and coalition activities. The Air to Ground role of the CF-18A also presents a high cognitive demand on the skills and abilities of the pilot.

The purpose of the Human Factors Engineering Analysis of the CF-18A HMD is to communicate the findings of the human factors analysis of the CF-18A in an operational Air to Ground role. This information will be presented in two parts: a Mission Analysis Report and a System Analysis Report. When combined these two reports will establish a baseline of information that can be used to assess the implications of employing HMD and NVIS technologies in the CF-18A.

The results of the HFE Analysis will establish a baseline of information that can be used to assess the impact of HMD and NVIS technologies and their impact on the flow of information in the cockpit of the Modernized CF-18A.

As a separate task, the results of the HFE Analysis will be entered into IPME to support future modelling activities.

PURPOSE

The purpose of the mission analysis report is to provide a detailed description of the assumed air vehicle and to present a mission scenario based on a defined CF-18A equipment suite and the employment of the CF-18A in an operational Air to Ground environment.

This Mission Analysis Report is the first of two documents and will include: a description of the assumed Air Vehicle and its capabilities as it will be modernized through the Omnibus CF-18A Incremental Modernization Project (CF-18A IMP) to provide a safe, reliable and effective fighter weapons platform; a Composite Mission Scenario that will describe a hypothetical Air to Ground mission that would be representative of a challenging engagement using modern weapons and threats consistent with the CONcept of OPerationS (CONOPS) for the CF-18A; and identify the potential Measures of Effectiveness (MOEs) to be used in assessing system design.

The mission analysis report is based on the defined CF-18A equipment suite and its employment in an Air to Ground operational environment. The specific areas relevant to these issues are documented in the portion of this report detailing the structure of the assumed air vehicle and the mission conduct. This report concludes with the "composite mission scenario" incorporating the hierarchical goal analysis decomposed to the fourth level.

The results of the System Analysis Report will include: a functional/goal decomposition, a goal allocation, a critical goal analysis, operational sequence diagrams, and an information flow and processing analysis. This information will be presented in the Final Report, Document Number 42-014-002.

OBJECTIVES

In order to achieve the purpose described in Subsection 1.2 above, the following objectives were identified:

a. review the existing CF-18A documentation as it relates to the aircraft's employment in an operational environment;

b. develop a detailed description of the capabilities of the assumed air vehicle represented in the CF-18A incremental modernization and associated capital procurement programs, as they relate to CF-18A employment in Air to Ground Operations;

c. conduct a mission analysis based on a defined CF-18A equipment suite and operational context for the CF-18A;

d. develop a composite mission scenario based on the mission analysis to reflect operational employment of the CF-18A in a tactical Air to Ground Operations; and

e. develop potential Measures of Effectiveness that can be used to assess system design.

SCOPE

The mission analysis report may be read as a standalone analysis of the employment of the CF-18A in an operational Air to Ground role. The mission analysis report provides the Project Manager the means to confirm and comment on the direction of the study prior to commencement of the detailed HFE Analysis of the Air to Ground mission segment.

REPORT ORGANIZATION

The report is organized into six sections as follows:

a. Section One – Introduction. Section One provides background information, the purpose and objectives of the analysis, and the scope and organization of the report.
b. Section Two – Operating Concept. Section Two provides an overview of the strategic/tactical environment, DND strategic direction applicable to CF-18A operations, and CF-18A pilot training and standards.
c. Section Three – Assumed Air Vehicle. Section Three provides a description of the modernized CF-18A through the Incremental Modernization Project (IMP), including avionics and weapons sub-systems.
d. Section Four – Composite Mission Scenario. Section Four consists of the composite mission scenario.
e. Section Five – Measures of Effectiveness. Section Five identifies the potential Measures of Effectiveness to be used in assessing system design.
f. Section Six– References. Section Six documents a listing of references used in producing this report.

Annex A – Glossary of Terms and Acronyms. Annex A provides a listing of terms and acronyms used throughout the report.

OPERATING CONCEPT

STRATEGIC/TACTICAL ENVIRONMENT

Over the past decade, Canada has deployed armed forces in support of operations ranging from preventative deployment and post-conflict peace building to classical peacekeeping, peacemaking and peace-enforcement. For the foreseeable future, although there is no credible threat of a deliberate military attack on Canada, conflict will continue to be a factor in international relations and the Canadian Forces (**CF**) will likely continue to be called upon to conduct operations across the spectrum of conflict. Canada will likely continue to pursue its defence objectives in combination with friends and allies through an array of treaties and alliances, such as the North American Air Defence (**NORAD**) security arrangement with the United States (**US**), and in combination with membership in the United Nations (**UN**) and North Atlantic Treaty Organization (**NATO**).

DND STRATEGIC DIRECTION APPLICABLE TO CF-18A OPERATIONS

The CF-18 constitutes the primary combat capability of the air force and is Canada's only means of exercising active control over unwanted activities in domestic and international airspace. [Reference17]. DND has directed that the CF must evolve to meet future challenges with modern, operationally capable, multi-purpose combat forces maintained at appropriate levels of readiness [Reference 18]. To that end, DND has undertaken an investment in technological innovations that will ensure that the CF remains interoperable with Canada's allies. Modernization of Canada's CF-18A fleet by DAR 5 is based on three separate but related project categories intended to provide a safe, reliable and effective fighter weapons platform for the future: the CF-18 IMP, the Weapons Projects and the Associated Projects. The CF-18A modernization phase 1 will integrate and install major new avionics components, including mission computers, radar, radios, an identification friend or foe interrogator/transponder, displays, a stores management system, night vision system, Operational Flight Program (**OFP**) and a global positioning system. Phase 2 will modernize the self-protection suite, install a data link and Helmet Mounted Display (HMD) for off boresight weapon and sensor employment. Weapons projects include an advanced multi-role infra-red sensor, advanced Precision Guided Munitions (**PGMs**) and new short range and medium range air-to-air missiles. The strategic environment is one in which the CF-18A must be capable of world-wide employment and operations under nuclear, biological, chemical, day/night and all weather conditions.

A no-warning mid-to-high intensity conflict/battlefield is not considered a viable threat scenario [Reference 1]. Today's threat is viewed as a mid-intensity conflict such as that posed by the Persian Gulf War, Bosnian relief effort or the Kosovo operation.

Additionally, international peacekeeping, peacemaking and peace enforcement commitments require the CF-18 weapons system to be effective, survivable and interoperable in a wide range of operational environments. Accordingly, the CF-18 will be flown under all weather conditions, during 24 hours a day, 7 days a week (**24/7**) operations and could employ a wide range of air-to-air and air-to-surface munitions. In all roles, interoperability with coalition, host or support nations is essential.

Rapid technological change is having a major effect on military operations, communications, equipment, doctrine and infrastructure, representing a significant challenge for the CF. Russian built equipment is abundant and in certain aspects (range, reaction time, lethality), is still considered as being amongst the world's most advanced systems. Global economics, particularly in the Former Soviet Union (**FSU**), have seen a marked increase [Reference 1] in the development, production and distribution of advanced weaponry to countries and organizations around the world that could not previously obtain these technologies. The proliferation and un-monitored distribution of these systems have significantly increased the threat to the CF and the CF-18 fleet in particular.

TACTICAL OPERATIONAL ENVIRONMENT

Potential adversaries' weapon systems and defences continue to evolve as the CF-18 ages. Many air forces continue to modernize their aircraft fleets with new variants of existing Russian Original Equipment Manufacturer (**OEM**) airframes, such as the MIG-29, SU-27 and SU-35. The CF-18 potential adversaries currently employ fighter aircraft equipped with helmet mounted sight systems and advanced off boresight air-to-air missiles that provides a substantial tactical advantage. Currently, the CF-18 does not have an effective High Off Boresight System (**HOBS**) and is equipped with missiles that are restricted in off boresight launch.

The Soviet-built AA-11 ARCHER Infra-Red (**IR**) guided air-to-air missile was introduced in 1984 and has been exported widely as one of the most capable close-in aerial combat missile in the world. It is currently used in conjunction with a helmet mounted sight system that allows high off boresight targeting and launch of the Archer. Several countries equip their MiG-29 fighter fleets with the AA-11 advanced air-to-air missile: Commonwealth of Independent States, Cuba, Iran, Iraq, Yugoslavia, Syria and North Korea. In addition, Israeli Aircraft Industries have developed, manufactured and exported to undisclosed countries a comparable IR air-to-air missile, the PYTHON IV missile.

The AA-10C ALAMO Semi Active Radar (**SAR**) guided air-to-air missile, as well as the AA-12 ADDER active missile have been introduced into operations in the FSU. These missiles are vastly superior to the CF-18's AIM-7 SAR guided missile in range, speed, Electronic Counter Counter Measures (**ECCM**) and multi targeting capability. As a result, the CF-18 is often required to use defensive reactions, turning away from the threat, unable to use it's weapon systems. The introduction of a HMD will give the CF-18 the opportunity to use its HOBS from a defensive reaction position.

There are dozens of countries that have access to and employ large numbers of vastly different, lethal Surface-to-Air Missile (**SAM**) systems. Many of these countries possess the US and FSU built state-of-the-art missile systems, while others produce indigenous systems or have reverse-engineered copies of other weapons systems. The current CF-18 arsenal of air-to-surface sensors and weapons requires the CF-18 pilot to perform targeting head-down tasks and weapons release at relatively close ranges to the target. The CF-18 pilot is therefore more vulnerable and the task to avoid or evade these SAMs is more difficult.

In order to survive and effectively engage these threats, the CF-18 needs to be equipped with a HMD [Reference 5]. The CF-18 HMD will become a critical component of the CF-18 sensors and weapon systems both in the air-to-air and in the air-to ground roles.

CF-18 FIGHTER PILOT TRAINING DIRECTIVE 2000

CF-18 tactical fighter pilots standards and training are designed to ensure aircrew are mission ready and capable for combat air operations anywhere, anytime. The training requirements for CF-18 operations are defined in the CF-18 Fighter Pilot Training Directive (**FPTD**) 2000 [Reference 5].

FPTD 2000 quantifies the Yearly Flying Rate (**YFR**) investment needed to ready CF-18 tactical fighter pilots for multi-role combat air operations to defend Canada and North America, as well as to contribute to international peace and security.

CF-18 Fighter Pilot Training Standards

There are three components to the skills and knowledge required of a multi-role CF-18 fighter pilot to be ready for combat air operations (i.e. Force Employment):

a. Pilot Skill and Knowledge Element (**PSKE**)

b. Pilot Skill and Knowledge Level (**PSKL**)

c. Pilot Tactical Leadership Level (**PTLL**)

Pilot Skill and Knowledge Element and Pilot Skill and Knowledge Level

The skills and knowledge of a CF-18 fighter pilot are divided into 9 different elements. Within each of the 9 PSKEs exist varying levels of ability. As a pilot's training and experience increase, his PSKL within each element should also increase.

Pilot Tactical Leadership Level

The PTLL indicates the tactical status, or Flight Lead status, of a CF-18 fighter pilot. The PTLLs range from a graduate of the CF-18 Operational Training Unit (PTLL1) to a Mass Attack Lead (PTLL5). For an increase in lead status (increase in PTLL), there would be an associated increase in PSKL in most of the 9 Pilot Skill and Knowledge Elements.

COMBAT CAPABILITY LEVELS

Two multi-role combat capability levels have been defined:

a. **Baseline.** Permits sustained combat air operations against a "modern air force." At the tactical, level a "modern air force" equates to a "medium threat" environment. In terms of level of effort, this requires the employment of large, multi-national force packages operating primarily at medium altitudes either during the day or night. Accordingly, CF-18 aircrew must be capable of conducting all altitude, all weather, day and night air-to-air missions and employing conventional and precision-guided munitions from medium altitude, day or night air-to-surface missions. Pilots retain a basic knowledge and familiarization in low altitude Air-to-Surface Tactics (**AST**). Combat Ready (**CR**) status and tactical leadership upgrade training (Element Lead, Section Lead, etc.) is sustained at this baseline level of combat capability.

b. **Enhanced.** An enhanced combat capability extends the capability of the baseline fighter pilot to conduct counter/anti-surface operations against a "modern air force" in the much more demanding low altitude environment. At the tactical level, a "modern air force" equates to a "high threat" environment. It typically takes three months for the baseline capable fighter pilot to achieve this enhanced combat capability.

INFLUENCE OF WEAPONS SYSTEMS UPGRADES ON AIRCREW STANDARDS AND TRAINING

The most recent review of FPTD 2000 was triggered by the integration of a Precision Guided Munitions (PGM) capability within the CF fighter force and re-assessed based on the subsequent direction embedded within the Chief Air Staff Planning Guidance 2000 (**CAS PG 2000**). The goal of the review was to re-orient the Air Force in terms of readiness levels, equipment, personnel, training and types of operations the Air Force will be expected to undertake in the new millennium. The impact on CF-18 operations has been an increase in the overall scope of CF-18 combat air operations training requirements. There has been a shift in emphasis within air-to-surface or Offensive Air Support (**OAS**) tactics training from day, low altitude flight profiles to medium altitude, day and night flight profiles. Employment of the CF-18 in the air-to-air or Counter Air Operations tactical environment has not been markedly influenced by these changes.

With the introduction of the "Modernized CF-18A", it is anticipated that the entire spectrum of missions performed will be affected, and the training requirements will be reviewed accordingly.

ASSUMED AIR VEHICLE

GENERAL DESCRIPTION

The CF-18 is a single-seat/piloted, twin tailed, twin engine, multi-role combat aircraft. It is a Canadian derivative of the Fighter Attack (**F/A**)-18 aircraft, originally designed to replace lightweight United States Navy (**USN**) and United States Marine Corps (**USMC**) ground attack and air superiority fighters of the day. The CF inventory of CF-18 aircraft stands at 122; it is inclusive of a number of CF-18A as well as, a two-place fighter/attack trainer version, CF-18B. The CF-18 has nine external weapons stores points that can be configured with a mix of air-to-air and air-to-surface weapons and external fuel tanks. All external stores can be jettisoned by activation of either the emergency or selective jettison systems.

