3-2003

Multimission Aircraft Design Study-Operational Scenarios

Nevin Coskuner

MULTIMISSION AIRCRAFT DESIGN STUDY - OPERATIONAL SCENARIOS

THESIS

Nevin Coskuner, First Lieutenant, TUAF

AFIT/GSE/ENY/03-1

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

AFIT/GSE/ENY/03-1

MULTIMISSION AIRCRAFT DESIGN STUDY - OPERATIONAL SCENARIOS

THESIS

Presented to the Faculty

Department of Aeronautics and Astronautics

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science (Systems Engineering)

Nevin Coskuner

First Lieutenant, TUAF

March 2003

AFIT/GSE/ENY/03-1

MULTIMISSION AIRCRAFT DESIGN STUDY - OPERATIONAL SCENARIOS

Nevin Coskuner
First Lieutenant, TUAF

Approved:

Curtis H. Spenny, PhD (Advisor) — 10 March 03 — date

Lt.Col. David R. Jacques (Reader) — 10 MAR 03 — date

Mikel M. Miller, PhD (Reader) — 10 March 03 — date

Acknowledgments

I would like to express my sincere appreciation to my faculty advisor, Prof. Curtis H. Spenny, for his guidance and support throughout the course of this thesis effort. The insight and experience was certainly appreciated. He was always very helpful for any kind of problems and questions. Also I would like to express many thanks to Lt. Col. Ernest P. Smith (Retired) for his great effort in order to make my time easy throughout the first year in AFIT.

Nevin Coskuner

Table of Contents

Page

Page

Page

Page

List of Figures

Figure **Page**

Figure **Page**

List of Tables

Table **Page**

Acronym List

1. Airborne Battlefield Command and Control Center (ABCCC)
2. Airborne Close Air Support Coordinators (ACASCO)
3. Aircraft (A/C)
4. Airborne Command Element (ACE)
5. Acoustic Intelligence (ACOUSTINT)
6. Air Campaign Planning Tool (ACPT)
7. Airborne Communication System Operators (ACSO)
8. Airborne Early Warning (AEW)
9. Air Force Wing Command and Control System (AFWCCS)
10. Air Force Mission Support System (AFMSS)
11. Automated Installation Intelligence File (AIF)
12. Airborne Intelligence Officer (AIO)
13. Airborne Intelligence Technician (AIT)
14. Airborne Maintenance Technician (AMT)
15. Area of Operations (AO)
16. Area of Operations Center (AOC)
17. Airborne Strike Controllers (ASC)
18. Airborne Support Operations Center (ASOC)
19. Airborne Warning and Control Center (AWACS)
20. Battlefield Coordination Element (BCE)
21. Bomb Damage Assessment (BDA)
22. Battle Staff Operations Officer (BSOO)
23. Chemical and Biological Intelligence (CBINT)
24. Command and Control (C2)
25. Command, Control and Communications (C3)
26. Command, Control, Communications and Counter Measures (C3CM)
27. Command, Control, Communications, Computers and Intelligence (C4I)
28. Command, Control, Communications, Computers and Intelligence, Surveillance and Reconnaissance (C4ISR)

29. Command, Control, Communications, Counter Measures and Intelligence, Surveillance and Reconnaissance (C3CMISR)
30. Counter Intelligence (CI)
31. Critical Design Review (CDR)
32. Computerized Movement Planning and Status System CALL (COMPASS CALL)
33. Commander In Chief (CINC)
34. Circular Error Probable (CEP)
35. Courses of Action (COA)
36. Communications Intelligence (COMINT)
37. Combat Air Patrol (CAP)
38. Contingency Theater Automated Planning System (CTAPS)
39. Director of the Airborne Battle Staff (DABS)
40. Directed Energy Weapons Intelligence (DEWINT)
41. Department of Defense (DOD)
42. Different Tail Numbers (DTN)
43. Digital Geographic Information (DGI)
44. Electronic Counter Measures (ECM)
45. Electronic Counter-Counter Measures (ECCM)
46. Electrical Facilities (ELE)
47. Electro-Optical Intelligence (ELECTRO-OPTINT)
48. Electronic Intelligence (ELINT)
49. Electro Magnetic Spectrum (EMS)
50. Electronic Support Measure (ESM)
51. Electronic Warfare (EW)
52. Fixed Target Indicator (FTI)
53. Forward Looking Infrared (FLIR)
54. Global Command and Control System (GCCS)
55. Global Combat Support System (GCSS)
56. Ground Order of Battle (GOB)
57. Global Positioning System (GPS)

58. Government Centers (GVC)
59. High Explosive (HE)
60. High Frequency (HF)
61. Hatley/Hruschka/Pirbhai Methodology (HHP)
62. Information Assurance (IA)
63. Intelligence and Electronic Warfare (IEW)
64. Institute of Electrical and Electronics Engineers (IEEE)
65. Identification of Friend or Foe (IFF)
66. International Council of Systems Engineering (INCOSE)
67. Internal Navigation System (INS)
68. Information Operations (IO)
69. Imagery Intelligence (IMINT)
70. Intelligence Preparation of the Battlefield (IPB)
71. Infrared Intelligence (IRINT)
72. Intelligence, Surveillance and Reconnaissance (ISR)
73. Joint Force Special Operations Component Commander (JFSOCC)
74. Joint Force Maritime Component Commander (JFMCC)
75. Joint Force Land Component Commander (JFLCC)
76. Joint Force Air Component Commander (JFACC)
77. Joint Surveillance Target Attack Radar System (JSTARS)
78. Joint Tactical Information Distribution System (JTIDS)
79. Joint Task Force (JTF)
80. Laser Intelligence (LASINT)
81. Liaison Officer (LNO)
82. Lines of Communication (LOC)
83. Measurement and Signature Intelligence (MASINT)
84. Mission Crew Commander (MCC)
85. Multi-Sensor Command and Control Aircraft (MC2A)
86. Mission Crew Supervisor (MCS)
87. Military Industrial Base (MIB)

88. Multi-Mission Aircraft (MMA)
89. Mission Planning System (MPS)
90. Moving Target Indicator (MTI)
91. Naval Facility (NAV)
92. Nuclear, Biological and Chemical Facility (NBC)
93. North Atlantic Treaty Organization (NATO)
94. National Command Authority (NCA)
95. Nuclear Intelligence (NUCINT)
96. Offensive Air Support (OAS)
97. Offensive Counter Air Installation (OCA)
98. Operations Security (OPSEC)
99. One Tail Number (OTN)
100. Radio-Controlled-135 V/W Rivet JOINT(RC-135 V/W Rivet JOINT)
101. Radio Detection and Ranging (RADAR)
102. Radar Intelligence (RADINT)
103. Unintentional Radiation Intelligence (RINT)
104. Radio Frequency/Electromagnetic Pulse Intelligence (RF/EMPINT)
105. Surface-to-Air Missile (SAM)
106. Synthetic Aperture Radar (SAR)
107. Satellite Communications (SATCOM)
108. Surveillance and Control Data Link (SCDL)
109. Signals Intelligence (SIGINT)
110. Tactical Air Control System (TACS)
111. Tactical Air Installation (TACAN)
112. Tactical Digital Link/A (TADIL/A)
113. Tactical Digital Link/J (TADIL/J)
114. Tactical Information Broadcast Service (TIBS)
115. Time on Target (TOT)
116. Turkish Air Force (TUAF)
117. Unmanned Air Vehicle (UAV)

118. United Nations (UN)
119. United States Code-48 (USC-48)
120. Value System Design (VSD)
121. Wide Area Surveillance (WAS)

AFIT/GSE/ENY/03-1

Abstract

In the most recent years, the Command, Control and Communications, Counter Measures, Intelligence, Surveillance and Reconnaissance (C3CMISR) aircrafts are used commonly in many NATO and UN Operations around the world. These aircrafts are AWACS, JSTARS, Rivet Joint, Compass Call and ABCCC. They provide close air support in the name of airborne surveillance, ground moving target surveillance, target reconnaissance, jamming, and command, control and communications issues in operational environments.

Those aircrafts are tasked with a wide variety of missions than ever before in operational theaters and each one of them comprises a specific amount of cost and risk factors. As a new vision, while replacing the existing legacy systems, multi-mission architectures are taken into consideration for the C3CMISR missions. The stated objective is designing a one tail number Multi-Mission Aircraft (MMA) that includes all the C3CMISR tasks on one airframe.

This study seeks some comments and advises about the MMA design technical feasibility. In order to search for these comments, four notional operational scenarios are created. First of all existing C3CMISR aircrafts are considered and evaluated in these operational scenarios and then different MMA architectures are defined and compared with the legacy systems in the name of adequacy.

MULTIMISSION AIRCRAFT DESIGN STUDY - OPERATIONAL SCENARIOS

Chapter 1 - Introduction

1.1 Chapter Overview

This thesis provides operational feasibility data for a Multi-Mission Aircraft (MMA) design by creating four notional operational scenarios which combine some of all the functions of the existing AWACS, JSTARS, RIVET JOINT, COMPASS CALL, and ABCCC aircrafts which are C-135 and C-130 theater-based command and control (C2) and intelligence, surveillance and reconnaissance (ISR) platforms. It also provides some technical information about the use of UAVs in operational environments. This chapter includes background, scope, problem statement, objectives, methodology, and assumptions and limitations of the study.

1.2 Background

In the last twenty years, the technology for battlefield Command, Control, Communications, and Counter Measures, Intelligence, Surveillance and Reconnaissance (C3CMISR) has greatly improved and has become a central element in battlefield operations. The ISR platforms are now "must-have" assets for any modern military force. The current operational ISR platforms for the USA and its allies are AWACS, JSTARS, RIVET JOINT, COMPASS CALL, ABCCC, and KC-135 Tanker Aircraft. Each system has its own capabilities and operational flexibilities. A MMA technical feasibility study has been requested to take the place of the aging fleet of C-130 and C-135 based theater

C2 and ISR Aircraft by the Director of Intelligence, Surveillance and Reconnaissance, DCS, Air and Space Operations. This official thesis topic proposal is presented in Appendix A. A new, modern wide-body commercial/noncommercial aircraft would be chosen by the US Air Force to replace these existing fleets. It is proposed that the MMA be out-fitted to combine some or all the functions of existing AWACS, JSTARS, RIVET JOINT, COMPASS CALL, and ABCCC platforms. The MMA would also have links to other manned or unmanned ISR aircraft and satellites. These five aircrafts are used individually as C3CMISR platforms in recent operational theaters by US or its allies. These missions include, battlefield surveillance, airborne early warning (AEW), jamming, and signals intelligence (SIGINT) missions.

The US is looking for a Multi-Mission Aircraft (MMA) which would have a larger body than the existing aircraft platforms in order to develop warfare issues and win the combats with less effort and cost with the highest benefit. This MMA platform will indicate current platforms and combine some or all of the functions.

An option for a cheap and easy solution for that problem would be Unmanned Air Vehicles (UAVs), but this is the most limited option. These aircrafts are too small to be able to carry the large payloads, such as Synthetic Aperture Radar (SAR) and other EW systems that are on existing platforms. Since there would be no C3CMISR operators onboard, the data acquired by a UAV would have to be shuttled over high-speed datalinks to a ground, air, or sea-based command centers. Because of this reason, the manned C3CMISR MMA architectures are considered in this study.

As a second thought, USAF has proposed to replace their existing tanker aircrafts which are Boeing KC-135 aerial tanker fleet, with Boeing 767 jetliners. The tankers are generally tasked to remain outside the Area of Operations (AO) and just outside battle areas in order to refuel aircrafts participating in the combat. It seems like a logical step to make the tanker aircrafts able to carry the required payloads and useful electronic warfare equipments as sensors as well. The first idea has been modulated for fitting the machines with a removable pallet of communications electronics to allow strike elements from different services and different nations to relay communications electronics to allow strike elements from different services and different nations to relay communications between each other. If this can be done, the idea of other payloads, such as SIGINT or surveillance equipment also could be carried as well. This idea is in consideration, but because of the possibility of rapid change in operational task needs, it might seem like tough to achieve.

As the most accepted option, a wide body commercial aircraft like the Boeing 767 would be modified for military needs. Such a Multi-Sensor Command & Control Aircraft (MC2A) could be modified and configured to perform airborne warning, ground surveillance, SIGINT, or countermeasures tasks. With an Active Electronically Scanned Array system, it might be possible to perform many of these functions using the same equipment. A fleet of MC2A Boeing 767 capable of different C3CMISR roles and with interchangeable payloads could be deployed to meet a wide range of missions and tasks. Based on this idea, US has been begun some projects to make the MC2A a reality. (1)

1.3 Scope of the Study

The primary aim of this study is to consider the Multi-Mission Aircraft design possibility to achieve success in operational environments and theaters. The study explores information on the feasibility of the five alternative MMA architectures based on four notional operational scenarios.

The study of MMA has been preceded by accepting the fact that the whole subject is a very complicated issue. It should be formed by numerous engineering fields and required a lot of scientific research. This MMA feasibility study in operational environments has been preceded by getting feedback from electromagnetic spectrum and payload integration of the aircraft. As we are looking for feasibility of a MMA design and its compatibility for all required tasks in notional operational scenarios, all the sensors for the joint missions and their compatibility, crew and all of the hardware and software to be placed into the fuselage of the selected aircraft are being considered. All of these factors affect the overall limits of the aircraft like weight, lift and range. Besides these limitations the electromagnetic compatibility and electromagnetic interference of the sensors and antennas are important issues which must be defined clearly in order to achieve the required tasks and missions.

The feasibility of alternative MMA architectures is evaluated in four notional operational scenarios. In these notional operational scenarios five alternative MMA architectures are defined in order to evaluate the feasibility of these architectures in a wide range of tasks and missions due to mission achievement of C3CMISR capabilities.

At the conclusions part, UAVs are also taken into consideration as additional elements that can accomplish missions in battle theaters that are not feasible to alternative MMA architectures.

1.4 Problem Statement

The problem statement can be defined basically as technical feasibility requirements of a designed multi-mission aircraft which contains all the existing C3CMISR sensors, antennas, crew, hardware and software. While designing an aircraft or modifying an existing fuselage for all of the required C3CMISR capabilities, various technical problems may occur. The aim of this study is to anticipate these possible technical problems and to consider feasible MMA designs.

1.5 Objectives of the Study

Considering a multi-mission aircraft design, the various technical risks involved in combining onto one aircraft fuselage with multiple functions has been faced. These risks, which have been mentioned before, are payload integration, electromagnetic interference and compatibility. The main goal of the MMA design feasibility study is to maintain current power requirements of the aircraft while achieving the required tasks in operational scenarios by the design parameters of a multi-functional aircraft. By studying all of the risk factors, general recommendations have been defined in order to combine all the C3CMISR functions into one aircraft with no or minimal technical risk. The study includes MMA design technical feasibility risks with just one aircraft as well as with different tail numbers in order to evaluate the achievement of the required operational tasks.

1.6 Methodology

This study uses a Systems Engineering approach. Systems Engineering Methodology is used for defining the problem and Hatley/Hruschka/Pirbhai (HHP) Methodology is used for creating the system model. Basically the Systems Engineering

Methodology includes problem definition, value system design, systems synthesis, and systems analysis, optimization of alternatives, decision making and planning for action. After defining the problem and goal of the study, an operational architecture is created and the entire mission tasks and system requirements are defined based on this architecture. Finally, systems requirements are determined and the whole system is modeled in order to provide some recommendations and create an idea of the possible risks and negative aspects of the MMA design in notional operational scenarios.

1.7 Assumptions and Limitations of the Study

By creating different notional scenarios of operational theaters, various situations and tasks have been checked and an idea of the feasibility of MMA has been formed. In order to form these feasibility approaches, some assumptions have been made in developing the scenarios because of the lack of specific data in aircraft design, besides the handicap of not being able to obtain classified or limited distribution information. The assumptions that are made in order to cerate the notional operational scenarios are shown as a table in Appendix B. Some of the past experiences, like early operations by NATO and UN Forces, have been also used in order to clarify and shed light on some aspects of the tasks and issues.

Chapter 2 – Literature Review

2.1 Chapter Overview

This chapter first describes the past and present usage and some technical operational data AWACS, JSTARS, RIVET JOINT, COMPASS CALL, and ABCCC ISR Aircrafts. Then definition of C3CMISR in operational theater, basic information about intelligence preparation of the battlefield (IPB), intelligence programs and systems, the information collection resources and the elements of intelligence support follow.

2.2 Current and Historical Operational Data of C3CMISR Aircrafts

In the past operations of USA and its allies, the above C3CMISR aircrafts have been used individually according to the needs of the Operation Theater, missions and tasks. Now these aircrafts' individual missions and capabilities are planned to be combined in one architecture or in different tail numbers if it appears that all of the ISR equipments, sensors, antennas and crew are not going to fit into one architecture.

2.2.1 AWACS Technical Data and Operational Use

AWACS E-3 Sentry is an airborne warning and control system aircraft that provides all-weather surveillance, command, control and communications in operation theaters. The data provided by these aircrafts is an essential operational element for commanders of NATO, USA and other allied air defense forces. AWACS is accepted as the premier air battle command and control aircraft in the world today.

The airframe of the E-3 Sentry, is a modified Boeing 707/320 commercial airframe with a rotating radar dome which is shown in Figure 2-1. It contains a radar subsystem that permits surveillance from the earth's surface up into the stratosphere, over land or water. The radar has a range of a more than 250 miles (375.5 kilometers) for low-flying targets and farther for aerospace vehicles flying at medium to high altitudes. The radar is combined with an identification friend or foe (IFF) subsystem that can look down to detect, identify and track enemy and friendly low-flying aircraft by eliminating ground space returns that confuse other radar systems.

The AWACS E-3 fleet went through an upgrade in 2001. This Block 30/35 Modification Program included major enchantments, including an Electronic Support Measure for passive detection, an electronic surveillance capability to detect and identify air and surface; a Joint Tactical Information Distribution System (JTIDS) to provide secure, anti-jam communication for information distribution, position location and identification capabilities; an increase in the memory capability in the computer to contain JTIDS, EMS and future enhancements and Global Positioning System (GPS), a satellite-based positioning capability to provide precise global navigation.(2)

Other major E-3 Sentry subsystems are navigation, communications and computers which process data. AWACS crew consists of 13 to 19 specialists which are console operators that perform surveillance, identification, weapons control, and battle management and communications functions. The radar and computer subsystems on the AWACS can gather and present wide and comprehensive battle field information. Data is collected in real-time in the operational theater. Operational data, including position and tracking information on enemy aircraft and ships, and location and status of friendly aircraft and naval vessels, is collected real. The information can be sent to major command and control centers in rear areas or aboard ships.

In support of air-to-ground operations, the AWACS can provide direct information needed for interdiction reconnaissance, airlift and close-air support for friendly ground forces. It can also provide information for air operation commanders to gain and maintain control of the air battle. As an air defense system, E-3 Sentry can detect, identify and track airborne enemy forces far from the boundaries of the countries. It can direct fighter-interceptor aircraft to these enemy targets. Operational experience has proved that the E-3 Sentry can respond quickly and effectively to a crisis and support worldwide military deployments. It is a jam-resistant system that has performed missions while experiencing heavy electronic countermeasures.

AWACS has a lot of superiority compared to ground–based radars. It has mobility which provides it a greater chance of surviving in warfare than fixed radar. It can quickly change its flight path according to mission and survival needs. It’s 8 hour mission profile and range can be increased through in-flight refueling and on-board crew rest support. (3)

Figure 2-1 E-3 Sentry AWACS

2.2.2 RIVET JOINT Technical Data and Operational Use

The RC-135V/W Rivet Joint is a reconnaissance aircraft that supports theater operations with near real-time on-scene intelligence collection, analysis and dissemination capabilities.

The RC-135 V/W Rivet Joint is a highly modified C-135 aircraft which is shown in Figure 2-2. These modifications are primarily related to its on-board sensor suite, which allows the mission crew to detect, identify and geolocate signals throughout the electromagnetic spectrum. So we can define the aircraft as a long-range, high-altitude version of the C-135, which is a military version of the Boeing 707. The mission crew, which are 21-27 depending on mission requirements, can provide forward information in a variety of formats to a wide range of consumers via Rivet Joint's extensive communications suite. Minimum mission flight crew consists of 3 electronic warfare officers, 14 intelligence operators and 4 in-flight/airborne maintenance technicians. (4)

This aircraft has an extensive antenna array and can provide direct, near real-time reconnaissance information and electronic warfare support to theater commanders and combat forces on operational theaters (5). The data collected by Rivet Joint is essential for effective combat operations. Although the flight crew stations are similar, the avionics of Rivet Joint varies in specialized electronics (for pick up of single point, short duration signals) as the type of sensors, receiver systems, probe, blade, wire and dielectric panel antenna, camera windows and fairings installed from the conventional international reconnaissance equipment. All RC-135s are equipped with an air refueling system and carry high, very high, and ultra high frequency radios, radar, and doppler/GPS/stellar/INS (Internal Navigation System) navigation system. It collects, analyzes, reports, and exploits enemy BM (Battle Management)/C4I (Command, Control, Communications, Computers and Intelligence). During most contingencies, it deploys to the theater operations with the airborne elements of TACS (AWACS, ABCCC, Joint STARS, etc.) and is connected to the aircraft via datalinks and voice as required. Refined data can be transferred from the Rivet Joint to AWACS through the Tactical Digital Link TADIL/A or into intelligence channels via satellite and the Tactical Information Broadcast Service (TIBS), which is nearly real-time theater information broadcast. (6)

Basic roles of RC-135 V/W Rivet Joint in an operational environment include providing indications about the location and intentions of enemy forces and warnings of threatening activity; broadcasting a variety of direct voice communications of highest priority which are combat advisory broadcasts and forthcoming threat warnings that can be sent direct to aircraft in danger; operating both data and voice links to provide target info to US ground based air defenses. The Rivet Joint aircraft is capable of conducting ELINT (Electronics Intelligence) and COMINT (Communications Intelligence) intercept operations against targets at ranges up to 240 kilometers.(7)

Some of the operations supported by Rivet Joint over the past decade includes Urgent Fury, Eldorado Canyon, Just Cause, Desert Shield/Desert Storm, Proven Force, Provide Comfort, Southern Watch, Vigilant Warrior, Deny Flight, Provide Promise, and Uphold Democracy. Most recently, it used over Bosnia. (8)

Figure 2-2 RC-135V/W Rivet Joint

2.2.3 JSTARS Technical Data and Operational Use

The E-8C Joint Surveillance Target Attack Radar System (Joint STARS) is an airborne battle management and command (C2) platform. It conducts ground surveillance to develop an understanding of the enemy situation and to support attack operations and targeting that contributes to the delay, disturbance and destruction of enemy forces. These functions support the primary mission of Joint STARS which is to provide dedicated support of ground and air theater commanders.

The E-8C shown in Figure 2-3 is a modified Boeing 707-300 series commercial airframe widely remanufactured and modified with the radar, communications, operations and control subsystems required to perform its operational mission. It has a canoe-shaped radome under the forward fuselage which contains the side-looking phased-array antenna. The Joint STARS can respond quickly and effectively to support worldwide military contingency operations. It is a jam-resistant system capable of operating while experiencing heavy electronic countermeasures. It has an increased range and on-station time through in-flight refueling. (9) Joint STARS operates in virtually any weather, on-line, in-real-time, around the clock. The augmented Army-Air Force mission crew can be deployed to a potential trouble spot within hours and provide valuable data on ground force movements. (10)

The radar and computer subsystems on the E-8C can gather and display broad and detailed battlefield information. Data is collected as events occur. This includes position and tracking information on enemy and friendly ground forces. The information is relayed in near-real time to the Army's common ground stations via the secure jam-resistant surveillance and control data link and to other ground command, control, communications, computers and intelligence (C4I) nodes beyond line-of-sight via ultra high frequency satellite communications.

The radar operating modes of E-3C include wide area surveillance (WAS), moving target indicator (MTI), fixed target indicator (FTI), target classification and synthetic aperture radar (SAR). The antenna can be tilted to either side of the aircraft where it can develop a 120-degree field of view covering nearly 19,305 square miles (50,000 square kilometers) and is capable of detecting targets at more than 250 kilometers (more than 820,000 feet). In addition to being able to detect, locate and track large numbers of ground vehicles the radar has some limited capability to detect helicopters, rotating antennas and low, slow-moving fixed wing aircraft. (9) WAS/MTI is designed to detect, locate and identify slow-moving targets. Through advanced signal processing, Joint STARS can differentiate between wheeled and tracked vehicles. By focusing on smaller terrain areas, the radar image can be enhanced for increased resolution display. This high resolution is used to define moving targets and provide combat units with accurate information for attack planning. SAR/FTI produces a photographic-like image or map of selected geographic regions. SAR data maps contain precise locations of critical non-moving targets such as bridges, harbors, airports, buildings, or stopped vehicles. The FTI display is available while operating in the SAR mode to identify and locate fixed targets within the SAR area. The SAR and FTI capability used in conjunction with MTI and MTI history display allows post-attack assessments to be made by onboard or ground operators following a weapon attack on hostile targets. (10)

Other major E-8C prime mission equipments are communications and operations and control subsystems. 18 operator workstations display computer-processed data in graphic and tabular format on video screens. On a long endurance mission the aircraft has a crew of 34, with 6 flight crew and 28 system operators. Operators and technicians perform battle management, surveillance, weapons, intelligence, communications and maintenance functions. (9)

The digital datalinks include a satellite communications link (SATCOM), surveillance and control datalink (SCDL) for transmission to mobile ground stations, and Joint Tactical Information Distribution System (JTIDS). The JTIDS provides tactical air navigation (TACAN) operation and Tactical Data Information Link-J (TADIL-J) generation and processing. The Cubic Defense Systems SCDL is a time division multiple access datalink incorporating flexible frequency management. The system employs wideband frequency hopping, coding and data diversity to achieve robustness against hostile jamming. Uplink transmissions use a modulation technique to determine the path delay between the ground system module and the E-8 aircraft.

In support of air-to-ground operations, the E-8C can provide real time information needed to increase ground situation awareness with intelligence support, attack support and targeting operations including attack aviation, naval surface fire, field artillery and friendly maneuver forces. It also provides information for air and land commanders to gain and maintain control of the battle-space and execute against enemy forces. As a battle management and command and control asset, the E-8C can support the full spectrum of roles and missions from peacekeeping operations to major theater war. (11)

JSTARS was first deployed in Operation Desert Storm in 1991 when still in development. Joint STARS developmental aircraft were also called to support the NATO peacekeeping mission, Operation Joint Endeavor, in December 1995. It monitored treaty compliance while NATO rotated troops through Bosnia-Herzegovina. It is deployed in support of Operation Enduring Freedom from November 2001 to April 2002 with a 98.4% mission effectiveness rate, supporting the war on terrorism. The E-3C Joint STARS routinely supports various taskings of the Combined Force Command Korea during the North Korean winter exercise cycle and for the United Nations enforcing resolutions on Iraq. (11) (9)

Figure 2-3 E-8C Joint STARS

2.2.4 COMPASS CALL Technical Data and Operational Use

Compass Call is a code name for an Electronic Countermeasure (ECM) system installed aboard the US EC-130H aircraft. The EC-130H Rivet Fire/Compass Call is the designation for a modified version of Lockheed corporation's C-130 Hercules aircraft configured to perform tactical command, control and communications countermeasures (C3CM) and it's shown in Figure 2-4. Targeting command and control provides commanders with an immense advantage before and during the air campaign. Compass Call provides a non-lethal means of denying and disrupting enemy command and control, degrading his combat capability and reducing losses to friendly forces.

The EC-130H Compass Call is the only US wide-area offensive information warfare platform and provides disruptive communications jamming and other unique capabilities to support the Joint Force Commander across the spectrum of conflict. Specifically, the modified aircraft uses noise jamming to prevent communication or degrade the transfer of information essential to command and control of weapon systems and other resources. It primarily supports tactical air operations but also can provide jamming support to ground force operations.

Modifications to the aircraft include an electronic countermeasures system (Rivet Fire) and air refueling capability and associated navigation and communication systems. Additional blade-shaped antennas were added to the basic C-130 Hercules along with trailing wire antennas deployed from pods on the tail and under the wings.

During Operation Desert Storm EC-130H Compass Call electronic warfare aircraft, operating outside Iraqi airspace, safe from Iraqi defenses, jammed communications, hindering the effectiveness of Iraq's integrated air defense network. Rivet Fire has demonstrated its powerful effect on enemy command and control networks in Panama and Iraq.

Compass Call integrates into tactical air operation at any level. Although Compass Call primarily supports interdiction and offensive counter-air campaigns, the truly versatile and flexible nature of the aircraft and its crew enable the power of EC-130H to be brought to bear on virtually any combat situations.

The EC-130H aircraft carries a combat crew of 13 people. Four members are responsible for aircraft flight and navigation, while nine members operate and maintain the Rivet Fire equipment. The mission crew consist of an electronic warfare officer, who is the mission crew commander (MCC), an experienced cryptologic linguist, an Acquisition Operator, a high Band Operator, four analysis operators, and an airborne maintenance technician (AMT). Either the Analysis Operator or the High Band Operator can be promoted to the position of mission crew supervisor (MCS).

Aided by the automated system, the crew analyzes the signal environment, designate targets and ensure the system is operating effectively. Targets can be designated before the mission takes off, acquired in flight or the MCC/MCS can receive additional tasking at any time from outside agencies (i.e. Airborne Warning and Control System, RC-135 and Airborne Command and Control System). A radio frequency signal runs from the beginning of the received path through the system and is analyzed at different points along the way. In a war situation, a signal may be received and linguists on board the plane analyze it to determine if it is an enemy signal. If the system decides there is a threat, communications would be jammed by the officer on board pressing the red buttons. On the back of the plane is microwave powered equipment which sends out high energy radio frequency output or interference.

