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Multimission Aircraft Design Study, Payload

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MULTIMISSION AIRCRAFT DESIGN STUDY, PAYLOAD

THESIS

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Ahmet Kahraman

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LIST OF ABBREVIATIONS

AA	Antenna Array
ABCCC	Airborne Battlefield Command and Control Center
AC	Alternative Current
A/C	Aircraft
ACC	Air Combat Command
ACE	Airborne Command Element
ACIDS	Automated Communications and Intercom Distribution System
ADT	Air Data Terminal
AFD	Architecture Flow Diagram
AFIT	Air Force Institute of Technology
AFSOC	Air Force Special Operations Command
AID	Architecture Interconnect Diagram
AJCN	Adaptive Joint C4ISR Node
AMC	Air Force Material Command
AMS	Airborne Maintenance Subsystem
AMTI	Air Moving Target Indication
APU	Auxiliary Power Units
AR	Analogue Receiver
ATA	Air Transport Association
ATR	Air Transport Tracking
Avgas	Aviation Gas
AWACS	Airborne Warning and Control System

BM	Battle Management
BPR	Bypass-Ratio
$C_{avionics}$	Avionics Cost
C_{eng}	Engineering Production Cost
C_D	Development Support Cost
C_F	Flight Test Cost
C_M	Manufacturing Materials Cost
C2	Command and Control
C3CM	Command, Control Communications and Countermeasures
C^3I	Command, Control and Communications, and Intelligence
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance
CFD	Control Flow Diagram
CINC	Commander in Chief
Com\Nav	Communication\Navigation
CONOP	Concept of Operation
COTS	Commercial Off-the-Shelf
CP	Command Post
CS	Capsule Subsystem
CS	Communications Subsystem
CSPEC	Control Specification
DCS	Deputy Chief of Staff
DDP	Digital Doppler Processor
DFD	Data Flow Diagram

DoD	Department of Defense
DTN	Different Tail Numbers
ECM	Electronic Counter Measures
ESM	Electronic Support Measure
FH	Flight Hour
FS	Finite State
FTA	Number of flight test A\C
FTI	Fixed Target Indicator
GE	General Electric
GMTI	Ground Moving Target Indication
GPS	Global Positioning System
H_E	Engineering Hours
H_M	Manufacturing Hours
H_Q	Quality Control Hours
H_T	Tooling Hours
H/H/P	Hatley, Hruschka and Pirbhai
HVPS	High Voltage Power Supply
IDG	Integrated Drive Generators
IFF	Identification Friend-or-Foe
INS	Inertial Navigation System
INTERCOM	Interior Communications System
ISAR	Inverse Synthetic Aperture Radar
ISR	Intelligence, Surveillance and Reconnaissance
JSTARS	Joint Surveillance and Target Attack Radar System

JTIDS	Joint Tactical Information Distribution System
JTRS	Joint Tactical Radio System
JTT	Joint Tactical Terminal
K_{buf}	Galley Weight Estimation Constant
K_{lav}	Lavatory Weight Estimation Constant
LAN	Local Area Network
LCC	Life Cycle Cost
M_{max}	Engine maximum Mach number
MC2A	Multisensor Command and Control Aircraft
MC2A-X	Multisensor Command and Control Aircraft Experiment
MIDS	Multifunctional Information and Distribution System
MLW	Maximum Design Landing Weight
MMA	Multi-Mission Aircraft
MMH	Maintenance Man Hours
MOE	Measure of Effectiveness
MP	Maritime Processor
MP-RTIP	Multi-Platform Radar Technology Improvement Program
MR	Microwave Receiver
MTOW	Maximum Design Takeoff Weight
MTW	Maximum Design Taxi Weight
MZFW	Maximum Design Zero Fuel Weight
NMI	Nautical Mile
N_{pax}	Number of Passengers
N_{eng}	Total Production Quantity Times Number of Engines per A\C

O&C	Operations and Control
OEW	Operating Empty Weight
OTN	One Tail Number
P_c	Design Ultimate Cabin Pressure in PSI
PCE	Phase Control Electronics
PW	Pratt and Whitney
Q	Lesser of production quantity or number to be produced in 5 years
R_E	Engineering Wrap Rate
R_M	Manufacturing Wrap Rate
R_Q	Quality Control Wrap Rate
R_T	Tooling Wrap Rate
RCMP	Radar Control and Maintenance Panel
RC	Rotary Coupler
RDC	Radar Data Correlator
RDT&E	Research, Development, Test and Evaluation
RelNav	Relative Navigation
RJ	Rivet Joint
RTC	Recruit Training Command
SA	Structured Analysis
SAR	Synthetic Aperture Radar
SATCOM	Satellite Communication
SDLT	Serial Datalink Translator
SFC	Specific Fuel Consumption
SHORAD	Short Range Air Defense

SIGINT	Signal Intelligence
SINCGARS	Single Channel Ground and Airborne System
SLR	Side Looking Radar
SMAD	Space Mission Analysis and Design
SS	Sector Search
SSR	Secondary Surveillance Radar
STALO	Stable Local Oscillator
T_{max}	Engine maximum thrust
$T_{turbine\ inlet}$	Turbine inlet temperature
TACAN	Tactical Air Navigation
TADIL-C	Tactical Data-Link Fighter-Control
TBMS	Tactical Battle Management Subsystem
TSPEC	Timing Specification
TIBS	Tactical Information Broadcast Service
TTP	Training, Techniques and Procedures
TUAF	Turkish Air Force
UAV	Uninhabited Aerial Vehicle
USAF	United States Air Force
V	Maximum Velocity
VSD	Value System Design
WAS	Wide Area Surveillance
W_{AU}	Uninstalled Avionics Equipment Weight
W_{empty}	Empty Weight
W_{fuel}	Weight of Fuel

W_{fur}	Weight of Furniture
W_i	Weight of the Aircraft at the end of the i^{th} Phase of the Flight
W_{iae}	Instrumentation, Avionics and Electronics Weight
$W_{in\text{-}flight}$	Weight of In-flight Refuel System
W_{lav}	Weight of the Lavatory
W_o	Maximum Design Takeoff Weight
$W_{payload}$	Weight of Payload
W_{TRON}	Installed Avionics Weight
YR	Year

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ABSTRACT

It is proposed that a Multi-Mission Aircraft (MMA) be prepared to combine some or all the functions of the aging AWACS, JSTARS, RIVET JOINT, COMPASS CALL, and ABCCC fleet. Three different thesis studies have been developed by three Air Force Institute of Technology GSE students to show the feasibility of replacing the current aging fleet with one or more MMA platforms. This is the thesis in which the *payload issues* have been examined.

Within this thesis, two different alternative architectures, which are One Tail Number and Different Tail Numbers including nine different configurations, have been considered. Estimated payload characteristics of these alternatives have been compared to those of Boeing 767-400ER, which is the aircraft selected as the baseline for MMA platform. Reduced life cycle cost, increased measure of aircraft specifications, and minimum risk are the main objectives pursued by means of several systems engineering and aircraft design methodologies.

MULTIMISSION AIRCRAFT DESIGN STUDY,

PAYLOAD

1 INTRODUCTION

1.1 Background

All units in the Air Force have their crucial missions none of which can be excluded for a total success. The principle attack powers of the Air Force, the fighters and bombers need the vital support and guidance of the C4ISR (Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance) units. They are considered the ears and eyes of the fighters.

Over the recent years, the Intelligence, Surveillance, Reconnaissance, Command and Control missions in the Air Force have been performed individually by different platforms with coordination. However, because of the reasons cited above and more, the idea of a Multi-Mission Aircraft (MMA), which will combine all the desired capabilities on a single platform, has evolved as a replacement of the aging current fleet.

On September 2001, the AFIT Faculty staff was contacted by USAF officials suggesting that the AFIT graduate students should perform a technical feasibility study of the newly proposed MMA concept. Following this coordination, the Major General Glen D. Shaffer, Director for Intelligence, Surveillance and Reconnaissance (ISR), DCS, Air and Space Operations, USAF has requested a technical feasibility study for a multi-mission aircraft. Memorandum of thesis topic proposal can be viewed from Appendix I.