The CF-18 fleet, based on 1970s technology, was acquired by Canada in 1982 with an Estimated Life Expectancy (**ELE**) of 2003. Growth / modernization potential was an important factor in selecting the CF-18. The requirement to modernize CF-18 systems and extend the initial airframe life was recognized from the outset and "mid-life" fleet modernization was originally planned to commence in the early 1990s. The CF-18 fleet has aged to a point where a number of avionics systems and components have reached obsolescence and are becoming increasingly difficult and expensive to support [Reference 5].

As a result of these realities, the CF-18's relative qualitative and quantitative abilities against increasingly capable threats are eroding and will reach an unacceptable level in the very near future. These deficiencies will continue to have an impact on Canada's ability to field a supportable, interoperable, survivable and operationally capable fighter force. To mitigate these deficiencies the CF-18 will be modernized through the Omnibus CF-18 Incremental Modernization Project (CF-18 IMP) to provide a safe, reliable and effective fighter weapons platform, through to the end of the CF18s ELE of the 2017 – 2020 timeframe [Reference 5].

Priorities for the CF-18 IMP are as follows:

a. **Modernization of Obsolete Systems.** The CF-18 IMP aims to alleviate current and future parts unavailability problems through the modernization of selected, economically unsupportable and obsolete systems;

b. **Rectification of Serious Operational Deficiencies.** Through the modernization process, the CF fighter force will retain its relative capabilities with respect to potential threats and evolving technologies. The CF-18 IMP will update CF-18 hardware and software necessary to ensure a survivable and viable fighter weapons platform capable of performing the government assigned roles and missions; and

c. **Integration of Related Projects.** Modern, single seat fighter aircraft are capable of multi-role operations, primarily due to the simplicity of the man-machine interface and total systems integration. CF-18 IMP must be fully compatible with all related CF-18 capital projects.

For the purposes of this study, the assumed air vehicle will comprise the post CF-18A modernization aircraft configuration, avionics sub-systems, weapons systems and Defensive Electronic Warfare Suite (DEWS). The assumed air vehicle will incorporate the CF-18A Incremental Modernization Program and Capital Program initiatives described in the following subsections. Although the CF-18A HMD will be an integral part of the CF-18A modernization, for the purpose of establishing an initial reference database, it will not be included as part of the assumed air vehicle. The goals and information requirements of the pilot are expected to remain the same irrespective of the display technology used, although some of the lowest level pilot activities required to achieve desired goals my differ in an HMD equipped CF-18A.

Airframe

The aircraft is comprised largely of composite materials. The CF-18 has an approximate wingspan of 40 feet, a length of 56 feet and a height of 15 feet at the top of the twin vertical stabilizers, which are angled outboard 20° from the vertical. Empty, the aircraft weighs 23,400 pounds; when configured for operational employment, with external fuel tanks and weapons, this weight can double.

Engines

Two General Electric F404-GE-400 turbofan engines with afterburner power the CF-18. The military power thrust of each engine is 10,700 pounds; with afterburner the thrust is in the 16,000-pound class, giving the aircraft a 0.97 thrust to weight ratio in the air-to-air configuration, and a 0.70 thrust to weight ratio when loaded with a typical air-to-surface configuration. The aircraft is capable of Mach 2.0 flight.

Fuel System

Fuel is stored internally in four interconnected fuselage tanks and two wing tanks. The CF-18 can be configured with up to three 1250-litre external fuel tanks on the centreline and inboard wing station pylons. Internal fuel transfer is accomplished through two airframe-mounted accessory drive motive-flow/boost pumps; external fuel transfer requires engine bleed-air pressure. For survivability, the internal tanks contain fire/explosion protection, are self-sealing and fuel lines are routed inside the tanks, where possible. An unrefuelled operational mission is normally two hours duration; however, the CF-18 is capable of probe and drogue, air-to-air refuelling.

Electrical Power

Two Alternating Current (**AC**) generators provide primary power to CF-18 systems. Two transformer-rectifiers, two batteries and a single battery-charger transformer rectifier unit complete the electrical power supply system. If one transformer-rectifier fails, the other is capable of powering the entire Direct Current (**DC**) system. Additionally, either generator is capable of supplying all AC electrical requirements.

Flight Controls

The CF-18 employs a highly survivable, quad-digital, control-by-wire primary flight control system, with fully integrated control surfaces. Primary CF-18 flight controls are the ailerons, twin rudders, differential/collective leading edge flaps, differential/collective trailing edge flaps and differential/collective stabilators. A secondary flight control, the speed brake, is mounted between the vertical stabilators. Flight (surface) control inputs are provided by two flight-control computers, directed through pilot stick and rudder inputs as well as a series of internal sensors to determine optimum aircraft response. The flight-control computers provide inputs to hydraulic actuators to position the control surfaces. The flight control computers schedule control surface deflection and simulate appropriate aerodynamic feedback to the pilot's stick and rudder pedals through spring cartridges. For survivability, the flight-control computers have four-channel, fly-by-wire, redundancy. Flight-control computer cooling is achieved by avionics air or by ram air in an emergency.

Hydraulic System

Hydraulic power is supplied to the flight control actuators by two separate but identical hydraulic systems, powered in turn by pumps mounted on each airframe mounted accessory drive unit. Hydraulic pressure output is maintained at 3000 pounds per square inch (**psi**).

Autopilot

The pilot-commanded autopilot mode consists of attitude hold (retains the current attitude of the aircraft regardless of heading or altitude), heading select, barometric altitude hold, radar altitude hold and coupled steering (to a designated waypoint or navigation aid) modes.

Flight Instruments

The CF-18 incorporates a series of other conventional avionics instruments/displays and warning panels. The altimeter, airspeed and rate of climb standby flight instruments receive static and pitot pressure, as applicable, from two pitot-static tubes mounted under the nose on either side of the CF-18. Each tube contains one pitot source and two static sources. The CF-18 also incorporates a self-contained, electrically driven gyro-horizon-type standby attitude indicator and a conventional aircraft magnetic compass. The CF-18's radar altimeter consists of a receiver-transmitter, antennas and a height indicator. It operates by generating electromagnetic energy pulses to the ground, receiving and processing the returned signal, and displaying the result as radar altitude on the Heads-Up Display (**HUD**).

Warning/Caution/Advisory

CF-18 instrumentation includes a light and display system to give visual indication of normal aircraft operation and system malfunctions. A master caution light and tone are activated in the event of caution light or display illumination. For certain critical warnings or cautions, a voice-alert provides a clear concise text message to the pilot headset. The voice alerts are remarkably distinct and unmistakable.

Ground Proximity Warning

The CF-18 uses a safety advisory system to provide visual and aural cues to the pilot in the event of a high probability of Controlled Flight Into Terrain (**CFIT**). The Ground Proximity Warning System (**GPWS**) provides warnings of potentially unsafe manoeuvring flight conditions (excessive angle of bank, sink rates, gear-up landing, set low altitude violations). GPWS uses radar altimeter, air data computer and Inertial Navigation System (**INS**) inputs. In the event of CFIT, a HUD recovery arrow indicating the correct direction to recover the aircraft and voice warnings are provided to the pilot.

Lighting

The CF-18 Lighting will be modified to be compatible with Night Vision Imaging Systems (NVIS).

Modified interior aircraft lighting. Interior aircraft lighting consists of consoles, instruments, utility, emergency instrument, engine instrument, console floodlighting, and warning and caution lights. While flying with Night Vision Goggles (**NVGs**), the aircrew view the outside world through the goggles, but look beneath them to view all cockpit displays and instruments, with the exception of the HUD. The interior lighting will be modified to conform to the MIL-L-85762A lighting standard, providing sufficient daylight readability so that all lighting is easily readable under direct sunlight conditions as well as providing sufficient illumination so that the instruments can be easily read while night flying both with and without night vision goggles. The interior lighting will not adversely affect the performance of the NVGs in any manner while performing night operations. Critical emergency lighting will be designed to minimally affect the NVGs when illuminated. The emergency lighting must get the pilot's attention, but not adversely affect the NVGs such that they fail to provide the aircrew with the required information. The interior lighting must seamlessly transition to any of the current missions that are being flown in the CF-18, day and night. It is essential that the lighting not inhibit the aircraft from being flown in any regime, including low level.

Modified exterior lighting. Exterior aircraft lighting includes position lights, formation lights, strobe lights, and a combination landing and taxi light. Two modifications will be included: friendly and covert lighting. The exterior lighting will contain "friendly" modified lighting as its primary mode. This lighting will be visible to the naked eye, yet not adversely affect the NVGs. It also conforms to Transport Canada and FAA guidelines governing brightness, colour and coverage for external lighting; the modified jet needs to be seen exactly as expected, eliminating any confusion that could arise from the use of non-conventional lighting. The exterior lighting will contain "covert" modified lighting as its secondary mode. This lighting must not be visible to the naked eye, yet be easily seen with the aid of NVGs. This lighting will be designed in order to maximize its visibility to friendly formation members, yet minimize its visibility to the enemy. Exterior lighting will contain both a brightness rheostat and a capability to program flash patterns. Both of these functions will be included in the friendly and the covert systems; the brightness rheostat will give the formation members the option of using the minimum brightness to fly a visual formation, which will minimize light that could potentially be seen by the enemy while the programmable flash patterns will allow each formation member to program a distinctive flash pattern into the exterior lights, making the lights stand out from stars, cultural lighting, and other point light sources, and make each aircraft recognizable within the formation. The exterior lighting will be visible, in the covert mode, from 20 nautical miles (**nm**). An additional, high powered, covert lighting source is therefore required allowing visual identification of aircraft at longer range. This additional light source must have the ability to be selected off and on independently from the rest of the system.

Other

The CF-18 landing gear is electrically controlled and hydraulically operated. The wing fold system is controlled by a mechanical/electrical drive.

Safety/Escape

The CF-18 ejection seat is equipped with a ballistic catapult/rocket system that provides a quick, safe and positive means of escape from the aircraft, in the event of critical emergency. The main parachute is a steerable 17-foot aeroconical canopy-type and is stored in a container on top of the ejection seat. This parachute incorporates a drogue chute to facilitate a faster opening time with about the same rate of descent as single, larger-diameter parachutes. The aircraft uses a simplified combined harness and a leg restraint system to prevent bodily injury during ejection. Four-season provisions for survival, escape and evasion are contained in a seat-pack that also includes a 7 to 10 minute emergency supply of bottled, gaseous oxygen.

Aviation Life Support/Environmental Controls

The CF-18 Environmental Control System (**ECS**) uses engine bleed-air to provide temperature controlled and pressure-regulated conditioned air for the cockpit, the fuel tanks, the radar wave guides and the avionics systems. The ECS provides suit ventilation, windshield anti-ice, anti-G and engine throttle boost. Normal oxygen is supplied to aircrew by a 10-litre liquid oxygen system through a hose from the left console, and then through the survival kit to the pilot's diluter-demand-type oxygen regulator, mounted on the pilot's shoulder harness.

Chemical Defence

Compatibility of the CF-18 oxygen system with the aircrew AR-5 chemical defence ensemble is achieved through a quick disconnect located on the oxygen line, on the inlet of the oxygen regulator. The Aircrew Chemical Defence Ventilator System (**ACDVS**) combines filtered ambient air and metered gaseous oxygen to the pilot.

AVIONICS SUB-SYSTEMS

Communications

Jam Resistant Secure Radios. Jam resistant secure communication will allow essential, operationally sensitive, clear voice communications in sophisticated electronic jamming environments. The inclusion of radios of this type will contribute significantly to the CF-18's ability to operate and communicate with other NATO forces. The CF-18 IMP jam resistant secure communications capability will be compatible with the allied forces of our collective defence agreements to ensure effective joint/combined combat operations and interoperability; it will contain a sufficiently wide frequency bandwidth, enough frequency agility and be easily and quickly programmable to counter existing and future threats. The radios will provide a minimum range of 200 nautical miles for air-to-air communication and 100 nautical miles for air-to-ground communication at an aircraft altitude of 30,000 ft. They will increase present radio performance and clarity in clear voice and be HaveQuick II - Fast Frequency Hopping ECCM Mode for Ultra High Frequency (**UHF**) Radio algorithm capable. The radios will be Frequency Modulation (**FM**) immune within Very High Frequency (**VHF**) transmission and reception bands; they will allow for the use of a HaveQuick II algorithm capable radio and a digital communications system radio in Comm 2 of the CF-18. They will provide a Satellite Communication (**SATCOM**) capability to the aircraft.

Enhanced Jam Resistant Digital Communications System. A jam resistant, frequency agile, secure, Digital Communication System (**DCS**) will augment the Jam Resistant Communications by allowing for the incorporation of digital communications and the eventual Military Satellite Communications (**MILSATCOM**) capability. The inclusion of radios of this type will contribute significantly to the CF-18's ability to operate and communicate with other NATO forces and will allow communications, both voice and data, and the use of the Multi-functional Information Distribution System (**MIDS**) / Link 16. This system will provide the same capabilities as listed in the Jam Resistant Secure Radios section but in a digital format. In addition, the enhanced jam resistant communication system will be able to communicate with the Canadian ground forces equipped with Tactical Command, Control and Communication System (**TCCCS**) digital secure frequency hopping radios and be compatible with Canadian and U.S. Army communications systems that include Forward Air Controller (FAC) systems. The system will be easily, quickly and digitally programmable and adjustable in order to tailor the sets to existing and future threats. It will be capable of functioning, with minimum modifications, to incorporate a MILSATCOM capability and will allow for the use of a HaveQuick II algorithm capable radio and a digital communications system radio in Comm 2 of the CF-18. It will be compatible with Canadian and Allied warships for (TASMO) operations or joint and combined operations with an ability to be interoperable with naval Fighter Controllers.