The latest technologies, referred to as Block 30 system, update the fleet and keep the 41st Electronic Combat Squadron's Combat Systems Flight busy ironing out the bugs. The flight's 25 computer and electronic warfare troops perform organizational level maintenance on EC-130H weapons systems. Block 30 totally rearranges the equipment on the EC-130H and incorporates fiber optics. There are more fiber optic terminations on this plane than any other plane flying, commercial; or military today. Block 30 improvements include faster and more powerful computers and integrated work stations which enable the fleet to accomplish its primary mission of denying enemy commanders the ability to command their troops in the battlefield. Unlike Block 20, which operates through a mainframe, Block 30 is broken down into different components which communicate with each other. (12)

Figure 2-4 EC-130H RIVET FIRE/COMPASS CALL

2.2.5 ABCCC Technical Data and Operational Use

The EC-130E ABCCC consists of seven aircrafts that are used as an Airborne Battlefield Command and Control Center. It is a modified C-130 Hercules aircraft designed to carry the USC-48 Airborne Battlefield Command and Control Center Capsules (ABCCC III). These one-of-a kind aircraft include the addition of external antennae to accommodate the vast number radios in the capsule, heat exchanger pods for additional air conditioning, an aerial refueling system and special mounted rails for uploading and downloading the USC-48 capsule. The ABCCC has distinctive air conditioner intakes fore of the engines ("Mickey Mouse ears"), two HF radio probes-towards the tips of both wings, and three mushroom-shaped antennas on the top of the aircraft-and, of course, numerous antennas on the belly.

As an Air Combat Command asset, ABCCC is an integral part of the Tactical Air Control System. While functioning as a direct extension of ground-based command and control authorities, the primary mission is providing flexibility in the overall control of tactical air resources. In addition, to maintain positive control of air operations, ABCCC can provide communications to higher headquarters, including national command authorities, in both peace and wartime environments.

The USC-48 ABCCC III capsule, which fits into the aircraft cargo compartment, measures 40 feet long, weighs approximately 20,000 pounds and costs $9 million each. The ABCCC provides unified and theater commanders an Airborne Battlefield Command and Control Center (ABCCC), with the capacity for combat operations during war, contingencies, exercises, and special classified missions. Mission roles include airborne extensions of the Air Operations Center (AOC) and Airborne Air Support Operations Center (ASOC) for command and control of Offensive Air Support (OAS) operations; and airborne on-scene command for special operations such as airdrops or evacuations.

The ABCCC system is a high-tech automated airborne command and control facility featuring computer generated color displays, digitally controlled communications, and rapid data retrieval. The platform's 23 fully securable radios, secure teletype, and 15 automatic fully computerized consoles, allow the battle staff to quick analyze current combat situations and direct offensive air support towards fast-developing targets. ABCCC, is equipped with its most recent upgrade the Joint Tactical Information Distribution System, allows real-time accountability of airborne tracks to capsule displays through data links with AWACS E-3 "Sentry" aircraft.

The flight deck crew is standard C-130 crew and the airborne battle staff can be tailored to fit any mission based on operational needs. The battle staff is comprised of four functional areas: command, operations, intelligence, and communications. Normally, it includes 12 members working in nine different specialties.

The Director of the Airborne Battle Staff (DABS)/Command Section is responsible for the overall battle staff operations for monitoring the current air situation and emphasizing integration of offensive and support operations. When an Airborne Command Element (ACE) is onboard the ABCCC, the ACE will provide theater/component commander representation increasing mission effectiveness by providing theater unique expertise (C2, logistics, communications, reconstitution, the air tasking order, and battle plans).

A Battle Staff Operations Officer (BSOO) runs the Operations Section which consists of Airborne Strike Controllers (ASC) and Airborne Close Air Support Coordinators (ACASCO). The operations section is responsible for monitoring and, if delegated the authority, directing changes in the employment of air resources within the AOR assigned.

The Intelligence Section: an Airborne Intelligence Officer (AIO) and Technician (AIT) continually correlates, analyzes, fuses, and disseminates intelligence and operational data to the battle staff and other agencies. This section updates battlefield intelligence, maintains friendly and enemy order of battle and fire support measures, and validates targets so tactical aircraft have the latest threat warning information. The AIO is also the focal point for coordination of electronic combat.

The Communications Section provides communication support for the battle staff. The Airborne Communications System Operators (ASCO) maintain voice communications (capsule radio and interphone systems), data link, and teletype equipment. While Airborne Maintenance Technician (AMT) performs necessary in-flight maintenance of the different systems in the ABCCC capsule to include booting, initialization, and loading of the tactical database taken from the ground-based mission planning system (MPS) into the capsule's onboard integrated computer processors.

In addition to these four basic sections, a Ground Liaison Section may be added the Liaison Section's composition and manning reflect the type of support required in relation to the ABCCC NATO mission tasking. Joint and combined operations dictate operational Liaison Officer (LNO) interface within the ABCCC battle staff. LNOs provide information regarding tasking which the ABCCC battle staff supports, current situation and planned operations, fire support measures, selected airspace deconfliction, and communications and intelligence information relay. The LNOs are members of the Ground Component effort, and overall ground scheme of maneuver to make decision recommendations to the DABS. LNOs serve as the focal point for the battle staff's ground force information requirements and have communications links to acquire additional information. The Army LNO(s) serve as a limited Battlefield Coordination Element (BCE) Operations and Fusion Section representative. (13)

Figure 2-5 EC-130E ABCCC

2.3 Definition of C3CMISR Capabilities in Operational Theaters

We can define the C3CMISR as a feature responsible for providing capabilities that enable the military forces of the US and its allies to generate, use, and share the information necessary to survive and succeed on every mission. This can be done if the information superiority is taken in battlefield. Information superiority is the capability to collect, process, and disseminate and interrupted flow of information while exploiting or denying an adversary's ability to do the same. To achieve this capability, the forces in the battlefield must have a comprehensive knowledge of the battlefield, including the status and intensions of both adversary and friendly forces. Information superiority is the backbone of military innovation. To significantly enhance joint operations on a battlefield, information and command and control are needed to be improved and comprehensively provided.

There are some global terms that have been used in the name of Global operations like The Global Command and Control System (GCCS) which has replaced the World Wide Military Command and Control System and provides friendly forces with an enhanced common operational picture, force status, intelligence support, enemy order of battle, related facility information, and air tasking orders. Also Global Combat Support System (GCSS) complements GCCS by providing warfighters with the ability to track the status and location of critical logistics, procurement, engineering, finance, personnel, and medical resources. All of these efforts are taken in order to promote information availability and interoperability between Services and multinational partners.

In this century's increased warfare demands for information have revealed the need for enhanced and comprehensive airborne reconnaissance coverage and increased reconnaissance operating pace. Unmanned Aerial Vehicles (UAVs) are been used in ISR activities to complement current manned systems with significant savings, but manned airborne surveillance and reconnaissance properties are developing better situational awareness by using enhanced and modernized capabilities, such as Moving Target Indicator.

There are some defense security programs which prevent or deter espionage, sabotage, subversion, theft, or the unauthorized use of classified or controlled information, systems, or war material. The Information Operations (IO) are actions taken across the entire conflict to achieve specific objectives over an adversary. Information assurance protects and defends information systems by ensuring their availability, integrity, authenticity, and confidentiality. Information Assurance (IA) is the component of Information Operations that assures operational readiness by providing for the continuous availability and reliability of information systems and networks.

On an overall C3CMISR architecture, to ensure consistent implementation and effective employment in all operations are critical. The joint tactical architecture, which facilitates use and exchange of information for operational planning and combat decision making, is most important C3CMISR architecture initiative. (14)

2.4 Intelligence Preparation of the Battlefield (IPB)

IPB is the best process for understanding the operation theater and the options it presents to friendly and threat forces. IPB is a systematic, continuous process of analyzing the threat and environment in a specific geographic area. It is designed to support staff estimates and military decision making. Applying the IPB process helps the commander selectively apply and maximize his combat power at critical points in time and space on the battlefield by; determining the threat's likely Courses of Action (COA), and describing the environment your unit is operating within and effects of the environment on your unit.

IPB is a continuous process which consists of four steps which you perform each time you conduct IPB. These steps are; define the battlefield environment, describe the battlefield's effects, evaluate the threat and determine threat COAs. The IPB process is continuous. You conduct IPB prior to and during the commandant's initial planning for an operation, but you also continue to perform IPB during the conduct of the operation. Each function in the process is performed continuously to ensure that; the products of IPB remain complete and valid and you provide support to the commander and direction to the intelligence system throughout the current mission and into preparation for the next. (15)

2.5 Intelligence Programs and Systems

As we would like to define the intelligence programs and systems in to basic steps, these categories are going to be core, tasking, collection, processing, dissemination, security and other systems.

Core systems include system architectures for intelligence systems and applications interoperability, as well as those technical standards and common infrastructure elements, such as operating systems, that support such interoperability.

Tasking systems are used to direct and prioritize collection requirements, and form the interface between consumers and producers of intelligence products.

Collection systems come from a variety of organizations, echelons, services, and intelligence disciplines. These include but are not limited to tactical ground-based

Intelligence and Electronic Warfare (IEW) systems, unmanned aerial vehicles (UAVs), and space systems.

Processing systems receive, convert and correlate information into a form usable as combat information or intelligence. These processors are found at all echelons of the intelligence architecture, and include both primary processing and secondary exploitation systems.

Dissemination systems provide the communications links between collection systems, processors, and users. These include both the physical communications channels, as well as networks, protocols and software, and databases and servers for the staging of products for dissemination.

Security systems provide information security protection to communication links, processors, and users.

Other programs are a catch-all residual category, which includes a variety of programs that appear to be intelligence-related but whose exact purpose and nature remains unintelligible. (16)

2.6 Information Collection Resources

Intelligence is the operational theater commanders' decision-making tool. To provide continuous intelligence and information for the battlefield procures successful operations and minimizes risks. (17)

Measurement and Signature Intelligence (MASINT) is considered the next frontier in establishing information superiority for several difficult tactical and intelligence problems, such as weapons of mass destruction, countermeasures, threat definition, and indications of warning on an operational theater. Many of the traditional

Imagery Intelligence (IMINT) and Signals Intelligence (SIGINT) systems provide part of the picture, but a more complete assessment is needed, particularly for quick reaction, in indefinite situations, or in the presence of camouflage, suppression, and deception. (18)

MASINT is a scientific and technical intelligence information obtained by quantitative and qualitative analysis of data (metric, angle, spatial, wavelength, time dependence, modulation, plasma, and hydromagnetic derived from specific technical sensors for the purpose of identifying any distinctive features associated with the source, emitter, or sender and to facilitate subsequent identification and/or measurement of the same. MASINT includes; Radar Intelligence (RADINT), Acoustic Intelligence (ACOUSTINT), Nuclear Intelligence (NUCINT), Radio Frequency/Electromagnetic Pulse Intelligence (RF/EMPINT), Electro-optical Intelligence (ELECTRO-OPTINT), Laser Intelligence (LASINT), Materials Intelligence, Unintentional Radiation Intelligence (RINT), Chemical and Biological Intelligence (CBINT), Directed Energy Weapons Intelligence (DEWINT), Effluent/Debris Collection, Spectroscopic Intelligence, and Infrared Intelligence (IRINT). (19)

2.7 Elements of Intelligence Support

The main goal for the C3CMISR aircrafts is to provide real-time on-scene data for the friendly operational units over the battlefield. If this data flow can be provided without any interference or interception over the battlefield, a continuous C3CMISR issues are provided among operational units. The proper and on-time battlefield intelligence provides the information superiority which allows increased choices for commanders and increased information at all levels. This also leads the commanders to enlist new tools and procedures. Information is the key capability for a force and it presents importance across the full range of operations. The factors of information superiority goes through full spectrum dominance, which can be achieved by carrying out some effective ways as being credible in peace, decisive in war and finest in any form of conflict. This concept is shown in Figure 2-6.

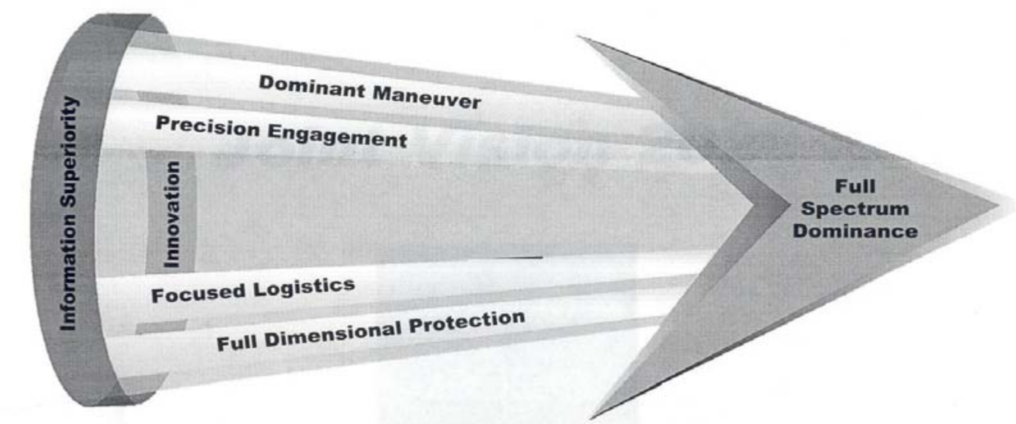


Figure 2 – 6 Information Superiority Concept (20)

In order to reach information superiority in an operational theater, Intelligence and Electronic Warfare (IEW), Electronic Warfare (EW) and Counter Intelligence (CI) issues provide intelligence at all echelons to support accomplishment of the mission. These IEW support elements are used by C3CMISR aircrafts in different theatres for different operational needs.

2.7.1 Signals Intelligence (SIGINT)

SIGINT is analyzed information resulting from monitoring and locating enemy communications and noncommunications system such as enemy radars. The two types of SIGINT are; intelligence derived from monitoring enemy communications is called communications intelligence (COMINT), and intelligence resulting from monitoring noncommunications emitters is called electronic intelligence (ELINT).

2.7.2 Electronic Warfare (EW)

EW is one of the combat multipliers. It can interrupt enemy command and control and fire support communications when used during a critical phase of the battle. Some aspects of it will protect friendly communications. The three elements of EW are: Electronic Warfare Support Measures (ESM) that gives us immediate risk recognition, combat information, and target acquisition as well as the specific frequencies and radio nets we want to jam; Electronic Countermeasures (ECM) consists of jamming enemy communications and electronic deception; Electronic Counter-Countermeasures (ECCM) are the responsibility of friend signal officer and consists of measures to protect friendly command, control and communications (C3).

2.7.3 Human Intelligence (HUMINT)

2.7.3.1 Counterintelligence (CI)

CI protects the force through evaluation of the enemy's multidiscipline intelligence gathering capabilities. It detects, evaluates, counteracts, and prevents hostile intelligence collection, subversion, and sabotage. CI also provides important support to the commander's Operations Security (OPSEC) and deception programs.

2.7.3.2 Imagery Intelligence (IMINT)

IMINT is used to acquire and exploit visual representations on the battlefield that contribute to situation development, targeting, and Bomb Damage Assessment (BDA). IMINT sensors include electro-optical, infrared, Forward Looking Infrared (FLIR), and RADAR imaging systems. An IR image that has been taken from an aerial vehicle is shown in Figure 2-7;

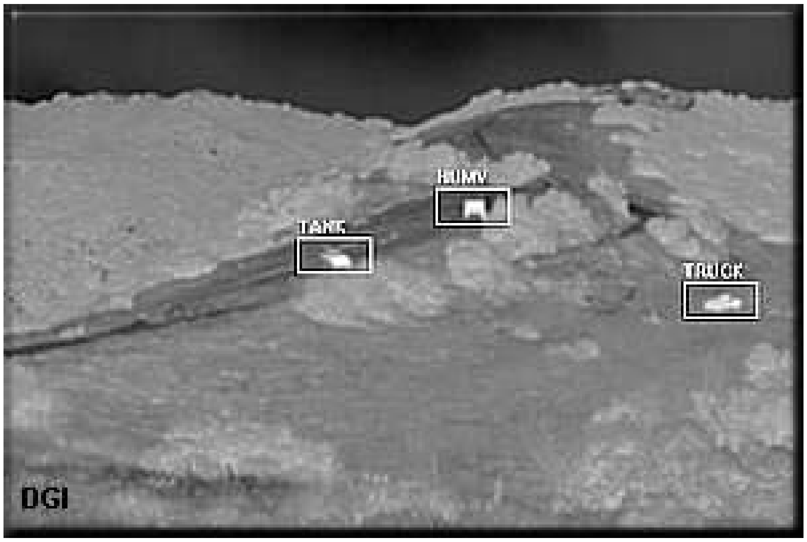


Figure 2 – 7 Aerial FLIR Image of an Operational Theater Scene

2.7.3.3 Intelligence System of Systems

No single level has sufficient organic intelligence capabilities to satisfy all our priority intelligence and targeting requirements. Friendly intelligence officer must know and understand how to obtain support from higher and lower elements of the intelligence system of requirements. In order to use friendly organic resources efficiently, the following topics must be understood; command relationship, IEW standard tactical missions, unit organizational capabilities, limitations, and employment considerations, detailed collection system capabilities and numbers. (21)

Chapter 3 – Methodology

3.1 Chapter Overview

In this chapter, the methodology of operations that utilize C3CMISR aircrafts in warfare theaters is defined. The MMA design is discussed as a Systems Engineering Process and it is studied by System Engineering methodologies and tools. A systems architecture approach is applied to the problem. As the main goal for using C3CMISR aircrafts in operational theaters is getting intelligence, surveillance, and reconnaissance and providing command, control and communication over the whole area, the second information step is to define the elements of intelligence support. Before creating notional operational scenarios, some of the targets on the warfare theater are defined and their importance for destruction is emphasized. Also the basic defense system of the target country is defined. After these statements, the notional operational theater scenarios are explained in detail.

3.2 Systems Architecture

All of the Systems Engineering processes, methodologies and tools are the equipments that model an actual system which defines the requested solution of the problem. The C3CMISR aircraft design study is analyzed by creating an architecture model. Before taking the main problem into architecture design process, we should define what really a systems architecture is. The definition of systems architecture is stated as;

"*the fundamental and unifying system structure defined in terms of system elements, interfaces, processes, constraints, and behaviors*" (22) by International Council of Systems Engineering (INCOSE) Systems Architecture Working Group. And it is also defined by the IEEE STD 610.12 as;

"the structure of components, their relationships, and the guidelines governing their design and evolution over time" (23)

The architecture is used in two different ways. These are descriptive and implementational architectures. The description of an architecture is the representation of a notional configuration of assets, regulations, and interactions. After describing the real problem and designing it, then the implementation takes place.

The architecture has three different perspectives which they are defined as operational, systems and technical views. Operational architecture view is defined in C4ISR Architecture Framework as;

"…a description of the tasks and activities, operational elements, and information flows required to accomplish or support a military operation" (24)

and it provides detail about the information-exchange, interoperability, and performance parameters required to support a particular mission. Systems architecture view is defined as;

"…description, including graphics, of systems and interconnections providing for, or supporting, warfighting functions" (25)

and it defines system attributes, provides the basis for comparing system performance against operational requirements. Technical architecture view is defined as;

"…the minimal set of rules governing the arrangement, interaction, and interdependence of system parts or elements, whose purpose is to ensure that a conformant system satisfies a specified set of requirements" (26)

and it defines the specific performance criteria that will result in the fielding of an interoperable system.

These three architecture views are all expressing different perspectives but pointing the same architecture design. Instead of taking these different perspectives individually, it is preferred to take and apply them integrated to each other as multiple views. That way, the approach to the problem gains a wider angle and this leads to a more useful and clear process. In order to get the integration between these architecture views, there must be interrelations between them which are shown in Figure 3-1.

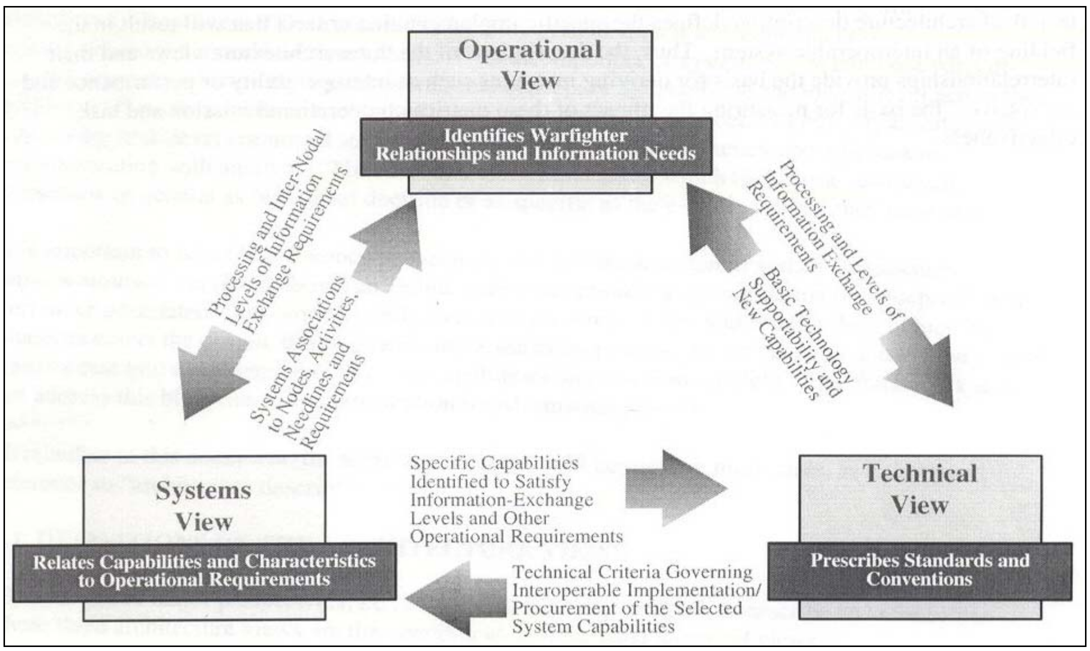


Figure 3 – 1 Interrelations Among the Systems Architecture Views from C4ISR Architecture Framework Version 2.0 (27)

As we talk about the architecture views, there are also three system aspects to the problem which are functional, technical and operational. These aspects can be defined as; what to do, how to do it and who will do it, respectively which are shown in Figure 3–2.

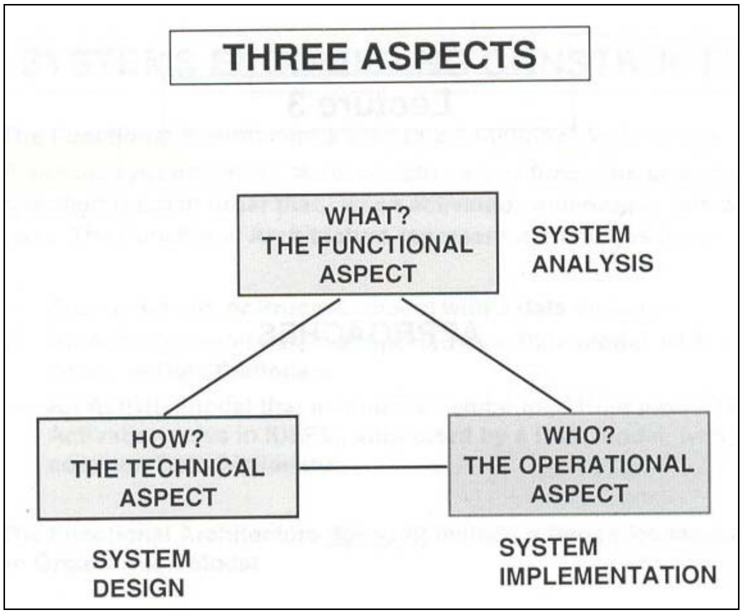


Figure 3 – 2 Three Aspects of System Engineering Process from Class Notes of Alexander H. Levis (28)

In MMA design feasibility study, all of these aspects must be applied and evaluated in order to cover all the system requirements. While creating a notional operational theater, the units of an operational theater and its elements are defined. These describe the functions to be performed in the theater. After defining the functions properly, the way in which these things are going to operate is explained. These are done by considering different operational scenarios and their applications in this MMA study. As a final step, who is going to operate the system and take the problem into the solution process is discussed. In operational scenarios, the users of C3CMISR, the attack and escort fighter aircrafts are considered as operators of the system. All these three aspects make us cover the system analysis, system design and system implementation steps in the whole study.

3.3 Architecture Development Process and Modeling Approach

The purpose of the architecture is defined in C4ISR Architecture Framework as;

"...to improve capabilities by enabling the quick synthesis of "go-to-war" requirements with sound investments leading to the rapid employment of improved operational capabilities, and enabling the efficient engineering of warrior systems" (29)

To carry out the MMA feasibility study in operational environments, the systems engineering operational concept is followed. The architecture development process starts with an operational concept. Notional operational theater and scenarios are used to describe how the missions of current C3CMISR aircrafts are carried out and if a MMA is put into these scenarios, what the effects would be and what the possible requirements changes are. The notional operational scenarios are presented as operational concept maps and the narrative form of each map is also given in order to clarify the existing and possible required situations. A detailed and suitable operational concept leads to an executable model for the problem.

The traditional systems engineering architecture modeling approach is structured analysis. It has four components as; process modeling which describes the process of the system, data modeling which describes the data structures, rule modeling which is represented by a set of formal assertions, and dynamics modeling which describes changes of the system state. All these lead to the executable model of the system. The modeling components are shown in Figure 3-3.

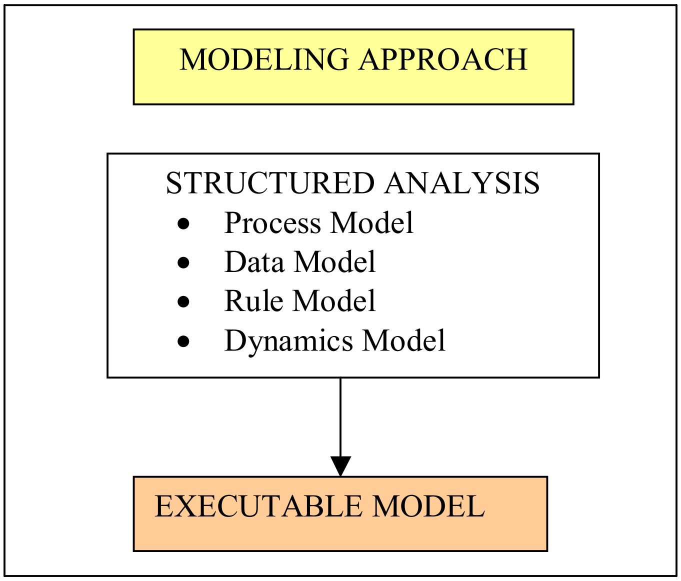


Figure 3 -3 Systems Engineering Architecture Modeling Approach

The architecture should provide basic principles as; being built with a purpose in mind, facilitate communication among humans, and being modular, reusable, comparable, integratable and decomposable. The MMA aircraft design architecture is required to cover these principles in order to reach few useful points about feasibility. (30)

3.4 Data Flow Diagrams for System Design

In this study, an executable model is not searched as a solution to MMA design. Because of the lack of the data and the assumptions of the classified information, it is not possible to give specific answers and solutions to this study. The only work has done by defining the C3CMISR system, its environment, operational requirements and constraints. The notional scenarios are the objects that point the MMA alternatives possibilities in operational theaters.

From the Systems Engineering perspective, the data flow diagrams are one of the processes that are used to develop systems and architectures. Data flow diagrams are tools for modeling the system and they show the flow of data within external and internal sources, transformation and the storing of data. The Context Diagram represents the highest level of the system design. It precedes with the lower level of data flow diagrams. Every system component has its subsystems within and the level can go as lower as the design requirements needed.

The MMA design in operational environments study has three down level decomposition. Each level defines the data flows and relations between the main function and its environment. It also points the operational constraints of the system.

The data flow diagrams for the MMA design in operational environments are shown in Appendix C.

3.5 Battle Planning Process

For an air campaign and a theater level planning, abilities of identify, locate track and engage fleeting, mobile targets should taken into consideration. The main objective is to improve joint operations in an operational theater. (31) While planning a battle on a theater, the main goal which is the national military strategy must be defined. Then the objectives of the plan must follow the main goal. The close air support in the concept of operations is one of the most important components of a mission. By planning the right units for the operation and using them as steps through achievement of the battle, the direction to executing the mission is taken. This process is shown in Figure 3-4.