The MMA concept has been proposed as a replacement for the aging fleet of C-135 and C-130 theater-based command and control (C2) and intelligence, surveillance and reconnaissance (ISR) fleet. The MMA is alternately designated as the Multisensor Command and Control Aircraft (MC2A) as indicated in this text. Figure 1-1 shows the role of MC2A within the system of systems constellation network. It has been proposed that the MMA be out-fitted to combine some or all the functions of the existing AWACS, JSTARS, RIVET JOINT, COMPASS CALL, and ABCCC platforms, which are to be defined later. It would also have links to other manned or unmanned ISR aircraft, as well as the satellites.

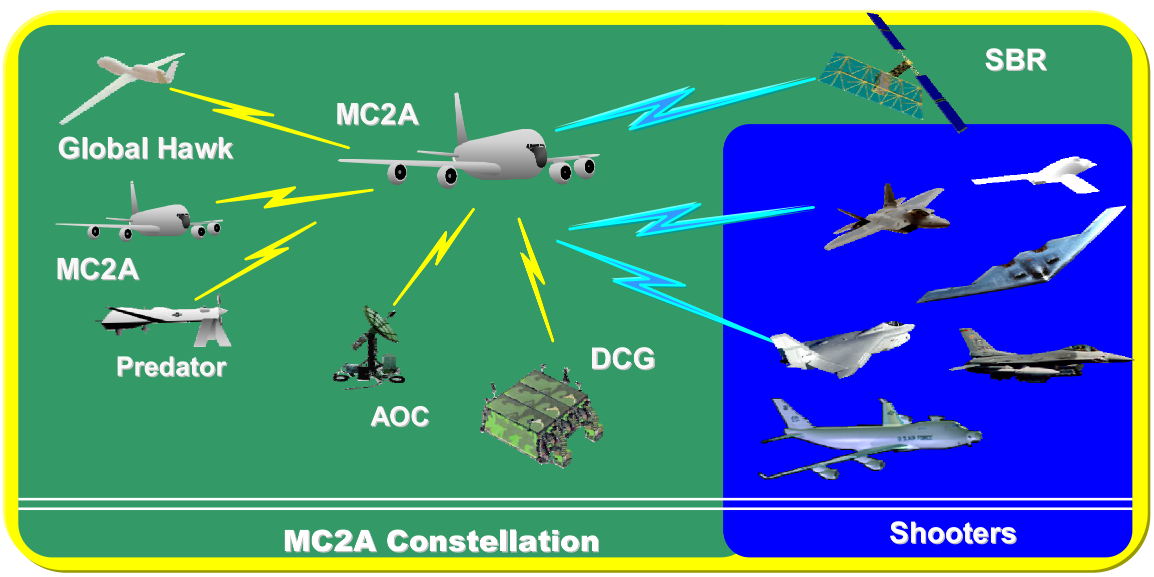


Figure 1-1: MC2A within the System of Systems Constellation Network (Wilson and Connor, 2001*)*

A Systems Engineering Design Team consisting of 1 USAF and 2 TUAF officers was established in order to examine the case as their thesis study. Three investigation areas, Payload Design, Operational Environment and Electromagnetic were selected for that are thought to be strongly interrelated and for which design tradeoffs are believed strongly influencing overall system performance. Under this perspective, every team member will perform and present their individual theses. This specific thesis deals with the Aircraft Payload Design of the proposed MMA.

1.2 Problem Statement

The primary goal of this thesis is to develop a dependable, expandable and repeatable Systems Engineering process tailored to the issue of replacing the current aging fleet with a single platform by ensuring that every mission currently being served will continue. To minimize the LCC and risk, to increase mission utility, integrability, compatibility and to identify some possible downfalls caused by overloading, oversizing and poor arranging will be the primary objectives considered. Other objectives also include the identification the risks and dangers of exceeding the limits of the aircraft. Some of those limitations could be named as follows:

- Airspeed: The weight of the loaded payload, which is required for the mission accomplishment, could cause the aircraft to perform out of its speed limits specifically during takeoff, cruising, loitering and landing phases.

- Range: The configuration of the aircraft could not meet the requirements of a specific operational scenario. For this reason, the idea of extending the range in order to satisfy those requirements could be considered.
- Altitude While Loitering: Some surveillance and reconnaissance missions could require the aircraft cruise over or below a specific altitude. This could prevent some missions be performed simultaneously.
- Payload Requirements: Composition of some equipment could cause degradations on the structure of the aircraft. Additionally, layout of the consoles, equipment, antenna etc. could cause exceedings in structural limitations.
- At this point, it is also thought that integrating different types of sensors and antennas from different aircraft into one –or two–may require a substantial amount of power. This issue will also be considered one of the main system drivers for this study.

As seen above, the requirements that may force the platform to exceed its design limits could be either of operational or electromagnetic origin. For this reason, it is intended to collaborate with the other Systems Engineering Design Team members in order to introduce a consistent presentation during this thesis work.

Needs, constraints, and alterables, which will be the baseline of the study under the systems engineering approach, are going to be defined at the very beginning of the Chapter 3. It should be also noted that those needs, constraints, and alterables are not necessarily the official views of the decision makers. However, they were determined after a very thorough research and brainstorming.

1.3 Problem Solution

Operational environment is converted to an H/H/P Model coded with TurboCASE/Sys™ believing that it will be a representation of the overall platform displaying the interactions between the three main aspects of the issue. H/H/P Methods are the architecture and requirements methods created by Hatley, Hruschka and Pirbhai. The H/H/P techniques help to stimulate system specifications to iteratively generate a set of system requirements and architecture models (Hatley and others, 2000).

TurboCASE/Sys™ is a Systems Engineering Case Tool created by StructSoft Inc. that supports H/H/P Methods. TurboCASE/Sys™ helps the user to build up models consisting of processes, terminators, and interconnections. It displays a clear representation of the system of the interest and arranges the interactions. A summary of both TurboCASE/Sys™ Tool and H/H/P Methods will be presented at the end of the Chapter 2.

This H/H/P model will certainly help us to figure out the overlapping areas of the Aircraft Design, Operational Environment, and Electromagnetic considerations. In this way, we have performed more effective studies and exchanged the ideas in a well-organized way.

After identifying the major areas to be investigated, common aircraft design approaches will be applied wherever needed to the fabricated scenarios. Some essential tradeoff studies have also been performed between the key areas that are considered to change the performance of the MMA platform dramatically.

In this thesis study, the best effort has been employed in an iterative way in order to dig into determined major pieces of the subject. I believe that as many iterations as possible should be implemented within the limitations of time, funding and manpower for more accurate and helpful results. So, the calculations were iterated several times up to the level time allowed.

1.4 Scope

It is necessary to recall that the backgrounds of the Systems Engineering Design Team members do not directly match to the crucial disciplines needed for this topic. Additionally, time limitations and possible restrictions to access the US only documentation have narrowed the scope of the effort. In some instances, it has been necessary to use hypothetical data to demonstrate the process that has been developed.

The major focus of this thesis study will be mainly on "Aircraft Design with respect to Payload Limitations". Basically; space, weight and power limitations on the integration of those aircraft mentioned earlier will be the main concern. In order to give specific answers for a MMA design and its compatibility, we should consider what is going to be integrated into the MMA architecture. Fundamentally, we can say that those should be the sensors, crew and all of the software and the hardware for the missions. By investigating the aircraft payload integration, we will be able to make decisions based on key factors such as weight, volume, speed and some other related configurations of the aircraft. To accomplish this, we need to understand the characteristics of the sensors, receivers, and transmitters.

However, because of the classification of the subject, it would not be possible to identify the entire payload on the current fleet. For this reason, sometimes, a set of payloads that is thought to be somewhat similar to the real ones has been assumed as the main payload to be integrated.

Another important issue on the aircraft design is the selection of the aircraft for the sensor platforms. When this study was initiated, there was not an official announcement declaring the type of the aircraft to be chosen as the baseline. However, it is speculated that there is a tendency to choose Boeing 767-400ER. For convenience, this aircraft has been considered as the basis on which the entire payload will be mounted. The specifications of the aircraft in question will be covered in the Chapter 2 of this thesis as well.

In this study, two different types of MMA system models are considered among several others. Different Tail Numbers (DTN) and One Tail Number (OTN) alternatives will be compared by adding or removing several tasks including air-refueling.