Identification Friend-or-Foe Interrogator/Transponder

This system, already operational on F/A-18s and many other fighter aircraft around the world, provides an electronic capability to identify airborne aircraft as friend or foe and to be identified as friend by air or ground based interrogators. The CF-18 Identification Friend-or-Foe (**IFF**) Interrogator Transponder will interrogate and reply in all aircraft transponders modes (1, 2, 3A, C, 4, and S). It will be capable of interrogating aircraft at a range of 130 nautical miles or greater and be capable of providing an IFF transponder reply to 200 nautical miles or greater. It will be fully compatible with Link 16 and provide a display indication of the aircraft category to include friend, foe, unknown, altitude, aircraft type code. It will incorporate azimuth coverage of +/- 70 degrees from aircraft centreline and a vertical field of view of at least + 60deg/-40deg referenced to the aircraft centerline at a range of 5 nautical miles. The system will perform interrogations in air-to-air (**A/A**), air-to-ground (**A/G**) and Navigation Master modes. The IFF Interrogator/Transponder will interrogate for a specific mode, any mode, all modes or combination of modes as selected by the pilot via the Up-Front Controller (**UFC**).

Data Link 16

The Data Link (**D/L**) 16 is the standard data link communications system that will be used by many allied air forces in the future [Reference 5]. The integration of Link 16 compatible equipment into the CF-18 will achieve commonality, interoperability and employability with major coalition participants. This system is an advanced secure communications system that provides position and identification capabilities in an integrated form for application to tactical military operations. The system distributes encrypted information at high rates to both airborne and surface elements, with sufficient jam resistance to yield high reliability in a hostile electromagnetic environment. .

The Data Link set will be compatible with the allied forces of our collective agreements and with Canadian Army and Navy capabilities to ensure effective joint/combined combat operations. It will be compatible with allied forces collective agreement on MIDS. Link 16 will allow two-way transfer of data and displays linked information on the HUD, Digital Display Indicators (**DDIs**) and Horizontal Situation Display (**HSD**). It will link information from the CF-18 sensors to both ground and airborne stations (including fighters) and generate display information for all standard data link symbology. Link 16 will allow for normal operating range of 300 nautical miles with ability to operate up to 500 nautical miles and will enable aircraft at 200 ft above ground level (**AGL**) to relay to a ground station 500 nautical miles away in a straight line through another aircraft 200 nautical miles away at 26,000 ft. The system will allow for cryptographically secure, jam resistant communications and allow near real-time data exchange. The system will have a secure data transmission capability, allow plain text message data link, have a relative navigation capability and allow for an identification capability.

Navigation

<u>Embedded Global Positioning/Inertial Navigation System</u>. The Embedded Global Positioning/Inertial Navigation System (**EGI**) is a small, low weight, inertial navigation system with embedded Global Positioning System (**GPS**). The GPS antenna system includes a Fixed Reception Pattern Antenna and Antenna Electronics. It is based on a 32-bit Intel 80960 microprocessor, MIL-STD-1553B databus, and four RS-422 buses on one card. The CF-18 will use the EGI as a self-contained, fully automatic, dead reckoning platform, along with associated cockpit controls and indicators. The EGI will detect aircraft motion and will provide acceleration, velocity, present position, pitch, roll and true heading to related systems. It will be used as both a primary mission navigation instrument and a weapons delivery support aid.

The Embedded GPS Receiver (**EGR**) will be a Precise Positioning Service (**PPS**) receiver capable of operating in Standard Positioning Service (**SPS**) mode either by manual selection or as a result of not being keyed. As well, the EGR shall be capable of receiving C/A, P, and Y codes, using both the L1 and L2 frequencies and be capable of tracking a minimum of 12 space vehicles (**SVs**) simultaneously. The INU will use the most advanced commercial Ring Laser Gyros technology available.

The navigation system will provide an updateable, but not manual editable, Navigation Database for use in Instrument Flight Rules (**IFR**) navigation. The database will contain as a minimum, the appropriate information referenced to WGS-84 or equivalent, for the aircraft's intended area of operation. As the CF-18 can be deployed to areas of interest anywhere in the world, the database requirement will therefore, be the world. However, to reduce data storage requirements, grouped geographical areas of interest would be adequate. All waypoints will be entered directly from the Mission Data Loader. The navigation system will provide for a "User Defined Database" capable of storing 200 waypoints in non-volatile memory. The waypoints can be entered manually, copied from the "Navigation Database" or directly from the Mission Data Loader. The navigation system shall use the WGS-84 datum unless otherwise selected by the operator and will support published GPS standalone and GPS overlay non-precision approaches.

Mission Data Loading System. The Mission Data Loading System (**MDLS**) will be capable of loading a valid "Navigation Database" and transferring "User Defined Waypoints" and flight plans from the approved Data Transfer Medium into the navigation system. The addition of a MDLS will aid the pilot in programming essential mission data and will allow the pilot to select, tailor or upload (**UDFs**) for the radar or DEWS based on the scenario and threat. The MDLS will be capable of programming, in an automated fashion, the (**INS**), GPS, (**TACAN**), Instrument Landing System (**ILS**), VHF Omni-Range (**VOR**), IFF, Stores Management Set (**SMS**), (**HMS**), radar, way-points and all communication systems. The system will be capable of retrieving analog mission flight data, post flight, including information from the DDIs, HUD, HSD and DEWS. The MDLS will be capable of single point data insertion, preferably from within the cockpit, and be capable of loading and downloading mission data with a standard Personal Computer (**PC**) or PC compatible notebook.

The CF-18 TACAN, the AN/ARN-118, operates in the L Band, providing precise relative bearing or slant-range distance from the aircraft to a TACAN ground, sea or airborne-based station. The TACAN is the CF-18's primary en route/area navigation aid when using the airways structure under IFR. In the air-to-air mode, the TACAN system provides line-of-sight distance between two aircraft operating their respective TACANs set 63 channels apart. The TACAN has its own associated cockpit controls and indicators.

The CF-18 VOR/ILS (navigation aid receiver and instrument landing system receiver), the AN/ARN-514, is the aircraft's primary precision instrument approach landing system.

The CF-18 ADF is a VHF/UHF direction finder only, operating in the 100-400 megahertz (**MHz**) frequency range. It is used primarily to locate emergency locator beacons.

Mission Computers

The brains of the CF-18 are its Mission Computers (**MCs**) and its' Stores Management Set (SMS). These combine the integration and automation necessary for single-pilot operation. The MCs control primary data transfer to aircraft avionics sub-systems through avionics multiplex buses. MC1 is the navigation computer; MC2 is the weapons delivery computer. The MCs are linked to the flight control computers, air data computer, communications system controller, armament control processor, Digital Display Indicators (DDIs), navigation aids (VOR/ILS, TACAN, ADF, INS), radios (Comm 1 and 2), radar, Forward Looking Infra-red (**FLIR**) and laser designator.

The XN 5 Mission Computer, designed in the mid-70s, will be replaced with the XN 10 MC, currently in production and in service with the United States Navy. The mission computers will support all current CF-18 mission computer functions, all software developments required under CF-18 IMP and all associated projects within the CF-18 modernization framework. The MC will support software that will in turn make the CF-18 effective and survivable in both the A/A and A/G roles throughout to ELE.

Operational Flight Program Software

The current Canadian unique Operational Flight Program (OFP) will be replaced with software version 17C based upon US Navy software. The new OFP will be capable of supporting all systems included in the modernized CF-18.

Multi-purpose Display Group

The CF-18 cockpit includes a multi-purpose display group that presents navigation, attack and aircraft attitude displays to the pilot. The Multi-purpose Display Group (**MDG**) consists of two multi-functional DDIs, a HSD, and a HUD. These displays allow the pilot to select critical aircraft system or tactical information displays using 20 pushbuttons on each display (excepting HUD).

The current monochrome Digital Display system will be replaced by a state-of-the-art, "made-in-Canada" Active Matrix Liquid Crystal Display (**AMLCD**). With the planned data link system, colour, high-resolution displays will be essential for assimilation and analysis of tactical information. The DDIs are the display processors for all of the cockpit displays and therefore form the heart of the CF-18 display suite.

The MDG will exceed current display system performance in all aspects, supporting high-resolution FLIR imaging and allowing screen dimming, with no loss of gradient or colour levels, to support night FLIR operations. It will indicate on all air-to-surface mapping displays, the location of a FLIR designation. It will provide the position of a FLIR designated target on all air-to-air radar displays, selectable by DDI push button or

Hands-On-Throttle-And-Stick (**HOTAS**). The system will be capable of having information refreshed at a rate of 16.67 msec (60 Hz) or faster in order to prevent perceived flicker. The MDG will incorporate colour presentation such that the visual communications process is enhanced for all present and future CF-18 systems. The system will provide "camera-less" recording and mission data storage retrieval options of up to six simultaneous signals that can be replayed on one or more displays simultaneously. The MDG will be NVG compatible, be able to display colour code symbology as developed for Link 16 and be capable of displaying the higher resolution, higher bandwidth, expand 5 mode of the APG 73 radar. The MDG will allow the digital moving map to be displayed on the HSD or either DDI.

In addition, the DDI shall improve air-to-air resolution in the Range While Search (**RWS**) mode. Specifically the DDIs will be capable of the clearly display two fighter size targets flying 6000 ft apart at a range of 25 nm. The DDIs will display FLIR imagery at a clarity level no less than that produced by the FLIR pod itself. Specifically the DDIs will clearly display FLIR imagery for objects with an approximate radar cross section of 10 m^2. For example, heavy artillery pieces, spaced 30 ft apart, can be detected, tracked, and designated from a slant range of 95000 ft or less with sufficient detail to allow for their identification and classification. The DDIs will provide an air-to-air expand mode that allows the pilot to expand information on the DDI in order to sort, target, designate and increase situational awareness. The HSD will display a digitized, moving-map.

WEAPONS SYSTEM

Stores Management Set

The current Stores Management System cannot support current digital weapons that are critical to an effective and survivable fighter weapons platform. To employ current and next generation weapons, such as the Advanced Medium Range Air-to-Air Missile (**AMRAAM**) and the Joint Direct Attack Munition (**JDAM**), an upgraded SMS will provide a faster, more capable processor and a digital format weapon interface. The modernized SMS will be capable of fully integrating an advanced, medium-range, air-to-air missile with a launch and leave/multi-targeting capability as well as an advanced short-range, air-to-air missile. It will also be capable of full integration of AIM 7M(H build)/AIM 7P, advanced GPS/digital weapons, all air-to-surface ordnance currently used by the CF-18 as well as foreseeable future air-to-ground ordnance. The SMS will be capable of full integration of a laser designator, Advanced Multi-Role Infrared Sensor (**AMIRS**) and laser tracker.

Hands-On-Throttle-And Stick

The capabilities of the MDG are complemented with a Hands-On-Throttle-And- Stick system. HOTAS allows the pilot to select and initiate critical radar settings, acquisition, targeting, sorting, discrimination and engagement functions, and weapons selection and launch, in the air-to-air and air-to-ground master modes without reverting to a head-down posture to glance at aircraft dials or select switches.

Up-Front Controller

The CF-18A is equipped with an Up-Front Controller (UFC), located on the main instrument panel just below the HUD. The UFC is used to select autopilot modes, to control the IFF, TACAN, VOR/ILS, radar beacon, radios, Data Link and ADF. It is used in conjunction with the DDIs and HSD to enter navigation, sensor and weapon delivery data.

APG-73 Radar

The new radar, the APG-73 will provide the pilot the ability to detect and track targets in an ECM environment. The APG-73 supports current and planned air-to-air and air-to-surface weapons to ensure successful, precise weapons employment. The APG-73 will meet or exceed current radar performance in each mode, in all respects.

Performance increases will include improved resolution of ground targets in order to identify them and fully exploit the capabilities of advanced air-to-surface weapons associated with the CF-18A. Improved identification and classification capabilities should reduce collateral damage and fratricide. The APG-73 radar will detect and track airborne and surface targets at a sufficient range so as to employ weapons at maximum range yet remain outside the lethal envelope of medium range air-to-air and surface-to-air missiles. Specifically, the radar will resolve two or more fighter size targets (approximate radar cross section of less than 10 m^2) flying 6000 ft apart at a range of 25 nautical miles; it will resolve groups of fighter sized targets (two or more fighters within 2 nautical miles of each other), greater than 3 nautical miles between groups, at a range of 40-45 nautical miles. The APG-73 will detect and designate heavy artillery pieces targets (approximate radar cross section of less than 10 m^2), spaced 30 ft apart, from a slant range of 95000 ft with sufficient detail to allow for their identification and classification. It will provide Track While Scan (**TWS**) that can build, display, and maintain a minimum of eight track files at greater than 25 nautical mile range throughout aggressive target and own-ship manoeuvring (7G).

The new radar will provide rapid lock-on in all Air Combat Manoeuvring (**ACM**) modes, specifically 1/2 second or less in Boresight Mode (**BST**) and 4 seconds or less in Wide Acquisition (**WACQ**) and Vertical Acquisition Modes (**VACQ**). The APG-73 will improve the Electronic Counter-Counter Measures (ECCM) capability of the CF-18 radar. The CF-18 radar will be able to detect and track fighter sized targets in an ECM environment outside of 45 nm in both AIM-7 and non-AIM 7 waveforms. Also, detection and track of moving or fixed ground targets must be able to occur outside of 15 nautical miles in the presence of moderate barrage jamming covering the full frequency range of the radar.

The APG-73 radar will include improved Non-Cooperative Target Recognition (**NCTR**) processing in the presence of light radar jamming such that helicopters, fighters, propeller aircraft and jet aircraft can be identified at ranges greater than 25 nautical miles with a Single Target Track (**STT**) or Track While Scan (TWS) of less than 10 seconds and with a 95 percent confidence level. It will be possible to modify the radar software such that different aircraft types can be identified with NCTR. The APG 73 will increase detection range of a single fighter sized target (approximate radar cross section of $10m^2$) to a range of at least 45 nautical miles using high or medium Pulse Repetition Frequency (**PRF**) in Range While Search (RWS), Velocity Search (**VS**) and Track While Scan radar search modes. It will also increase the capability to track targets performing three dimensional, 360 degree turns at 7Gs and targets that maintain beam aspect (± 10 knots) for up to 20 seconds.