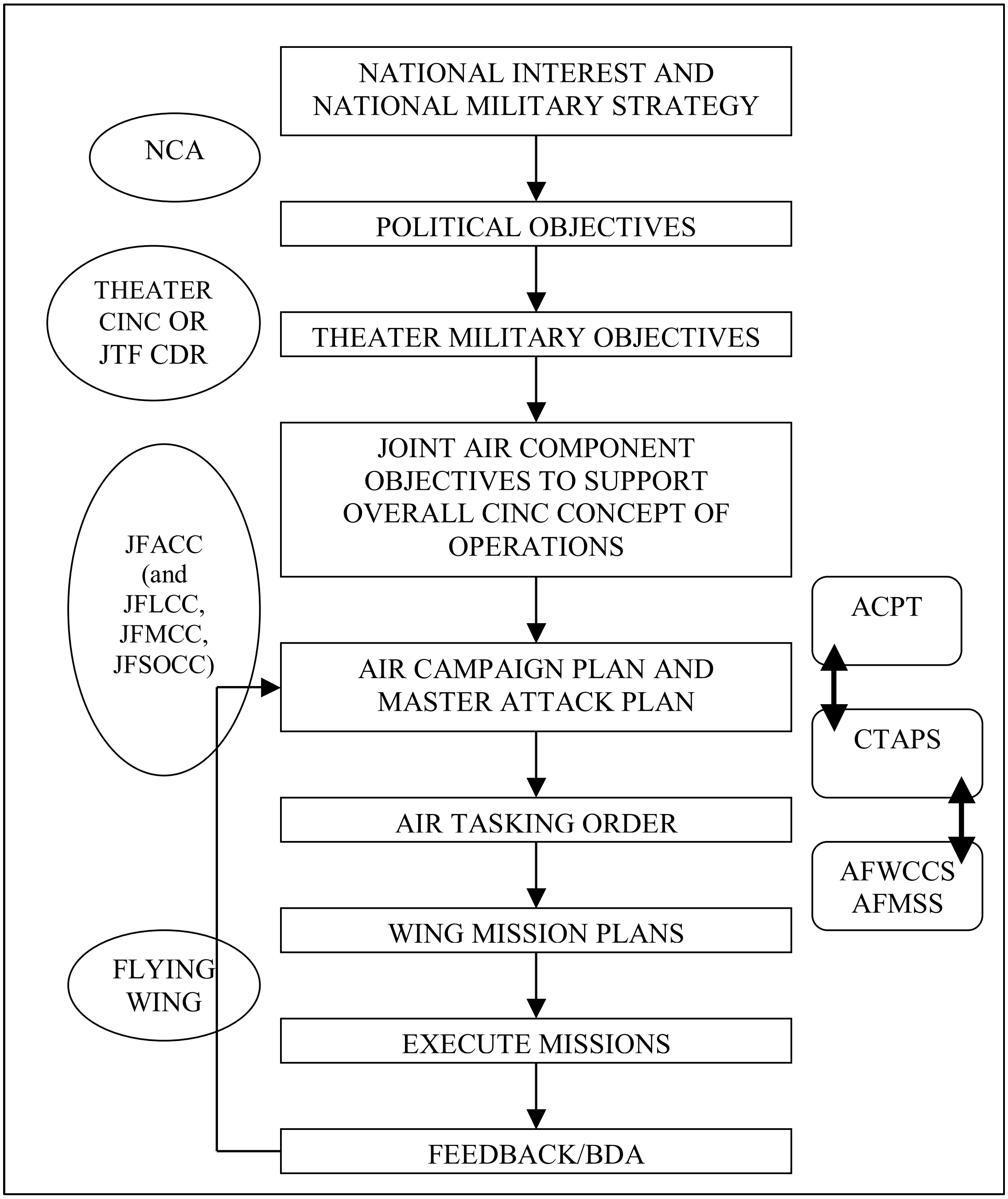


Figure 3 – 4 Battle Planning Process (32)

3.6 Strategic Targets in Theater of Operations

In theater of operations there are numerous targets that need to be destroyed in order to win the battle. These targets represent the strategic importance in the foe country and they are very essential in the war. Basic strategic targets are; command, control and communication facilities (C3), electrical facilities (ELE), ground order of battle field (GOB), government centers (GVC), lines of communication (LOC), military industrial base facilities (MIB), naval facilities (NAV), nuclear, biological, and chemical facilities (NBC), offensive counter air installations (OCA), oil refining, storage, and distribution facilities (OIL), surface-to-air missile installations (SAM). To further define these strategic targets and show a comprehensive level, Table 3-1 is created.

Target Category	**Target Type**
Government Control (GVC) Facility	• Government Control Centers • Government Bodies, General • Government Ministries and Administrative Bodies, Nonmilitary, General • Government Detention Facilities, General • Unidentified Control Facility • Trade, Commerce, and Government, General • Civil Defense Facilities (In Military Use)
Electricity (ELE) Facility	• Electric Power Generating, Transmission, and Control Facilities
Command, Control and Communications (C3) Facility	• Offensive Air Command Control Headquarters and Schools • Air Defense Headquarters • Telecommunications • Electronic Warfare • Space Systems

	• Missile Headquarters, Surface-to-Surface • National, Combined and Joint Commands • Naval Headquarters and Staff Activities
Surface-To-Air Missiles (SAM) Installation	• Missile Support Facilities, Defensive, General • SAM Missile Sites/Complexes • Tactical SAM Sites/Installation • SAM Support Facilities
Offensive Air Counter Air (OCA) Installation	• Airfields (air bases, reserve fields, helicopter bases) • Noncommunications Electronic Installations (Radar installations, Radars Collocated with SAM Sites, ATC/Nav Aids, Meteorological Radars) • Air Logistics, General (Air Depots) • Air Ammo Depots (Maintenance and Repair Bases, Aircraft and Component Production and Assembly)
Nuclear, Biologiocal, and Chemical (NBC) Facility	• Atomic Energy Feed and Moderator Materials Production • Chemical and Biological Production and Storage • Atomic Energy-Associated Facilities Production and Storage • Basic and Applied Nuclear Research and Development, General
Military Industrial Base (MIB)	• Basic Processing and Equipment Production • End Products (Chiefly Civilian) • Technical Research, Development and Testing, Nonnuclear

	• Covered Storage Facilities, General • Material (Chiefly Military) • Industrial Production Centers • Defense Logistics Agencies
Naval (NAV) Facility	• Mineable Areas • Maritime Port Facilities • Cruise Missile Support Facilities, Defensive • Shipborne Missile Support Facilities • Cruise Surface-to-Surface Missile Launch Positions • Naval Bases, Installations, and Supply Depots
Petroleum, Oil, and Lubricants (POL) Facility	• POL and Related Products, Pipelines, and Storage Facilities
Lines of Communication (LOC) Facility	• Highway and Railway Transportation • Inland Water Transportation
Ground Order of Battle (GOB) Field	• Military Troop Installations • Ground Force Material and Storage Depots • Fortifications and Defense Systems

Table 3 - 1 (AIF) Target Categories and Target Types (33)

3.7 Notional Operational Theater Scenario

Notional operational theater scenarios are created in order to analyze current C3CMISR aircrafts in operational theaters. In a notional operational theater, different scenarios are created and C3CMISR aircrafts are assigned in special varieties. For these scenarios, some assumptions are made. Those assumptions are shown in Appendix B.

3.7.1 Basic Map of a Notional Operational Theater

Before creating operational scenarios, the basic map of a notional battle theater is defined. The map of the basic operational scenario is shown in Figure 3-5. The basic map shows besides target points and airbases, also the values of length and width of the whole battle theater. Basically, the battle theater has five different strategic attack points and two different airbases are set for the friendly aircrafts. The targets and airbases are named as T1, T2, T3, T4, and T5, and the airbases are named as A1 and A2. The friendly aircrafts take off from either or both of these airbases and attack to one or more of the targets through defined missions which are specified as scenarios. A1 and A2 serve as airbases for the C3CMISR and tanker aircrafts.

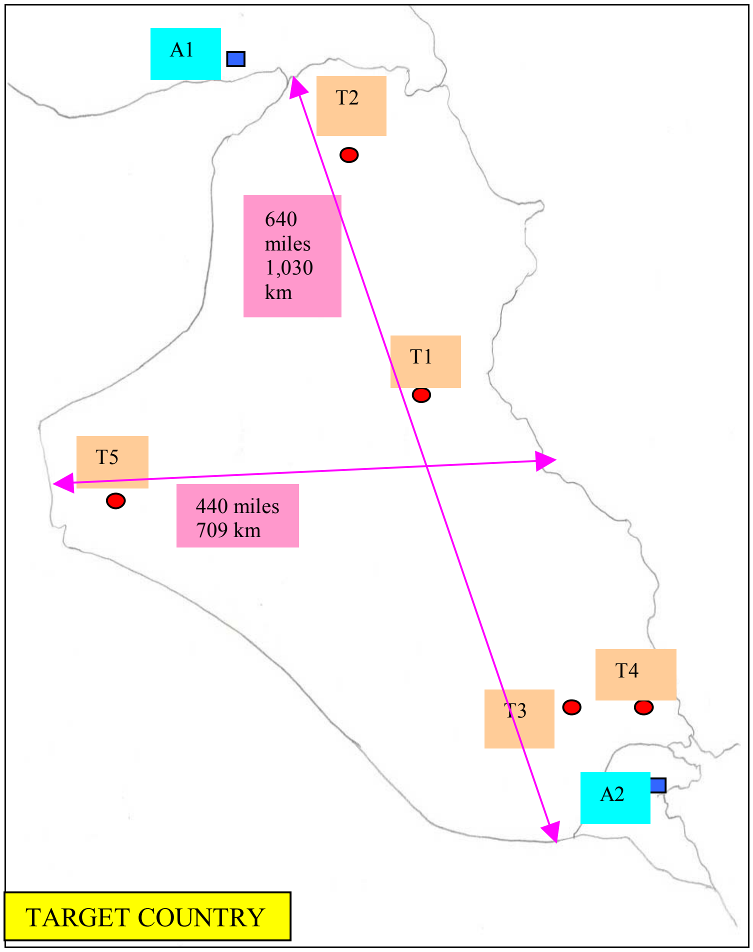


Figure 3 - 5 Map of Notional Operational Theater Scenario

3.7.2 Notional Target and Airbase Definitions and Coordinates

Table 3–2 shows the definitions and the coordinates of the targets that have been shown on the notional scenario map. Also the coordinates of airbases are given at Table 3-3.

TARGET	DEFINITION	COORDINATES
T1	Command, Control & Communication (C3) Facility	33° 19′ 38″ N 44° 22′ 09″ E
T2	Military Industrial Base (MIB)	36° 18′ 23″ N 43° 08′ 38″ E
T3	Offensive Counter Air (OCA)	30° 32′ 32″ N

	Installation	$46^\circ 36' 07'' E$
T4	Surface-to-Air Missile (SAM) Installations	$30^\circ 25' 18'' N$ $47^\circ 38' 32'' E$
T5	Ground Order of Battle (GOB) Field	$33^\circ 21' 20'' N$ $40^\circ 35' 48'' E$

Table 3 – 2 Target Definitions and Coordinates

AIRBASE	COORDINATES
A1	$36^\circ 59' 16''$ N $35^\circ 18' 48''$ E
A2	$28^\circ 56' 05''$ N $47^\circ 47' 31''$ E

Table 3 - 3 Coordinates of Airbases

3.7.3 Distance Calculations between Notional Airbases and Targets

Before the mission is planned, the distances between the airbases and the targets in the operational theater have to be calculated in order to achieve the given process. After the exact coordinates are given, by some specific formulas the distances between points are calculated. The formulas of distance calculation are presented in Appendix D.

First the distances between points are calculated in normal miles and then converted into kilometers. The spreadsheet of actual calculations is shown in Appendix E. By the formula for distance calculation, the distances between airbases and targets on the notional operational theater are shown at Table 3-5;

POINT	COORDINATES IN DEGREES	COORDINATES IN RADIANS
A1	$36^\circ 59' 16''$ N $35^\circ 18' 48''$ E	0.645481 N 0.616101 E
A2	$28^\circ 56' 05''$ N $47^\circ 47' 31''$ E	0.505006 N 0.834127 E
T1	$33^\circ 19' 38''$ N $44^\circ 22' 09''$ E	0.583328 N 0.774388 E
T2	$36^\circ 18' 23''$ N $43^\circ 08' 38''$ E	0.633666 N 0.753003 E
T3	$30^\circ 32' 32''$ N $46^\circ 36' 07''$ E	0.533062 N 0.813357 E
T4	$30^\circ 25' 18''$ N $47^\circ 38' 32''$ E	0.530958 N 0.831514 E
T5	$33^\circ 21' 20''$ N $40^\circ 35' 48''$ E	0.582164 N 0.708545 E

Table 3 - 4 Conversions from Degrees to Radians

DISTANCES BETWEEN POINTS	DISTANCES IN NORMAL MILES	DISTANCES IN KILOMETERS
A1 - T1	580	950
A1 – T2	440	710
A1 – T3	790	1,280
A1 – T4	840	1,350
A1 – T5	390	630
A2 – T1	370	590
A2 – T2	580	935
A2 – T3	130	210

A2 – T4	105	170
A2 – T5	525	845
T1 – T2	212	400
T1 – T3	239	384
T1 – T4	283	455
T1 – T5	218	351
T2 – T3	446	718
T2 – T4	483	778
T2 – T5	251	404
T3 – T4	63	102
T3 – T5	403	649
T4 – T5	461	742

Table 3 – 5 Distances between Airbases and Targets

3.7.4 Defense of Notional Operational Battle Theater

As it can be seen from the map of the notional operational theater in Figure 3–9, the battle theater has two main airfields that have defensive missile coverage with different ranges of coverage. Each airfield has three missile types for air defense named as M1, M2 and M3. These missiles are defined as short-range, mid-range and long-range missiles respectively. The capabilities of these missiles are shown in Table 3-6 and the missile radar range coverages are shown in Figure 3-6.

The terms which are expressed in missile capabilities are clarified before proceed into any further. CEP (Circular Error Probable) is an indicator of the accuracy of a missile/projectile, used as a factor in determining probable damage to a target as a NATO and DOD definition. It is the radius of a circle within which half of the missiles/projectiles are expected to fall. (34) (35)

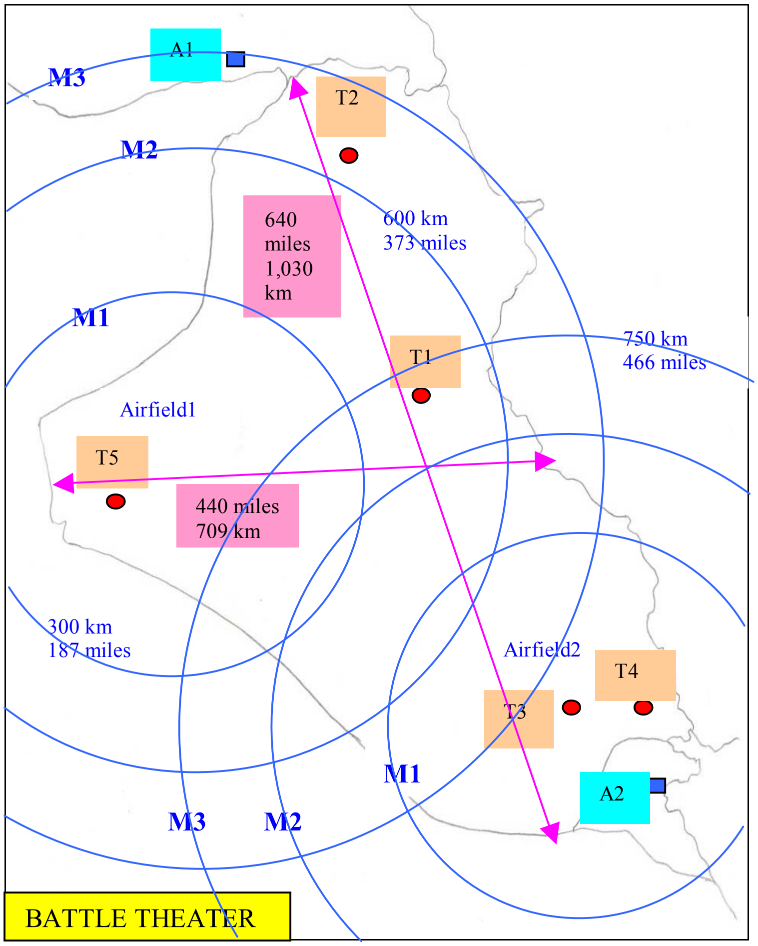


Figure 3 – 6 Map of Defense System of the Battle Theater

MISSILE	RANGE
M1	300 km 187 miles
M2	600 km 373 miles
M3	750 km 466 miles

Table 3 – 6 Missile Capabilities of the Battle Theater (36)

3.7.5 Notional Operational Theater Scenarios

Four notional operational scenarios are created on a battle theater that is defined in Figures 3-5 and 3-6 in order to show the recent usage of C3CMISR and tanker aircrafts. By assumed data of the scenario, the aircraft circumstances are shown and analyzed.

3.7.5.1 Notional Operational Scenario 1

In the first scenario, a package of fighter and bomber aircrafts takes off from Airbase 1 (A1) and attack Target 1 (T1). T1 is a Command, Control and Communication Facility (C3) as defined before and it has strategic importance. Its coordinates are shown in Table 3-4. The attack package used in the scenario has a notional number of fighter and bomber aircrafts. This number changes and is defined with the type and requirements of the assigned mission. This data is classified and it is declared to the exact operational units right before the mission is get started. So the numbers of fighter and bomber aircrafts shown in the notional scenarios are just the representations of these notional numbers. The missiles of the aircraft and their capabilities are defined in Appendix F. After the attack and bombing of T1, it leaves the battle theater and turns back to the A1. T1 is not in the center of both 300 km/187 miles diametric defense coverage airfields but it is included in the 600 km/373 miles and 750 km/466 miles diametric defense coverage of Missile 2 (M2) and Missile 3 (M3) respectively.

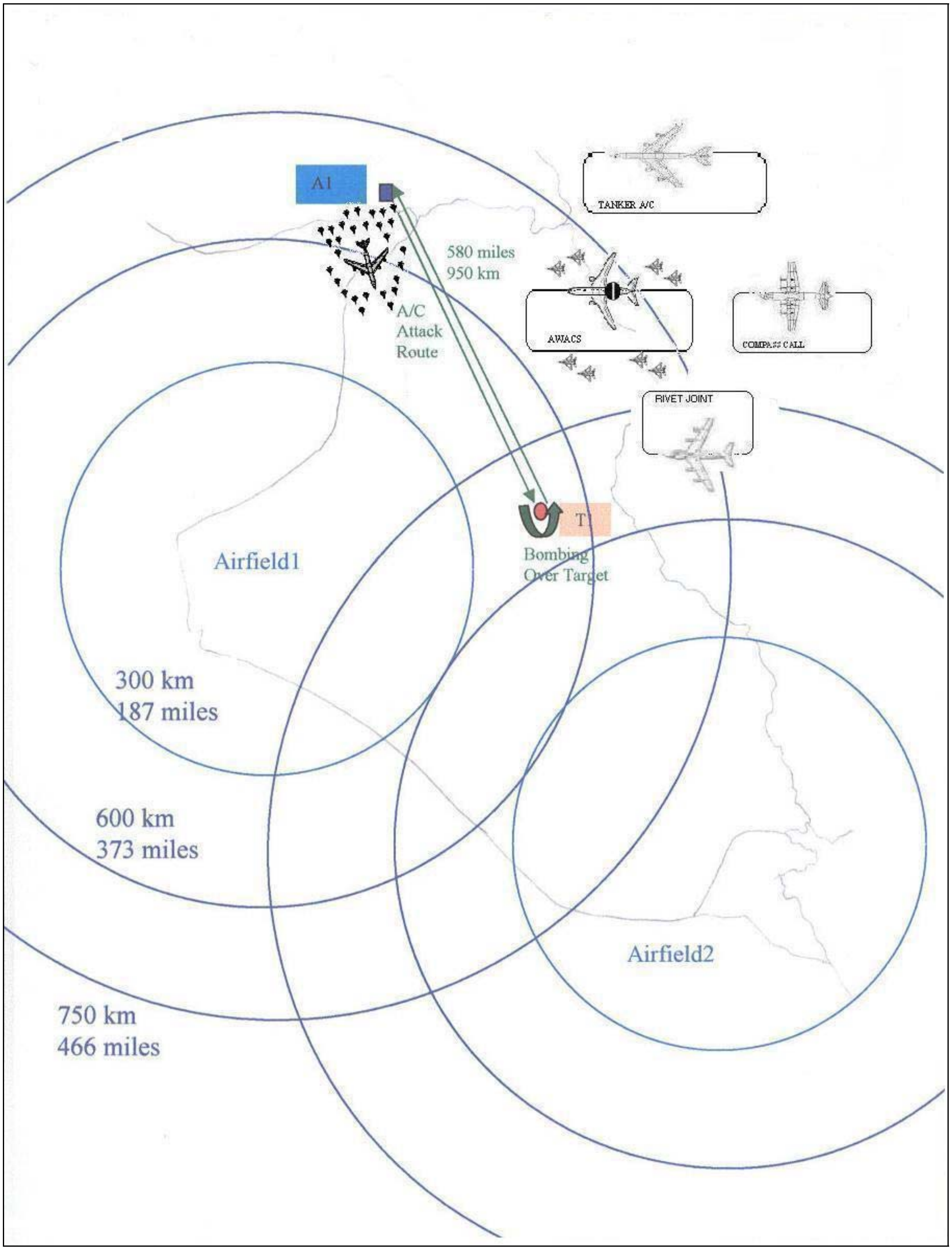


Figure 3 – 7 Map of Notional Operational Scenario 1

For this scenario which is shown in Figure 3-7, since only one target is planned, AWACS, Rivet Joint and Compass Call are assigned for the mission. The attack package needs AWACS support over the entire mission for identification of counter attack. The AWACS radar range is 250 miles/355.5 km, so it has to achieve its task within the range near the target. Because the AWACS orbit is inside the defense coverage range of two missiles M1 and M2, escort fighter aircraft must accompany the AWACS aircraft. Also a Compass Call aircraft is needed for jamming in order to protect the fighter package and AWACS through the flight until reaching the target and achieving the mission. It can operate outside the range of the missile defense coverage, so it doesn't require any dedicated escort fighter aircraft. Target 1 is tracked by the Rivet Joint aircraft and it flies within the missile defense coverage because its radar range is 155 miles/240 km. So it also requires fighter escorts. A Tanker aircraft is following a pattern out of the missile defense area. For an operation, a Tanker Aircraft is an essential unit. Capabilities of legacy C3CMISR aircrafts are shown in Appendix G.

3.7.5.2 Notional Operational Scenario 2

In the second scenario, a fighter and bomber aircraft package takes off from airbase A2 and follows a task route in sequence to T4, T3 and T5 and then proceeds to airbase A1. After bombing target T3 the fighter aircrafts air refueled. All of the aircrafts have critical TOTs (Time on Target) for each target which must be achieved for the mission to be successful.

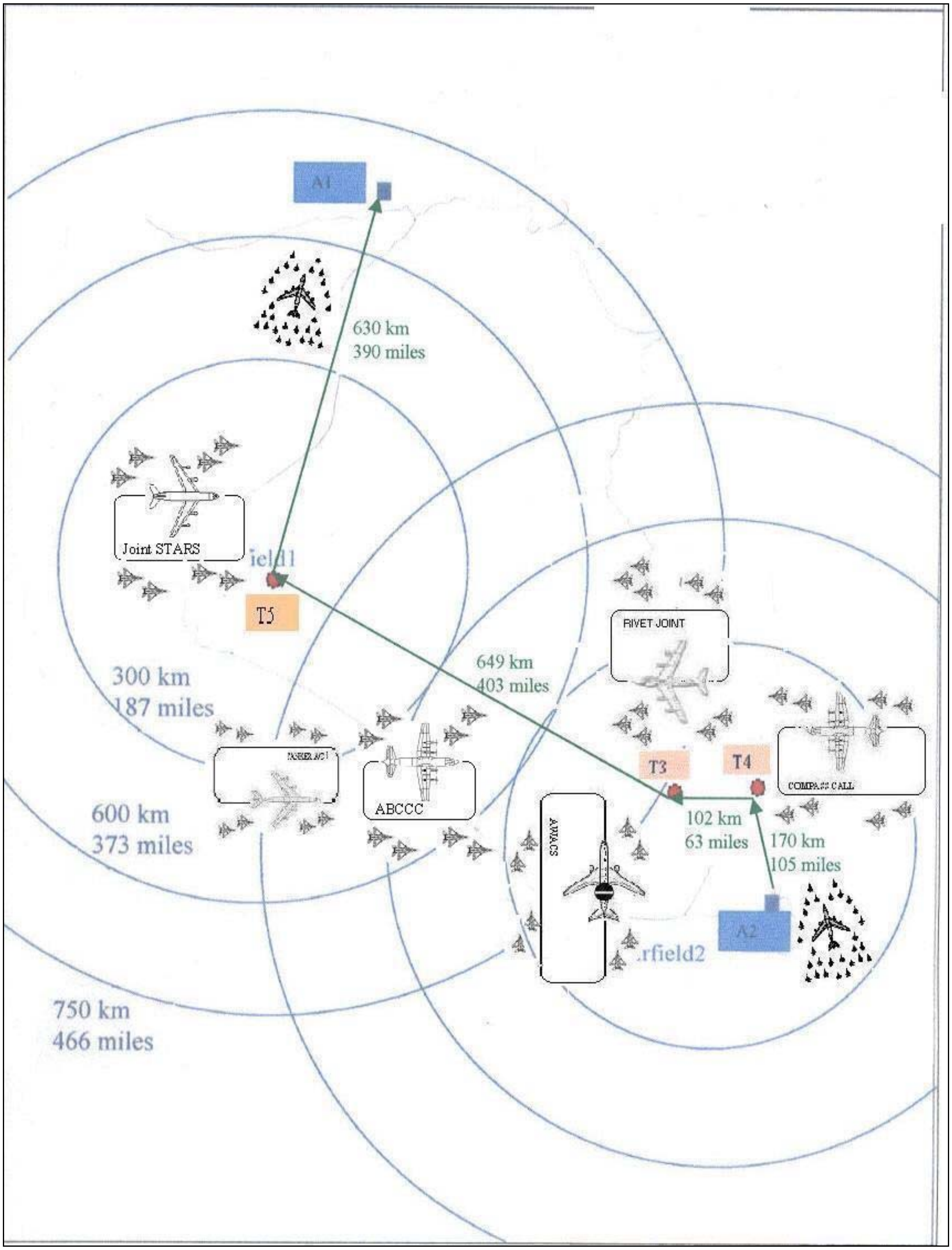


Figure 3 – 8 Map of Notional Operational Scenario 2

The basic map of Operational Scenario 2 is shown in Figure 3-8. T3 is an offensive counter air installation facility (OCA). T4 is a surface-to-air missile installation facility (SAM). T5 is a ground order of battle (GOB) field. The coordinates of each target are shown in Table 3-4. Targets T3, T4 and T5 are within all three battle theater defense missiles coverage. T3 and T4 are within the air defense of airfield 2 and T5 is within the air defense of airfield 1. Both airfields have same diametric coverage. The battle theater is capable of using all three missiles M1, M2 and M3. By taking this fact into consideration, all battlefield operational tasks must be planned carefully.

The distance between A2 and target T4 is 105 miles/170 km. Before and over T4, AWACS aircraft provides airborne tracking and warning for the attack package and all the friendly aircrafts through the flight mission route. After getting over T4, while aircraft package does its mission, AWACS aircraft keeps track of all the friendly and foe aircrafts and airborne activities. Because of its range, which is 250 miles/355.5 km, AWACS aircraft doesn't have to redo its orbit route while the aircraft package follows its mission flight route. It flies over southwest of T4, within the 250 miles diameter which includes both A2 and T4. Because of being within the battle theater defense missile coverage, it needs to be escorted by fighter aircrafts. The Rivet Joint aircraft is needed for reconnaissance of the targets. Its range is 155 miles/240 km and it also has to fly within the target defense missile coverage. So it definitely needs escort fighter aircrafts. The distance between A2 and T4 is not exceeds Rivet Joint aircraft's range, so it flies over the north of T4 and the orbit diameter of 155 miles includes both A2 and T4. For a strict and effective attack to the target and achieving the mission, a Compass Call aircraft is needed.

Mainly it provides jamming for the friendly units. It also has escorts fighter aircrafts for being within the defense coverage. The Compass Call aircraft flies over the northeast of T4.

The distance between the targets T4 and T3 is 63 miles/102 km, which is a very short range. After attacking the targets at T4, the package proceeds to T3. Because of the short distance between targets, none of the C3CMISR aircrafts need to change their orbit position. Their radar ranges allow them to achieve their planned tasks. They provide requested information, intelligence, reconnaissance and jamming during the attack over T3.

After the attack over T3, the fighter aircrafts need to be refueled. A tanker aircraft flies out of the target area with escort fighter aircraft. The fighter aircraft do air refueling. After air refueling, the attack package gathers and moves towards target T5. On T5 there is a ground battle is in progress and the fighter aircraft are scheduled to attack and bomb ground moving targets. Since they are not fixed targets, a Joint STAR aircraft is needed for this mission. The radar range of the JSTAR aircraft is 160 miles/250 km. So it flies over west of T5 within its radar range and provides ground target tracking information. The distance between T3 and T5 is 403 miles/649 km. So the C3CMISR aircrafts need to relocate their orbit positions for the mission over T5. The AWACS aircraft keeps providing airborne intelligence and data while the attack package flies through their mission route towards T5. It especially gives information about the counter attack aircrafts and missiles of the battle theater. Through out the whole operation an ABCCC aircraft provides all of the command, control and communication issues of the scenario theater. It flies inside the battle theater defense coverage and escorted by fighter aircraft.

After destroying the specified targets over T5, the package and all the C3CMISR aircrafts leave the battle theater and proceed towards airbase A1. The distance between, T5 and A1 is 390 miles/630 km. This is less then the distance between T5 and A2 which is 525 miles/845 km. Because of this reason, the flight route is planned towards A1.