1.5 Sequence of Presentation

Chapter 2 provides the review of the current airframes and tasks that are intended to be replaced by the MMA platform. Technical specifications of those airframes along with the candidate aircraft 767-400ER are presented in tabular forms. It also includes summaries of the H/H/P Methods and TurboCASE/Sys™ Tool, which have been used in outlining the overall system of interest.

In the first part of Chapter 3, basic systems engineering approach and other helpful methodologies used to carry out the research have been explained. Then, some important issues affecting the integration process are examined. Definitions of the MMA alternatives have also been introduced in this chapter.

In Chapter 4, two alternative architectures were compared based on the Value System Design (VSD) generated in previous chapter. Chapter 4 also details the results attained after the research and provides a sensitivity analysis by changing the initially assigned importance factors.

Chapter 5 presents the conclusions of conducted study and recommendations for further researches. There are several Excel spreadsheets available in the Appendices C, D, E and F that are utilized in making the estimations. Besides, a list of assumptions made in this thesis is also presented in the Appendix H.

Overall interactions and conclusions from all three Systems Engineering Team Members have been summarized in the Chapter 5 of the thesis prepared by the Operational Environment representative of the team.

2 LITERATURE REVIEW

2.1 Current Airframe and Tasks

Currently, C-135, C-130 and Boeing 707 theater-based AWACS, JSTARS, RIVET JOINT, COMPASS CALL and ABCCC platforms have been performing command & control and intelligence, surveillance and reconnaissance tasks of the USAF. The MC2A concept has been proposed as a replacement of those aging fleets in question. In this chapter, the status of the ISR and Command & control platforms and the ongoing studies about MC2A will be scanned briefly.

After an extended exploration and brainstorming with the Systems Engineering Team in AFIT, I have decided to focus mainly on payload integration including space, power and weight. I believe that the Air Force's primary challenge is "to which extent the MC2A can concurrently perform ground moving target indication (GMTI) and air moving target indication (AMTI) tasks". However, the operational perspective is not going to be included in this study. It will be covered by the other System Engineering Team Members along with Electromagnetic perspective.

USAF Chief of Staff General John Jumper summarizes the main objective of building the MC2A as to shorten the "find, fix, track, target, engage, and assess loop", which is the definition of the "kill chain". Integrating all ISR and Command& Control tasks under a platform is the milestone to attain this objective.

For this reason, Air Force began negotiations with Boeing for the lease of 100 commercial wide-body 767 air-refueling tankers in 2002. These aircraft are being explored under the study of forming the "smart tanker" that would carry communication relays and perhaps surveillance sensors and a new MC2A. This new platform will eventually replace previously mentioned Air Force intelligence gathering and battle management aircraft. Congress authorized the lease as a first step toward replacing the fleet in question in 2001 Fall.

In 2002, Boeing 767-400ER was announced to be the platform of MC2A. A total of 55 MC2As are planned to be built and the first aircraft delivery is scheduled for 2010. During the first development phase, Raytheon and Boeing Companies will fabricate, test and integrate the MP-RTIP (multi-platform radar technology improvement program) radar onto the MC2A.

Two different alternatives MMA models are believed to be considered by the Air Force Staff:

1. One Tail Number (OTN): All missions within a single aircraft,

2. Different Tail Numbers (DTN): Tail numbers representing the different sets of sensors within a particular aircraft

However, according to the announcements made by the officials, it seems that the main consideration is given to the DTN architecture. Moreover, DTN MC2A will likely be built in two alternatives. The first one is the active emitter version that is going to be the combination of the AWACS' aerial surveillance and Joint STARS' ground surveillance missions. The second variant will perform Rivet Joint and other passive electronic surveillance functions. These issues are displayed on Figure 2-1.

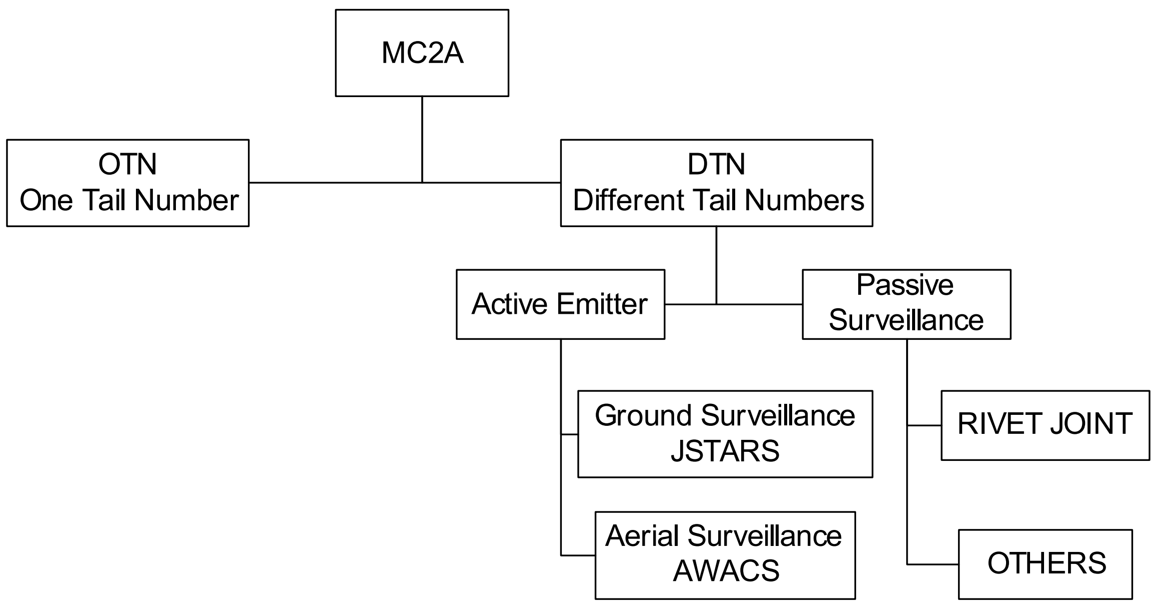


Figure 2-1: MC2A Variations

A Boeing 707 based platform called MC2A-X or Paul Revere is being used as a testbed for the proposed platforms. However, use of another Boeing 767-400ER based testbed is desired for more effective test and integration. It is reported that one of the main lessons learned after those experiments is that new antennas should be located in such a way that data links will not get lost, especially during critical times of transfer.

During the tests and evaluations performed in the year 2002, designers faced with many technical and political challenges. The immediate concerns are:

1. Funding needed for the Boeing 767-400ER based testbed is waiting for the Congress approval.
2. Integrating the JSTARS' ground-surveillance mission and AWACS' airborne target tracking capability on one aircraft could be unachievable because of interference of the radars and substantial amount of power needed for both the air- and ground-surveillance radars.
3. The enterprises, which are not included in the project, are accusing the decision makers for making noncompetitive bidding. (Wall, Robert. "Challenges Mount for Surveillance Aircraft", Aviation Week & Space Technology, 26 August 2002, Issue 9)

The MC2A program seems to be implemented under three steps or so-called *spirals:*

Spiral 1: Upgrade to the 767 platform. The major change would be to shift from a 707 platform to the 767. This step will be led by Northrop Grumman and Raytheon.

Spiral 2: The common wide-body ISR program would add the E-3 airborne battle management capability. Boeing is scheduled to lead this phase. If technically feasible, it will be in this step that the ability to see and track moving air targets, as well as ground targets, will be integrated.

Spiral 3: A signals collection and intelligence function will be added to the MC2A. In this case, Raytheon will lead this successor to the Rivet Joint. However, this step is not as clear and defined as former two steps yet.

It is also reported that how many of the MC2A be produced has not been decided yet and will be clear after the tests and evaluations finished (Airforce Magazine Online: Nov 2002, Vol 85, No 11).

2.1.1 Current ISR and C2 Fleet

In this section, the general characteristics of the current platforms will be reviewed. Following is the brief summary of the current fleets' missions and specifications that are going to be replaced by MC2A:

2.1.1.1 E-3 Sentry (AWACS)

The E-3 Sentry is an Airborne Warning and Control System aircraft that provides all-weather surveillance, command, control and communications for both tactical and air defense forces.