The APG-73 will fully integrate an advanced medium range air-to-air missile with a launch and leave, multi-targeting capability. It will be operated manually or automatically, slewable using the HOTAS to the laser or FLIR line of sight within 0.5 seconds while in the A/G and A/A modes. The APG-73 will designate targets from either laser or FLIR designations using the HOTAS.

The APG-73 will allow for full integration with the most current MC OFP and the IFF Interrogator/Transponder. It will be fully compatible with Multi-Sensor Integration (**MSI**).

Advanced Multi-role Infra Red Sensor

The Advanced Multi-Role Infrared Sensor (AMIRS) will be fully integrated within the CF-18. This includes, but is not limited by, the ability to target all weapons and sensors displayed on the new head-down displays, and will be fully integrated with in the OFP.

The AMIRS will be designed to be carried on station #4 of the CF-18. The AMIRS will be able to passively search and track multiple airborne targets. It will provide tracking and cueing information to the pilot, passively provide targeting information to A/A weapons to allow launch without the radar, and use advanced target recognition technology to assist in target identification.

The AMIRS will support all current and planned future A/G weapons, including laser-guided munitions, GPS guided munitions, and unguided munitions, in both close and stand-off configurations. It will have a Laser Spot Tracker (**LST**) and an IR pointer. The

AMIRS will provide tactical Bomb Damage Assessment (**BDA**) and tactical reconnaissance. Additionally, it will be able to track ground targets and will provide a Navigation capability.

The AMIRS will Incorporate advanced Focal Plane Array and Electro-Optic sensors, and a Navigation FLIR. It will use the existing Nitehawk B interface and be integrated with all current, and future, displays, including current and colour HDDs and the HUD. It will be fully compatible with Multi-Sensor Integration and will use automatic boresighting and alignment.

Night Vision Imaging System

Night Vision Goggles (NVGs) improve the aircrew's ability to see at night, enhancing situational awareness, tracking of friendly and enemy aircraft, target and target area visibility. NVGs should significantly increase the effectiveness of the aircrew while performing air-to-air and air-to-ground missions at night, allowing the pilot to distinguish finer detail and critical information than with unaided vision.

The NVGs will fit onto the current helmet without adversely affecting ejection performance or safety. Advanced Life Support Equipment (**ALSE**) integration of the NVGs must provide protection of the aircrew from bird strike or ejection hazards. They will represent the current state-of-the-art technology in order to maximize visual acuity, while minimizing the tendency to display a halo around light sources.

The NVGs will be integrated with a clear visor and with laser eye protection. The NVGs will have a stowage case that is integrated into the cockpit and with other equipment carried by the aircrew, like the NORAD 35 mm camera or a helmet bag. As well, it will be easily accessible, as the aircrew must don and remove the NVGs in flight.

CF-18 Air-to-Air Ordnance

The CF-18 weapons system will include the 20 mm M61, 6 barrel, Gatling gun, the AIM-9M and AIM-7P, a new imaging infrared Short Range Air-to-Air Missile (**SRAAM**) and an active radar guided Advanced Medium Range Air-to-Air Missile (AMRAAM).

The CF-18's relatively small calibre Gatling gun is generally used only when air-to-air missile use is inappropriate. The gun is usually selected only when an adversary is in the CF-18 HUD and within gun firing range.

The new SRAAM will have a launch and leave capability, an advanced imaging infrared system capable of medium range detection and lock-on, and an increased resistance to decoy by flares and clutter. It will have a short time of flight and will be extremely manoeuvrable at close ranges. The SRAAM will greatly enhance self-protection in all CF-18 roles. Use of the SRAAM will be significantly limited without a complementary

Helmet Mounted Display that would allow high off boresight launches. It will be required to slew the missile seeker head using other CF-18 sensors.

The AIM-120 AMRAAM is an all-weather, all-aspect, active radar-guided missile, powered by a solid propellant motor and armed with a fragmentation warhead. Guidance is by an active radar terminal seeker that has the ability to lock on after launch, providing a launch and leave capability for the pilot. The AMRAAM will be the CF-18 weapon of choice at longer ranges. Due to the active seeker of the AMRAAM, it requires a clear line of fire when employed in close proximity of friendly aircraft. The radar and weapons give the CF-18 an all-weather intercept, identify-and-destroy, air-to-air capability.

CF-18 Air-to-Surface Ordnance

The CF-18 weapons system will include the M61 Gatling gun, CRV-7 Rockets, General Purpose (**GP**) bombs, Laser Guided Bombs (**LGB**), an Air-to-Surface IR Missile and Advanced Precision Guided Munitions (PGM).

With the help of the modernized CF-18 sensors (APG-73/AMIRS), the GP bombs will provide very accurate results. Once released from the aircraft, these bombs will freefall, unguided to the target area. The GP bombs will generally be used where collateral damage is not a factor. The CF-18 GP will include the MK-82, MK-83 and the MK84.

The current CF-18 LGBs will be modified to include a GPS capability. The CF-18 Advanced Paveway II and Enhanced Paveway III guidance sections will be used with the GBU-10, GBU-12, GBU-16 and GBU24. These LGBs will be used in conjunction with the AMIRS to provide very accurate strike results in clear weather conditions. The GPS interface will provide guidance in the event of laser designation malfunction and weather obscuration.

The AGM 65-G Maverick G will give the CF-18 an IR day and night Air-to-Surface missile capability. The digital centroid seeker guides the missile to the centre of the target, with the pilot able to select a specific aim point within a large target complex.

The CF-18 Advanced Precision Guided Munitions will provide the CF-18 with an Air-to-Surface precision capability that will enable the weapons to be released in all weather conditions. The advanced weapons will be GPS based, air launchable from all altitudes and will provide for both pre-programmed targets or real time targeting. In addition, these weapons will be capable of launch outside the threat envelope of contemporary tactical Surface-to-Air (SAM) missiles. It is assumed that the CF-18 Advanced PGM will include the Joint Direct Attack Munition (JDAM) and the Joint Stand Off Weapon (**JSOW**).

Defensive Electronic Warfare Suite

For self-protection, the modernized CF-18 will employ a state-of-the-art Defensive Electronic Warfare Suite comprised of a new generation Radar Warning Receiver (**RWR**), a Multi-Function Defensive Electronic Counter Measures (**ECM**) Receiver/Transmitter (Jammer), and an ALE-47 chaff/flare Counter Measure Dispensing System (CMDS).

The RWR will provide detection and warning of threats to the system. The Jammer will be able to counter Pulse, Pulse Doppler, Continuous Wave and Monopulse radar systems. Specifically, once detected by the system, the Jammer will be able to Jam an incoming active missile. The ALE-47 will be fully programmable to ensure optimum reaction to the incoming threats.

The CF-18 DEWS, will be an entirely integrated system capable of responding to contemporary airborne, sea-borne and land-based threats. The CF-18 DEWS will be able to operate in manual mode, semi-automatic mode and a fully automatic mode. The combined threat and reaction information will be available in all CF-18 tactical displays, providing the pilot with a clear, complete and accurate display of the incoming threats.

CF-18 Airframe – Handling and Performance

The CF-18, in addition to possessing advanced all-aspect air-to-air missiles, has superior rudder and pitch authority compared to many modern era fighters. This allows the CF-18 to point the nose of the aircraft and employ weapons fairly easily. The CF-18 also enjoys favourable turn performance, low-to-moderate energy bleed rates and an advantageous thrust-to-weight ratio, resulting in favourable acceleration. Performance diagrams confirm that the CF-18 is superior to most foreign-built aircraft, depending on aircraft configuration. Various combinations of wing pylons, fuel tanks, air-to-air missiles and air-to-ground weapons entirely integrated system can be expected on both the CF-18 and adversary aircraft. Tactics development and pilot training is therefore conducted in realistic operational aircraft configurations.

Performance differences between the CF-18 and similar category fighter aircraft are generally small. CF-18 strengths versus other similar category fighter aircraft include better agility, smaller turn radius and better radar ACM modes. CF-18 weaknesses versus other similar category fighter aircraft include higher energy bleed rate, lower thrust-to-weight and lack of in-close IR acquisition system, such as those possessed by soviet built MiG-29 and SU-27 aircraft. As a general rule, during any close-in aerial combat situation, the more the fight decelerates, the greater the advantage the CF-18 will enjoy.

However, it is important to note that the single largest factor in the outcome of an air-to-air engagement is usually the ability of the aircrew and the tactics employed. Pilot proficiency and training remains the key to CF-18 survivability in aerial combat.

COMPOSITE MISSION SCENARIO

INTRODUTION

The purpose of the composite mission scenario is to provide CF-18A HMDS Project team members with a baseline document that describes the key elements, implied requirements and essential system functions. This document will be used in the development of the Operational Sequence Diagrams (**OSDs**) and eventually as a reference during the production of the CF-18 HMD. The mission scenario reflects the employment of the CF-18 in the air-to-ground role and is intended as a means to ensure that all the top-level functions associated with the new Assumed Air Vehicle for the CF18A Analysis of HMDS are identified. The functional decomposition of the top-level functions will be reported separately in the Functional/Goal Analysis.

The reason for using a composite CF-18 multi-task, anti-surface role scenario is twofold: first, to focus the analysis on mission sequences that are particularly demanding from a workload perspective or are likely to be critical to requirements definition and the eventual design of the user interface; and second, to avoid wasting effort by analyzing functions that have already been analyzed, are unlikely to be critical to overall system performance, or are unlikely to provide any added value.

Although the scenario was written as a straightforward narrative, it was necessary for the sake of authenticity to use some terms that will not be familiar to the non-fighter pilot user. These terms are highlighted and their meaning defined in Annex A. Some artificialities may appear in the overall mission but only when necessary to ensure that all relevant issues are included during the actual mission execution.

The following rules govern the preparation of the composite scenario:

a. there should be one, and only one, occurrence of each top-level mission function

b. mission duration is not determined by artificial factors such as aircraft fuel or ammunition loads; nevertheless, mission execution will be highly influenced by these factors

c. re-locating forces in time and/or space is acceptable

d. weapon loads and fuel may be replenished as necessary

AIM

The specific aim of this composite mission scenario is to portray the planning and execution of a CF-18 anti-surface operation that:

a. focuses on the tactical application of air operations solely – not the overarching strategic objectives;

b. integrates the air power capabilities of several different nations and services;

c. exploits the capabilities and roles of the Modernized CF-18 while considering its limitations;

d. incorporates an all weather and night aspect to the overall mission profile and taskings;

e. is based on future, realistic CF-18 operational training and aircrew proficiency levels;

f. necessitates positive identification in the air when called for by scenario Rules Of Engagement (**ROE**);

g. uses a single ATO, easily disseminated by a Tactical Air Operations Centre (**TAOC**); and

h. relies on comprehensive, timely, accurate and current intelligence which is air focused.

SITUATION

The political situation is illustrated in Figure 5-1. The time is November 1999. The government of country "X" has unilaterally declared an Xarian Economic and Fishing Zone (**XEFZ**), which effectively moves X's territorial waters out to 300 nm, in order to protect its Sea Lines Of Communication (**SLOC**) and, more particularly, its access to the Deep Fathom Fishing Grounds (**DFFG**). The DFFG provide X a critical food staple; moreover, revenue from the export sales of fish products abroad sustains the Xarian economy.

The new Xarian territorial limit encompasses an adjacent, neighbouring and sympathetic island country "Y". It also encroaches on the 12 nm territorial waters of country "Z". County Z has had long standing internal boundary disputes with extremist factions in its northern provinces. These Extremist factions (E) have been motivated by perceived ethnic and religious persecution to commit linked but infrequent incidents of terrorism in the northern provinces.

The time is January 2000. Country X has claimed that country Z has discovered oil reserves in the seabed below the DFFG. X's establishment of the XEFZ in November 1999 and this latest allegation have chilled considerably the decades-long indifferent relations between the country's two governing bodies. Clashes involving the boarding and seizing by both countries of the other's commercial fishing vessels have occurred at an increasingly alarming rate. These incidents have contributed to the enormous upheaval and instability in the region in recent months and have caused near panic amongst neighbouring countries and great concern in the UN.

The time is February 2000. Countries X and Y have formed a security coalition. At the same time, extremist elements in country Z's northern provinces have ousted the provincial government and laid siege to all major installations in the northern provinces. All Zardian civil authority has collapsed and the provinces are under a state of martial law imposed by the extremist factions. A considerable number of refugees, sympathetic to country Z's governing body, have left the northern provinces for reasons of safety and security.

The time is March 2000. A regional military alliance has been struck between countries X, Y and the extremist groups, E, in the northern provinces of country Z. On the invitation of the extremist groups' leadership, well-equipped and armed components of countries X and Y military forces have taken foothold in the northern provinces of country Z. While there is no credible threat of a deliberate military attack on country Z, outside the northern provinces, Z has nevertheless petitioned the UN to intervene with action appropriate to bring the hostile parties (X, Y and E) to a negotiated agreement to leave its sovereign territory and to re-establish the provincial authority and sovereign rule. Such diplomacy and mediation efforts, under the UN Charter, have failed. All effort to negotiate with the provisional extremist government, bolstered by elements of X and Y armed forces, has collapsed.

The time is April 2000. Z has reacted strongly to the crisis and has placed an air and sea embargo on the island country of Y. It has also positioned ground forces along the perimeter with its northern provinces and stopped all flow of people and material into the provinces.

In response to the crisis, country Z has requested Canada to deploy armed forces in support of operations aimed at re-establishing Zardian rule of law on its northern provinces and to assist, as may be required, in the eviction of all X-Y-E armed forces and extremist elements. Canada, through its long-standing bilateral security alliance with Z, has agreed to deploy a Squadron of its Reaction Force Air CF-18s. Several other nations have also agreed to support country Z with naval, air and ground forces, logistics supply groups, engineering and hospital support elements, and the like. Armed conflict between the Z Coalition and the X, Y, E force is inevitable as the deadline imposed by Z for the voluntary withdrawal of the intrusive elements has passed.