3.7.5.3 Notional Operational Scenario 3

In the third scenario, two different aircraft packages take off from the same airbase and attack to two different targets at the same time. Aircraft package 1 takes off from airbase A1 and is headed towards target T5, and aircraft package 2 takes off from airbase A1 and is headed towards target T2. Concurrently, a jamming aircraft, Compass Call, also takes off from A1 and heads towards target T1. This notional operational scenario consists of three inclusive tasks that each one must be accomplished individually.

The basic map of Scenario 3 is shown in Figure 3-9.

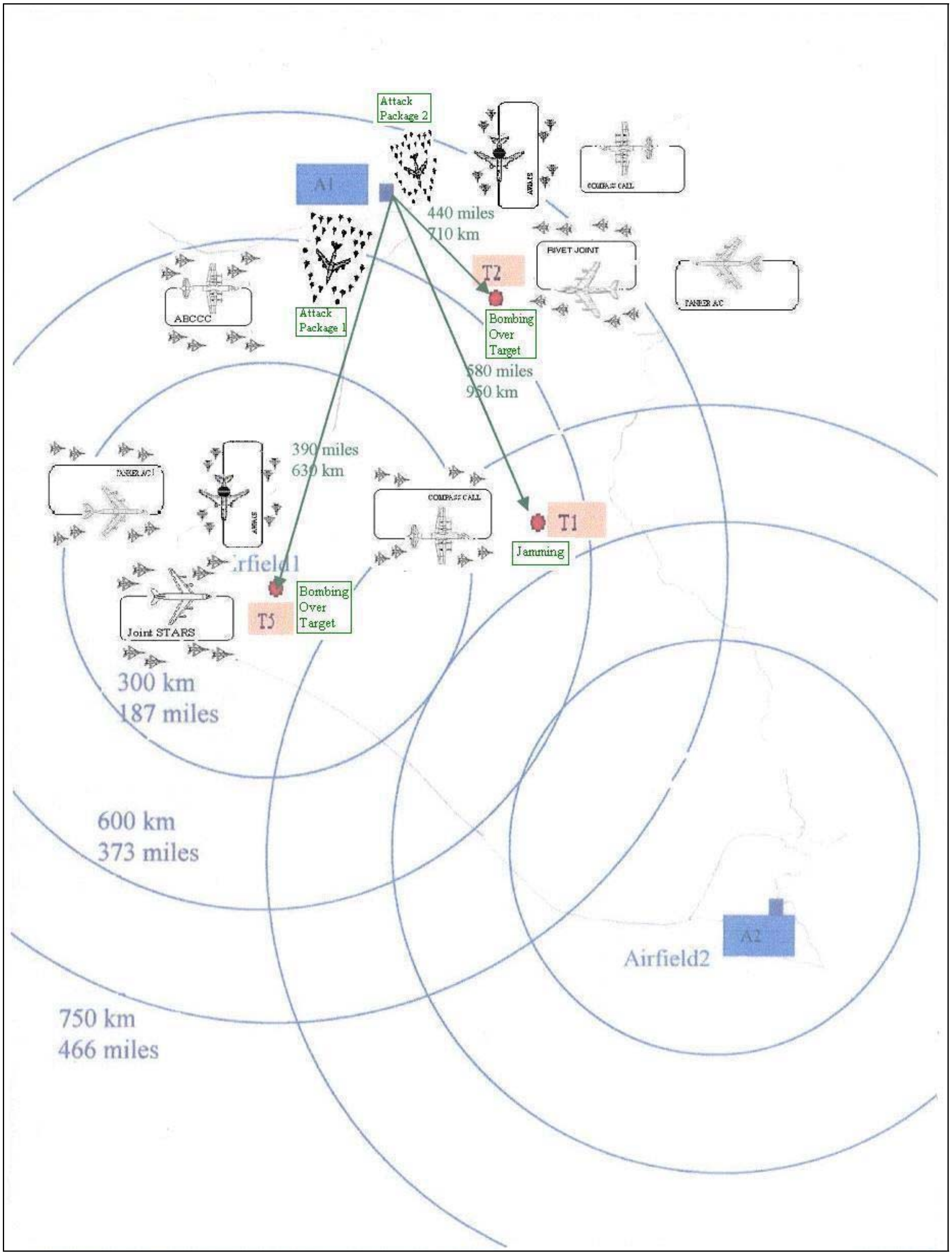


Figure 3 – 9 Map of Notional Operational Scenario 3

T1 is a command, control and communication (C3) facility. T2 is a military industrial base (MIB) facility. T5 is a ground order of battle (GOB) field. The coordinates of each targets are shown in Table 3-4. T1 is within the battle theater defense coverage of missiles M2 and M3 of airfield 1 and M3 of airfield 2. T2 is within the coverage of missile M3 of airfield 1. T5 is within the coverage of missiles M1, M2 and M3 of airfield 1.

At T5 a ground battlefield in progress and ground moving targets exist. For this mission an AWACS aircraft should follow the mission route of the aircraft package along that leg of the mission for A2 to T5 to provide airborne intelligence and warning continuously. It then orbits north of T5 within its radar range of 250 miles/355.5 km. A Joint Star aircraft flies over the west of T5 which is within its radar range of 160 miles/250 km. A tanker aircraft flies northwest of the target T5. All C3CMISR aircrafts and the tanker aircraft have escort fighter aircrafts, because of being inside the battle theater defense missile system.

At the same time for aircraft package 2 attacking target T2, an AWACS aircraft is also needed. The distance between A1 and T2 is 440 miles/710 km and the distance between T5 and T2 is 251 miles/404 km. Since airborne intelligence is needed continuously for the aircraft package 2, one AWACS aircraft cannot achieve both missions. So another AWACS aircraft is assigned for the second mission. It provides airborne data to the aircraft package 2 through its flight route. After the package comes over T2, AWACS aircraft takes position and flies over north of T2 within its radar range. For the target reconnaissance, a Rivet Joint aircraft is assigned for the second mission. T2 is a fixed target, so Joint Stars aircraft is not included. A Compass Call aircraft is assigned for jamming because of the target country defense and communications system. It flies over the northeast of T2. For the mission continuity, a tanker aircraft is needed for the second mission. Since the distance between T5 and T2 is far and both missions over targets might require air refueling, another tanker aircraft is assigned for the second mission. It flies over east of T2. Over this target T2, AWACS and Rivet Joint aircrafts have escort fighter aircrafts. Compass Call and tanker aircrafts don't have any, because their fly out of the battle theater defense missile system.

While the aircraft packages are bombing targets T5 and T2, a Compass Call aircraft jams over target T1. By jamming T1, the effect of command, control and communications is prevented over T5 and T2. The distance between T1 and T2 is 212 miles/400 km. Because of this wide range, a second Compass Call aircraft is assigned for T1. It also jams T5 and protected by escort fighter aircrafts. An ABCCC aircraft is assigned for the whole scenario as a command, control and communications aircraft.

After the missions are achieved, all C3CMISR and fighter aircrafts leave the battle theater and land to the airbase A1.

3.7.5.4 Notional Operational Scenario 4

In scenario 4, two fighter and bomber aircrafts package take off from airbase A2 in order to bomb targets T3 and T4 respectively and one package takes off from airbase A1 in order to bomb T5. And while the packages are bombing the targets, a Compass Call aircraft is jamming the target T1.

The basic map of the scenario 4 is shown in Figure 3-10.

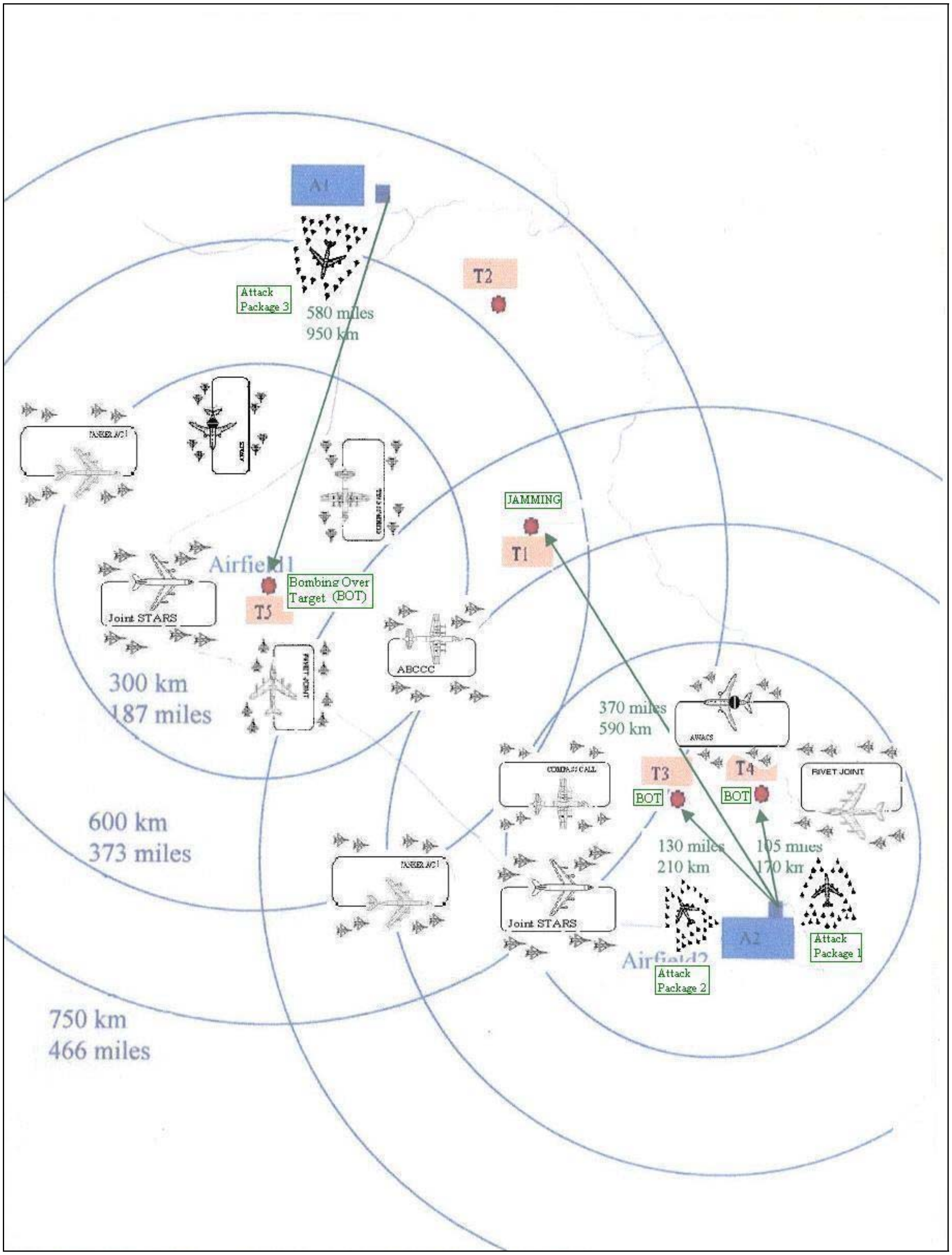


Figure 3 – 10 Map of Notional Operational Scenario 4

T1 is a command, control and communication (C3) facility. T3 is an offensive counter air installation facility (OCA). T4 is a surface-to-air missile installation facility (SAM). T5 is a ground order of battle (GOB) field. The coordinates of each target are shown in Table 3-4. T3 and T4 are within the battle theater defense missiles M1, M2, and M3 coverage of airfield 2. T1 is within the battle theater defense coverage of missiles M2 and M3 of airfield 1 and M3 of airfield 2. T5 is within the coverage of missiles M1, M2 and M3 of airfield 1.

The distance between A2 and T4 is 105 miles/170 km. An AWACS aircraft and a Rivet Joint aircraft are assigned for airborne tracking and target reconnaissance. Since the distance is within these aircrafts' radar range, they fly over the north and northeast of T4 respectively. They can achieve the mission tasks from these points. The distance between A2 and T3 is 130 miles/ 590 km, and the distance between T3 and T4 is 63 miles/102 km. Both distances are within the radar range of AWACS and Rivet Joint aircrafts, so the exact orbit positions of these aircrafts are suitable for the second attack mission over T3. A single Joint Stars aircraft is assigned for both missions and it achieves the mission over the southwest of target T3. Because its radar range is 160 miles/250 km, it provides data for both missions over T3 and T4. All the C3CMISR aircrafts are within the battle theater defense missile coverage and they all need escort fighter aircrafts. Also a Compass Call aircraft is assigned for jamming the target T1 in order to prevent the target country's command, control and communication issues. The distance between A2 and T1 is 370 miles/ 590 km. The Compass Call aircraft flies over south of target T1 and this allows it to does jamming over targets T3 and T4 also. A tanker aircraft flies over the west of targets T3 and T4 while the missions go on.

Besides missions over targets T1, T3 and T4 at the same time a fighter and bomber aircrafts package takes off from airbase A1 and attacks to target T5. The distance between A1 and T5 is 580 miles/950 km, so an AWACS aircraft follows the flight route of the package until it comes over the target T5. After the package arrives to T5, AWACS aircraft starts its orbit route over north of T5 within its radar range. Clearly, this is the second AWACS aircraft assigned for the notional operational scenario. Because target T5 is a ground battlefield, a Joint Stars aircraft is assigned for the ground surveillance tasks of the mission. This has to be the second Joint Stars aircraft in the scenario theater as AWACS aircraft, because its radar range doesn't allow it to provide data for all target locations. Besides, a second Rivet Joint aircraft is needed for target reconnaissance over T5.The Joint Stars aircraft flies over west of T5 and the Rivet Joint aircraft flies over south of T5. For the long range of the mission from airbase A1 and the possible duration of the mission, a tanker aircraft is assigned and it flies over northwest of T5. All of the C3CMISR and tanker aircrafts fly inside the battle theater defense missile coverage and they are escorted by fighter aircrafts. A Compass Call aircraft is assigned for jamming over T5 in order to prevent command, control and communications issues of the enemy ground units. It flies over northeast of T5.

All these missions and aircrafts are controlled and directed by an ABCCC aircraft which flies in the middle of the scenario theater.

Chapter 4 – Results and Analysis

4.1 Chapter Overview

In this chapter, the MMA design feasibility is studied by using notional scenarios over a battle theater. In order to study the feasible MMA design, alternative MMA architectures are defined. These different MMA designs are studied in notional operational scenarios which are defined in chapter 3. The study includes alternative architecture operational effectiveness, payload limitations and electromagnetic compatibility and interference in the exact same notional operational theaters with the same threats in the battle theater.

4.2 Alternative MMA Architectures

The best way of analyzing the MMA design from the operational viewpoint is to create a notional operational theater and make up few warfare scenarios in order to exercise the range of applications of C3CMISR aircraft. Basically two alternative MMA architectures are defined. These are one tail number (OTN) and different tail numbers (DTN). In OTN, all of the C3CMISR aircrafts are put on one airframe. This one airframe includes all the sensors and mission crew inside it. The payload has to include everything that is needed to achieve the missions of C3CMISR aircrafts. The DTN is formed by two aircrafts and these aircraft frames include payload and sensors of alternatively chosen C3CMISR aircrafts in four different combinations. The definitions of alternative MMA architectures are given in Table 4-1.

MMA ARCHITECTURE	TITLE		CAPABILITIES
ONE TAIL NUMBER	OTN		AWACS JSTARS RIVET JOINT ABCCC COMPASS CALL
DIFFERENT TAIL NUMBERS	DTN1	DTN11	AWACS JSTARS
		DTN12	RIVET JOINT ABCCC COMPASS CALL
	DTN2	DTN21	AWACS ABCCC
		DTN22	JSTARS RIVET JOINT COMPASS CALL
	DTN3	DTN31	AWACS RIVET JOINT
		DTN32	JSTARS COMPASS CALL ABCCC
	DTN4	DTN41	AWACS COMPASS CALL
		DTN42	JSTARS RIVET JOINT ABCCC

Table 4 -1 Alternative MMA Architectures

4.2.1 Notional Operational Scenario 1

Scenario 1 is a very basic attack plan. A fighter and bomber aircraft package takes off from airbase A1 and hits the target T1. Target T1 is a command, control and communication (C3) facility. The numbers of fighter and bomber aircrafts are notional. After the mission is completed the package turns back to A1. While the aircraft package flies through its attack route, it needs continuous airborne tracking and warning. The attack route is within the battle theater defense missiles coverage and their ranges are 373 miles/600 km and 466 miles/750 km respectively. Besides defense missiles, the battle theater uses intercept fighter aircrafts in order to block the attacking aircrafts by engagement. In order to track all of these foe activities, an airborne tracking and warning system must be used. After coming over the target T1, a reconnaissance system is needed. While the friendly fighter and bomber aircrafts are attacking the specified targets over T1, the foe signal intelligence and the targets' reconnaissance is needed. A tanker aircraft is also requested for air refueling in order to completely achieve the mission. By in-flight refueling, the duration of the mission and the mission capabilities of the aircrafts are increased.

. **4.2.1.1 Notional Operational Scenario 1a**

In Scenario 1a, MMA architecture as defined in table 3, OTN is used. The mission operators are also needed to be specified. This number is determined by taking the essential number of each specialized task for each C3CMISR aircraft. The crew numbers and their specialties are listed in Appendix H. The total crew number is calculated by adding a number of 4 flight crew to the number of operators needed. These numbers are defined by the operational requirements of the C3CMISR architecture. The titles and capabilities of alternative MMA architectures are listed in Appendix I.

The fighter and bomber aircraft package takes off from airbase A1 and follows the attack route through target T1. The distance between A1 and T1 is 580 miles/950 km. This distance is out of the OTN aircraft's radar range. This radar range formed by the constraint of AWACS, RIVET JOINT, JSTARS, ABCCC and COMPASS CALL sensor ranges. When each sensor is in use, the range of its sensor is taken as a range of OTN. Because of airborne attack and warning tracking needs, OTN aircraft follows the attack route through T1 with the package and provides real-time intelligence data to the operational units. After arriving over T1, the package starts its mission and OTN aircraft forms an orbit over the north of T1 within its radar range. Even though AWACS has a radar range of 250 miles/355.5 km and JSTARS has a range of 160 miles/250 km, the radar range of OTN is constrained into 155 miles/240 km because of RIVET JOINT's radar range. OTN aircraft's mission is now; provide airborne tracking and warning, target surveillance and signals intelligence collection, and jamming of foe activities. The OTN aircraft must accomplish its tasks within the target country defense missile coverage, so it is escorted by fighter aircrafts. With this OTN combination, the notional numbers of escort fighter aircrafts are decreased to 1 in 3 compared to the Scenario 1 which is achieved by individual aircrafts. This brings an important effect about cost and risk issues.

This scenario can be achieved by one OTN aircraft, because it only requires a single target tracking and surveillance. One tanker aircraft flies out of the defense missile coverage in case of any air refueling needs for completion of the mission. It doesn't require any escort fighter aircrafts.

After the mission achieved over T1, the package and OTN aircraft leaves the target area and heads through A1. OTN keeps providing airborne tracking and warning data for the operational units in case of a foe activity and command and control issues. All the operational units and aircrafts land on airbase A1.

The basic map of Scenario 1a is shown in Figure 4-1.

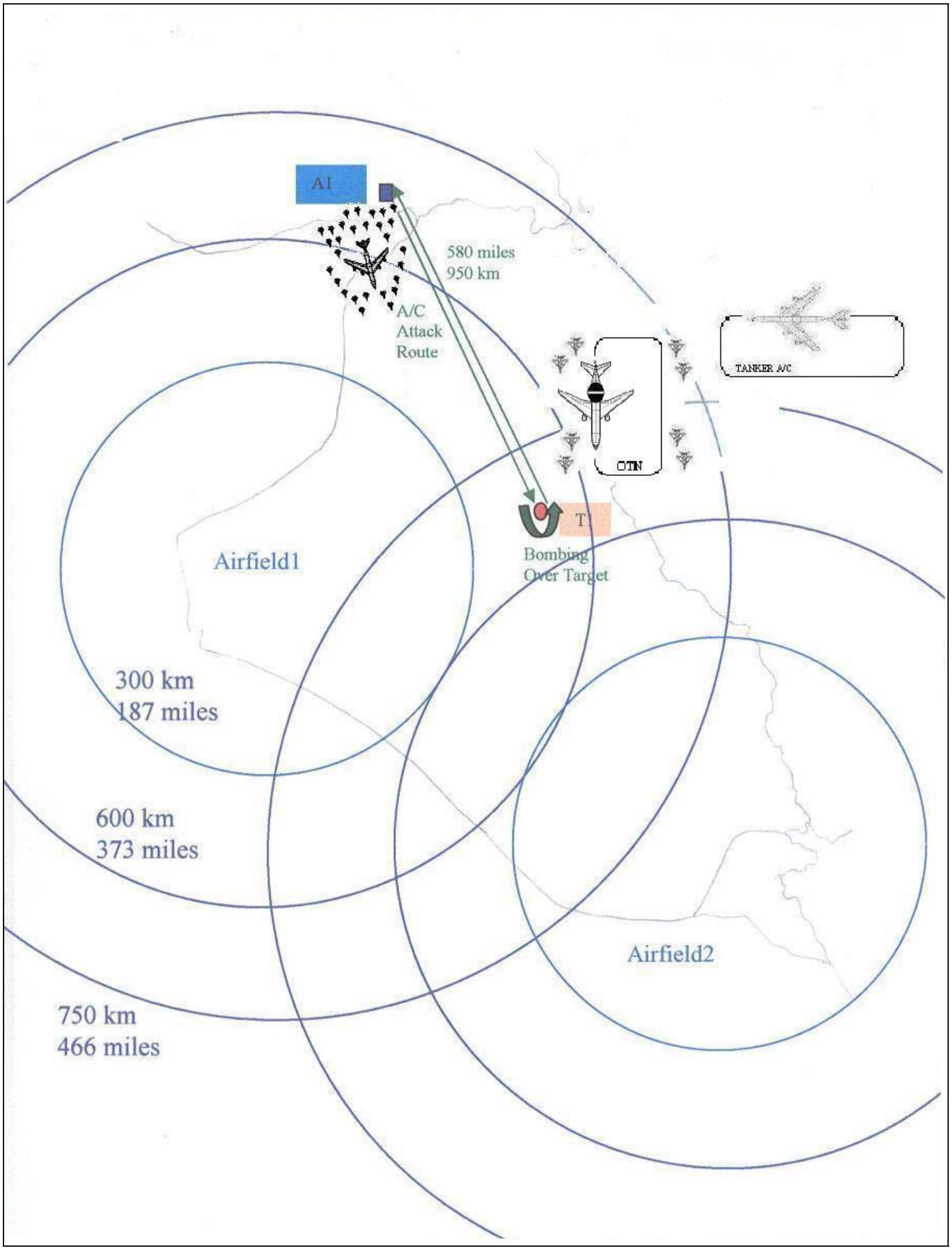


Figure 4 -1 Map of Notional Operational Scenario 1a

4.2.1.2 Notional Operational Scenario 1b

In Scenario 1b, different tail number (DTN) is used as an alternative MMA architecture. As it can be seen from the Table 4-1, the alternative DTN architectures are formed by two airframes. The first airframe fixed capability is AWACS and the other sensor and capabilities on board change. The capabilities on second airframe are changing according to the first airframe.

With the distance between A1 and T1 which is 580 miles/950 km, first airframe of DTN architectures follows the fighter and bomber aircraft package through its attack route. The radar ranges of different DTN airframes are formed by the radars and sensors on board and they are shown in Appendix H with the specialties of operators and their numbers for the architectures. The DTN airframes capabilities are listed in Appendix I. While the package flies on its attack route, the first airframe of DTN architectures provides only airborne tracking and warning to the operational units. There is no need for ground surveillance at this point.

After arriving over T1, the first airframe of DTN architectures forms an orbit route over northwest of T1 within its radar range. The first airframe of DTN architectures provides real-time airborne surveillance and command, and the other C3CMISR issue on board. At the same time, the second airframe of DTN architectures flies over the northeast of T1 and provides the C3CMISR capabilities on board. Both architectures are within the target country defense missile coverage, and they need escort fighter aircrafts. This time the notional numbers of these fighter aircrafts are decreased to 2 in 3, compared to the Scenario 1 which is achieved by individual aircrafts which is an improvement in cost and risk issues of the operation.

A tanker aircraft flies over the northeast of T1, out of defense missile coverage. All aircrafts get air refueling if there exists any need in order to achieve the required mission. No fighter aircraft is needed for escort the tanker aircraft.

After the mission is completed, all aircrafts leave the target area and head through the airbase A1. On the flight route of the aircraft package, the first airframe of DTN architectures provides airborne surveillance for the operational units and command and control issues. All the operational units and aircrafts land on airbase A1.

The basic map of scenario 1b is shown in Figure 4-2.

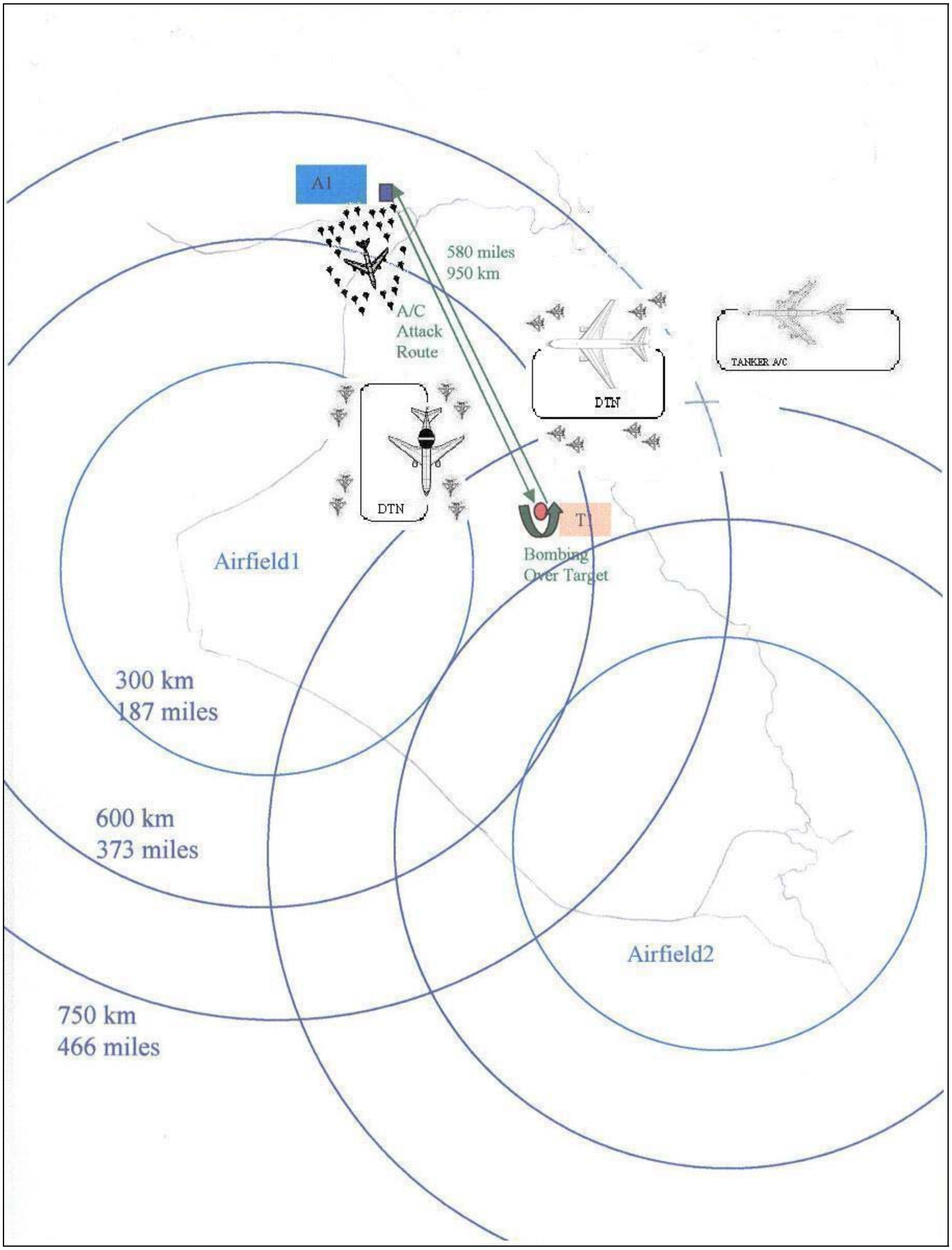


Figure 4 -2 Map of Notional Operational Scenario 1b

4.2.2 Notional Operational Scenario 2

Scenario 2 includes three different target points. These target points are attacked by a fighter and bomber aircraft package. Numbers of these aircrafts are notional because they are mostly classified and specified according to the mission requirements. The only clue can be given about this issue is; the number of fighter and bomber aircrafts required for Scenario 2 is more than required number for Scenario 1. Because in Scenario 2, there are 3 targets and the mission includes continuous tasks that followed by each other. Also the time requested for the mission completion is more than Scenario 1. This leads to exact air refueling requirements which causes more intervals in the mission. The increase in the number of aircrafts prevents this interval for blocking the mission achievement in case of risk assessment. The attack package takes off from airbase A2 and flies through target T4 first. The distance between A2 and T4 is 105 miles/170 km. After the accomplishment of the task over T4, the package proceeds towards target T3. The distance between T4 and T3 is 63 miles/102 km. The package proceeds towards target T5 after the assigned task is achieved over T3. Target T4 is a surface-to-air missile (SAM) installation facility, T3 is an offensive counter air (OCA) installation facility and T5 is a ground order of battle (GOB) field. After the completion of the task over T5, all aircrafts leave the target country and land on airbase A1. This is because the distance between T5 and A1 is less then the distance between T5 and A2. They are 390 miles/630 km and 403 miles/649 km respectively. The shorter distance lessens the risk issues.