The E-3 system is carried onboard by a militarized version of the Boeing 707-320B commercial jetliner. It is distinguished by the addition of a large, rotating rotodome that houses its radar antenna and identification friend-or-foe (IFF) and data-link fighter-control (TADIL-C) antennas. The rotating radar dome is held 14 feet (4.2 meters) above the fuselage by two struts. The dome is 30 feet (9.1 meters) in diameter and 6 ft (1.8 meters) thick. It contains a radar subsystem that enables the aircraft to perform air, ground and even water surveillance. At operational altitudes, the radar has 360-degree view of the horizon and a range of 250 miles (375.5 kilometers) for low-flying objects and a larger range for the higher-flying targets. The radar's IFF subsystem can detect the enemy forces by eliminating the obstacles caused by the ground contours that could easily confuse other radars systems. Figure 2-2 shows the detailed sensors and equipment placement of E-3 AWACS.

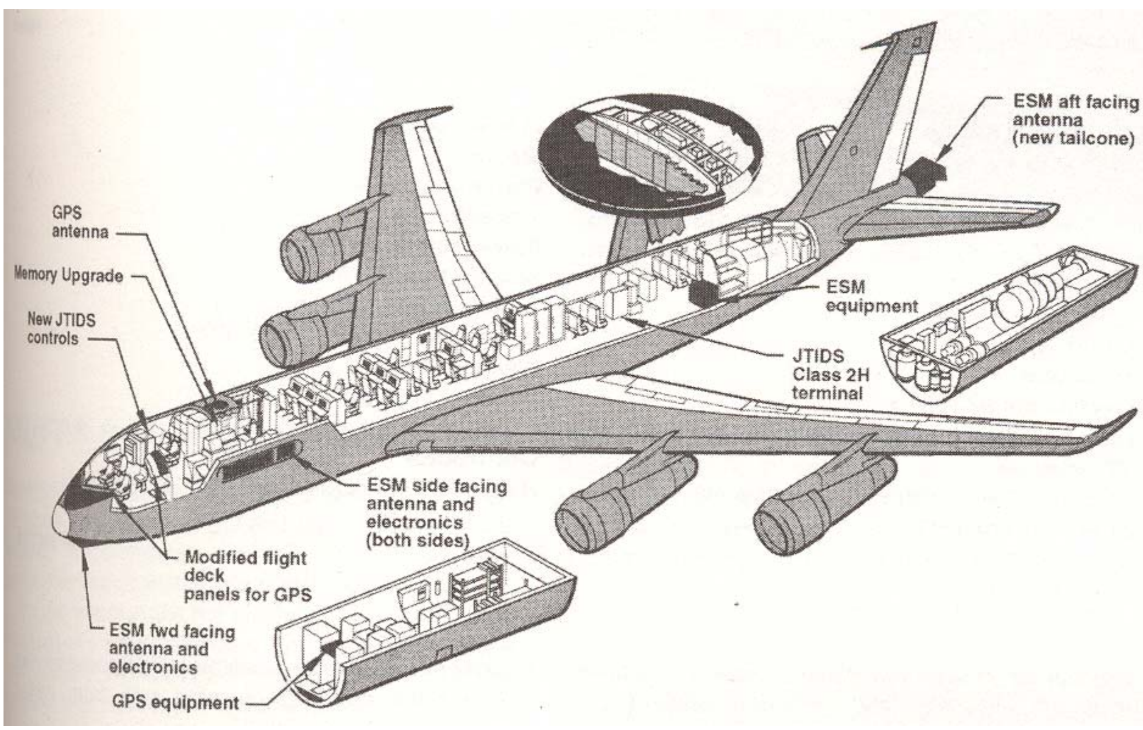


Figure 2-2: E-3 Sentry AWACS (Jane's C4I Systems, 1996)

The AWACS houses either AN/APY-1 or AN/APY-2 airborne warning and control radars. Actually, APY-1 and 2 are generally similar with the primary difference being the APY-2's full maritime research capability. The radars have six operating modes together with a radar technician controlled test and maintenance format.

The slotted planar-array antenna is located inside the rotodome. The radar receivers and processors are housed in the center of the aircraft cabin, and the radar transmitter is located in the lower cargo bay to the rear on the main cargo floor. The maritime capable radar weighs around 3629 kg and consists of 12 components group (Jane's Avionics, 2001-2002, 2001). Some known details of those components are as follows:

- Radar Control and Maintenance Panel (RCMP): Located in the main cabin, RCMP houses the radar's on\off control and radar technician's systems access keyboard.
- Radar Synchronizer: Mounted in the main cabin, software controlled synchronizer generates all the radar's timing signals and maintains stability.
- Stable Local Oscillator (STALO): Located in the main cabin, STALO generates radio signals for transmission and reception. It is also the system's central clock and serves as a bridge between a signal generator, system clocks, and a clutter oscillator.
- Transmitter Group: Mounted beneath the rear section of the main cabin, the transmitter group consists of 21 elements put into 8 pressurized containers. An

overhead rail system permits easy removal of the transmitter. Some of the known elements are listed below:

- High Voltage Power Supply (HVPS): The HVPS converts input prime power into high voltage and includes a 90kV transformer, filter and regulators.
- Transmit Electronics:
- Rotary Coupler (RC): The RC provides circuit continuity between the rotodome electronics and the cabin.
- Phase Control Electronics (PCE): The PCE is mounted in the rotodome and receives orders from the radar's computer to scan or stabilize the beam.
- Antenna Array (AA): Housed in the rotodome. The radar transmission array is located back-to-back with an IFF/SSR (Identification Friend or Foe / Secondary Surveillance Radar) aerial with the whole assembly. The AA consists of 30 slotted sticks and measures 7.3m x 1.5 m.
- Microwave Receiver (MR): MR is located in the rotodome and includes three channels.
- Analogue Receiver (AR): It is located in the main cabin of the aircraft. To convert the received Doppler signals from analogue to digital format is one of the several tasks that AR carries out.
- Maritime Processor (MP): It is used in the over-water missions and also located in the cabin.

- Digital Doppler Processor (DDP): DDP is located in the aircraft's main cabin and outputs digital detection data to the RDC.
- Radar Data Correlator (RDC): RDC processes all target and status data and provides central computer and RCMP with these data. It also controls the radar's internal functions including self-test performance measurement. It is located in the cabin of the aircraft (Streely, 1999).

The design of the rotodome and the antenna provides great advantages to E-3 AWACS. The low antenna sidelobes minimize the side-lobe clutter and increase the resistance to jamming. The only way the antenna to be affected by jamming is that it is directly pointed to the source of jamming. Another feature of the radar, which is the fact that it can shift to another radar frequency that is not affected at that time, ensures the E-3 to operate effectively under electronic countermeasures. However, simultaneous use of two or more E-3 aircraft enhances the overall system effectiveness against jammers.

The phase shifters, phase-control electronics and, receiver protectors and receiver paramplifiers mounted on the back of the antenna inside the dome. The phase shifters located in the one side of the antenna and the electronics on the other side for weight balance and easy access during maintenance.

The high-power transmitter chain is completely redundant with an in-flight switchover capability in case of a malfunction. This redundancy in transmitter group along with other overall system redundancies provides a high reliability to E-3 aircraft.

Built-in test continually monitors radar operation under control of radar computer software. The radar demonstrated a 98.5 percent probability of detecting online faults.

The E-3 fleet was upgraded in recent years with Electronic Support Measure (ESM) for passive detection, Joint Tactical Information System (JTIDS) for secure communication and Global Positioning System (GPS) for precise global positioning.

The radar and other surveillance subsystems can gather simultaneous data including the position, heading and the identification of the target. During the course of any crises or a war, the data can be directly forwarded to any command and control center or to the president and secretary of the United States.

The layout of the equipment in the fuselage is arranged in bays with areas allocated for communications, signal and data processing, command and control consoles, navigation and target identification systems. The signal and data processing is carried out on a high-speed powerful CC-2E central computer

The aircraft is equipped with 14 command and control consoles fitted with high-resolution color displays. Console operators can perform surveillance, identification, weapons control, battle management and communication tasks on the consoles that display the processed data on video screens.

Four Pratt and Whitney TF-33-PW- 100/100A turbofan, 21,000-pound-thrust jet engines, which are mounted in pods under the wings, power the USA and NATO E-3 AWACS aircraft. The fuel tanks located in the wings have a capacity of 90,500 liters.