The time is May 2000. CF-18s, along with all supporting elements, have deployed to Z. Operational Control of Canada's fighters has been chopped to the Joint Force Commander (JFC) appointed by the Zardian Armed Forces Chief of Staff. For the past 2 weeks, CF-18s have been conducting enforcement flights along the perimeter established at the Zardian perimeter (boundary) with its northern provinces.

The time is 0000 Zulu (Z), 21 May 2000. An Air Campaign Plan has been developed and is being implemented. Z-coalition offensive air activity has commenced. An ATO has been issued and Canada's CF-18s have been tasked to provide a multi-role war fighting capability. An Airspace Coordination Order (**ACO**) is in effect.

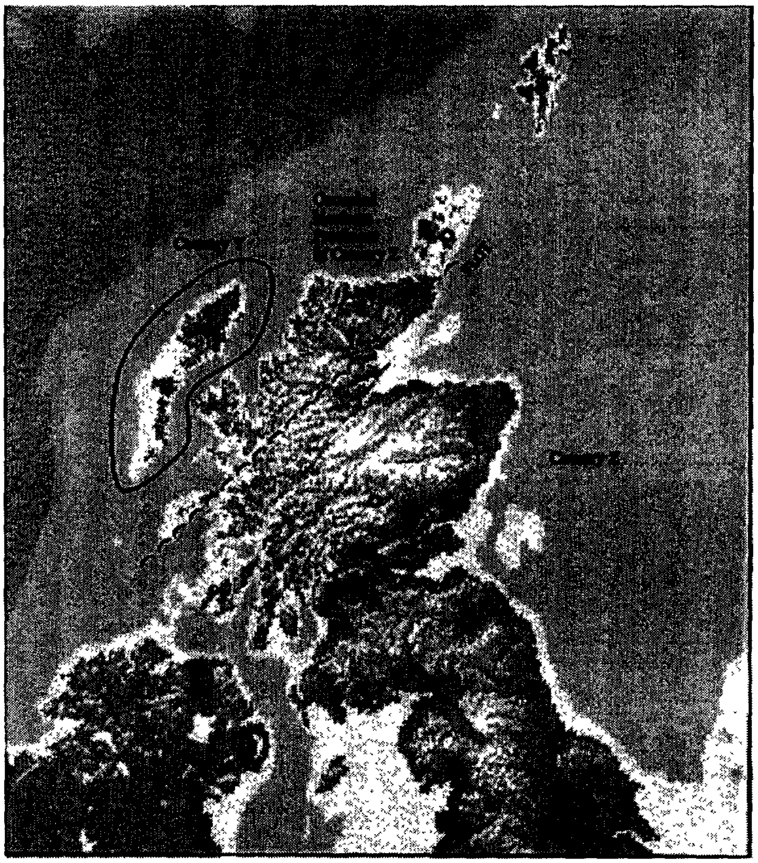


Figure 1 Political Situation

MISSION

The ATO assigns a composite mission for a four aircraft flight of CF-18s to support the air campaign plan. The section of four CF-18s is tasked to:

a. conduct an Air Interdiction (**AI**) deep strike attack (High Threat/DAY/Low Level Ingress/Low level Attack), self escort, leading a package with 6 Belgian F-16 Ground attack aircraft, on the re-supply choke point on the island of Y, using General Purpose Mk-83;

b. re-commit and conduct an OAS Battle AI strike, (Med Threat/NIGHT/Med Level Ingress/Med Level attack), using GBU-16 on a Communication facility and MAV to take down a large Bridge (B/U JDAM);

c. re-commit and conduct an OAS Close Air Support with a Ground FAC, (Med Threat/NIGHT/Med Level Ingress/Med Level Attack), using PGM GBU-16 on a weapons storage bunker (B/U MAV); and

d. recover to a deployment base/aerodrome.

Departure time to commence the mission is 1615Z with recovery at the deployment base at 2100Z. Airspace Control Measures (**ACM**) are in effect (ACO is valid for the entire period) with Border Crossing Authority (**BCA**), along the Zardian perimeter with its northern provinces, has been issued to friendly forces.

Threat

Collection and analysis of the OPposing FORces (**OPFOR**) is completed and has established the Air, Ground and Electronic Orders of Battles (**AOB/GOB/EOB**). The intelligence data applicable for the period of the mission scenario identifies the following threats:

a. Air-to-Air: MiG-29 FULCRUM and Su-27 FLANKER employing SLOTBACK - INDIA Band, TWS, Coherent, Look-Down, Shoot-Down, Radar; AA-10 missiles (SAR and IR Variants), AA-11 IR missiles and AA-12 active radar-guided missiles.

b. Surface-to-Air: a fully Integrated Air Defence (**IAD**) System and SAM: SA-6, SA-7, SA-8, SA-11, SA-13, SA-14 and SA-16.

Planning

On receipt of the ATO at 1000Z, a decision is taken to configure the flight of four CF-18s as follows:

a. Two (330 U.S. gallon) external fuel tanks on Stns 5 & 7;

b. Two SRAAM on Stns 1 & 9;

c. Two AMRAAM on Stn 2, one on Stn 6;

d. 500 Rounds 20 mm;

e. One AMIRS pod on Stn 4;

f. One DEWS;

g. Configuration (1). Four Mk-83s on Stn 3 & 8;

h. Configuration (2). One GBU-16/MAVon Stn 3,one JDAM on Stn 8;

i. Configuration (3). One GBU-16 on Stn 3, one MAV on Stn 8.

At 1030Z, a flight lead, along with other formation members, are assigned to the CF-18 four-ship (section) mission tasking. The flight lead commences mission planning at 1100Z, coordinating requirements and operations for the air-to-air and the air-to ground taskings. Commencing at 1200Z, formation members execute their mission planning duties and responsibilities in accordance with Standard Operating Procedures (**SOPs**). The mission planning culminates with the CF-18 mission briefing at 1400Z. At 1520Z, the CF-18 aircrew don their aviation life support equipment, gather their mission cards, checklists, classified codes, charts and other mission materials, and step to the squadron operations desk for aircraft assignment, review of aircraft documentation and aircraft sign-out. At 1540Z the section members proceed out to the restricted area of the aerodrome ramp for aircraft external inspection/walk around, acceptance and cockpit strap-in.

Start and Taxi

At 1550Z the aircraft are started, mission critical data is loaded into the aircraft via the Mission Data Loader, DDIs, and UFC. The section lead calls for formation status check-in followed with radios and data link synchronization. The section lead requests and is cleared to taxi at 1610Z. After passing through the arming point, the CF-18 section taxies to the active runway, staggered with a minimum interval of 200 feet spacing on the taxiway, via the most expeditious routing, and lines up for departure on time, in accordance with the mission briefing.

Take-Off and Climb

The CF-18 section lines up on the runway for departure as 2 plus one plus one. Section lead lines up 2,000 feet down the runway, offset to downwind, with #2 on the upwind side of lead and slightly forward of lead's tailpipes. Lateral separation is such that potential directional control problems would not result in a risk of collision on the runway during the take-off roll. The trailing element, #3 and #4, line up in similar fashion, but to the upwind side of lead's formation and at the button of the runway. At 1615Z, when all aircraft are in position and all pre-take-off checks are complete (#4 calls "4 ready"), lead requests and is authorized take-off. Lead gives the engine run-up signal to his #2 and both pilots run-up their aircraft engines to 80 percent. When both aircraft have completed their final checks, lead initiates take-off roll with a head nod for brake release. Simultaneous with brake release, both pilots smoothly advance the power to full afterburner, with lead aircraft retarding them slightly to allow #2 a small power margin. After lift-off and once safely airborne, the lead element raises gear and flaps, deselects afterburner and accelerates to an en route airspeed of 360 knots Indicated Air Speed (**KIAS**). #3 and #4 take-off in sequence, as single-ships and with 20 seconds spacing on the aircraft in front. The take-off sequence is uneventful. Once safely airborne, the section climbs to 2,000 feet Above Ground Level (AGL), manoeuvres to an OFFSET **CARD** tactical formation and initiates en route transit to the Tactical Rendezvous Point (**TRP**).

Transit to Tactical Rendezvous Point

During en route transit to the TRP, the CF-18 section, callsign **HORNET** performs "G" awareness turns and completes airborne weapons systems checks, while maintaining an OFFSET CARD tactical formation at 1000 feet AGL. The formation then checks-in with Airborne Warning and Control System (**AWACS**), call sign MAGIC using HaveQuick II secure voice transmission. They then receive from **ABC^3**, callsign GUNSLINGER, updated tactical, threat, and target information via secure-voice transmission and MIDS. At 1621Z the section arrives at the TRP and enters a 2-minute left-hand racetrack pattern, using tactical turns, while waiting for their assigned departure time from the TRP. The CF-18s switch back to MAGIC for threat information during the tactical portion of the mission. During the hold at the TRP all section members complete a FENCE CHECK. As well, they ensure that their INS/GPS navigation platform is displaying the required accuracy, and update their navigation system if required. The CF-18s adjust their pattern to depart the TRP, in OFFSET CARD tactical formation at an altitude of 2000 feet AGL, at 1626Z, at a Ground Speed (**G/S**) of 420 kts.

The CF-18 section leads the Belgian F-16 6-ship formation departing the TRP.

Day Low Level AI Strike

The formation of CF-18 (callsign **HORNET**) departs the TRP in CARD formation at 2000 feet AGL and 420 knots ground speed, with the lead of 6 Belgian F-16s (callsign FALCON) in visual 3nm trail. Hornet Flight is sanitizing the airspace using their APG 73 in RWS mode in the pre-briefed vertical search volume (Lead and #4 looking low, and #2 and #3 looking high). Twenty (20) nautical miles back from the **FLOT**, #2 and #4 close in to FIGHTING WING tactical formation, while the formation descends to 200 feet AGL and accelerates to 540 knots ground speed.

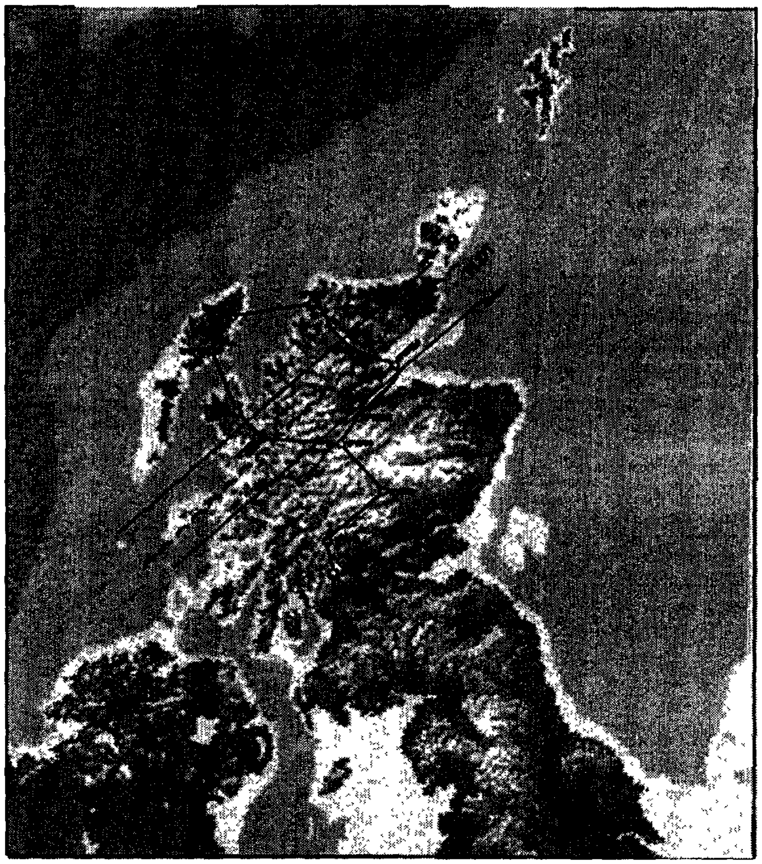


Figure 2 Day AI Mission

While crossing the FLOT, AWACS (callsign MAGIC,) calls "Bogey, Bull 240/30 nm, high" and MIDS simultaneously transmits the location of the Bogey to the Link 16 display. #2 and #3 move their TDC to the Link 16 display and depress the coloured bogey, automatically slaving their radar to his position in TWS. Lead continues to sanitize low with his radar, commands a 10-deg offset based on his Link 16 display, and calls #2 and #4 back to DOUBLE ATTACK/CARD. The radars are beginning to depict a 2-ship formation at 40 nm with high closure. At a distance of 35 nm, MAGIC declares the 2-ship formation "Bandit" and the Link 16/Rdr display now depict the 2-ship in the colour red. Hornet #2 and #3 interrogate the declared bandit with their IFF, and confirm the bandit status. #2 and #3 each command a lock based on their sort contract, and each launch a single AMRAAM missile.

Lead then receives a "27" lethal spike indicating that he is being locked by the Bandit SU-27. Lead goes into a notching manoeuvre and deploys a pre-programmed chaff bundle. The rest of the formation (followed by Falcon) offsets to maintain formation, while allowing #2 and #3 maintain a radar lock. Lead's spike goes away, and as he turns back on route, he notice's via the Link 16 display (from #2's radar) that the bandit formation is turning cold. #2 keeps his radar in centred TWS on the bandit formation now 23 nm cold, and #3 returns to his radar search responsibilities. Lead slows the formation to the planned post-FLOT G/S of 480 knots, but aims slightly inside his next turning point to compensate for the time lost manoeuvring. Lead is able to make up the lost time, yet still keep outside the red SA-13 threat ring displayed on his HSD (information loaded into his database via the MDLS, and based on intelligence from previous strike missions).