The three targets are located within different battle theater defense missile coverage. Targets T3, T4 and T5 are within three missiles M1, M2 and M3 coverage which have ranges of 187 miles/300 km, 373 miles/600 km and 466 miles/750 km respectively. The target country defense coverage has two main airfields, which are Airfield 1 and Airfield 2. T3 and T4 are within Airfield 2. Target T5 is within Airfield 1.

Scenario 2 requires continuous airborne surveillance, command, control and communications issues and jamming. Since all the operation takes place within a highly defended enemy field, C3 CMISR and escort fighter aircrafts needs are at the high level. Because of a continuing task over the scenario theater, a tanker aircraft is needed in order to provide air refueling for the aircrafts to increase their endurance.

4.2.2.1 Notional Operational Scenario 2a

In Scenario 2a, one tail number (OTN) is used as an alternative MMA architecture. The crew number is defined by taking the essential amount of the specialists needed for the required task and it is show in Appendix H.

The distance between A2 and T4 allows OTN to fly over the north of T4 and wait for the fighter and bomber aircraft package. The package takes off from airbase A2 and follows an attack route through target T4. The radar range of OTN is 155 miles/240 km because this is the radar range of RIVET JOINT and it has the lowest value within all C3CMISR aircraft sensor ranges. The radar range of OTN covers the attack route and it provides continuous airborne surveillance, command, control and communications issues, airborne tracking and warning, jamming and airborne reconnaissance for the operational units. Since T3 and T4 are fixed targets, the tasks over them require AWACS, RIVET JOINT, COMPASS CALL, and ABCCC.

After the attack package arrives over T4, OTN provides real-time on-scene C3CMISR data to the operational units. After the completion of the task over T4, the package proceeds towards T3. The distance between T4 and T3 is within OTN radar range so it still provides continuous data for required needs. After T3, the package heads to target T5. The distance between T3 and T5 is out of OTN radar range, so it follows the package throughout the attack route towards T5. Within the mission, in according to the necessity and to keep the aircrafts' endurance convenient to the tasks, air refueling is required. For this purpose, a tanker aircraft is assigned and it flies 100 miles west of the attack route and 100 miles north east of T3.

The tanker and OTN aircrafts require escort fighter aircrafts because of being within the enemy defense missile coverage. In Scenario 2a, the assigned number of escort aircrafts is decreased to 1 in 5 of the number assigned for the Scenario 2 which is achieved with five different tail numbers of C3CMISR aircrafts. This is a great improvement for the risk and cost assessment of the operation.Target T5 has moving ground targets and it requires ground surveillance. At T5, all C3CMISR capabilities are needed.

The basic map of Scenario 2a is shown in Figure 4-3.

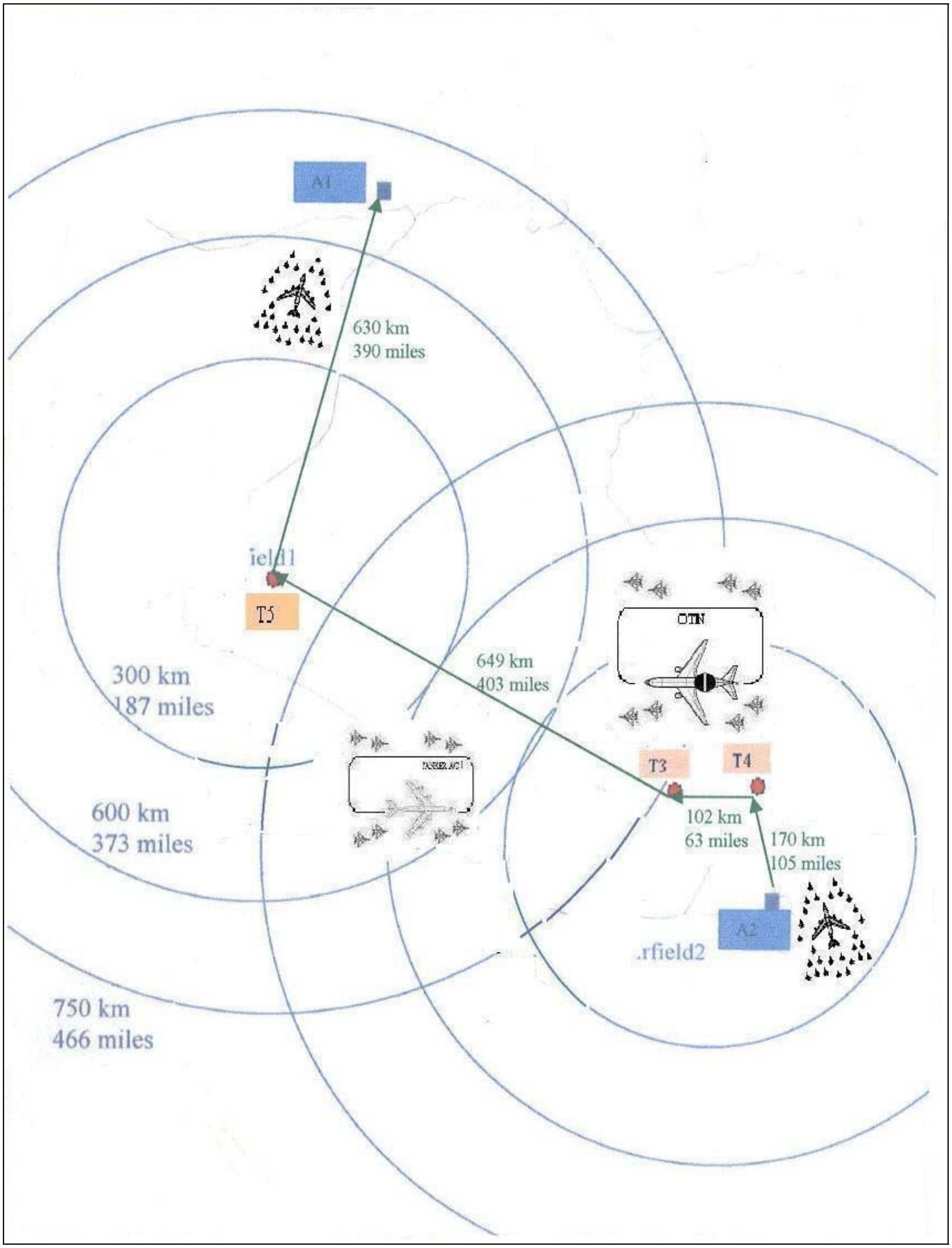


Figure 4 -3 Map of Notional Operational Scenario 2a

4.2.2.2 Notional Operational Scenario 2b

Different Tail Number (DTN) is used as an alternative MMA architecture in Scenario 2b. DTN includes four different MMA architectures formed by two airframes includes different C3CMISR aircraft capabilities. The C3CMISR capabilities and the crew numbers of the DTN architectures are shown in Appendixes I and H respectively.

The distances between A2 and T3, and T3 and T4 are allows the first and second airframes of DTN architectures to form an orbit and wait for the attack package to take off from A2 and flies through the targets. After the attack package arrives over the target T4, they provide airborne surveillance, target reconnaissance, command, control and C3CMISR capabilities on board to the operational units. After bombing over the target T4, all the attack units proceed towards target T3 and the C3CMISR aircrafts keep providing required tasks to the operational units.

The distance between T3 and T5 is 403 miles/649 km and between this route, a tanker aircrafts flies in order to provide air refueling to the required operational units for the endurance of the mission. While the attack package flies through the target T5, the first airframe of DTN architectures keeps providing airborne surveillance, attack and warning issues. After the package arrives over T5, the DTN architectures set flight orbits over T5, in order to achieve their tasks. Over T5, all five C3CMISR capabilities, especially the ground moving target surveillance, are required because it is a ground order of battle field.

All of the C3CMISR and tanker aircrafts need escort fighter aircrafts because of being within the target country defense missile system but the notional number is less.

The decrease in the number of escort fighter aircrafts required for DTN architectures is 2 in 5 and it is a benefit for risk and cost issues. After the mission is accomplish over T5, all the operational units leave the target country and proceed to airbase A1.

The basic map of Scenario 2b is shown in Figure 4-4.

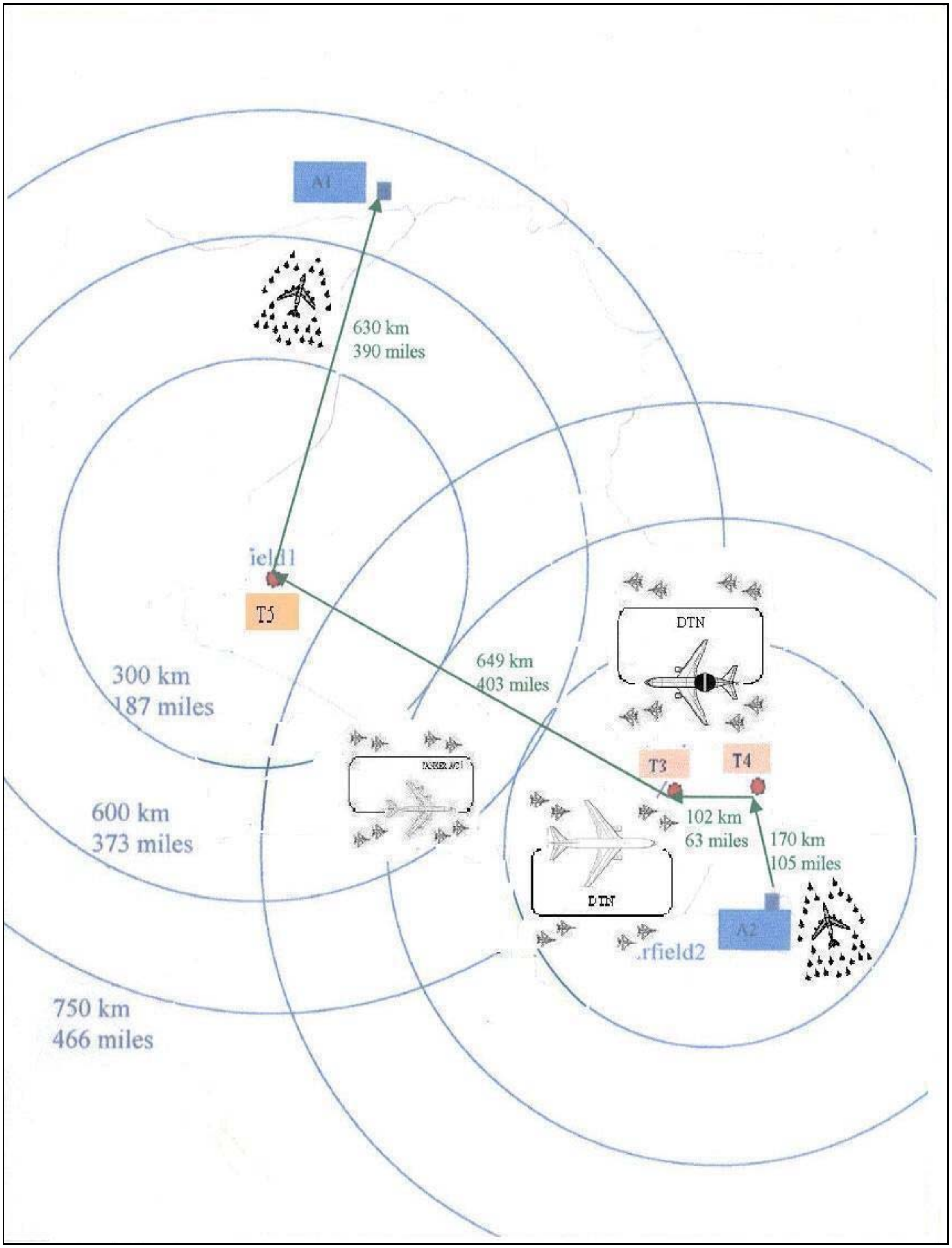


Figure 4 - 4 Map of Notional Operational Scenario 2b

4.2.3 Notional Operational Scenario 3

In Scenario 3, there are three different targets which are T1, T2 and T5. Target T1 is a command, control and communication facility (C3), target T2 is a military industrial base (MIB) facility and target T5 is a ground order of battle (GOB) field. In this scenario two fighter and bomber aircrafts packages are assigned, because the targets T2 and T5 are attacked at the same time. The Attack Package 1 and Attack Package 2 take off from airbase A1 and fly through targets T5 and T2 respectively. Besides these, target T1 is jammed in order to prevent command, control and communications activities of the enemy while the packages are hitting the targets. The distance between A1 and T2 is 440 miles/710 km, and the distance between A1 and T5 is 390 miles/630 km. Both targets require airborne surveillance, tracking and warning, command, control and communications, and jamming. The only differences between target C3CMISR capability requirements are the ground surveillance need over target T5 and target reconnaissance need over target T2. T5 is a ground order of battle field and requires ground moving target tracking and T2 is a fixed ground target. Over T5, Rivet JOINT capability is not required and over T2, JSTARS capability is not required. Target T1 requires only jamming capability of C3CMISR aircrafts. Because of the two different targets T2 and T5 and their distance from each other which is 251 miles/404 km, two tanker aircrafts are assigned for keeping the mission endurance in order to succeed.

Target T2 is within the battle theater defense missile M3 coverage which has a 373 miles/600 km diametric range. Target T5 is within missiles M1, M2 and M3 which have 187 miles/300 km, 373 miles/600 km and 466 miles/750 km diametric ranges respectively. T2 and T5 are within defense airfield 1. Target T1 is within the 466 miles/750 km diametric ranged missile M3 of defense airfield 2 and 373 miles/600 km and 466 miles/750 km diametric ranged missiles M2 and M3 of defense airfield 2. Besides these defense missiles, target country uses intercept fighter aircrafts in order to block the friendly attack aircrafts by engagement. All C3CMISR and tanker aircrafts require escort fighter aircrafts against enemy threat.

4.2.3.1 Notional Operational Scenario 3a

In Scenario 3a, one tail number (OTN) is used as an alternative MMA architecture.

The Attack Package 1 takes off from airbase A1 and proceeds towards the target T5. Its mission is hitting the ground order of battle field and destroying the ground moving targets and strategic points. The mostly required C3CMISR capabilities over T5 are AWACS and JSTARS. AWACS capability provides airborne surveillance, tracking and warning, and JSTARS capability provides ground surveillance. Besides jamming, command, control and communication issues are also required. Because of the distance, OTN1 follows the Attack Package 1 through its flight route. After the Package 1 arrives to T5, OTN1 form an orbit route over the east of T5 within its radar range. The Tanker Aircraft1 flies over the northwest of T5 for this task in order to provide in-flight refueling to the operational units to keep them operable throughout the mission.

To hit the target T2, the Attack Package 2 takes off from airbase A1 and proceeds to the target. Over T2, four C3CMISR capabilities of airborne surveillance, command, control and communications, target reconnaissance and jamming are required. Only ground moving target surveillance is not needed over T2. The distance between target T5 and target T2 is 251 miles/404 km. Because of this distance, one OTN cannot be able to cover both targets T5 and T2 at the same time. For T2, a second OTN that is OTN2 is required and it moves with the Attack Package 2 throughout the mission. After the Attack Package 2 arrives over T2, the OTN2 flies over east of T2 and provides the required C3CMISR data to the operational units of the mission. The Tanker Aircraft2 flies over the southeast of T2 in order to provide air refueling to the friendly aircrafts. The distance between T2 and T5 affects the required tanker number for the mission. For the accomplishment of the mission two tanker aircrafts are assigned.

While attack packages are hitting the targets T5 and T2, target T1 needs to be done ineffective. Target T1 is a command, control and communication facility. By jamming target T1, ground command, control and communications capabilities of the target country is done ineffective. This achievement helps the tasks over T5 and T2. Over T1, a COMPASS CALL capability is required. For this purpose, the OTN1 is assigned. While it flies for the target T5, it also provides jamming for the target T1, because the distance between T5 and T1 is 218 miles/351 km. The OTN1 flies at most 160 miles east of the target T5 and the remaining distance allows it to provide the required task for T1.

All of the C3CMISR and tanker aircrafts are within the enemy country defense system and they all require escort fighter aircrafts. Compared with the Scenario 3 which requires escorts for 9 aircrafts, in Scenario 3a fighter escorts are required for only 4 aircrafts. According to the decreased ratio in escorts, a great advantage is gained in the cost and risk issues in this Scenario.

From the operational side, this Scenario is achievable only if two one tail number MMA architectures and two tanker aircrafts are assigned for the operation.

The basic map of Scenario 3a is shown in Figure 4-5.

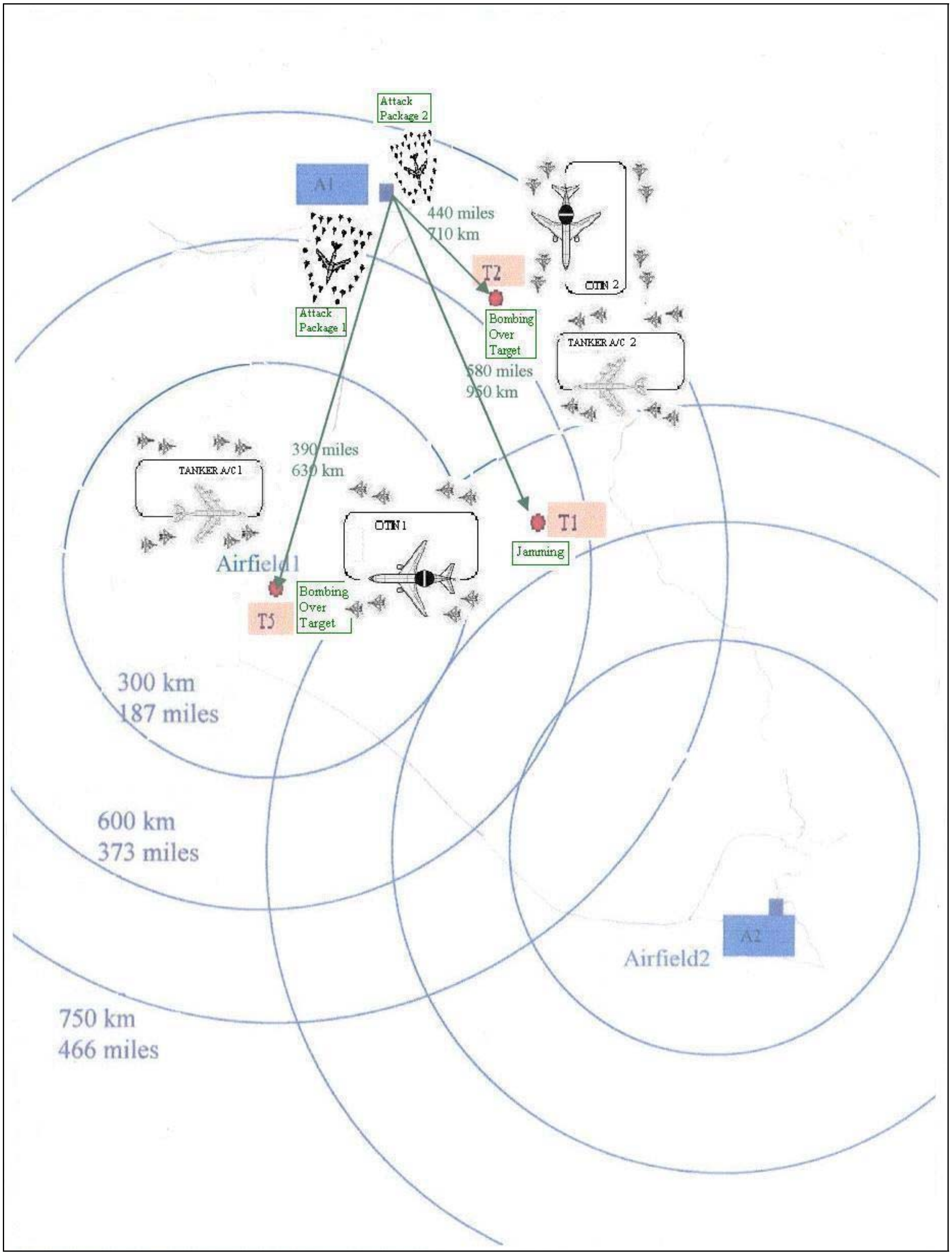


Figure 4 - 5 Map of Notional Operational Scenario 3a

4.2.3.2 Notional Operational Scenario 3b

In Scenario 3b, different tail numbers (DTN) 1, 2 and 3 are used as an alternative MMA architecture.

In Scenario 3b, the Attack Package 1 and Attack Package 2 take off from A1 and head towards T5 and T2 respectively. Because of the distances between A1 with T5 and T2, and the distance between T5 and T2, two DTN architectures apiece are required for the mission. Besides two tanker aircrafts are needed for the in-flight refueling over the targets. For the sake of clarity, the first and second airframes of DTN architectures proceeds with Attack Package 1 are defined as DTN1a and DTN1b, and DTN architectures with Package 2 are defined as DTN2a and DTN2b on the map of the Scenarios 3b.

While Attack Package 1 is hitting the target T5, DTN1a and DTN1b provide required C3CMISR capabilities. DTN1b flies over the east of T5 and DTN1a flies over the northwest of T5 within their radar ranges. The Tanker Aircraft 1 flies over the southwest of T5 for air refueling. DTN2a and DTN2b also provide required C3CMISR capabilities for the Attack Package 2 over the target T2. The radar range of DTN2a flies over the north of T2 and DTN2a flies over the east of T2. Besides, the Tanker Aircraft 2 flies over the northeast of T2. As a third mission in Scenario 3b, target T1 is jammed by DTN1b which flies over T5. The distance between T5 and T1 is acceptable by DTN1b's radar range. This jamming provides the operational units to achieve their tasks without the interception of command, control and communications issues of the enemy country.

All of the C3CMISR and tanker aircrafts are escorted by fighter aircrafts. The notional numbers of these escorts assigned in Scenario 3b are less then assigned in

Scenario 3. In Scenario 3, there are 9 aircrafts requires escorts and in Scenario 3b there are 6 aircrafts require escorts.

The basic map of Scenario 3b is shown in Figure 4-6.

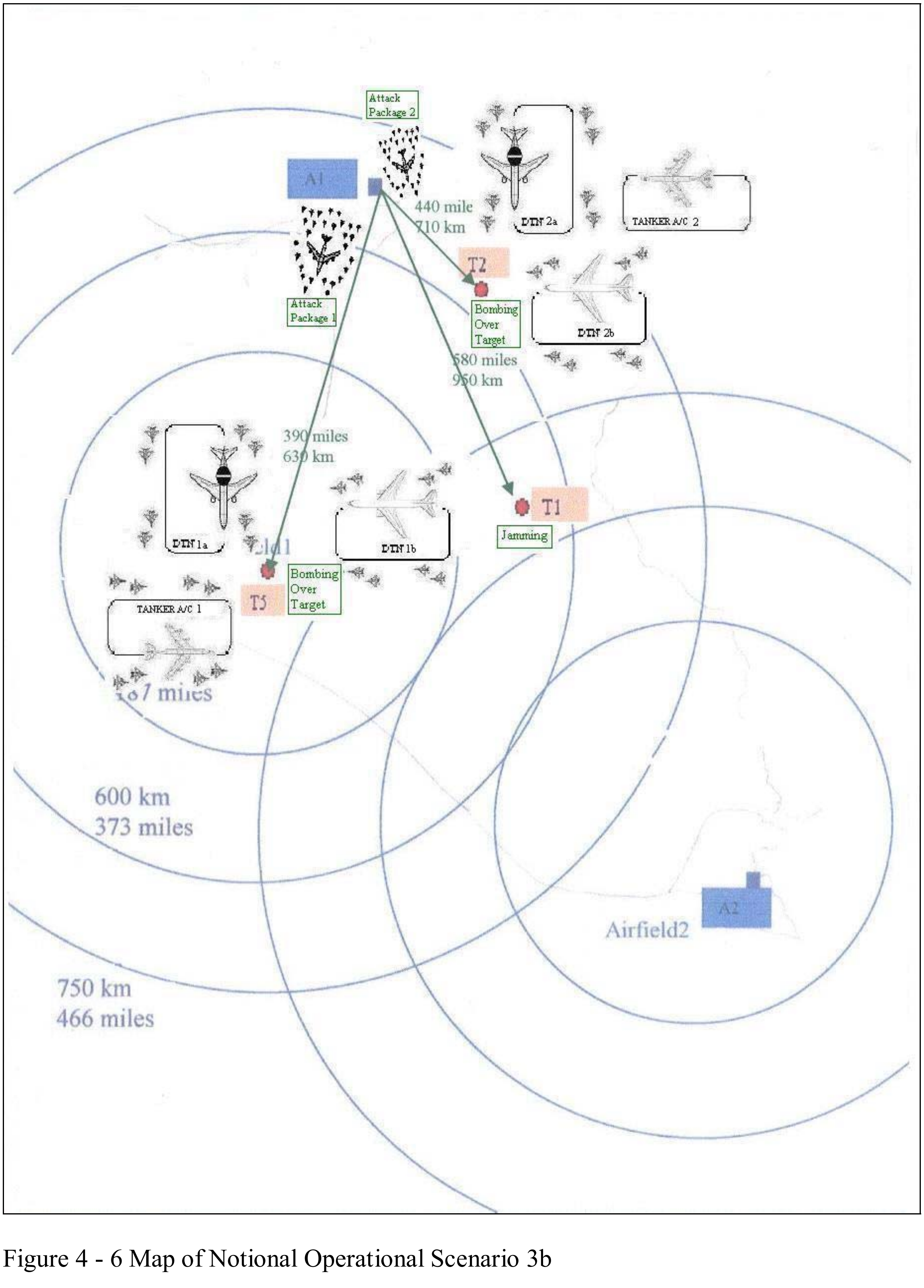


Figure 4 - 6 Map of Notional Operational Scenario 3b

4.2.3.3 Notional Operational Scenario 3c

In Scenario 3e, different tail numbers (DTN) 4 is used as an alternative MMA architecture.

Basically, the Scenario 3c tasks are similar to the ones assigned in Scenario 3b. The only difference in the arrangement of the scenario map is the change in the flight orbits of DTN1a and DTN1b. For target T1, COMPASS CALL capability is required in order to achieve jamming. In DTN4 architecture, DTN41 has this capability on board. In the map of Scenario 3c, DTN1a and DTN1b provide C3CMISR data over target T5. In this scenario, DTN1a flies over the east of T5 instead of DTN1b. Now, DTN1a provides jamming over target T2. The radar range of DTN1a is 250 miles/355.5 km and the range of DTN1b is 155 miles/240 km in Scenario 3c.

The basic map of Scenario 3c is shown in Figure 4-7.

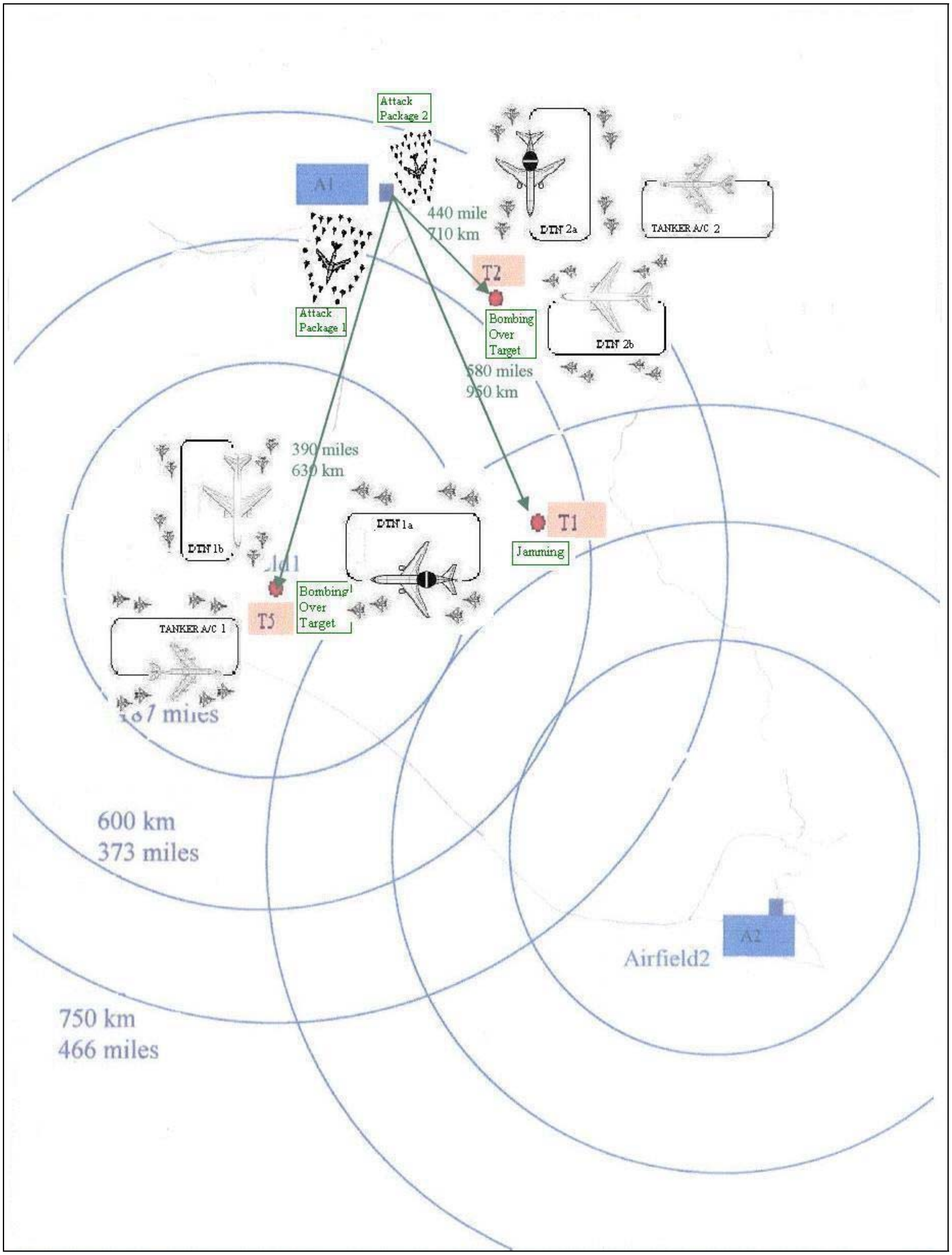


Figure 4 - 7 Map of Notional Operational Scenario 3c

4.2.4 Notional Operational Scenario 4

In Scenario 4, there are four different targets and three different fighter and bomber aircrafts packages take off from two different airbases. All the packages act and achieve their tasks at the same time. Attack packages 1 and 2 take off from airbase A2 and hit the targets T3, T4 and T1. Attack package 3 takes off from airbase A1 and hits the target T5. Target T1 is a command, control and communication (C3) facility, target T3 is an offensive counter air installation (OCA) facility, target T4 is a surface-to-missile (SAM) installation, and Target T5 is a ground order of battle (GOB) field. While the attack packages hit the targets, one jamming aircraft makes the target T1 ineffective. This prevents the command, control and communications activities of the target country.