The aircraft has in-flight refueling capability that increases its range. General specifications of AWACS are listed in Table 2-1.

Function	Airborne surveillance and C3
Thrust	24,000 lb.
Powerplant	Four TF-33-PW-1 00 A turbofan engines
Thrust	21,000 lb
Dimensions:	
Wingspan	44.43 m (130 ft 10 in)
Length	46.62 m (145 ft 6 in)
Height with Rotodome	12.5 m (41 ft 9 in)
Rotodome diameter	9.1 m (30 ft)
Rotodome thickness	1.8 m (6 ft)
Rotodome height above fuselage	3.35 m (11 ft)
Wing Area	283.4m^2
Speed	More than 500 mph (800 km/h) Optimum Cruise 360mph (Mach 0.48)
Aircraft Ceiling	more than 8788 m (29,000 ft)
Endurance	more than 8 hr (unrefueled)
Range	more than 9,250 km (5,000 n.mi)
Unit Cost	$123.4 million(fiscal 98 constant dollars)
Maximum Take-off Weight	156,150 kg (347,000 lb)
Armament	None.
Crew	
Flight Crew	4
Mission Crew	13-19 specialists (varies according to mission)
Inventory	Active force 33, Reserve 0, Coast Guard 0

Table 2-1: AWACS Specifications (http://www.af.mil/factsheet/AWACS html, 2002)

A key element to synchronizing data is the Boeing-developed interface adaptor. This adaptor provides a common time reference for use throughout the system and interconnects the radar, IFF/SSR, avionics, navigation and guidance instruments and display and control subsystems.

Boeing offered a modified 767 commercial jetliner as the new platform for the system. The 767 provides several advantages over the 707. Because of its larger body, 767 has around 50% more floor space and nearly twice the volume of the 707. Additionally, its modernized engines provide a better fuel consumption performance. The Japanese Air Force received four of Boeing 767 AWACS in 2002 and some other countries like South Korea are seeking for purchasing the platform.

2.1.1.2 Joint Surveillance and Target Attack Radar System (JSTARS)

The Joint Surveillance and Target Attack Radar System (JSTARS) is a long range, air-to-ground surveillance and battle management system that is capable of looking inside the enemy territory and tracking the hostile movements. It is actually a joint development project of the US Air Force and the Army.

JSTARS provides ground situation information through communication via secure data links to the Air Force command posts, the Army mobile ground stations and centers of military analysis far from the point of conflict. JSTARS offers a picture of the ground situation equivalent to that of the air situation provided by AWACS. JSTARS is capable of determining the direction, speed and patterns of military activity of ground vehicles and helicopters.

The JSTARS, which is also designated as E-8C, is a militarized version of the Boeing 707-300 commercial aircraft. It is powered by four Pratt and Whitney JT3D-3B turbojet engines, each providing 18,000 lb of thrust. It has a flight endurance of 11 hr or 20 hr with in-flight refueling.

The aircraft is equipped with the 24 ft diameter AN/APY-3 radar installed in canoe shaped radome under forward fuselage behind the nose landing gear. It is mechanically revolved and pointed to scan in elevation. It scans electronically in azimuth to determine the location and heading of moving targets. The radar is capable of looking deep into potentially hostile regions to detect, locate, classify, and track a variety of targets.

JSTARS comprises an airborne segment together with a big number of Ground Station Modules that receive real-time data from the airborne platform. On a standard mission, the aircraft has a crew of 21 with three flight crew and 18 systems operators. On a long endurance mission, the aircraft has a crew of 34, with 6 flight crew and 28 system operators. Figure 2-3 and Figure 2-4 display two different interior layout alternatives of JSTARS.

JSTARS has 17 operations consoles and 1 navigation/self-defense console. A console operator can carry out sector search focusing on smaller sectors and automatically track selected targets. There is a rest area within the aircraft to maintain the high personnel performance during the long missions.

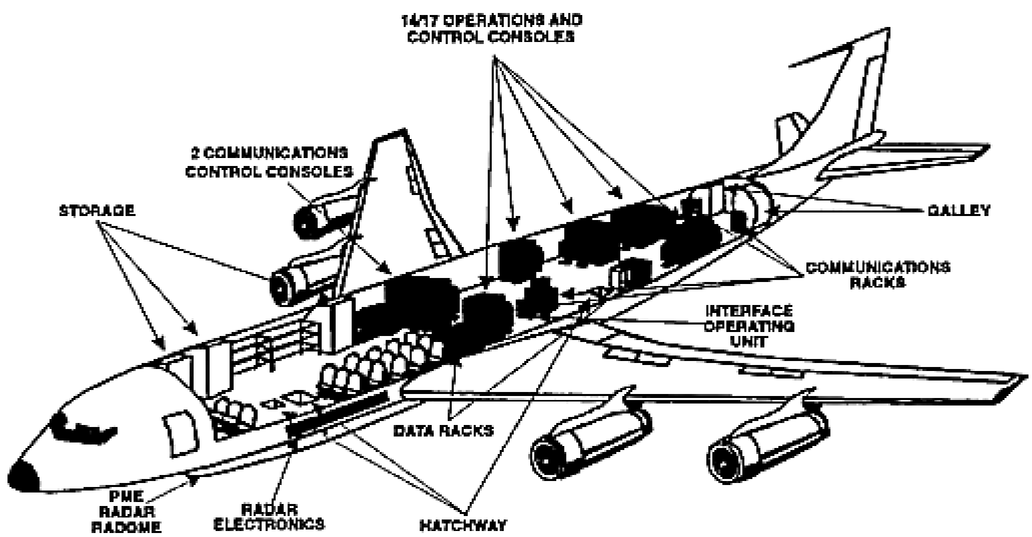


Figure 2-3: Configuration of Interior of JSTARS (www.fas.org/doddir/fm34-25-1)

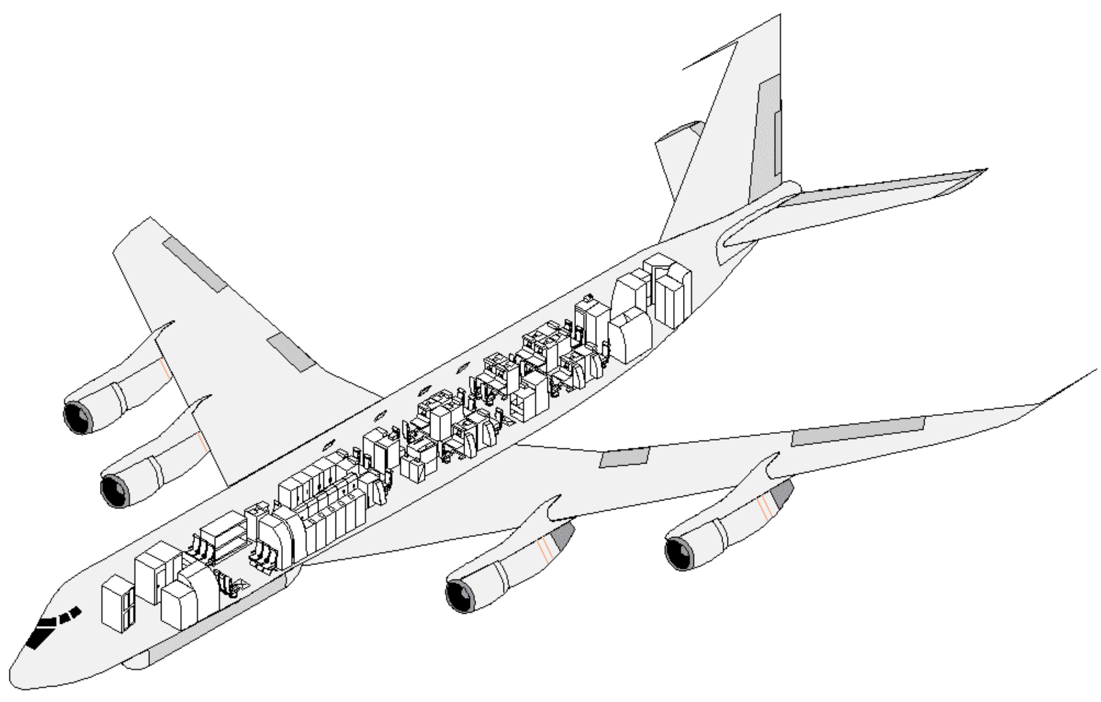


Figure 2-4: Alternative JSTARS Interior Layout (www.fas.org)

The crew generally conducts the missions in coordination with a variety of other command, control and communications, and intelligence (C3I) and sensor platforms, weapons systems and ground C4I nodes. The crew can access the radar data in real-time on their consoles. They can also perform history playback, construct Synthetic Aperture Radar (SAR) mosaics, track targets, and perform target position predictions.