Forty (40) nm back from the target area, Falcon flight splits off slightly from Hornet flight to carry out their own target attack (20 nm offset from Hornet's target). Hornet's target is a supply depot at a critical supply choke point. At 25nm back from the target, Hornet lead calls for the Air to Ground check. The formation switches to Air to Ground master mode, yet continue to sanitize the airspace with their radars. The entire formation ensures that the correct bomb Multiple, Release, and Interval (**MRI**) program is set for the 4 general purpose Mk-83 bombs they are carrying, and they change the programming of the chaff and flare bundles via the UFC to the DEWS/ALE-47. The DEWS is now configured in the semi-automatic mode to dispense chaff bundles at a rate more suitable for the **AAA** that is suspected to be protecting the target area. At 20 nm, in preparation for a **FRAG** spacing manoeuvre, #3 briefly radar locks then slaves his AMIRS to lead as a back up to the timed spacing that #3 requires from lead. #3 and #4 then executes a spacing manoeuvre, and #3 rolls out 8 nm behind Lead, as confirmed by his AMIRS.

With lead now approaching the **IP** at 10 nm back from the target, #3 looks out towards #4 and notices a visible smoke trail heading up towards his wingman. #3 calls "Hornet 4 break right! SAM your 3 o'clock 2 nm." #4 immediately goes into a break turn, jettisons his stores, dumps flares, looks out and visually acquires the missile. He then goes into a defensive 3-D last-ditch manoeuvre while continually dispensing chaff/flare. The missile attempts to track #4, but it lags behind and misses #4 by at least 4000 feet. #3 hits the HSD mark button, and along with his wingman turns back to the target.

At this time Lead has flown over the IP and done an over fly designation of the target. At 4 nm back Lead opens 15deg lateral, and at 3 nm lead pops up 15deg vertical to visually acquire the target. Lead sees his **DMPI**, and rolls over to point his nose above the target and line up the **CCIP** line. As he over flies the target lead pickles his bombs away, performs a safe-escape manoeuvre and goes into a pre-emptive chaff weave. #2 is 30secs in trail and opening for the similar manoeuvre. As #2 rolls in on his DMPI he receives an "AAA" spike from his RWR. #2 goes into a defensive manoeuvre, while monitoring his DEWS automatically dispensing chaff and commanding the multi-function jammer to use the appropriate ECM on the AAA radar. #2 visually confirms that the DEWS has been effective as he sees AAA bullets firing well behind him. Unfortunately for #2 he is not able to realign himself with the target on time.

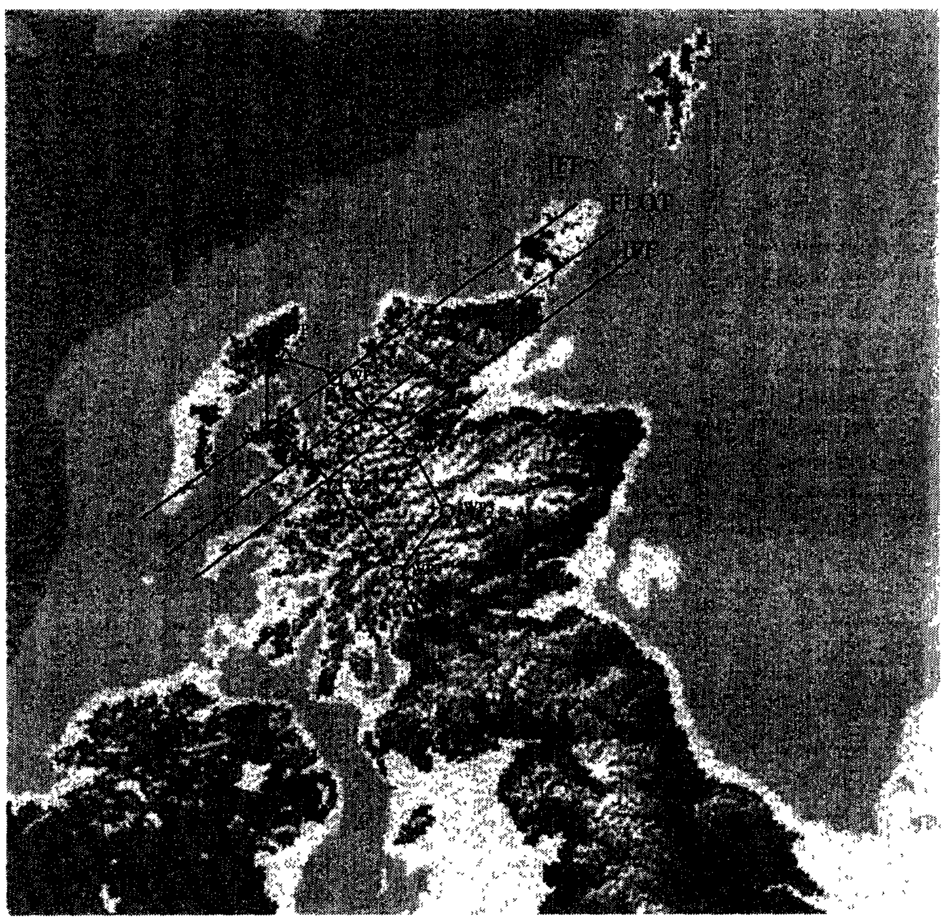
At the same time #3 and 4 are about 45 seconds in trail, and #3 determines that it will be difficult to over fly the IP. #3 decides to do an INS/GPS designation of the target and then carries out his own attack. AMIRS is slewed to the target designation, and #3 selects Wide Field of View (**WFOV**). Lead is now heading with #2 towards the dump target, to drop #2's bombs. He notices on his LINK 16 display that the original group of bandits is turning back towards them. Lead calls for #4 to engage the bandits. #4 slaves his radar to the bandits, via his Link 16, and fires both his AMRAAM's at them. #3 and #4 now turn towards the Rendezvous (**RV**) point for the Egress, leaving the AMRAAM's to engage the bandits in their active mode. #2 is able to designate the dump target, and carries out an attack on it. #3 and #4 are now at the egress RV point, and Falcon lead calls that he is 1 minute back from the RV. Lead now makes the decision to allow the entire Falcon flight to egress ahead of him, and using his LINK 16 display, backed up with his radar in RWS mode and AMIRS, forms up behind Falcon flight.

The entire formation is now established in an egress, with Hornet #3 and #4 out in front, Falcon flight in the middle, and Hornet lead and #2 in the rear. As they are approaching the FLOT, the wingmen rejoin into FIGHTING WING formation, and lead looks back to see an airborne explosion. He can see on his LINK 16 that Magic is still showing one bandit who has now turned back cold, so the assumption is made that one of #4's AMRAAMs was successful. The egress is completed with no further incident, the formation climbs to the ACO friendly altitude of 4000 feet and slows to 360 knots. Lead then timely completes a mission report. There will be other AI missions launching within the next hour. Lead contacts the command and control centre at home base via secure MILSATCOM. He reports that one SU-27 was splashed, that Lead and #3 dropped on the primary target, and that #2 dropped on the dump target. He then has #3 digitally transmit his AMIRS recording, so that pilots at base can begin the critical task of BDA. He verbally reports that #2 was successful on the dump target. #3 digitally transmits his Mark point, and instructs **CCC** that this point has troops armed with handheld heat seeking SAMS, as no indication was received from the RWR when #2 was engaged. Lead also verbally reports the AAA in the target area, and both the handheld SAMS and the AAA are entered into the MIDS database for follow-on formations. The time is 1728Z.

Night BAI Mission

At 1849Z, during en route transit to the TRP, the CF-18 section, callsign PULLER, dons their Night Vision Goggles and adjusts exterior aircraft and interior cockpit lighting accordingly. The formation of CF-18s leaves the TRP in the briefed formation of OFFSET CARD, at an altitude of 25,000 feet, flying at 480 knots ground speed. Proceeding on their route towards **WYPT** 2, they notice on their HSDs, via MIDS, that there is a group of aircraft approaching from the northeast at an altitude of 32,000 feet. MIDS has tagged these aircraft as friendly, their altitude is **IAW** the published ACO, and they appear to be squawking the appropriate Mode 1 and 4 IFF codes upon interrogation by the CF-18s. Lead uses the passive NCTR processing feature of his APG-73, operating in TWS mode, and identifies the aircraft as a flight of 4 F-16 aircraft, now approximately 25 nm from the CF-18's current position. As well, as soon as TWS processing began, the AMIRS was slaved to the radar **LOS**, allowing the pilot to visually identify the inbound aircraft using the magnified IR image displayed to him. As the range closes between the two formations, the CF-18 aircrew begin to receive intermittent F-16 Search SPIKEs on their respective RWRs. Referring to their HSDs, they confirm via MIDS that the SPIKEs are from the approaching formation of F-16s. Having a very high confidence level that the formation is indeed friendly, the CF-18s make no defensive reactions or calls to AWACS, and continue to travel northbound on their route towards the FLOT. As the two formations merge, the NVG-equipped CF-18 formation members monitor visually the friendly formation of coalition F-16s that has been encountered.

Figure 3 Night BAI Mission



Turning north at WYPT 3, the CF-18s notice that MIDS is displaying an active SA-8 battery along their route near the FLOT. As the formation turns to enter the Transit

Corridor (**TC**) overhead WYPT 4, #2 calls an SA-8 SPIKE at 12 o'clock. Simultaneously, his on-board jammer begins to jam the incoming radar signal. Lead notices that his RWR is also beginning to show lethal SA-8 indications, and that his on-board jammer is attempting to deceive the hostile radar signal as well. In order to counter the threat he calls for the formation to increase to **MIL** power and maintain their altitude. Using his HSD as a reference, Lead turns his formation 45 degrees to the right, away from the known SA-8 location. During the turn all formation members release a program of chaff from their ALE-47 to further confuse the enemy's radar. Rolling out of the turn, Lead notes on his HSD that his flight path should now pass outside of the SA-8's lethal range (based on the current position of the SAM as down linked in real-time from MIDS), and that the enemy radar signal falls within his jammer's rear cone of coverage. Lead and #2 quickly drop their spikes, and both call NAKED.

Almost immediately #3 and #4 begin to pick-up RWR indications that the SA-8 operators have switched their attention to them. #4, closest to the threat and just inside the SA-8's maximum engagement range, calls a critical SPIKE, as his RWR now indicates a missile launch has just occurred. Because of layers of cloud below them, none of the formation members are able to pick-up the missile launch visually. #4, still spiked, turns hard right away from the threat and begins a CHAFF WEAVE, ensuring on his HSD that the enemy signal is in the optimum location for his on-board jammer, and that his flight path will keep him outside the SA-8's maximum range for any follow on engagements. He notes that his on-board jammer is successfully jamming the guidance signal for the incoming missile(s). #3 watches off his beam for visual indications of the missile(s)'s approach. A few seconds later he sights two missiles, their boosters still burning, bursting through the cloud deck below. While they appear to be trying to track #4, they are both lagging his position badly. #3 calls the missiles out, and #4 turns back hard to the left, preparing to carryout a visual missile defence. However, before he has even completed his turn, both missiles go ballistic, diving erratically away into the cloud below. The combination of manoeuvres, jamming, and chaff succeed to defeat the SA-8 launch, and within a few seconds #4 calls NAKED. All other formation members are also NAKED. Lead calls for the formation to proceed north until they are approximately 15 miles beyond the FLOT, allowing the formation time to regain the briefed OFFSET CARD formation. Once formation integrity is re-established, Lead turns his 4-ship back northwest towards the target area. With another 60 miles to go before arriving overhead the target, Lead slows his formation back to the pre-planned ingress speed of 480 kts ground speed.

As the CF-18s continue towards their target, GUNSLINGER informs Lead that the target area is entirely obscured by cloud, negating the primary plan of carrying out a medium level attack with AMIRS/GBU-16/MAV G. Lead decides to continue with the mission. His formation will resort to their back-up plan of conducting a medium-level weapons delivery against their primary target using JDAM. As the formation approaches the target, they are still flying in an OFFSET CARD formation at 25,000 feet above sea level **(ASL)**. They are in night **VMC** weather conditions, with an undercast approximately 10,000 feet below them, and reported cloud layers in the target area down to 1,000 feet

AGL. They are using NVGs to visually maintain formation position and perform a visual lookout.

At 40 nm from the target, the four CF-18 formation members carryout their initial air-to-ground checks, ensuring on their STORES page that JDAM is communicating normally with their aircraft, and that the target coordinates entered into each weapon are correct. The pilots also verify that the required number of satellites are being received by both the CF-18's INS/GPS and each individual JDAM to ensure that the required degree of accuracy is achieved during the weapon's release and terminal guidance to the target. At 30 nm from the target, all formation members return to air-to-air mode on their APG-73 radars and sanitize the target area for any undetected air-to-air threats. MAGIC calls the target area clear, and all formation members are CLEAN as they approach 25 nm from the target area.

Lead increases his formation to the pre-briefed attack speed of 540 kts true air speed (**TAS**). At 20 nm from the target the formation members designate the target waypoint on their HSD and open away from the target, turning 10 degrees to the right. They then select EXP 2 mode, in the air-to-ground mapping function of the APG-73, and allow the radar to build a radar image of the target area. The turn to the right improves the look angle of the radar onto the target. As the scene builds on their radar displays, and formation members are confident they have designated the correct coordinates, they cycle down through the more detailed EXP 3, EXP 4, and finally EXP 5 mapping modes of the APG-73. Using real-time satellite imagery down linked to them via MIDS and target area maps carried with them in the cockpit, they confirm that the designation on their radar corresponds to the aim points assigned to them in the mission briefing. If their designations need correcting, this is accomplished by assigning the **TDC** to the radar, and then no-action slewing the designation over the desired aim point on the radar display. **NLT** 15nm, and once satisfied with their designations, formation members turn back towards the target and centre the ASL line in their HUDs. Lead/#2 proceed towards their bridge target, and #3/#4 towards the communications facility just north of the bridge. The CF-18 pilots individually verify that all of their cockpit switch selections are correct to allow a proper release of their weapons. As release cues come alive in the top of their HUDs, the pilots' depress the weapons release switch on the top of the stick, enabling the SMS to release the JDAMs at the optimum computed release point. At the appropriate time, all weapons separate normally from the CF-18s. Once clear of the launch aircraft the JDAM's guidance control unit generates steering commands to fly the bomb towards its specific target based on GPS-data. All four weapons fall through the various cloud layers and impact their desired aim points accurately.