The distance between A1 and T5 is 580 miles/950 km, the distances between A2 and T3, T1 and T4 are 130 miles/210 km, 370 miles/590 km and 105 miles/170 km respectively. All of the targets T5, T3 and T4 require airborne tracking, warning and surveillance, command, control and communications, target reconnaissance and jamming. Additional to these C3CMISR capabilities, ground surveillance is required over target T5 and jamming is required over target T1. Two tanker aircrafts are assigned for the mission, because there are mainly two different target areas and they are covered within a wide area.

Targets T3, T4 and T5 are within three missiles M1, M2 and M3 coverage which have ranges of 187 miles/300 km, 373 miles/600 km and 466 miles/750 km respectively. The target country defense coverage has two main airfields, which are Airfield 1 and Airfield 2. T3 and T4 are within Airfield 2. Target T5 is within Airfield 1. Target T1 is within the 466 miles/750 km diametric ranged missile M3 of defense airfield 2 and 373 miles/600 km and 466 miles/750 km diametric ranged missiles M2 and M3 of defense airfield 2. Besides these defense missiles, target country also sends its interceptor aircrafts against the friendly aircrafts and operational units. Because of this highly enemy defensive risk, all of the friendly C3CMISR and tanker aircrafts require escort fighter aircrafts throughout the mission.

4.2.4.1 Fictitious Operational Scenario 4a

In Scenario 4a, one tail number (OTN) is used as an alternative MMA architecture.

Attack Package 1 takes off from airbase A2 and proceeds towards target T4. The distance between A2 and T4 is 105 miles/170 km. The radar range of OTN is 155 miles/240 km and it covers the distance between A2 and T4. It flies over the north of T4 and provides airborne surveillance, target reconnaissance, command, control and communications and jamming to the operational units over the area. The Attack Package 2 takes off from airbase A2 also and proceeds towards target T3. The OTN architecture is capable enough to cover all the area over targets T3 and T4. The OTN architecture which is assigned for the targets T3 and T4 is defined as OTN1. While the Attack Package 1 and Attack Package 2 are hitting the targets T3 and T4, OTN1 is providing real-time on-scene data for the required operational units. For the mission endurance, a tanker aircraft is assigned over the southwest of target T3. This tanker aircraft is defined as Tanker Aircraft 1.

The attack Package 3 takes off from airbase A1 and proceeds towards target T5. The distance between A1 and T5 is 580 miles/950 km which can not be covered by a OTN architecture. The distance between targets T5 and T3 is 403 miles/649 km and the distance between T5 and T4 is 461 miles/742 km. The radar range of OTN1 can not cover these distances. So, another OTN architecture is assigned for the C3CMISR requirements of target T5. The second OTN architecture is defined as OTN2. OTN2 provides airborne surveillance to the Attack Package 3 on their attack route and it follows the package through out the route. After the package arrives over T5, it forms an orbit over the east of T5 and provides airborne surveillance, ground surveillance, command, control and communications and jamming for the operational units. And also for the endurance of aircrafts over the target T5, there is another tanker aircraft is assigned. This is defined as Tanker Aircraft 2.

As a fourth target, T1 is jammed in order to block the command, control and communications activities of the target country while all the operational units achieving their tasks over the defined targets in Scenario 4a. The distance between T5 and T1 is 218 miles/351 km, the distance between T4 and T1 is 283 miles/455 km, and the distance between T3 and T1 is 239 miles/384 km. By taking the shortest distance which is the one between T5 and T1, the OTN2 is also assigned for the jamming task over T1.

In Scenario 4a, the mission covers a wide area. As a main command, control and communication unit a third OTN platform is assigned over the area. It flies between two main mission regions which is between targets T5 and T3. The accomplishment of the Scenario 4a at the operational level can be done by three OTN platforms only. The C3CMISR platforms and tanker aircrafts require escort fighter aircrafts in order to provide their defense against the target country defense system. In different tail numbered Scenario 4, the notional numbers of the escort fighter aircrafts required for the 9 different

C3CMISR and 2 tanker aircrafts are decreased to a requirement of only for 5 aircrafts in Scenario 4a. This ensures a great benefit for cost and risk assessment in an operation.

The basic map of Scenario 4a is shown in Figure 4-8.

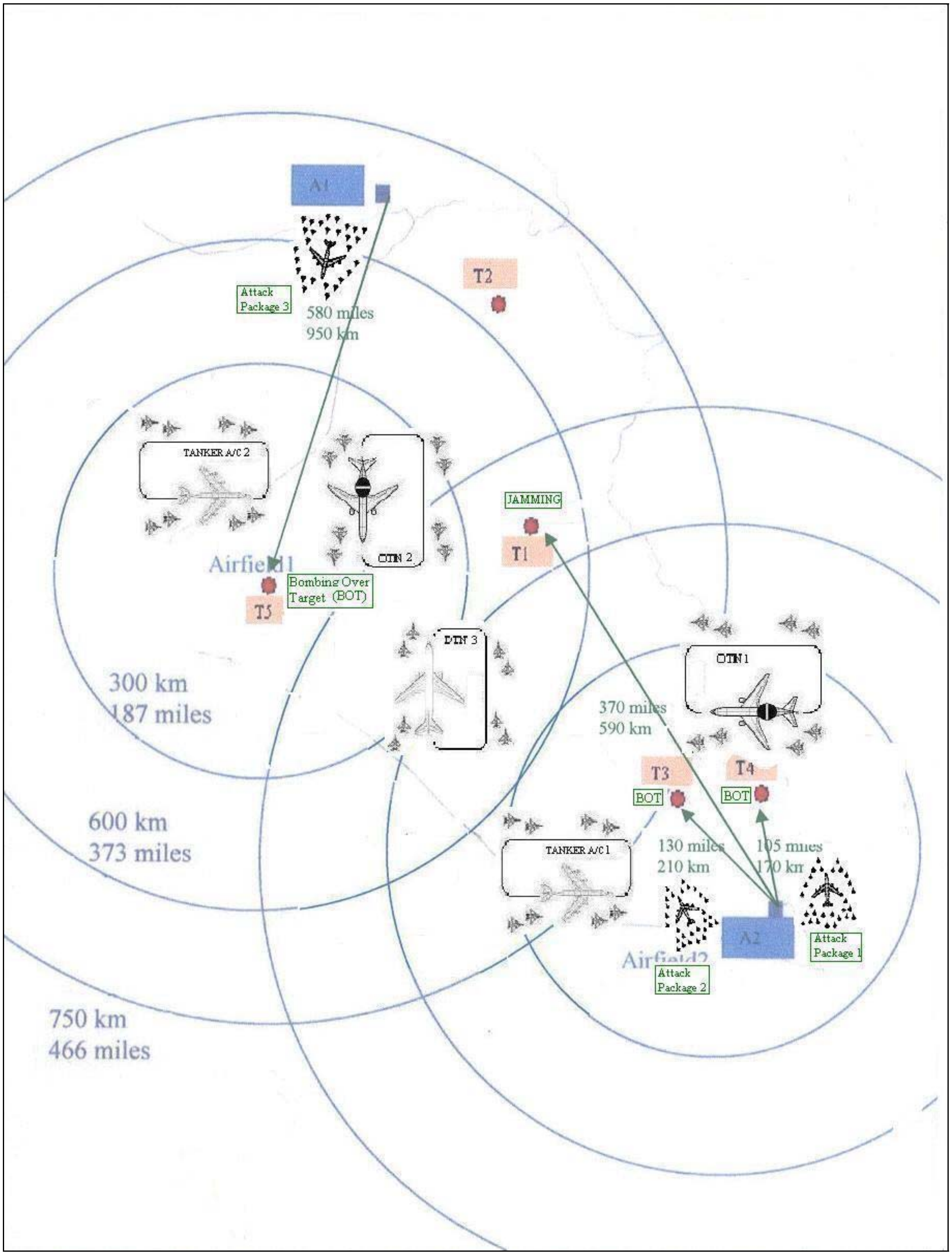


Figure 4 - 8 Map of Notional Operational Scenario 4a

4.2.4.2 Notional Operational Scenario 4b

Different tail numbers 1 (DTN1) is used as an alternative MMA architecture in Scenario 4b.

In Scenario 4b, Attack Package 1 and Attack Package 2 take off from airbase A2 and hit the targets T4 and T3 respectively. One DTN1 architecture provides continuous airborne surveillance, target reconnaissance, command, control and communications, and jamming over the targets. Because of the complexity of the mission and need for clarifying the tasks, the DTN11 and DTN12 are defined as DTN1a and DTN1b over the targets T3 and T4. DTN1a flies over the north of target T4, and DTN1b flies over the southeast of target T3. The radar ranges of DTN1a and DTN 1b are 160 miles/250 km and 155 miles/240 km respectively. Both ranges cover the distances between T3 and A2, and T4 and A2. Same as in Scenario 4a, the Tanker Aircraft 1 is assigned for the endurance of the mission and it flies over the west of T3 for air refueling.

The Attack Package 3 takes off from airbase A1 and hits the target T5. Because of the distances between the targets another DTN1 architecture is assigned for this region of the target country. For clarification, DTN11 and DTN12 aircrafts are defined as DTN2a and DTN2b over target T5. DTN 2a follows the Attack Package 3 throughout its attack route until it gets over the target T5. DTN2b flies over the east of T5 and after the package arrives over T5, DTN2a forms flight route over the northwest of T5. For jamming task over T1, DTN2b is assigned. For the operation over T1, the Tanker Aircraft 2 is assigned for in-flight refueling.

For the whole operation over the battle theater, a main command, control and communications platform is assigned. For this purpose, a DTN12 aircraft is assigned and it is defined as DTN3 for the clarification issues of the task. All of the C3CMISR and tanker aircrafts require escort fighter aircrafts over the target country defense system. The notional numbers of escort aircrafts decreased to a lesser number in Scenario 4b and this ensures a fine amount of decrease in cost and risk issues.

At the operational level, this mission can be achieved by 2 DTN11 and 3 DTN12 aircrafts. And also 2 tanker aircrafts are needed in order to ensure the required endurance of the mission completion.

The basic map of Scenario 4b is shown in Figure 4-9.

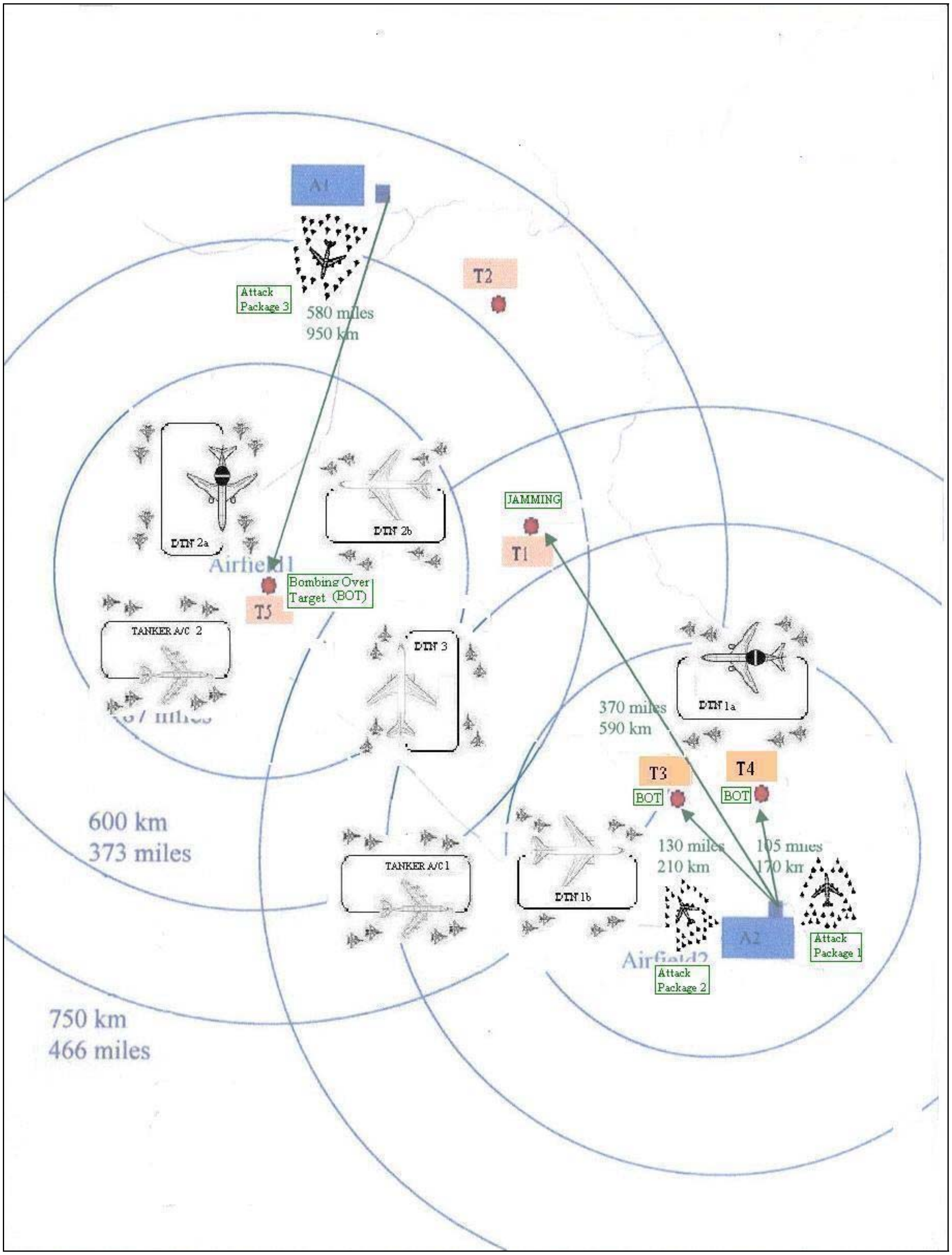


Figure 4 - 9 Map of Notional Operational Scenarios 4b, 4d

4.2.4.3 Notional Operational Scenario 4c

In Scenario 4c, the different tail numbers 2 (DTN2) is used as an alternative MMA architecture.

The C3CMISR tasks over the targets T3 and T4 are achieved by the aircrafts DTN21 and DTN22. The radar ranges of DTN21 and DTN22 are 250 miles/355.5 km and 155 miles/240 km respectively. For clarification, DTN21 and DTN22 over the targets T3 and T4 are defined as DTN1a and DTN1b. DTN1a flies over the north of T4 and DTN1b flies over the southwest of T3. The Tanker Aircraft flies over the southeast of T3 and provides air refueling for the friendly aircrafts.

Over target T5, a second DTN2 architecture is assigned for C3CMISR tasks. These DTN21 and DDTN22 aircrafts are defined as DTN2a and DTN2b for clarification. DTN2a flies over the northwest of T5 and DTN2b flies over the east of T5. For the jamming task over target T1, DTN2b is assigned. The Tanker Aircraft 2 is assigned for air refueling and it flies over the southwest of T5.

For the whole mission area, a third DTN21 aircraft is assigned in order to achieve command, control and communications activities. This C3 aircraft is defined as DTN3. The notional escort fighter aircraft requirement for the C3CMISR and tanker aircrafts is the same as in Scenario 4b. In Scenario 4c, the planned mission can be achieved by 3 DTN21 and 2 DTN22 aircrafts.

The basic map of Scenario 4c is shown in Figure 4-10.

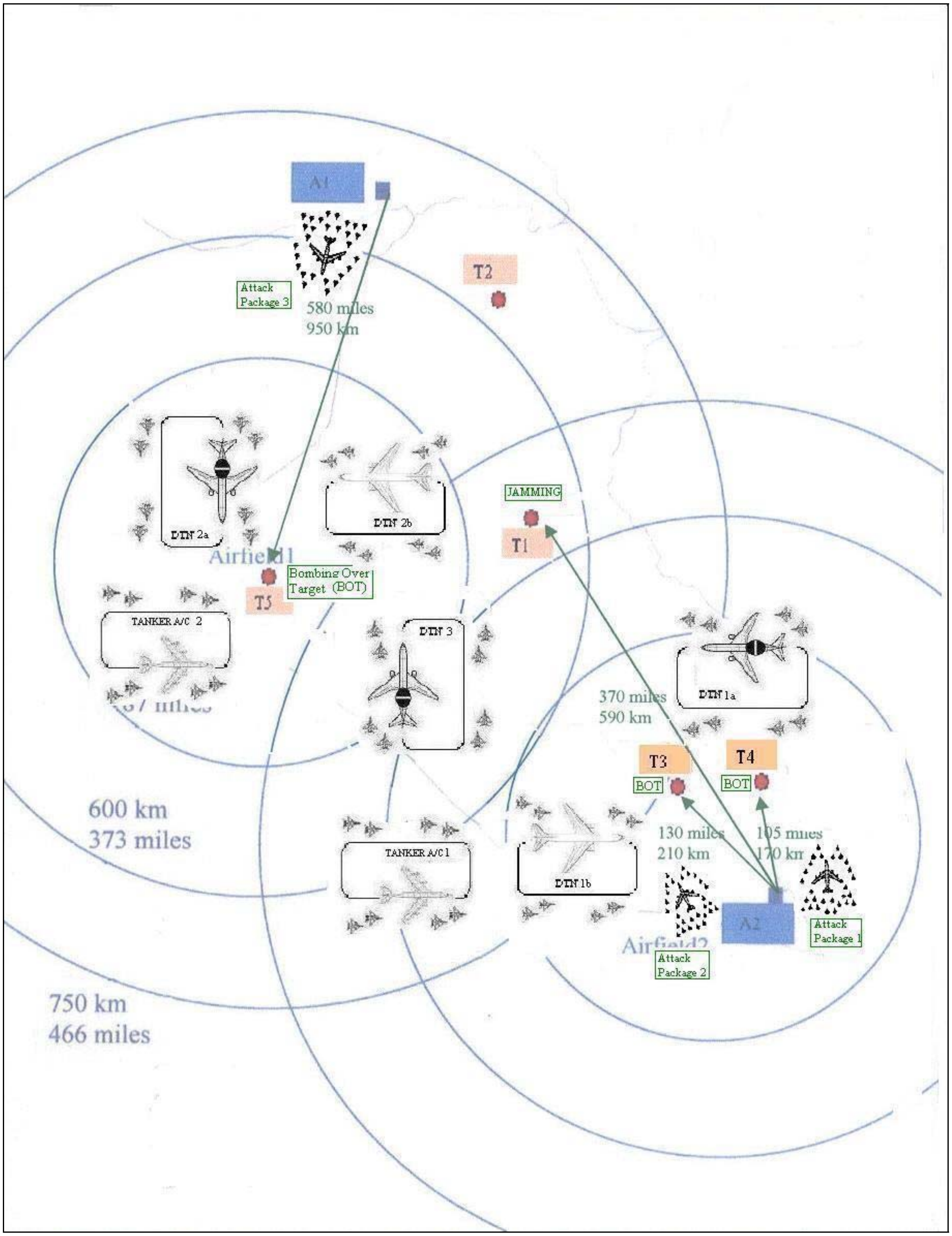


Figure 4 - 10 Map of Notional Operational Scenario 4c

4.2.4.4 Notional Operational Scenario 4d

In Scenario 4d, different tail numbers 3 (DTN3) is used as an alternative MMA architecture.

The tasks over targets are the same as above scenarios. Over targets T3 and T4, a DTN3 architecture is assigned which is formed by DTN31 and DTN32 aircrafts. DTN31 and DTN32 over targets T3 and T4 are defined as DTN1a and DTN1b for clarification. Over targets T5 and T1, a second DTN3 architecture is assigned. These DTN31 and DTN32 aircrafts over T5 and T1 are defined as DTN2a and DTN2b for clarification. For jamming over T1, DTN2b is assigned.

For the whole mission, a C3 aircraft which is another DTN32 is assigned. DTN32 is defined as DTN3. The escort fighter aircrafts numbers are the same as in Scenario 4b. At the operational level, the mission can be completed with 2 DTN31 and 3 DTN32 aircrafts. Also 2 tanker aircrafts are required for the endurance of the mission.

The basic map of Scenario 4d is shown in Figure 4-9.

4.2.4.5 Notional Operational Scenario 4e

In Scenario 4e, different tail numbers 4 (DTN4) is assigned as an alternative MMA architecture.

The attack packages 1 and 2 take off from airbase A2 and hit the targets T4 and T3 respectively. For the tasks over T3 and T4, a DTN4 architecture is assigned which is formed by DTN41 and DTN42 aircrafts. The radar ranges of DTN41 and DTN42 are 250 miles/355.5 km and 155 miles/240 km respectively. DTN41 and DTN42 aircrafts over T3 and T4 are defined as DTN1a and DTN1b for clarification. They provide required C3CMISR capabilities over T3 and T4 to the operational units.

The Attack Package 3 takes off from airbase A1 and hits the target T5. A second DTN4 architecture is assigned for that task. DTN41 and DTN42 over T5 are defined as DTN2a and DTN2b for clarification. DTN2a flies over the east of T5 and DTN2b flies over the northwest of T5. DTN2a also provides jamming over the target T1.

For the whole mission, a C3 aircraft which is another DTN42 is assigned. DTN42 is defined as DTN3. The escort fighter aircrafts numbers are the same as in Scenario 4d. At the operational level, the mission can be completed with 2 DTN41 and 3 DTN42 aircrafts. Also 2 tanker aircrafts are required for the endurance of the mission.

The basic map of Scenario 4e is shown in Figure 4-11.

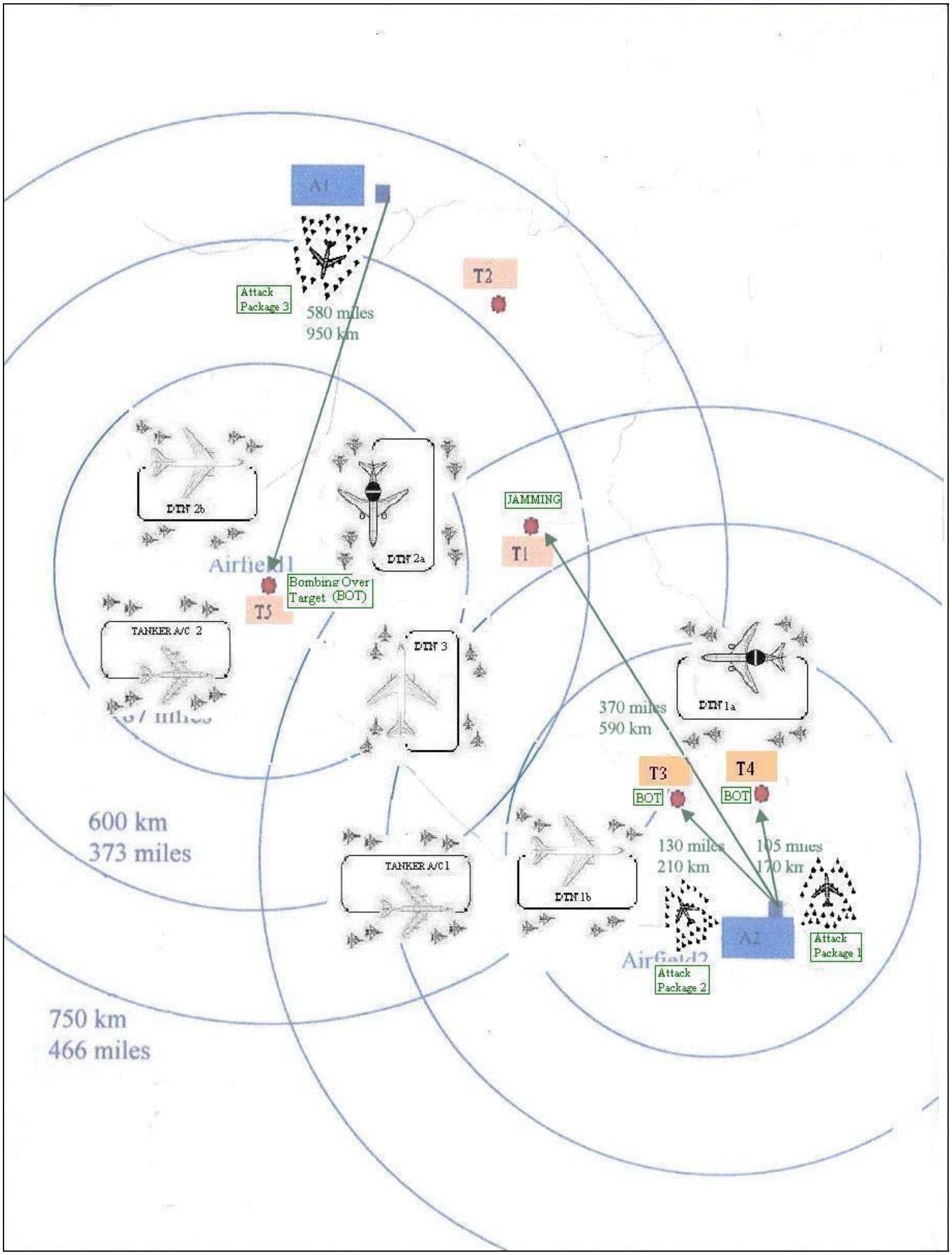


Figure 4 - 11 Map of Notional Operational Scenario 4e

Chapter 5 – Discussion and Conclusions

5.1 Chapter Overview

This chapter basically defines the MMA design feasibility at three levels of investigation which are operational, payload and electromagnetic interference. When the alternative C3CMISR architectures are not feasible for the notional operational scenarios, the achievement of the mission by UAV is defined.

5.2 Overall Evaluation of Alternative MMA Architectures

The notional operational scenarios are created in order to show the feasibility of alternative MMA architectures in operational environments. The attained results from these scenarios are shown in Table 5-1. When the alternative MMA architectures are studied at the operational level, it can be seen that the feasibility and convenience of them depend upon the operational scenario. In this study, there are basically four operational scenarios. Each scenario requires different tasks and C3CMISR capabilities. In each scenario the location of the targets are different and the mission routes are changing. The target definitions are the main factor in determining the C3CMISR capabilities that are required for the mission. At the main level, the distances between the targets and the tasks are designating the required numbers of the MMA architectures. The radar ranges and capabilities of the C3CMISR aircrafts are affecting the whole operation. As it is shown in Table 5-1, some scenarios are more worthwhile by using MMA architectures then the legacy system. In Scenario 1, three aircrafts are required for the mission, but when OTN is used, the number of aircrafts is decreased in 1 to 3. Besides the C3CMISR aircrafts, the number of the escort fighter aircrafts that provides the defense of these aircrafts is decreased. In Scenario 1, like OTN architecture, DTN architecture is also valuable. Instead of assigning 3 C3CMISR aircrafts, by DTN11 and DTN12, only 2 aircrafts are assigned to the mission. In Scenario 2, the benefit of OTN and DTN architectures is clearer. Instead of assigning 5 different aircrafts, by OTN only 1 aircraft and by DTN only 2 aircrafts can achieve the mission. In Scenarios 3 and 4 the required number of legacy aircrafts is comparably too much to the MMA architectures, but the required MMA architectures are more than 1 and this situation is keeping the aim of achieving the mission by 1 architecture out of the scope. At the design feasibility level this is not the desired result. On the other hand, the decreased required number of MMA aircrafts compared to the required number of legacy aircrafts in the operational theater, brings the advantages of decreasing the notional number of defensive units.

In this study besides operational feasibility, the payload design and electro magnetic interference are also considered as affective factors in the whole MMA design. When the alternative MMA architectures are considered as a new design, they studied at the payload and electro magnetic compatibility level and these studies lead to basic results. The possibility of the alternative MMA architectures at the payload design and electromagnetic compatibility levels are presented in Table 5-2. The payload data is provided from the master thesis of 1Lt Ahmet Kahraman (TUAF) namely Multimission Aircraft Design Study- Payload, and the electro magnetic compatibility data is provided from the master thesis of Capt. Jenna Davis (USAF) namely Multimission Aircraft Design Study- Electromagnetic Compatibility.