While the authorities do not confirm, it is suggested that JSTARS configuration can scan a region of 1million km^2 between the altitudes of 9,144 and 12,192 meters during an 8-hour sortie (Streely, 1999).

Radar operating modes include:

- Moving Target Indicator / Wide Area Surveillance (MTI/WAS),
- Moving Target Indicator / Sector Search (MTI/SS),
- Synthetic Aperture Radar / Fixed Target Indicator (SAR/FTI).

The antenna can be twisted to either side of the aircraft where it can develop a 120-degree field of view covering nearly 19,305 square miles (50,000 km^2) and is capable of detecting targets at more than 250 km (820,000 ft) away. MTI is the prime mode that covers beyond a notional service area. SAR helps to identify possible assembly areas, command posts (CPs). In other words, fixed high value targets are detected through SAR.

Northrop Grumman was awarded with a US$14.5 million contract to upgrade the current AN/AP-3 radar in December 1998. The new much more powerful radar will be an electronically scanned 2-D X-band active aperture radar that will have also a helicopter detection mode and inverse synthetic aperture (ISAR) imaging capability, as well as the MTI mode, allowing real-time imaging of moving objects.

The E-8's Operations and Control (O&C) subsystem controls the radar. As a whole, the subsystem is built around a real-time, VAX-based, distributed processing architecture. This includes individual DEC ALPHA based digital processors at each of the aircraft's 18 Raytheon AXP-3000/500 workstations. The layout of the subsystem is so well organized that all operators can simultaneously access the needed data. Other elements of the O&C subsystem are believed to be Raytheon 920/866 supermini computers, three programmable signal processors, Miltope message printers and Interstate Electronics workstation color displays.

The aircraft have two JTIDS terminals used in communication with the air elements. JTIDS is a US joint service, jam-resistant, secure communication system. JTIDS terminals allow the interchange of tactical information between aircraft, ships, and land stations. The system offers situation awareness and a command and control capability that could never be imagined before. The voice communication needs are provided by a set of 12 encrypted UHF band, three encrypted VHF band and two encrypted HF band radios. A Single Channel Ground and Airborne System (SINCGARS) could also be accommodated by the E-8, but it is not confirmed (Rackham, 1996).

There are totally 13 JSTARS and three more will be delivered by 2004, and its unit cost is $244.4 million according to FY98. Table 2-2 summarizes the communication and radar subsystems while Table 2-3 displays general specifications of JSTARS (http:// www.af.mil/ factsheets/ JSTARS, April 13 2002).

Radar Subsystems	
Antenna	24-foot long, side-looking, phased array housed in radome
Processors	3 signal processors, each containing 5 high-speed, fixed point distributed processors
Operation and Control Subsystems	
Workstations	Seventeen identical workstations for operators; One navigation/self-defense workstation
Communications Subsystem	
Digital Data Links	Surveillance and control data link (SCDL) Joint Tactical Information Distribution System (JTIDS) Tactical Data Information Link-J (TADIL-J) Satellite Communications Link (SATCOM) Constant Source with joint tactical terminal (JTT).
Voice Communication	Twelve encrypted AN/ARC-l64/HAVE QUICK UHF radios Twelve UHF agile filters Twelve UHF crypto TSEC KY-58 Two encrypted HF radios (RT-1341 (V) 3/ARC 190) Two HF crypto Three encrypted RT-1300C VHF radios with SINCGARS Three VHF collocation filters, F-1613/A Three VHF crypto TSEC KY-58. Multiple intercom nets

Table 2-2: Subsystems of JSTARS

Aircraft	Boeing 707-300
Primary Function:	Ground Surveillance
Power Plant:	Four JT3D engines
Length:	152'11" (46.6 m);
Height:	42'6" (12.9 m);
Weight:	171,000 pounds (77,565 Kg)-- Empty 155,000 pounds (70,307 Kg)-- Max Fuel 336,000 pounds (152,408 Kg)-- Max Gross
Wingspan:	145'9" (44.4 m);
Speed:	.84 Mach
Service ceiling	42,000 feet
Range:	11 hours -- 20 hours with air refueling
Crew-Standard mission Long endurance	21 comprising 18 operators and 3 flight crew 34 comprising 28 operators and 6 flight crew

Table 2-3: JSTARS Technical Characteristics (http\\www.fas.org)

2.1.1.3 Rivet Joint

The Rivet Joint surveillance aircraft are equipped with an extensive array of sophisticated intelligence gathering equipment enabling military specialists to monitor the electronic activity of the adversaries. Also known as "RJ", the aircraft has been widely used in the 1990's during the operation Desert Storm, the occupation of Haiti, and over Bosnia.

Using automated and manual equipment, electronic and intelligence specialists can precisely locate, record and analyze much of what is being done in the electromagnetic spectrum. The fleet of 14 RC-135 RIVET JOINT aircraft increased to 15 in late 1999 with the addition of a converted C-135B.

The interior seats 32 people, including the cockpit crew, electronic warfare officers, intelligence operators and in-flight maintenance technicians. Table 2-4 shows the specifications of the Rivet Joint.

Primary Function:	Reconnaissance
Contractor:	L3 Communications
Power Plant:	Four CFM 56-2B-1 engines
Length:	135 feet (41.1 meters)
Height:	42'6" (12.9 m);
Max. Takeoff Weight:	322,500 pounds (146,284 kilograms)
Wingspan:	131 feet (39.9 meters)
Speed:	500+ miles per hour (Mach.66)
Service Altitude:	28,000 ft
Crew:	5 flight + 21-to 27 mission crew according to the mission
Inventory:	Active force, 17

Table 2-4: Rivet Joint Specifications

The aircraft has secure UHF, VHF, HF and SATCOM communications. The information can be transferred to AWACS via TADIL/A, satellite and Tactical Information Broadcast Service (TIBS), which is nearly a real-time information broadcast. Rivet Joint fleet is structurally the best in shape of all the big ISR platforms which could be considered a reason its mission would be the last to be migrated to the MC2A. (Airforce Magazine Online: Nov 2002, Vol 85, No 11)

The Rivet Joint has been under an upgrade program called Block 7 including an engine and 17 sensor modernizations. Following is the summary of the Block 7 upgrade:

- More powerful CFM 56-2B-1 engines
- Increased endurance and maximum takeoff weight, reduced takeoff roll,
- Track Management Processor occupying less space with a better performance.
- ELINT Signal Processor,
- New full-color 19inch displays,
- Common Data and Retrieval System having a new, smaller, and high-capacity storage system,
- Multiple Communications Emitter Location System replacing existing direction-finding system with a smaller and more powerful commercial off-the-shelf (COTS) processor providing increased accuracy in geolocationing,
- Background Search System offering increased speed,
- Beamformer Processor which is ready for a full integration,

- New Search Database Processor as a replacement of the former one which couldn't handle the dense airborne signal environments,
- Operator Productivity Enhancements including new workstations with new mouse and better lighting,
- ETD 100 Integration which switches the communication controls from manual operations to new workstations,
- Video Display Improvements,
- ELINT Enhancements added VHF/UHF direction-finding improvements,
- NSA Subsystem Integration

Other than those developments mentioned above, four airborne integrated terminal group radios are integrated and two JTIDS improvements have been performed concerning upgrade of the system to TADIL-J.

Figure 2-5 shows the layout of the antennas on the body. Unfortunately, the recognized bulk shaped antenna located in the nose is not identified on the open literature. The antennas, which are located at the top of the fuselage including the tail, are such arranged that they provide an accuracy of 120° field of view in targeting. Additionally, these antennas are positioned in a way that aircraft's wings do not blank signals from the ground during the turns (Fulghum, David A. "Crew Positions Reconfigured for Long, Complex Flights", *Aviation Week & Space Technology*, 25 Nov 2002: 59-61).