Having completed their individual weapons deliveries, formation members return their radars to air-to-air mode and sanitize for any airborne threats that may have appeared while they were performing their weapons delivery. The information displayed by MIDS, called by AWACS, and seen by formation members on their radars, confirm that there are no threats in their immediate vicinity. The formation quickly regains OFFSET CARD formation, and begins the egress portion of the mission at 480 kts TAS, at an altitude of 25,000 feet ASL. The egress portion of the mission is mostly uneventful, with only intermittent SA-8 RWR indications observed by formation members while transiting overhead the FLOT. Once across the FLOT homebound, the formation climbs to 32,000 feet IAW the published ACO, and an in-flight Situation Report (**SITREP**) is passed to GUNSLINGER. FENCE OUT checks are then carried out by the CF-18 formation. The time is 1951Z.

Night OAS/CAS Mission

The 2-ship formation of CF-18s, callsign MOLSON, has been tasked to conduct a night time **OAS/CAS** mission in a **ROZ** along the FLOT near WYPT 5.

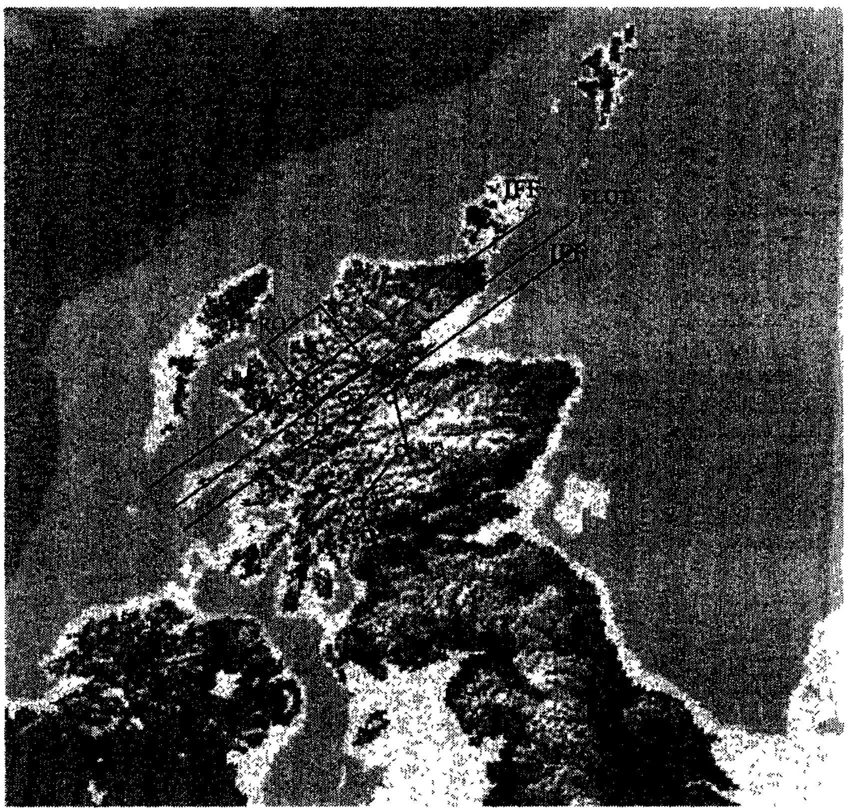


Figure 4 Night OAS Mission

At 2037Z, leaving the TRP, the 2-ship formation of CF-18s is flying in a DOUBLE ATTACK visual formation, using NVGs, at an altitude of 22,000 feet mean sea level (**MSL**). They are transiting at an air speed of 450 kts TAS, following the published ACO routing towards their assigned operating area near the FLOT. AWACS, callsign MAGIC, informs them PICTURE CLEAR. The CF-18s are sanitizing the airspace north of their position using the APG-73 and cross-checking MIDS which concurs. Overhead WYPT 3, Lead contacts ABC[3], call sign GUNSLINGER, using HaveQuick II to receive his mission briefing. Using MIDS, GUNSLINGER updates all active surface-to-air and air-to-air activity in the area. All air activity is currently tagged as friendly, except a pair of Mig-29s flying well north of the FLOT, and sporadic enemy helicopter traffic flying low-level along the FLOT. There is no significant radar-guided SAM/AAA activity near the formation of CF-18s, however there have been several **MANPAD** SAM launches reported in the target area where the CF-18s will be operating. GUNSLINGER reports the weather in the target area is generally **CAVOK**, with light winds out of the northwest. A **PIREP** from a previous formation of Dutch (**RNLAF**) F-16 fighters indicates that there are scattered low-level clouds in the target area. GUNSLINGER then passes the following mission briefing to the CF-18s via MIDS:

A. CP -------------------------- WHISKEY
B. MAG BRG ---------------- 320 DEGREES
C. DIST ----------------------- 21.6 NAUTICAL MILES
D. UTM ----------------------- CD 1435 8219
E. LAT/LONG --------------- N 56 34.5 W 021 14.8
F. TGT ------------------------ WEAPONS STORAGE COMPLEX
G. MAND ATTK HDG ----- 320 to 030 DEGREES
H. FRIENDLY FORCES --- 1 KM SSW
I. TGT ELEVATION ------ 1045 FEET
J. LASER CODE ----------- 1604
K. REF PT -------------------- N/A
L. THREATS ---------------- MANPADS ON HILLTOPS

Lead reads back the mandatory briefing items via secure voice on HaveQuick II. GUNSLINGER then instructs the CF-18 formation to proceed to CP Whiskey, climb to 25,000 feet, and contact their FAC, callsign LONDON, on the pre-assigned frequency.

Lead begins a slow climb to 25,000 feet as they transit northbound towards **CP** Whiskey. Both pilots perform their initial air-to-ground systems checks, confirming that their weapons programming has been done correctly, and that all weapons carried are communicating properly with the SMS. Both formation members then confirm that their INS/GPS's accuracy is sufficient, updating their navigation system if required. Target coordinates are then entered into their navigation database and plotted on target area maps.

Next, a detailed target and target area study is conducted by both formation members, while maintaining a proper visual lookout as they continue towards the CP. The target is a series of weapons storage bunkers lying inside a north-south valley. There is heavy, rolling terrain on both the east and west sides of the valley. They have been tasked to destroy the two southernmost bunkers in the complex. Using this information, Lead decides that once he passes CP WHISKEY he will offset his formation to the west before he turns inbound to the target, so that he can approach the target on a heading of roughly 360 degrees. This manoeuvre will accomplish two tasks. First, it will ensure that his formation honours the assigned attack axis from the mission briefing. Second, it will allow the CF-18s to approach along the axis of the valley, optimizing the AMIRS LOS to the target, and maximizing the opportunity for a first run attack on the target. Using target photos, Lead notices that the bunkers themselves are concrete structures, located partially above ground. He decides that his formation will employ Advanced Paveway II GBU-16 weapons against the target. Lead informs #2 of this fact, and instructs him to set a 25-millisecond delay in the GBU-16's **EFUZ** to ensure the concrete roof of each bunker is fully penetrated before warhead detonation occurs. Both pilots modify their GBU-16 program on the STORES page accordingly. Since Lead will drop first, his bomb will likely impact its target slightly before #2. Also considering the orientation of the wind, Lead advises #2 to designate the far, or northernmost, of the two bunkers. This way the smoke from Lead's explosion should not interfere with the terminal guidance of #2's weapon into its target. Lead, therefore, will drop on the southernmost bunker in the complex.

At 10 nm from CP Whiskey, MAGIC calls PICTURE CLEAR, again confirming to the formation members that there is no known enemy air activity nearby. Lead switches his formation to the assigned discreet frequency, and they contact LONDON. Following proper authentication procedures on HaveQuick II, LONDON informs the formation that their target has been changed. They are now to attack the two northernmost bunkers in the weapons storage complex, as their original targets have already been destroyed by a previous formation. LONDON uplinks the new target coordinates to each aircraft, and tells them that the balance of the briefing remains unchanged. Lead calls by WHISKEY, and LONDON clears the CF-18s into the target area. Lead advises he will be approaching from the south, and that he intends to conduct a first run attack if possible. LONDON acknowledges Lead's intentions.

Using standard tactical turns, the element of CF-18s turns inbound the target from the south. At 20 nm from the target, both formation members designate the target WYPT, open 10 degrees to the right, and uncage their AMIRS pod, selecting WFOV. The two CF-18s are flying in double attack at 25,000 feet ASL, 540 knots TAS, with #2 on the east side of the formation stacked slightly high, and swept back to allow him a better visual on Lead. The weather is generally good, and both formation members have an excellent view of the ground below using NVGs. On the left DDI, the formation members study the IR image presented to them by the AMIRS, ensuring that the scene matches the target area they have been assigned. Satisfied that this is the case, both pilots then select Narrow Field of View **(NFOV)** on the AMIRS and carefully scrutinize the exact location of their designation. Lead's designation is directly over his target, and he calls CAPTURED. #2, seeing his designation is a few hundred feet west of the northernmost bunker, ensures that the TDC is assigned to the AMIRS and then no-action slews his designation over his target. #2, then calls CAPTURED. LONDON asks Lead to confirm what he sees immediately north of his bunker. Referring to his AMIRS display on the left DDI, Lead replies that there is a small bridge with a vehicle on it, moving from east to west, just north of his target. #2 concurs. LONDON, confident the CF-18s have acquired the proper targets, asks them to call IN HOT. Lead calls IN HOT for his formation, and LONDON replies, CLEARED HOT.

Both aircraft turn left to centre the ASL line in their HUD, and confirm their switches are properly selected to ensure weapon release. As release cues come alive at the top of their HUDs, the pilots select the weapon release switch on the stick, enabling the MC2 to release the GBU-16s at the proper time. As the pilots fly through their release cues, one GBU-16 is released from each aircraft. Lead and #2 both call DROP. The weapons falls ballistically until clear of the launch aircraft, and then the seeker at the front of each weapon begins to search for the appropriate laser signal being reflected off its' target by the AMIRS pod on each aircraft. Having acquired the properly coded laser signal, the weapons begin to guide on the reflected laser energy towards their targets. Both formation members refine their designation using the TDC during their weapons' time of flight (**TOF**). With 10 seconds TOF remaining before weapons impact, a band of low-level cloud passes over the bunker complex, completely obscuring the target. Automatically, the weapons revert to back-up internal GPS guidance, and continue towards their targets. Even though the target remains covered with cloud for the remainder of the delivery, the weapons impact squarely on the roof of their assigned bunkers, penetrating the reinforced concrete and completely destroying both structures. Lead calls OFF HOT for the formation. LONDON acknowledges, and directs the CF-18s to return to CP WHISKEY to await BDA and follow-on tasking. The CF-18s execute an in place 180 degree turn to the left, proceeding back to the CP, ensuring their post-attack switchology is correct. Approaching the CP, LONDON calls Lead to inform him that their attack was successful.

A few seconds later, LONDON informs the CF-18s that his position is taking direct fire from heavy artillery located on a hilltop, directly across the valley from his position. Due to the urgent nature of the tasking, LONDON asks the CF-18s to turn back immediately into the target area, and plan to use MAV G against the artillery pieces, with the designation being provided by LONDON's laser spot. Lead acknowledges, and calls for an in-place 180 degree turn back towards the target area. Both formation members quickly carry out their air-to-ground systems check, select their MAV G on the stores page, and call up the MAV display on the right DDI. The pilots also ensure that the LST function on their AMIRS pod is functioning as they proceed inbound to the target area. At 15 nm, LONDON advises the CF-18s that he is about to begin lasing the hostile artillery position. A few seconds later LONDON calls SPOT ON, as he focuses his ground laser-designator on the target on the other side of the valley from his position. The formation members, pick-up the laser spot on their AMIRS display, and their LSTs begin tracking the LONDON's laser spot. Lead/#2 both call CAPTURED. Both pilots then designate the laser spot on their AMIRS display, and select NFOV. On their DDIs, they can both see two artillery pieces in an open area on a hilltop on the east side of the valley. Lead calls for a near/far sort considering the wind orientation, and then slews his designation over the nearer of the two artillery pieces. #2 designates the farther of the two targets. Lead calls IN HOT for the formation as they approach 10 nm. LONDON calls CLEARED HOT. Lead/#2 begins a gentle pushover from 25,000 feet at 10 nm, and uncage their MAV Gs, watching them slave to the AMIRS LOS. Assigning their TDCs to the MAV display, both formation members lock onto their respective targets. Confident they have acquired the proper targets and that they have satisfied all the launch requirements for their delivery, the two pilots depress their weapons release switches, and watch as the missiles launch from their aircraft and begin guiding towards their targets. Lead calls OFF HOT as both formation members, now passing 20,000 feet in a 10 degree dive, pull up sharply following their weapons delivery and begin sanitizing the area around them both visually and on radar. The formation quickly regains a DOUBLE ATTACK formation, and climbs back up to 25,000 feet. A few seconds later the missiles, armed with an **INST** fuse delay, impact and destroy the two artillery pieces. LONDON passes the successful BDA to the formation. #2 calls JOKER, and Lead advises LONDON that his formation is **RTB**. LONDON acknowledges and clears the formation out of the target area, advising them to contact GUNSLINGER overhead CP Whiskey.

The formation egresses as directed via CP Whiskey, and contacts GUNSLINGER, passing a SITREP to him, and advising that they are RTB. GUNSLINGER acknowledges, and the formation again monitors MAGIC, as they begin their transit home via the ACO. A FENCE OUT check is carried out by the 2 CF-18s. The time is 2135Z.