Even though the notional scenarios are achievable at the operational level, at the payload design and electromagnetic compatibility levels the accomplishment of the most alternative MMA architecture design is not feasible. As it is presented in Table 5-2, the one tail number (OTN) architecture is not feasible at both levels. From the payload design side, the power limitation is exceeded and from the electromagnetic interference side, the sensors on board are not compatible with each other. The other alternative different tail numbers (DTN) architectures are all compatible at the electromagnetic level but at the payload design level except DTN21 architecture, the all other DTN alternatives are not feasible. All of them have power restrictions. At this point we can say that, only DTN21 is feasible for MMA design, but this is not a solution that we are looking for. The feasibility of DTN21 doesn't cover all the C3CMISR capabilities on board so it can give a solution for only the part of the problem. If the DTN21 is accepted then for an exact completion of the operational needs, JSTARS, Rivet JOINT and COMPASS CALL must be assigned individually as legacy systems to the required operational theaters. If this is decided as an option to be designed, for another option of the legacy system would be unmanned air vehicles (UAVs) in order to provide risk, cost and manpower issues.

	Legacy System			**MMA Alternatives**	
Scenario	**Aircrafts Required**	**Required Number**	**Scenario**	**Alternatives Required**	**Required Number**
1	AWACS	1	1a	OTN	1
	COMPASS CALL	1	1b	DTN11	1
	Rivet JOINT	1		DTN12	1
2	AWACS	1	1b	DTN21	1
	COMPASS CALL	1		DTN22	1
	Rivet JOINT	1	1b	DTN31	1
	Joint STARS	1		DTN32	1
	ABCCC	1	1b	DTN41	1
3	AWACS	2		DTN42	1

	COMPASS CALL	2	2a	OTN	1
3	Rivet JOINT	1	2b	DTN11	1
	Joint STARS	1		DTN12	1
	ABCCC	1	2b	DTN21	1
	AWACS	2		DTN22	1
	COMPASS CALL	2	2b	DTN31	1
4	Rivet JOINT	2		DTN32	1
	Joint STARS	2	2b	DTN41	1
	ABCCC	1		DTN42	1
			3a	OTN	2
			3b	DTN11	2
				DTN12	2
			3b	DTN21	2
				DTN22	2
			3b	DTN31	2
				DTN32	2
			3c	DTN41	2
				DTN42	2
			4a	OTN	3
			4b	DTN11	2
				DTN12	3
			4c	DTN21	3
				DTN22	2
			4d	DTN31	2
				DTN32	3
			4e	DTN41	2
				DTN42	3

Table 5 – 1 Attained Results from Notional Scenarios

				PAYLOAD			**EMAG**
Architecture Type	**Architecture Alternative**	**Alternative Title**	**A/C on Board**	***Crew # Possibility***	***Power Possibility***	***Weight Possibility***	***Sensor Compatibility***
One Tail	OTN	OTN	AWACS JSTARS	YES	NO	YES	Yes Yes

Number	OTN	OTN	Rivet JOINT	Yes	No	Yes	No
			C.CALL				Yes
			ABCCC				Yes
		Overall		**Yes**	**No**	**Yes**	**No**
Different Tail Numbers	DTN1	DTN11	AWACS	Yes	No	Yes	Yes
			JSTARS				Yes
		DTN12	Rivet JOINT	Yes	No	Yes	Yes
			C.CALL				Yes
			ABCCC				Yes
		Overall		**Yes**	**No**	**Yes**	**Yes**
	DTN2	DTN21	AWACS	Yes	Yes	Yes	Assume Yes
			ABCCC				Assume Yes
		DTN22	JSTARS	Yes	No	Yes	Yes
			Rivet JOINT				Yes
			C.CALL				Yes
		Overall		**Yes**	**No**	**Yes**	**Yes**
	DTN3	DTN31	AWACS	Yes	No	Yes	No
			Rivet JOINT				Yes
		DTN32	JSTARS	Yes	No	Yes	Assume Yes
			C.CALL				Yes
			ABCCC				Assume Yes
		Overall		**Yes**	**No**	**Yes**	**Yes**
	DTN4	DTN41	AWACS	Yes	No	Yes	Yes
			C.CALL				Yes
		DTN42	JSTARS	Yes	No	Yes	Yes
			Rivet JOINT				Assume Yes
			ABCCC				Assume Yes
		Overall		**Yes**	**No**	**Yes**	**Yes**

Table 5 – 2 Payload Design and Electromagnetic Compatibility of MMA Alternatives

5.3 Unmanned Aerial Vehicles (UAVs) in Operational Scenarios

As a well-known and recently most used platform in operations, Unmanned Aerial Vehicles (UAVs) are remotely piloted or self-piloted aircrafts that can carry cameras, sensors, communications equipments or other required payloads for the mission. They have been used in operational environments for reconnaissance and intelligence gathering role since 1950s. Besides its incredible value in operation theaters, it has a disadvantage of having high cost and technology requirements. Since 1964 11 different UAVs have been developed by the Defense Department, but only 3 of them have entered production because of acquisition and development problems. Presently a number of UAVs are used both domestically and internationally. Their payload weight carrying capability and their accommodations (volume, environment), their mission profile (altitude, range, duration) and their command, control and data acquisition capabilities vary significantly.

At the beginning of the last twenty years, the Department of Defense required satisfaction of surveillance requirements in Close Range, Short Range or endurance categories from UAVs. Close range and Short Range were defined to be within 50 km, and 200 km respectively. The endurance was defined as anything beyond these ranges. Then the Close and Short ranges are combined together and now the categories are defined as Tactical UAV and the Endurance category. The titles of UAVs' and their capabilities are shown in Table 5-3.

5.3.1 Tactical UAV

The Tactical UAV is designed to support tactical commanders with near-real-time imagery intelligence at ranges up to 200 km. The material solution for TUAV requirements is being pursued through a completive acquisition process.

5.3.2 Joint Tactical UAV (Hunter)

The Joint Tactical UAV is developed to provide ground and maritime forces with near-real-time imagery intelligence at ranges up to 200 km; extensible to 300+ km by using another Hunter UAV as an airborne relay.

5.3.3 Medium Altitude Endurance UAV (Predator)

The Medium Altitude Endurance UAV provides imagery intelligence to satisfy Joint Task Force and Theater Commanders at ranges out to 500 nautical miles. It is transferred from US Army inventory to US Air Force in 1996.

5.3.4 High Altitude Endurance UAV (Global Hawk)

The High Altitude Endurance UAV is intended for missions requiring lon-range deployment and wide-area surveillance (EO/and SAR) or long sensor dwell over the target area. It is directly deployable from Continental United States (CONUS) to the theater of operations. The US Air Force manages the Advanced Concept Technology Demonstration (ACTD).

5.3.5 Tactical Control Station (TCS)

The Tactical Control Station is the software and communications links required to control the TUAV, MAE-UAV, and other tactical UAVs. The other C4I systems are also provided.

5.3.6 Micro Unmanned Aerial Vehicles (MAVs)

This is a very small aircrafts which is less than 15 cm/6 inch in any dimensions. This is still in development for future military operations. The development and flight enabling studies continue.

Unmanned Aerial Vehicle Name	**Endurance (Hours)**	**Payload Weight (Pounds)**	**Altitude Capability (Feet)**
AQM-34N Firebee	Classified.	Classified	Classified.
Aquila	Classified.	Classified.	Classified.
COMPASS ARROW	Classified.	Classified.	Classified.
COMPASS BIN	Classified.	Classified.	Classified.
COMPASS COPE	Classified.	Classified.	Classified.
COMPASS DAWN	Classified.	Classified.	Classified.
Condor	Classified.	Classified.	Classified.
CR-TUAV	Classified.	Classified.	Classified.
CR-UAV	Classified.	Classified.	Classified.
Darkstar	8 hrs.	1,000 lbs.	45,000 ft.
Dragon	Classified.	Classified.	Classified.
Eagle Eye	8 hrs.	300 lbs.	20,000 ft.
Exdrone	2.5 hr.	25 lbs	10,000 ft.
Firebee	1.25 hrs.	470 lbs.	60,000 ft.
Global Hawk	42 hrs.	1,960 lbs.	65,000 ft.
Gnat 750	48 hrs.	140 lbs.	25,000 ft.
Hunter	12 hrs.	200 lbs.	15,000 ft.
Model 324	2.5 hrs.	200 lbs.	43,000 ft.
Model 410	12 hrs.	300 lbs.	30,000 ft.
MR-UAV	Classified.	Classified.	Classified.
MRE	Classified.	Classified.	Classified.
Outrider	4 hrs.	160 lbs.	15,000 ft.

Pioneer	5.5 hrs.	75 lbs.	12,000 ft.
Pointer	1 hr.	2 lbs.	3,000 ft.
Predator	29 hrs.	700 lbs.	+40,000 ft.
SEA FERRET	Classified.	Classified.	Classified.
SENIOR BOWL [D-21]	Classified.	Classified.	Classified.
VT-UAV	Classified.	Classified.	Classified.
VT-UAV Dragonfly	Classified.	Classified.	Classified.
VT-UAV Vigilante	Classified.	Classified.	Classified.
VT-UAV Guardian	Classified.	Classified.	Classified.

Table 5 – 3 Titles and Capabilities of UAVs (41) (42)

5.4 Conclusion

As a whole study, multimission aircraft design study-operational scenarios, presents some very high level results based on assumed and notional operational data. In order to reach exact results and conclusions for this MMA feasibility study, the person who is studying the subject must be an expert in this field and also this person has to be able to access to all kind of classified data.

This study is also based on few alternative MMA architectures. By studying the other alternative MMA architecture options, more realistic results can be evaluated. This would require a lot of time and investigations. Besides the future technology developments should be evaluated and presented within the study.

DEPARTMENT OF THE AIR FORCE
DIRECTOR FOR INTELLIGENCE, SURVEILLANCE AND RECONNAISSANCE
DCS/AIR AND SPACE OPERATIONS

MEMORANDUM FOR AFIT/CC

FROM: HQ USAF/XOI
1480 Air Force Pentagon
Washington DC 20330-1480

SUBJECT: Thesis Topic Proposal

Thank you for the opportunity to submit thesis topic proposals for AFIT graduate students. We submit the following for consideration: multi-mission aircraft (MMA) technical feasibility study. The MMA concept has been proposed as a replacement for the aging fleet of C-135 and C-130 theater-based command & control (C2) and intelligence, surveillance and reconnaissance (ISR) fleet. It is proposed that the MMA be out-fitted to combine some or all the functions of existing AWACS, JSTARS, RIVET JOINT, COMPASS CALL, and ABCCC platforms. It would also have links to other manned or unmanned ISR aircraft, as well as satellites.

The objective of the proposed feasibility study is to examine the technical risks involved in combining multiple functions onto one aircraft that currently reside on separate aircraft. These risks might include electromagnetic interference between transmitters; interference between active and passive sensors; and space, weight and power limitations. The student should define these risks in detail and make recommendations as to which functions could be combined with minimal technical risk. The project would require use of AFIT's computers, plus some travel costs to gather and brief data/results.

My POCs for this subject are Mr Mike Burgan, DSN 225-8065 and Lt Col Charlie Bartlett, DSN 227-0412.

GLEN D. SHAFFER, Maj Gen, USAF
Director of Intelligence, Surveillance
and Reconnaissance
DCS, Air and Space Operations

1. THESIS TOPIC: Multi-Mission Aircraft Technical Feasibility Study

2. INDIVIDUAL SPONSORS: Mr. Mike Burgan & Lt Col Charlie Bartlett
HQ USAF/XOIR
1480 Air Force Pentagon
Washington, DC 20330-1480
Phone: DSN 225-8065

3. AFIT FACULTY CONTACTED: Lt Col Ernest Price Smith, AFIT/ENY

4. BACKGROUND: A multi-mission aircraft (MMA) concept has been proposed to take the place of the aging fleet of C-135 and C-130 based theater C2 & ISR aircraft. A new, modern wide-body commercial aircraft would be chosen by the Air Force to replace the C-135 fleet. Then this aircraft would be fitted to combine some or all of the functions of existing AWACS, JSTARS, RIVET JOINT, COMPASS CALL and ABCCC aircraft. The MMA would also have links to other manned or unmanned ISR aircraft and satellites.

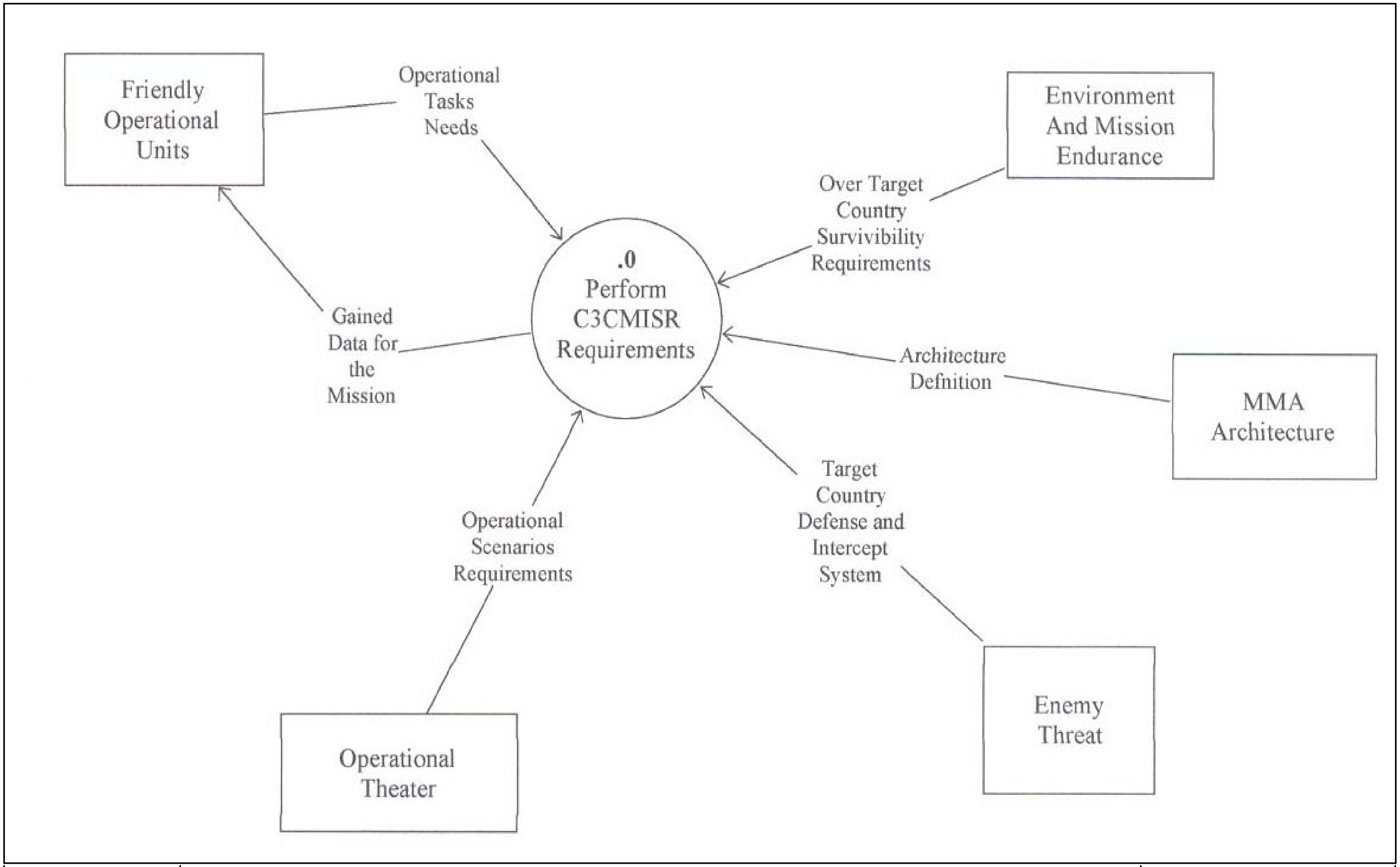
5. OBJECTIVE: Study the technical risks involved in combining onto one aircraft multiple functions that now reside on separate aircraft. These risks might include electromagnetic interference between transmitters; interference between active and passive sensors; and space, weight, and especially power limitations. Define these risks in detail and make recommendations as to which functions could be combined with minimal technical risk.

6. RESOURCE REQUIREMENTS: AFIT computer resources, possibly some travel costs to gather information and brief results.

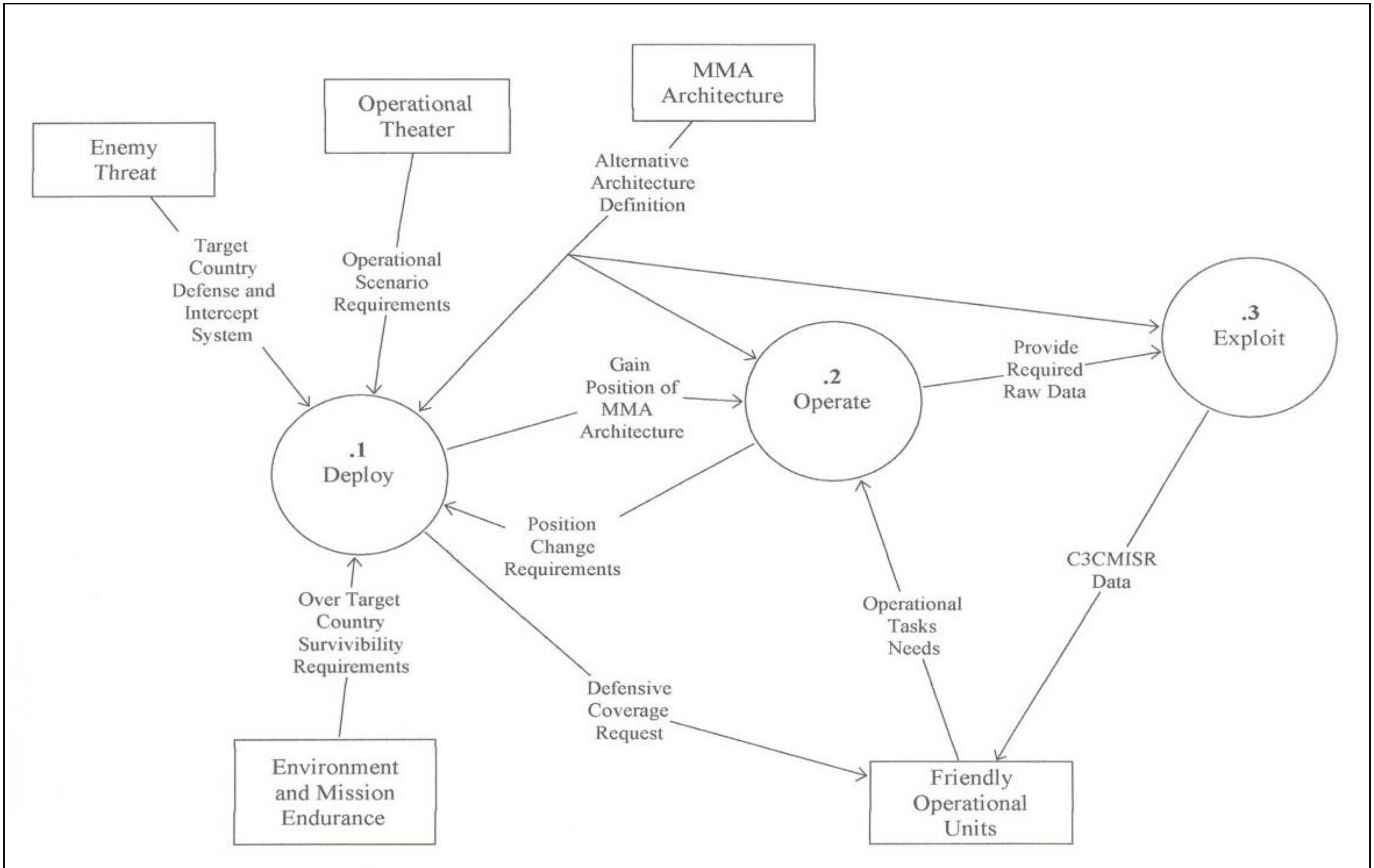
7. REFERENCES: When approved, background information on the MMA concept and the legacy platforms involved will be provided.

The sensor on board of individual AWACS, JSTARS, RIVET JOINT, ABCCC AND COMPASS CALL aircrafts doesn't interfere with each other. So the radar range of each Aircraft doesn't have any distance limitation when aircrafts are planned in an operational scenario.
In an operational scenario, each C3CMISR can be able to track more than one fixed and moving target.
The orbit diameter of each C3CMISR and Tanker aircraft is 40 miles.
The escort fighter aircrafts fly around the C3CMISR and Tanker aircrafts within a safe orbit.
The airbases A1 and A2 have all the capabilities and facilities that required for all C3CMISR, Tanker and fighter aircrafts. The maintenance of all aircrafts can be handled without any problem.
The ratio of Pilot/Chair for an aircraft is within the requirements.
Tanker aircrafts cap over at least 100 miles out of the area of operation and forward line of troops (FLOT).
The C3CMISR, Tanker and fighter aircrafts flies in an area which is cleared from civilian airlines route.
The alternative MMA aircrafts' crew numbers are notional.
The fighter and bomber aircrafts and escort aircrafts' number are totally notional. They cannot be specified, because they change through the mission type and requirements.
The maximum crew flight limitation is not exceeded in missions. When the time exceeds, the crew is taken to rest room.

The radar ranges of COMPASS CALL and ABCCC are assumed not farther than AWACS' radar range which is 250 miles/355.5 km.
Because of the cruise speed difference, while the fighter and bomber aircrafts attack package fly the C3CMISR architectures cannot proceed with the same speed with it. It proceeds within the radar range of it and provide continuous coverage for the operational units.
The sensors on board have on-off capabilities while performing the mission.

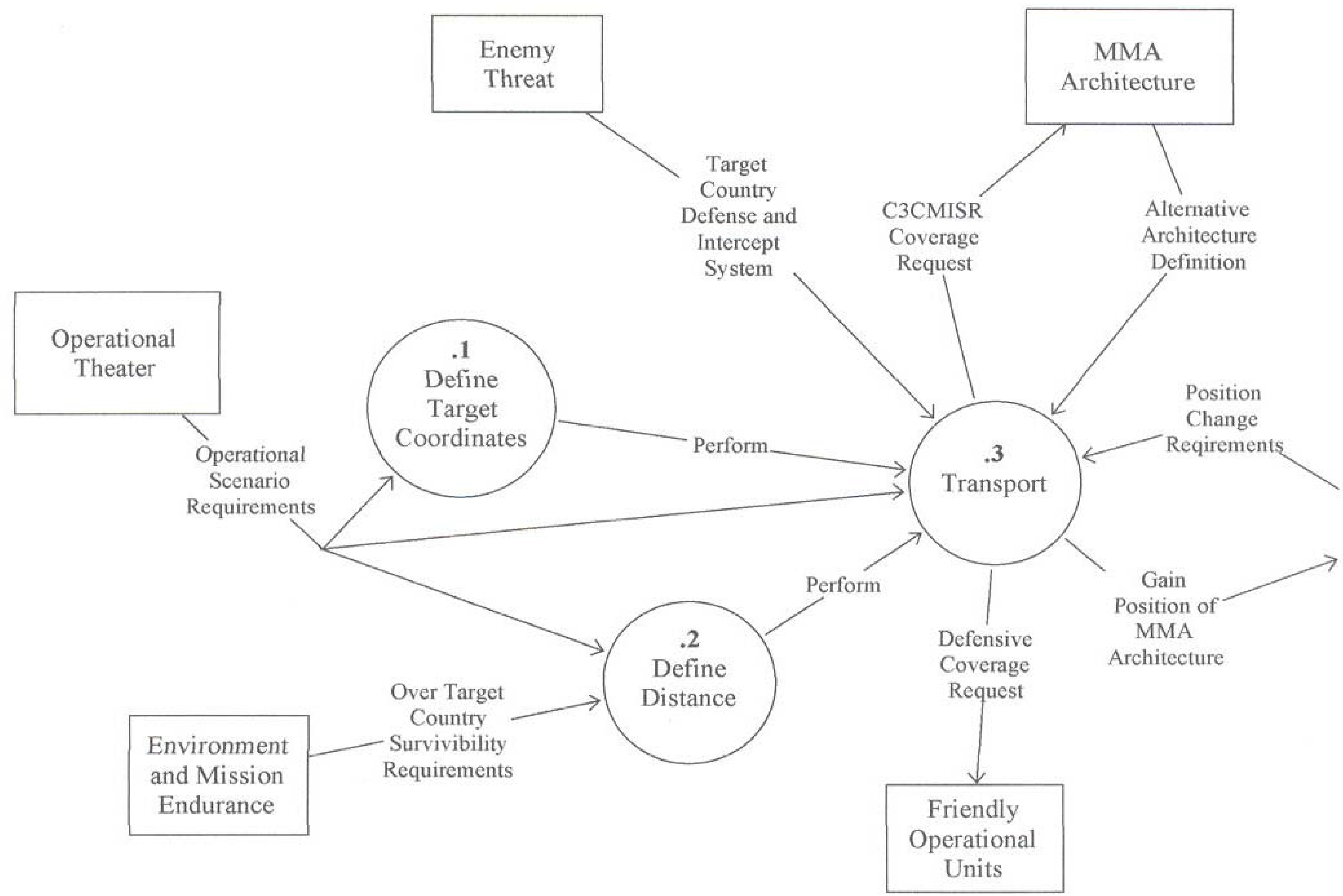


C/DFD – 1: CONTEXT DIAGRAM

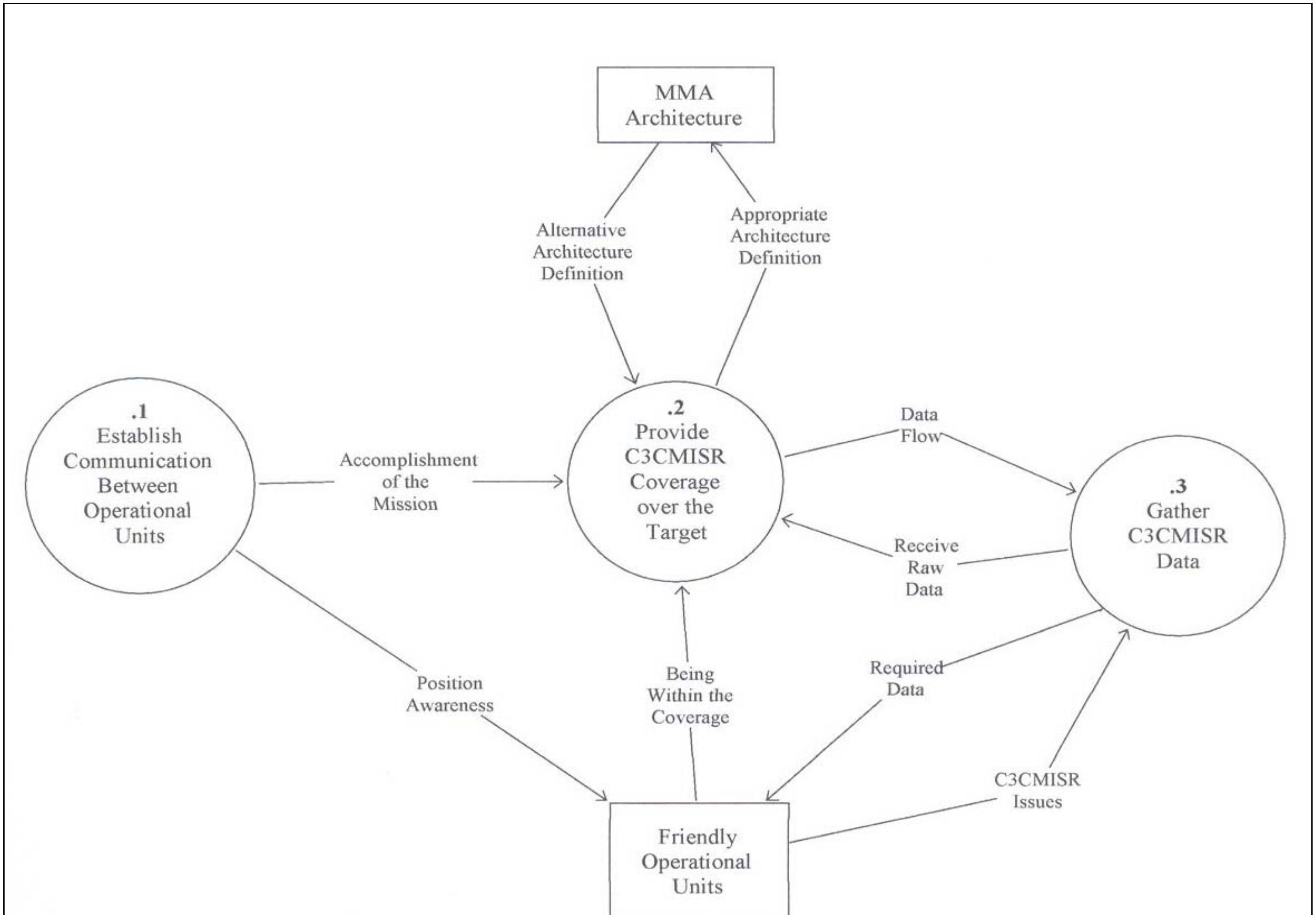


C/DFD 0: PERFORM_C3CMISR_REQUIREMENTS

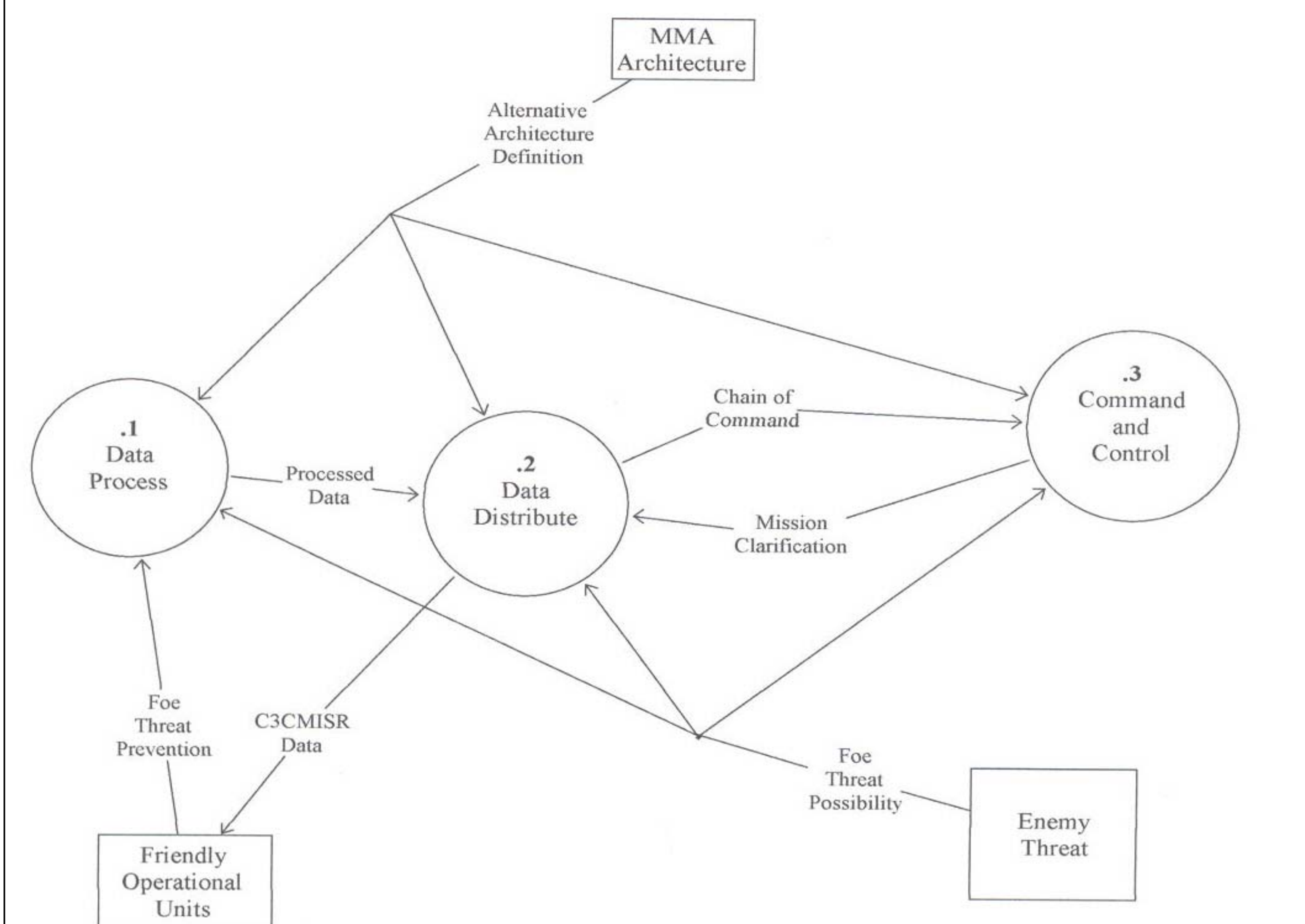
APPENDIX D



C/DFD 1: DEPLOY



C/DFD 2: OPERATE



C/DFD 3: EXPLOIT

Distance Calculations between Two Points

Because of the spherical shape of the Earth, calculating the exact distance between two points requires the use of spherical geometry and trigonometric math functions. However, the approximate distance can be calculated by using much simpler math functions. For many applications the approximate distance calculation provides sufficient accuracy with much less complexity. The following approximate distance calculations are relatively simple, but can produce distance errors of 10 percent of more. These approximate calculations are performed using latitude and longitude values in degrees. The first approximation requires only simple math functions:

approximate distance in miles = sqrt(x * x + y * y) *(1)*

where x = 69.1 * (lat2 - lat1)

and y = 53 * (lon2 - lon1)