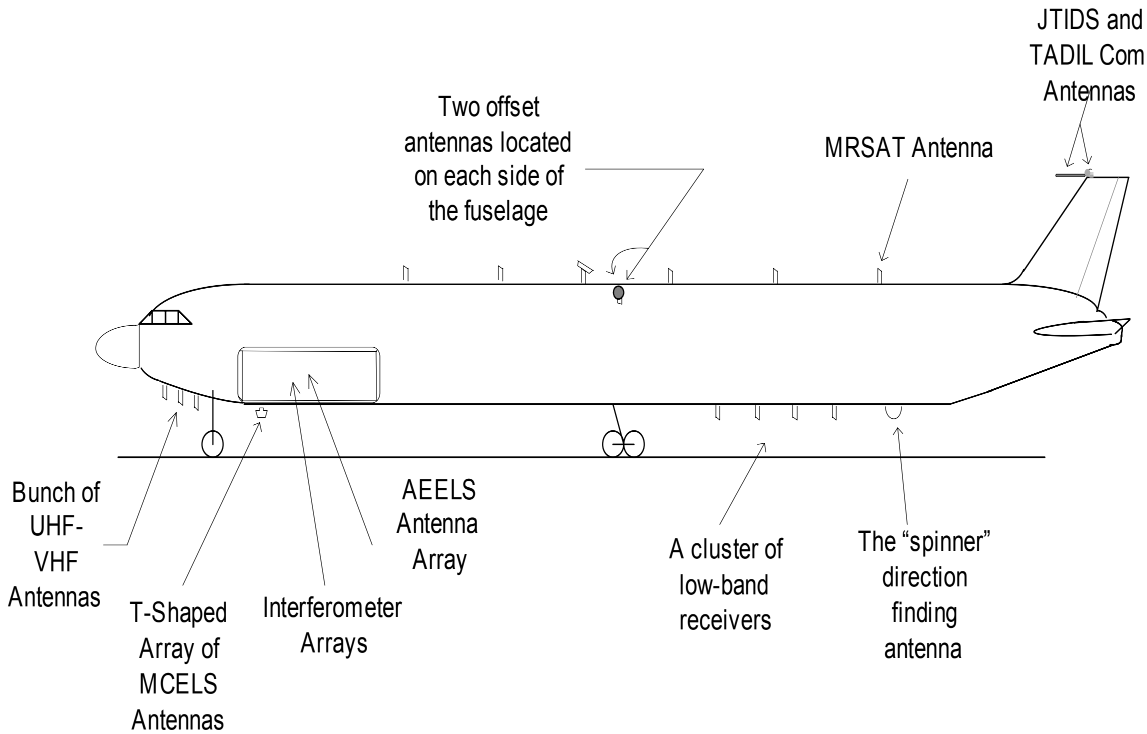


Figure 2-5 RIVET JOINT Antenna Layout

2.1.1.4 Airborne Battlefield Command and Control Center (ABCCC)

The ABCCC is a C-130 based Airborne Command and Control Airplane designed to carry USC-48 Airborne Command and Control Capsules onboard. 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).

The ABCCC consists of four major subsystems: The Communications Subsystem (CS), the Tactical Management Subsystem (TBMS), the Airborne Maintenance Subsystem (AMS) and the Capsule Subsystem (CS).

The CS and its Automated Communications and Intercom Distribution System (ACIDS) monitors and ensures the security of all communications between the capsule and other aircraft and bases along with the communication within the capsule. The TBMS provides battle management capabilities for up to 12 consoles stationed in the CS. Finally, the Capsule Subsystem consists of the physical and environmental support for operating subsystems (Jane's Avionics, 2001-2002, 2001).

The aircraft have two HF radio probes towards the tips of the both wings, three mushroom shaped antennas on the top, and numerous antennas on the belly. The aircraft's length is 40 ft and it weighs around 20000 lb. There are 23 totally secure radios, secure teletype and 15 computerized consoles inside the platform. Additionally, ABCCC is equipped with the JTIDS. Totally 7 ABCCC are in use and each costs around $9 million.

The battle staff is comprised of four functional areas: command, operations, intelligence, and communications. Normally, it includes 12 members working in 9 different specialties.

The USAF is planning to retire the fleet of seven EC-130E (ABCCC) aircraft that costs more than $100 million per year to operate in FY03 and to transfer their missions to the AWACS and the JSTARS aircrafts. The ABCCC has been used for especially providing close air support to the Army over a conflict area. It also has provided a communications link between the ground commanders and air operations centers.

However, especially the developments in the satellite communications and other improvements over the AWACS and JSTARS' battle management capability have somewhat outdated the ABCCC. Some specialized equipment will be mounted on the AWACS and JSTARS in order to offset the missions of the ABCCC (http:// www.af.mil/ factsheets/ ABCCC, April 13 2002).

2.1.1.5 Compass Call

Compass Call is a modified version of Lockheed corporation's C-130 Hercules aircraft arranged to carry out tactical command, control and communications countermeasures (C3CM). Targeting command and control systems provides commanders with a huge advantage before and during the air operation. The fleet provides disruptive communications jamming and other unique capabilities to support the joint force commander across the spectrum of conflict. At the back of the plane is a set of microwave-powered equipment that sends out high-energy radio frequency output or interference.

All new hardware and five-fold improved software, which includes over one million lines of computer code, have produced the usual minor bugs that always seem to appear with new technology improvements. One common problem is the failure of the built-in self-test. The main issue related to the hardware is the shortage of the spare parts and components caused by the budget cuts and appropriations.

The Compass Call aircraft carries a crew of 13 people. Four of those members are responsible for flight while others operate and maintain the mission equipment. The mission crew consists of an electronic warfare officer, an experienced cryptologist linguist, an acquisition operator, a high band operator, four analysis operators, and an airborne maintenance technician (http:// www.af.mil/ factsheets/ Compass Call, August 18 2002).

Some modifications are being made to the aircraft including an electronic countermeasures system (Rivet Fire), and air refueling capability. Rivet Fire has demonstrated its powerful effect on enemy command and control networks in Panama and Iraq. It is understood that the USAF is on the way to enable the system to jam more signals concurrently and at longer ranges. There are totally 13 Compass Call in active duty. Systems on the Compass Call include Raytheon Electronics ALQ-173 Blink Jammer, ALQ-175 High-Band Electronic Counter Measures (ECM) System and ALQ-198 high band systems with digitally tuned receivers (Jane's Avionics, 2001-2002, 2001).

The COMPASS CALL houses an extensive communication suite including three *Have Quick* capable UHF, one VHF, one SATCOM (KY-58) and two HF (KY-75 or ANDVT) radios. Have Quick radios provide high security, anti-jam capability, survivability, and the joint and combined interoperability implications with the help of their channel hopping capability. It is suggested that single channel radios could be easily jammed or monitored by a very sophisticated enemy (MacKenzie, 2000).

There is a tendency toward putting the role of Compass Call into Uninhabited Aerial Vehicles (UAV) and space systems so that communications intelligence tasks could be executed in a more effective manner. MMA will certainly play a key role in commanding those jamming systems.

2.1.2 Uninhabited Aerial Vehicles (UAVs)

Concept of unmanned aircraft has been a part of aviation since before the Wright Brothers. In fact, although there had been several realistic models before 1903, Wright Bros are distinguished from early other initiators in such a way that their flight was the first controlled inhabited one.

The term *unmanned* entails that a person is not flying the aircraft. However, an unmanned aircraft has actually a pilot or operator on the ground. That's why a more correct term *uninhabited* is more commonly used in the literature. Previous terms such as *drone*, *pilotless* and *remotely piloted* have been left in the past and people prefer calling those aircraft as UAVs, which means unmanned or uninhabited aerial aircraft.

UAVs are self-piloted or remotely piloted aircraft that can carry cameras, communication equipment, sensors and other payload regarding to the mission type they perform. They have been used for reconnaissance and surveillance purposes since 1950s. Moreover, UAVs are planned to carry out even tougher missions.

Having many UAV projects deterred because of high cost and lack of technology during the period after 1950s, they were considered as surveillance aircraft for Close Range, Short Range, and Endurance categories by the early 1990s. Close Range was commonly defined as up to 50 kilometers while Short Range was defined to be within 200 kilometers. Finally, any range beyond 200 kilometers was considered as Endurance.