Recovery to Operating Base

At 2140Z, BULMER issues clearance for PULLER to depart the CP, direct routing to the recovery aerodrome outer approach beacon, descending ANGELS 6 and contacting Victor surveillance radar on TAD 26. PULLER Lead acknowledges, asks his formation for final fuel and ammo states and directs #3 and #4 to assume 3 nm radar trail. Once #3 calls tied (with #4 in close formation), Lead commences descent and routes directly to Victor outer marker, using EGI and MMD.

On check-in with Victor PULLER Lead is asked to authenticate, change IFF codes and squawk **IDENT**. He is also advised that **SHORAD** approach procedures to runway 11 are in effect, that navigation approach aids are out and that flight traffic advisory to commencement of the SHORAD approach, only, would be provided. Airfield altimeter is 29.74 and weather has deteriorated to a surface visibility of 1 nm and a ceiling of 300 feet AGL. At this notification, PULLER requests the status of the pre-planned mission diversion base but is informed that the diversion aerodrome is not usable for reasons other than cloud or visibility minima. PULLER is directed to land at Victor via the SHORAD approach.

PULLER offsets his radar trail formation to join the runway centreline at 45 degrees, 15 nm back, in accordance with the SHORAD approach procedure. Lead establishes this intercept, slows to 300 KIAS and switches the 3-ship over to GAMBIT operations to give status reports. PULLER is informed that the **MOS** is 6,000 feet, commencing at the runway 4-bar extending to the high-speed cut-off.

At 15 nm back Lead joins the runway centreline and slows the (radar trail) formation to 250 KIAS at 1500 feet AGL. At this point Lead and #3 (with #4 in close formation) fly independent, radar-designated, SHORAD approaches to short final and landing. At 7 nm back they extend landing gear and land flap, set the radar altimeter to 150 feet AGL, and fly a 2 and a half-degree glide path to their point of radar designation. At 200 feet AGL, the CF-18s break out of cloud and execute uneventful full stop landing. The time is 2155Z.

The CF-18s taxi in for de-arming and are shut down in designated parking in assigned **HASs**. Post shutdown, the aircrew debrief the recovery and turn-around crews and proceed to operations area for aircraft sign-in and full mission debrief. The composite mission scenario tasking is deemed concluded.

Measures of Effectiveness

Metrics by which the overall effectiveness of the system will be assessed were developed in the form of Measures of Effectiveness (MOEs). This list is an initial investigation into the types of information that may make good candidates for assessing overall system (man and machine) effectiveness in the completion of operational missions. It is important to note that this list contains many items which cannot be quantified and that there is no relative weight or importance assigned to each. Further work is required to decompose each of these statements into quantifiable MOEs that can be subsequently ranked by importance and assigned weighting factors.

General:

- Serviceability of the basic aircraft and aircraft systems.
- Level of aircraft system redundancy to compensate for unserviceabilities, degrades, or damage once airborne.
- Aircraft range and endurance based on its inner fuel capacity, external fuel capacity (configuration,) ability to refuel once airborne, and rate-of-burn for the configuration.
- Level of aircrew proficiency in operating and managing the different systems and components of the aircraft.

Mission Planning & Briefing:

- Aircrew ability to mission plan and brief in an accurate, efficient, and expedient manner. This includes aircrew's access to the best available recce.

Pre-Taxi Phase:

- Accurate and timely transfer of all data from both the mission planning phase and outside sources into aircraft systems.

Airborne MOEs which apply to all Phases of a Mission

- 100% Survival
- Clarity and security of voice communications

- Security and quantity of data communications
- Accuracy of aircraft navigation throughout all mission phases
- Accuracy and ease of formation keeping in all phases of flight under both VMC and IMC conditions
- Efficiency and accuracy of a visual lookout during day and night VMC conditions
- Level of pilot workload and degree of task saturation during any and all critical mission tasks
- Situational Awareness on ACO friendly routing and areas

En-Route Air-to-Air Engagements:

- Time and Ability to identify Friend or Foe beyond visual range using all available sensors and systems
- A/A missile effectiveness; This includes the range that the aircraft can threaten potential bandits, and the effectiveness of any a/a missiles in an actual engagement
- Ability to accurately detect all significant air-to-air threats
- Minimum Time to Kill A/A Bandit
- Effectiveness of air-to-air counter-measures
- Ability to maintain situational awareness of all friendly and enemy aircraft
- Ability to provide mutual support to formation members
- Ability (time) to visually pick up **WVR** aircraft
- Ability (time) to assess success of A/A missile

En-Route Surface-to-Air Engagements:

- Ability to accurately detect all significant surface-to-air threats
- Effectiveness of surface-to-air counter-measures
- Ability to maintain situational awareness of all friendly and enemy SAM systems
- Ability (time) for the pilot to assimilate information
- Ability to visually pick up incoming missile
- Ability to defeat missile / radar
- Ability to retain ordnance through maneuvers

Target Area and Weapons Delivery

- Effectiveness of selected weapon against assigned target

- Ability to maintain a safe distance from the target area to avoid both unfriendly fire/detection and weapons frag
- Precision of initial target designation, and ability to quickly and easily update the target designation
- Range at which assigned target can be positively identified
- Time to positively identify the target
- Ability to timely and accurately identify assigned target and desired mean point of impact (DMPI)
- Number of redundant weapons delivery profiles and methods available to ensure attack success
- Precision of weapons delivery
- Amount of cockpit workload associated with weapons delivery
- The ability to do real time self bomb damage assessment using on board systems
- Ability to maintain situational awareness on all friendly and enemy ground troops and aircraft
- Ability to perform BDA
- Ability (time) to complete weapon delivery

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Glossary

24/7	24 hours a day, 7 days a week
A/A	Air-to-Air
A/G	Air-to-Ground
AAA	Anti-Aircraft Artillery
AAR	Air-to-Air Refuelling
ABC^3	Airborne Battlefield Command, Control and Communications
AC	Alternating Current
ACDVS	Aircrew Chemical Defence Ventilator System
ACM	Air Combat Manoeuvring
ACM	Airspace Control Measures
ACO	Airspace Coordination Order
ADF	Automatic Direction Finder
AGL	Above Ground Level
AI	Air Interdiction
ALSE	Advanced Life Support Equipment
AMIRS	Advanced Multi-Role Infrared Sensor
AMLCD	Active Matrix Liquid Crystal Display
AMRAAM	Advanced Medium Range Air-to-Air Missile
AOB/GOB/EOB	Air, Ground and Electronic Orders of Battles
ASL	Above Sea Level
AST	Air-to-Surface Tactics
ATO	Air Tasking Order
AWACS	Airborne Warning and Control System
BCA	Border Crossing Authority
BDA	Bomb Damage Assessment
BSC	BAE Systems Canada Inc.
BST	Boresight Mode
CAMAO	Combined Allied Military Air Operation
CARD	4 Ship Tactical Formation

CAS	Close Air Support
CAS PG 2000	Chief Air Staff Planning Guidance 2000
CAVOK	Ceiling and Visibility OK (Clear Weather)
CCC	Command, Control and Communications
CCIP	Constantly Computed Impact Point
CD	Counter Drug
CF	Canadian Forces
CFIT	Controlled Flight Into Terrain
CMDS	Counter Measures Dispensing System
CONOPS	CONcept of OperationS
CP	Contact Point
CR	Combat Ready
D/L	Data Link
DAR	Directorate of Air Requirements
DC	Direct Current
DCIEM	Defence and Civil Institute of Environmental Medicine
DCS	Digital Communication System
DDIs	Digital Display Indicators
DEWS	Defensive Electronic Warfare Suite
DFFG	Deep Fathom Fishing Grounds
DIST	Distance
DMPI	Desired Mean Point of Impact
DND	Department of National Defence
DSTA	Director Science & Technology, Air
ECCM	Electronic Counter-Counter Measures
ECM	Electronic Counter Measures
ECS	Environmental Control System
EFUZ	Electronic Fuze
EGI	Embedded Global Positioning/Inertial Navigation System
EGR	Embedded GPS Receiver
ELE	Estimated Life Expectancy
F/A	Fighter Attack

FAC	Forward Air Controller
FAOR	Fighter Area of Operational Responsibility
FLIR	Forward Looking Infra-Red
FLOT	Forward Line of Own Troops
FM	Frequency Modulation
FPTD	Fighter Pilot Training Directive
FRAG	Fragmentation
FSU	Former Soviet Union
GP	General Purpose
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
G/S	Ground Speed
HAS	Hardened Aircraft Shelter
HDD	Head-Down Display
HF	Human Factors
HFE	Human Factors Engineering
HMD	Helmet Mounted Display
HMS	Helmet Mounted Sight
HOBS	High Off Boresight System
HOTAS	Hands-On-Throttle-And-Stick
HSD	Horizontal Situation Display
HUD	Heads-Up Display
HVAA	High Value Airborne Asset
Hz	Hertz
IAD	Integrated Air Defence (IAD) System and SAM: SA-6, SA-7, SA-8, SA-11, SA-13, SA-14 and SA-16
IAW	In Accordance With
IDENT	Identification
IFF	Identification Friend-or-Foe
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
IMP	Incremental Modernization Project

INS	Inertial Navigation System
INST	Instantaneous
INU	Inertial Reference Unit
IP	Initial Point
IPME	Integrated Performance Modelling Environment
IR	Infra-Red
JDAM	Joint Direct Attack Munitions
JFC	Joint Force Commander
JSOW	Joint Stand Off Weapon
KIAS	Knots Indicated Air Speed
Lat/Long	Latitude and Longitude
LGB	Laser Guided Bombs
LOS	Line of Sight
LST	Laser Spot Tracker
MAG BRG	Magnetic Bearing
MAND ATTK HDG	Mandatory Attack Heading
MANPAD	Man-Portable Air Defence
MAV	Maverick
MCs	Mission Computers
MDG	Multi-purpose Display Group
MDLS	Mission Data Loading System
MFFOs	Mixed Fighter Force Operations
MHz	Megahertz
MIDS	Multi-functional Information Distribution System
MIL	Military Power
MIL-HDBK	Military Handbook
MILSATCOM	Military Satellite Communications
MOEs	Measures of Effectiveness
MOS	Maximum Operating Surface
MRI	Multiple, Release, and Interval
MSI	Multi-Sensor Integration
MSL	Mean Sea Level

NATO	North Atlantic Treaty Organization
NCTR	Non-Cooperative Target Recognition
NFOV	Narrow Field of View
NLT	No Later Than
nm	Nautical miles
NORAD	North American Air Defence
NVGs	Night Vision Goggles
NVIS	Night Vision Imaging Systems
OAS	Offensive Air Support
OEM	Original Equipment Manufacturer
OFP	Operational Flight Program
OPFOR	OPposing FORces
OSDs	Operational Sequence Diagrams
PC	Personal Computer
PGMs	Precision Guided Munitions
PIREP	Pilot Report
PPS	Precise Positioning Service
PRF	Pulse Repetition Frequency
psi	Pounds per square inch
PSKE	Pilot Skill and Knowledge Element
PSKL	Pilot Skill and Knowledge Level
PTLL	Pilot Tactical Leadership Level
PWGSC	Public Works and Government Services Canada
REF PT	Reference Point
ROE	Rules Of Engagement
ROZ	Restricted Operating Zone
RTB	Return To Base
RV	Rendezvous
RWR	Radar Warning Receiver
RWS	Range While Search
SAM	Surface-to-Air Missile
SAR	Semi Active Radar

SATCOM	Satellite Communications
SHORAD	Short Range Air Defence
SITREP	Situation Report
SLOC	Sea Lines Of Communication
SMS	Stores Management Set
SOPs	Standard Operating Procedures
SOW	Statement Of Work
SPS	Standard Positioning Service
SRAAM	Short Range Air-to-Air Missile
STT	Single Target Track
SVs	Space Vehicles
TACAN	Tactical Air Navigation
TAOC	Tactical Air Operations Centre
TAS	True Air Speed
TC	Transit Corridor
TCCCS	Tactical Command, Control and Communication System
TDC	Target Designator Control
TGT	Target
TOF	Time Of Flight
TRP	Tactical Rendezvous Point
TWS	Track While Scan
UDFs	User Data Files
UFC	Up-Front Controller
UHF	Ultra High Frequency
UN	United Nations
US	United States
USMC	United States Marine Corps
USN	United States Navy
UTM	Universal Transverse Mercator
VACQ	Vertical Acquisition Modes
VHF	Very High Frequency
VMC	Visual Meteorological Conditions

VOR	VHF Omni-Range
VS	Velocity Search
WACQ	Wide Acquisition
WFOV	Wide Field of View
WVR	Within Visual Range
WYPT	Waypoint
XEFZ	Xarian Economic and Fishing Zone
YFR	Yearly Flying Rate
Z	Zulu

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14. ABSTRACT

(U) The Directorate of Aerospace Requirements (DAR 5) is in the process of upgrading the CF-18A to maintain its technical currency over the next 20 years. Part of this upgrade will be the inclusion of a Helmet Mounted Display (HMD) with a Night Vision Imaging System (NVIS) capability.

As the use of HMD and NVIS technologies in the CF-18A represent new ways of performing old tasks, it was determined essential to establish how this technology would be used and to document the flow of information in the cockpit.

The Defence and Civil Institute of Environmental Medicine (DCIEM) has undertaken an investigation of HMD and NVIS technologies in order to provide DAR with advice on human factors issues that may arise from their use in the CF-18A. The investigation will focus on the Air to Ground role of the CF-18A as this is the most likely role in North Atlantic Treaty Organization (NATO) and coalition activities. The Air to Ground role of the CF-18A also presents a high cognitive demand on the skills and abilities of the pilot.

This report provides a detailed description of the assumed air vehicle and presents a mission scenario based on a defined CF-18A equipment suite and the employment of the CF-18A in an operational Air to Ground environment. The results of the Human Factors (HF) Analysis will be used to assess the impact of HMD and NVIS technologies and the flow of information in the cockpit of the Modernized CF-18A.

15. KEYWORDS, DESCRIPTORS or IDENTIFIERS

(U) F18; air to ground; Hornet; CF18