The accuracy of this approximate distance calculation can be improved by adding the cosine math function:

Approximate distance in miles = sqrt(x * x + y * y) *(2)*

where x = 69.1 * (lat2 - lat1)

and y = 69.1 * (lon2 - lon1) * cos(lat1/57.3)

If a greater accuracy is needed, the exact distance calculation must be used. The exact distance calculation requires use of spherical geometry, since the Earth is a sphere. The exact distance calculation also requires a high level of floating point mathematical accuracy - about 15 digits of accuracy (sometimes called "double-precision"). Many computer languages do not provide sufficient accuracy for this calculation. In addition, the trigonometric math functions used in the exact calculation require conversion of the latitude and longitude values from degrees to radians. To convert latitude or longitude from degrees to radians, the latitude and longitude values must be divided by 180/pi, or 57.2958. The radius of the Earth is assumed to be 6,378 kilometers, or 3,963 miles. If all latitude and longitude values are converted to radians before the calculation, the following equation is used;

Exact distance in miles = 3963 * arccos[sin(lat1) * sin(lat2) + cos(lat1) *
cos(lat2) * cos(lon2 – lon1)] *(3)*

If the latitude and longitude values aren't converted to radians first, the degrees-to-radians conversion must be included in the calculation. Substituting degrees for radians, the calculation becomes:

Exact distance in miles = 3963 * arccos[sin(lat1/57.2958) * sin(lat2/57.2958) +
cos(lat1/57.2958) * cos(lat2/57.2958) *
cos(lon2/57.2958 – lon1/57.2958)] *(4)*

or

Exact distance = arccos[sin(lat1) * sin(lat2) + cos(lat1) *
cos(lat2) * cos(lon2 – lon1)] * r *(5)*

where r is the radius of the earth in whatever units are desired, like;

r = 3437.74677 (statute miles)

r = 6378 (kilometers)

r = 3963 (normal miles)

All of the above formulas are giving the same answers in different units. As known;

1 degree = 0.01745329 radians

1 degree = 60 minutes = 3600 seconds

1 minute = 0.000291 radians

1 second = 0.000005 radians

1 mile = 1.609344 kilometers

POINT	LATITUTE (degree)	LONGITUTE (degree)	LATITUTE (radian)	LONGITUTE (radian)
A1	36 59 16 N	35 18 48 E	0.645481 N	0.616101 E
A2	28 56 05 N	47 47 31 E	0.505006 N	0.834127 E
T1	33 19 38 N	44 22 09 E	0.583328 N	0.774388 E
T2	36 18 23 N	43 08 38 E	0.633666 N	0.753003 E
T3	30 32 32 N	46 36 07 E	0.533062 N	0.813357 E
T4	30 25 18 N	47 38 32 E	0.530958 N	0.831514 E
T5	33 21 20 N	40 35 48 E	0.582164 N	0.708545 E

Exact Distance = arccos[sin(lat1)*sin(lat2) + cos(lat1)*cos(lat2)*cos(lon2-lon1)] * 3963

DISTANCE BETWEEN	DISTANCE (n.miles)	DISTANCE (kms)
A1 - T1	580	950
A1 - T2	440	710
A1 - T3	790	1,280
A1 - T4	840	1,350
A1 - T5	390	630
A2 - T1	370	590
A2 - T2	580	935
A2 - T3	130	210
A2 - T4	105	170
A2 - T5	525	845
T1 - T2	212	400
T1 - T3	239	384
T1 - T4	283	455
T1 - T5	218	351
T2- T3	446	718
T2- T4	483	778
T2- T5	251	404
T3- T4	63	102
T3- T5	403	649
T4- T5	461	742

	MISSILE	SEEKER	SPEED	WARHEAD	RANGE
AIR-TO-AIR MISSILES	AIM-9M SIDEWINDER	All-aspect Infrared	Mach 2+	22 lb blast fragmentation	10 miles
	AIM-9P SIDEWINDER	Rear-aspect Infrared	Mach 2+	22 lb blast fragmentation	10 miles
	AIM-120 AMRAAM	Active Radar	Mach 4+	40 lb High Explosive (HE)	25 miles
	AIM-7 SPARROW	Raytheon Semi-Active on Either Continuous Wave or Pulsed Doppler Radar Energy	Classified	Annular Blast Fragmentation	Classified
	MICA	Command, Inertial and Active Radar or Imaging IR	Mach 4	12 kg HE Blast Fragmentation	50 km/ 28 miles
	MAGIC R.550	All-aspect Infrared	Mach 2.7/ 500 m/s	HE Blast Fragmentation	8 miles
	AIM-132 ASRAAM	Strap down Inertial and Imaging Infrared	Mach 3+	22.05 lb (10kg) Blast Fragmentation	8 nm (300 m to 15 km)
AIR-TO-GROUND MISSILES	AGM-65B MAVERICK	TV with Magnification	Mach 0.65	125 lb Shaped Charge	0.6 to 14 miles
	AGM-65D MAVERICK	Imaging Infrared	Mach 0.65	125 lb Shaped Charge	0.6 to 14 miles
	AGM-45A SHRIKE	Passive Radar	Classified	145 lb Fragmentation	12 miles
	AGM-84D HARPOON	Sea-skimming Cruise Using Radar Altimeter, Active Radar Terminal Homing	High Subsonic	Penetrating HE (488 lb)	Over the Horizon
	AGM-88A HARM	Passive Radar	Classified	145 lb Fragmentation	30 miles
	AGM-119 PENGUIN ANTI-SHIP MISSILE	Inertial and Infrared Terminal	Mach 1.2	265 lb gross, 11o lb HE, Semi-armor Piercing	25 nm/ 35 km
	AGM-136 TACIT RAINBOW	Preprogrammed Anti-Radar Missile	Subsonic	40 lb Blast Fragmentation	50 miles +

	MISSILE	SEEKER	SPEED	WARHEAD	RANGE
AIR-TO-GROUND MISSILES	AGM-137 TRI-SERVICE STAND OFF ATTACK MISSILE (TSSAM)	INS With GPS Updates	Classified	1000 lb	100 nm +
	AGM-154A JOINT STAND OFF WEAPON (JSOW)	Classified	Classified	Classified	From 15 nm to 40 nm
	AGM-158 JOINT AIR TO SURFACE STANDOFF MISSILE (JASSM)	GPS-Aided Inertial Navigation System (INS)	Classified	Classified	Classified
	AS-30L	Semi-Active Laser-Homing	1700 km/h	Impact-Fused HE Semi-Armor Piercing 240 kg	3 to 10 km

AIRCRAFT	MISSION	RADAR RANGE	CREW	MAX FLIGHT HR	PRIMARY FUNCTION	UNREFUELED RANGE	SPEED
E-3 Sentry ***AWACS***	*Surveillance *C2 *Communications	More than 250 miles (375.5 km) *360 degree Surveillance from the Earth Surface up to the Stratosphere *300,000 sq km field of view	***13-19 Operators*** *Surveillance *Identification *Weapon Control *Battle Management *Communications	More than 8 hrs mission profile (w/o air refueling)	*Airborne Surveillance *Command, Control and Communications	Classified	Optimum cruise 360 mph (Mach 0.48)
RC-135 V/W ***RIVET JOINT***	*Reconnaissance *Intelligence Collection (near real time on-scene) *ELINT *IMINT	Up to 240 km (155 miles)	***21-27 Operators*** *3 EW Officers *14 Intelligence Operators *4 in-flight/airborne maintenance technicians	* 11 hrs (w/o air refueling) * 20 hrs (w/ air refueling)	*Signals Intelligence Collection *Reconnaissance	3,900 miles (6,500 kms) (unlimited w/ air refueling)	500+ mph (Mach 0.66)
E-8C ***Joint STARS***	*Joint Surveillance Target Attack Radar System (Jam-Resistant)	*more than 250 km (160 miles) *120 degree field of view *19,306 sq miles (50,000 sq km)	***28 Operators*** *Battle Management *Surveillance *Weapons *Intelligence *Communications *Maintenance	* 11 hrs (w/o air refueling) * 20 hrs (w/ air refueling)	*Ground Surveillance	2,800 miles +	(Mach 0.84)
EC-130H ***COMPASS*** ***CALL***	*ECM System *Tactical Command *Control *Communications *Counter Measure *Jamming	Classified	***9 Operators*** *Operate and Maintain *EWO (MCC) *Cryptologic Linguist *Acquisition Operator *High Band Operator *4 Analysis Operators *AMT	* 10 hrs (w/o air refueling)	*Jamming	Classified	Classified
EC-130E ***ABCCC***	*Battlefield Command and Control Center *Communications	Classified	***12 Operators*** *Command *Operations *Intelligence *Communications	Classified	Classified	Classified	Classified

A/C NAME	CREW NEEDED
AWACS	*19 Operators* *4 Surveillance *4 Identification *3 Weapon Control *4 Battle Management *4 Communications
JSTARS	*28 Operators* *5 Battle Management *5 Surveillance *5 Weapons *5 Intelligence *5 Communications *3 Maintenance
RIVET JOINT	*21 Operators* *3 EW Officers *14 Intelligence Operators *4 in-flight/airborne maintenance technicians
ABCCC	*12 Operators* *3 Command *3 Operations *3 Intelligence *3 Communications
COMPASS CALL	*9 Operators* *1 Operate and Maintain *1 EWO (MCC) *1 Cryptologic

ALTERNATIVE MMA	TITLE		CONFIGURATON	CREW NEEDED	TOTAL
ONE TAIL NUMBER	*OTN*		AWACS JSTARS RIVET JOINT ABCCC COMPASS CALL	*5 Surveillance *4 Identification *5 Weapon Control *5 Battle Management *5 Communications *3 EW Officers *14 Intelligence Operators *1 Cryptologic Linguist *1 Acquisition Operator *4 Analysis Operators *3 Operations *3 Command *4 in-flight/airborne maintenance	*57* Operators
DIFFERENT TAIL NUMBERS	*DTN1*	*DTN11*	AWACS JSTARS	*5 Surveillance *4 Identification *5 Weapon Control *5 Battle Management *5 Communications *5 Intelligence *3 in-flight/airborne maintenance	*32* Operators
		DTN12	RIVET JOINT ABCCC COMPASS CALL	*3 Communications *3 EW Officers *14 Intelligence *3 Command *4 in-flight/airborne maintenance *1 Cryptologic Linguist *1 Acquisition Operator *4 Analysis Operators *1 AMT *3 Operations	*37* Operators

	Linguist *1 Acquisition Operator
COMPASS CALL	*4 Analysis Operators *1 AMT

DIFFERENT TAIL NUMBERS	*DTN2*	*DTN21*	AWACS ABCCC	*4 Surveillance *4 Identification *3 Weapon Control *4 Battle Management *4 Communications *3 Intelligence *3 Command *3 Operations	*28 Operators*
		DTN22	JSTARS RIVET JOINT COMPASS CALL	*5 Battle Management *5 Surveillance *5 Weapons *14 Intelligence *5 Communications *3 EW Officers *4 in-flight/airborne maintenance *1 Cryptologic Linguist *1 Acquisition Operator *4 Analysis Operators *1 AMT	*48 Operators*
	DTN3	*DTN31*	AWACS RIVET JOINT	*4 Surveillance *4 Identification *3 Weapon Control *4 Battle Management *4 Communications *3 EW Officers *4 in-flight/airborne maintenance *14 Intelligence	*40 Operators*

				*5 Battle Management *5 Surveillance *5 Weapons *5 Intelligence	
DIFFERENT TAIL NUMBERS		*DTN32*	JSTARS COMPASS CALL ABCCC	*5 Communications *1 EW Officers *3 Command *3 Operations *3 in-flight/airborne maintenance *1 Cryptologic Linguist *1 Acquisition Operator *4 Analysis Operators *1 AMT	*42 Operators*
	DTN4	*DTN41*	AWACS COMPASS CALL	*4 Surveillance *4 Identification *3 Weapon Control *4 Battle Management *4 Communications *1 EW Officers *1 in-flight/airborne maintenance *1 Cryptologic Linguist *1 Acquisition Operator *4 Analysis Operators *1 AMT	*28 Operators*
		DTN42	JSTARS RIVET JOINT ABCCC	*5 Battle Management *5 Surveillance *5 Weapons *5 Intelligence *5 Communications *3 EW Officers *14 Intelligence	*52 Operators*

				*3 Command *3 Operations *4 in-flight/airborne maintenance	

ARCHITECTURE TYPE	ARCHITECTURE ALTERNATIVE	ALTERNATIVE TITLE	A/C ON BOARD	RADAR RANGE	CRUISE SPEED	CREW NUMBER	MAXIMUM WEIGHT	MAXIMUM CEILING	CRUISE ALTITUDE
One Tail Number	OTN	OTN	AWACS JSTARS Rivet JOINT C.CALL ABCCC	155 miles 240 km	850 km/hr	61	Cannot Defined	5Ok ft	36k ft
Different Tail Numbers	DTN1	DTN11	AWACS JSTARS	160 miles 250 km	N/A	36	YES	50k ft	36k ft
		DTN12	Rivet JOINT C.CALL ABCCC	155 miles 240 km	N/A	41	YES	50k ft	36k ft
	DTN2	DTN21	AWACS ABCCC	250 miles 355.5 km	N/A	32	YES	50k ft	36k ft
		DTN22	JSTARS Rivet JOINT C.CALL	155 miles 240 km	N/A	52	YES	50k ft	36k ft
	DTN3	DTN31	AWACS Rivet JOINT	155 miles 240 km	N/A	44	YES	50k ft	36k ft
		DTN32	JSTARS C.CALL ABCCC	160 miles 250 km	N/A	46	YES	50k ft	36k ft
	DTN4	DTN41	AWACS C.CALL	250 miles 355.5 km	N/A	32	YES	50k ft	36k ft
		DTN42	JSTARS Rivet JOINT ABCCC	155 miles 240 km	N/A	56	YES	50k ft	36k ft

CREW # POSSIBILITY	*WEIGHT POSSIBILITY*	REFUELS REQUIRED	*SENSOR COMPATIBILITY*	*POWER POSSIBILITY*
YES	Cannot Defined	2	NO	NO
YES	YES	1	YES	NO
YES	YES	2	YES	YES
YES	YES	1	YES	NO
YES	YES	2	YES	NO
YES	YES	2	YES	NO
YES	YES	2	YES	NO
YES	YES	1	YES	NO
YES	YES	2	YES	NO

RUNWAY LENGTH		REFUELS REQUIRED	
8000FT	ENDURANCE(hr)	TAKE OFF FROM SEA LEVEL	TAKE OFF FROM 8000FEET
OTN	9.26	2	3
DTN11	12.09294118	2	2
DTN12	11.80941176	2	2
DTN21	12.52823529	2	2
DTN22	11.54823529	2	3
DTN31	11.91764706	2	2
DTN32	11.22117647	2	3
DTN41	12.41882353	2	2
DTN42	11.65647059	2	2

OTN CAN NOT TAKE OFF FROM AN 8000 FEET LONG RUNWAY AT 8000 FEET ALTITUDE

OTN HAS TO BE REFUELED JUST 0.5447 HOUR AFTER THE TAKEOFF FROM 8000 FEET LONG AT 6000FT ALTITUDE

Bibliography

1. "[4.3] USAF MC2A / US NAVY MMA (2002)" Excerpt from unpublished article. n. pag. http://www.vectorsite.net/avbtsv4.html.

2. "E-3 Sentry AWACS", Excerpt from unpublished article. n. pag. http://www.af.mil/news/factsheets/E_3_Sentry_AWACS.html , Air Combat Command, Public Affairs Office, July 2000.

3. "E-3 Sentry (AWACS)", Excerpt from unpublished article. n. pag. http://www.fas.org/man/dod-101/sys/ac/e-3.htm , Maintained by Webmaster, April 23, 2000.

4. "RC-135V/W Rivet Joint", Excerpt from unpublished article. n. pag. http://www.af.mil/news/factsheets/RC_135V_W_Rivet_Joint.html , Air Combat Command, Public Affairs Office, March 2001.

5. "Rivet Joint", Excerpt from unpublished article. n. pag. http://www.af.mil/photos/Jul2000/000731f-0000d-012.html RC-135 .

6. "RC-135V/W Rivet Joint, Air Force's Primary Airborne Reconnaissance Platform", Excerpt from unpublished article. n. pag. http://www.fas.org/irp/agency/aia/cyberspokesman/97aug/rivet_joint.htm .

7. "Rivet Joint", Excerpt from unpublished article. n. pag. http://www.fas.org/irp/program/collect/rivet_joint.htm, Created by John Pike, Maintained by Steven Aftergood, March 05, 2000.

8. "RC-135 Rivet Joint", Excerpt from unpublished article. n. pag. http://www.au.af.mil/au/database/projects/ay1996/ascs/96-004/hardware/docs/rj.htm.

9. "E-8C Joint Stars", Excerpt from unpublished article. n. pag. http://www.af.mil/news/factsheets/E-8C_Joint_Stars.html, Air Combat Command, Public Affairs Office, June 2002.

10. "Joint Surveillance Target Attack Radar System (Joint STARS / JSTARS)", Excerpt from unpublished article. n. pag. http://www.fas.org/irp/program/collect/jstars.htm, Created by John Pike, Maintained by Steven Aftergood, July 25, 1999.

11. "JSTARS Joint Surveillance and Target Attack Radar System, USA", Excerpt from unpublished article. n. pag. http://www.airforce-technology.com/projects/jstars.

12. "EC-130H Rivet Fire/Compass Call", Excerpt from unpublished article. n. pag. http://www.globalsecurity.org/military/systems/aircraft/ec-130h.htm, Maintained by John Pike, March 21, 2002.

13. "EC-130E ABCCC", Excerpt from unpublished article. n. pag. http://www.globalsecurity.org/military/systems/aircraft/ec-130e-abccc.htm, Maintained by John Pike, April 04, 2002.

14. "ASD C3I CIO", Excerpt from unpublished article. n. pag. http://www.iwar.org.uk/rma/resources/c4i/faq.html.

15. "FM 34-130 Intelligence Preparation of the Battlefield, Chapter 1, Introduction", Excerpt from unpublished article. n. pag. http://www.adtdl.army.mil/cgi-bin/atdl.dll/fm/34-130/ch1.htm.

16. "Intelligence Programs and Systems", Excerpt from unpublished article. n. pag. http://www.fas.org/irp/program/index.html, Created by John Pike.

17. "FM 34-8-2, Chapter 1, G2/S2 Roles and Missions", Excerpt from unpublished article. n. pag. http://www.adtdl.army.mil/cgi-bin/atdl.dll/fm/34-8-2/8-2ch1.pdf.

18. "Enhancing MASINT Sensor Effectiveness", Excerpt from unpublished article. n. pag. http://www.mitre.org/technology/mtp00/sensors_2000.shtml.

19. "Measurement And Signature Intelligence (MASINT)", Excerpt from unpublished article. n. pag. http://arat.iew.sed.monmouth.army.mil/ARAT/ARAT_information/arat_terms/masint.htm.

20. "Joint Vision 2020, Joint Vision 2020 Briefing – 417 k (jv2020.doc)", Excerpt from unpublished article. n. pag. http://www.dtic.mil/jv2020/1.

21. " Military Intelligence Unit Capabilities, Chapter 4", Excerpt from unpublished article. n. pag. www.fas.org/irp/doddir/army/fm34-8/ch4.htm.

22. INCOSE Systems Architecture Working Group (Processes and Methods Technical Committee), http://www.incose.org/cmtes/sawg.html.

23. C4ISR Architecture Working Group (AWG), C4ISR Architecture Framework Version 2.0, 18 December 1997, Section 2, Page 2-1.

24. C4ISR Architecture Working Group (AWG), C4ISR Architecture Framework Version 2.0, 18 December 1997, Section 2.1.1, Page 2-2.

25. C4ISR Architecture Working Group (AWG), C4ISR Architecture Framework Version 2.0, 18 December 1997, Section 2.1.2, Page 2-2.

26. C4ISR Architecture Working Group (AWG), C4ISR Architecture Framework Version 2.0, 18 December 1997, Section 2.1.3, Page 2-3.

27. C4ISR Architecture Working Group (AWG), C4ISR Architecture Framework Version 2.0, 18 December 1997, Section 2.3, Page 2-7, Figure 2-2.

28. Alexander H. Levis, Architecture Information Systems, SENG 640 Systems Architecture Class Notes, Chapter 1, Systems Engineering Architectures, Architects and the Air Force, Chp.1-33.

29. Alexander H. Levis, Architecture Information Systems, SENG 640 Systems Architecture Class Notes, Chapter 1, Systems Engineering Architectures, Architects and the Air Force, Chp.1-58.

30. C4ISR Architecture Working Group (AWG), C4ISR Architecture Framework Version 2.0, 18 December 1997.

31. "Joint Command and Control, Intelligence, Surveillance and Reconnaissance (JC2ISR)", www.globalsecurity.org/military/library/budget/fy2001/dot-e/jte/01jc2isr.html.

32. Mark T. Maybury, "Distributed, Collaborative, Knowledge Based Air Campaign Planning", Figure 1. Battle Planning Process, http://www.mitre.org/support/papers/dc_kkb/.

33. Operational Desert Storm: Evaluation of the Air Campaign (Letter Report; 06/12/97, GAO/NSIAD-97-134), "Scope and Methodolgy", Excerpt from unpublished article. n. pag. www.fas.org/man/gao/nsiad97134/app_01.htm.

34. "Circular Error Probable", http://www.dtic.mil/doctrine/jel/doddict/natoterm/c/00245.html.

35. "Circular Error Probable", http://www.gulflink.osd.mil/scud_info/scud_info_refs/n41en174/01154.htm.

36. Missile Capabilities, http://www.cdiss.org/iraq_t.htm, http://fas.org/irp/threat/wmd_state.htm , http://fas.org/nuke/guide/iraq/missile/index.html.

37. Dimitri N. Mavris and Nicholas K. Borer, "Development of a Multi-Sizing Methodology Applied to the Common Support Aircraft", Excerpt from unpublished article. n. pag. http://www.asdl.gatech.edu/publications/pdf/2001/SAE-2001-01-3014.pdf, 2001-01-3014.

38. "General Dynamics F-16 Fighting Falcon, F-16 Armament and Stores", http://www.voodoo.cz/falcon/armament.html.

39. Derek Hatley, Peter Hruschka, and Imtiaz Pirbhai. Process For System Architecture And Requirements Engineering. New York: Dorset House Publishing Co., Inc., 2000.

40. "Distance Calculation, How to Calculate the Distance between Two Points on the Earth", http://www.meridianworlddata.com/HTML8/find-distances-between-cities-3.asp.

41. "Unmanned Aerial Vehicles (UAVs)", Excerpt from unpublished article. n. pag. http://www.fas.org/irp/program/collect/uav.htm, John Pike, July 17, 2002.

42. "Unmanned Aerial Vehicles Web Site", Excerpt from unpublished article. n. pag. http://uav.wff.nasa.gov/.

Vita

First Lieutenant Nevin COSKUNER graduated from Canakkale Anatolia High School in Canakkale, Turkey. She entered undergraduate studies at the Air Force Academy in Istanbul, Turkey where she graduated as a Second Lieutenant with a Bachelor of Science degree in Industrial Engineering on 30 August 1996. Her first assignment was at the Cigli Air Force Base, Izmir for undergraduate pilot training (UPT). After graduating from UPT in March 13 1998, she was assigned to Air Force Academy, 5^{th} Squadron, Search and Rescue Command, Istanbul, Turkey as a helicopter pilot. In August 2001, she entered the Graduate School of Engineering and Management, Aeronautics and Astronautics Department, Systems Engineering Program, AFIT. After graduation she will return to her previous assignment, as a search and rescue mission helicopter pilot.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 074-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From – To)*
25-03-2003	**Master's Thesis**	Jun 2001 – Mar 2003

4. TITLE AND SUBTITLE

MULTIMISSION AIRCRAFT DESIGN STUDY - OPERATIONAL SCENARIOS

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Nevin Coskuner, First Lieutenant, TUAF

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S)

Air Force Institute of Technology
Graduate School of Engineering and Management (AFIT/EN)
2950 Hobson Way, Building 640
WPAFB OH 45433-7765

8. PERFORMING ORGANIZATION REPORT NUMBER

AFIT/GSE/ENY/03-1

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

HQ USAF/XOI
Attn: Mr. Mike Burgan & Lt. Col Charlie Bartlett
1480 Air Force Pentagon DSN: 225-8065/227-0412
Washington DC 20330-1480 e-mail: N/A

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Currently in the U.S and many NATO and UN operations around the world, command, control and communications, counter measures, intelligence, surveillance and reconnaissance (C3CMISR) operations utilize separate aircraft, namely AWACS, JSTARS, Rivet JOINT, COMPASS CALL and ABCCC. They provide both air and ground surveillance and support strategic, tactical and battlefield decision making. A multi-mission aircraft (MMA) that accomplishes all the C3CMISR tasks on one airframe is being considered by many, including a team study by three AFIT students in the Systems Engineering program class of 2003. This study is part of that effort and addresses the development of operational scenarios with which to assess the feasibility of various MMA configurations.

15. SUBJECT TERMS

Multi-Mission Aircraft, Operational Scenarios, Tanker Aircraft, AWACS, JSTARS, RIVET JOINT, ABCCC, COMPASS CALL, C3CMISR Aircrafts

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					Curtis H. Spenny, P.E. (AFIT/ENY)
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER *(Include area code)*
U	U	U	UU	156	(937) 255-7777, ext 3296; e-mail: curtis.spenny@afit.edu

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39-18