During the following years, close and short-range definitions were combined and a different category came out as Shipboard. At present, these aircraft are categorized into two classes, which are Tactical UAV and Endurance. Additionally, each of these two categories is divided into high and low-altitude subcategories.

Currently, there are tens of ongoing UAV development studies all over the world. Both propeller and jet engines have been selected by various numbers of unmanned aircraft. Needles to say, the ones with the prop-powered engines have considerably lower speed than the others do.

There is a great effort on developing UAVs all around the world especially in the recent years. They are preferred maybe because they provide the commanders with very valuable data in a cheaper way than the conventional ISR platforms just because they are easily portable or they diminish the odds for casualties. However, it is apparent that a long-endurance UAV can go where others cannot and send back many data.

A very simple version of UAVs is being used as a flying target to the fighters or SHORAD (Short Range Air Defense) units during air-to-air or surface-to-air missile exercises. The aircraft in question are not equipped with any specific mission equipment such that they can be easily sacrificed.

Design of a UAV is much similar to design of any other aircraft, yet with some additional considerations especially in terms of takeoff and landing. Besides, the special avionics and systems for uninhabited flight should be taken into consideration.

There are many takeoff options including usual wheeled takeoff, via a launching rail, air or car launching, boosted vertical launch, and several others. Analogously, some landing options are as wheels, skids, parachutes, airbags and none; that is, letting it fly forever or crash. Trade studies should be done in order to choose between these alternatives.

In fact, removing the crew from design requirements would not provide so much reduction in required weight and cost. On the other hand, it would allow us loosen the reliability and structural limitations, which have been set significantly high for inhabited flight. It also allows the designers to get rid of some redundancies, which are also taken into account for manned aircraft design. On the contrary, safety of ground personnel emerges as an issue that should be considered.

With modern computer and guidance capabilities, the UAVs will certainly perform a wide variety of tactical tasks including dropping bombs and even air-to-air dogfighting. In this way, advanced tactical UAVs loaded with conventional bombs and missiles would be programmed or leaded to attack to any specific target.

If UAVs could be equipped with adequate payload, they could perform air-to-air combat. The most significant asset of this improvement would be the fact that it would give an end to the possibility of pilot casualties. That does not mean that there will be no inhabited aircraft in the future. However, it is apparent that UAVs will replace most of the missions that have been done by the pilots. Those aircraft could do such maneuvers that a pilot could not because of the enormous g-force that is intolerable for a human being.

Use of satellite communications is one of the greatest aspects of UAV concept. A UAV sneaking over an area of interest could instantly inform missile launches, adversaries' interferences or hostile settlements via satellite communication links. The fact that it could fly at low or high altitudes gives these aircraft the capability of carry out missions without being tracked by the adversaries' detectors. Even if they crash during a very low-altitude flight, the loss is tolerable in comparison with a $20 million fighter jet along with its pilot.

A basic UAV platform consists of one or more aircraft, one ground control station, one ground control terminal, and ground support equipment. Several uplink and downlink data links establish the full duplex communication between the aircraft and the ground control station.

In this section, only two of those UAVs will be examined below although there are tens of others under development.

2.1.2.1 RQ-1A Predator

The RQ-1 Predator is a medium-altitude, long-endurance uninhabited aerial vehicle system that provides reconnaissance, surveillance and target acquisition support under the order of the Joint Forces Air Component Commander. The aircraft is fully autonomous but could be reprogrammed during the course of mission or remotely piloted (Munson, 2000).

Predator is a system including four aircraft, a ground control station, a satellite link and 55 people serving 24 hours a day. The crew, consisting of one pilot and two sensor operators fly the aircraft from the ground control station via satellite link. The aircraft carries one day-use camera, one infrared camera and one synthetic aperture radar. However, those sensors could not be controlled simultaneously. In the future, the Predator is intended to be equipped with a Multispectral Targeting System and an anti-tank missile. Each aircraft can be separated into pieces and deployed easily to any area of interest by the cargo aircrafts.

The aircraft has a range of 454 miles and a ceiling of 25000 ft. Its maximum takeoff weight is 1020kg and it can carry up to 204kg of payload. Unit cost is $40 million in 1998 dollars. There are totally 48 Predators all in active duty. It showed its asset by performing successful tasks over Bosnia and Kosovo theatre. It was also employed during the exercises performed in the recent years such as Southern Watch (1999), Allied Force (1999) and Enduring Freedom (2001). Test flights of the Predator have been performed at Wright Patterson AFB, Dayton, Ohio and it reached 50000 flight hours that is considered as a major milestone. The predator is intended to receive data and be controlled from the proposed MC2A platform. (ACC Public Affairs Office. "RQ-1 Predator". Excerpt from the article http: // www.langley.af.mil / factsheets / RQ-1 Predator, May 2002).

2.1.2.2 The Global Hawk

The Global Hawk is an intelligence, surveillance and reconnaissance UAV that can provide high quality images by flying at high altitudes. It can perform a full mission from taxi to landing once the mission parameters are programmed. At present, it is performing the test flights successfully.

The Mission Control Element, which generally consists of four people, guides the Global Hawk. The ground segment can control up to three air vehicles simultaneously.

On April 2000, Global Hawk attended two exercises; one of them was a long-range flight. It flew 7,500 miles nonstop across the Pacific to Australia on April 22 2001, setting new world records for UAV endurance.

During a typical mission, the aircraft can fly 1,200 miles to an area of interest and remain on station for 24 hours. Global Hawk weighs approximately 25,600 pounds (11,612 kg) when fully fueled. Most of its components are made up of lightweight, strong composite materials. It is still in the development phase conducted by several contractors (http:// www.af.mil/ factsheets/ The Global Hawk Unmanned Aerial Vehicle, Feb 2002).

MMA concept could utilize Global Hawk for surveillance and intelligence purposes with the help of its 42-hour maximum endurance time and 635 km/h loiter speed. Northrop Grumman company officials state that the Global Hawk could provide enhanced capabilities by reducing the number of MMAs needed, and eliminating crew exposure to threats, yet in a more cost efficient way (Erwin, 2001).

2.1.3 Candidate Aircraft

2.1.3.1 Boeing 767-400ER

Boeing 767-400ER Extended Range is the aircraft that seems to be the main platform for MMA although it has not been declared yet. A team of designers from the

Boeing and former McDonnell Douglas Aircraft Company performed studies of design improvements in order to meet the customer needs.

Many capacity and performance improvements have been implemented to Boeing 767-400ER differing from the earlier 767-300ER fleet including takeoff payload capability, passenger capacity, interiors, rotation capability, flight deck, electrical power system, engines, performance, and corrosion control.

Boeing 767-400ER has the maximum takeoff weight of 450,000lb (204,120kg) which is 38,000lb (17240kg) greater than that of the 767-300ER. This is attained by increasing the fuselage length and wingspan of the aircraft. This enhancement allows the aircraft to carry additional passengers and payload.

The larger tanks are located in the bulk cargo compartment area and the available bulk cargo capacity is reduced to 9.77m^3 (345 ft^3) which is balanced by adding that reduction to the forward and aft cargo compartments. The aircraft has an increased cargo capacity of 139m^3 (4905ft^3) as a result of these adjustments in the cargo compartments.

The air-conditioning system has been upgraded to a more reliable digital bleed system that provides better cooling and ventilation.

The stretched fuselage caused some downsides on the aircraft's performance characteristics during the takeoff and landing. These problems have been solved by switching to all-new landing gears that are also strengthened for considerably heavy 767-400ER. A shorter tailskid has also been added which eventually offers up to a 1000lb (455kg) additional payload capacity when departing from obstacle limited airports.

A new electrical power system provides a considerably enhanced supply for the operators and passengers. The 120kVA AC integrated drive generators (IDG) has been mounted along with reasonably powerful Honeywell 331-400 Auxiliary Power Units (APU). The aircraft is available with two engine types; Pratt Whitney PW4062 or General Electric CF6-80C2B7F1. Additionally, another version of General Electric B8F is available which offers an increased thrust. Newly installed swept-back wingtips reduce the fuel consumption and takeoff field length and increase aircraft's climb performance.

Boeing Company announces that the systematic weight management resulted in an 8000lb (3630kg) reduction in gross weight in spite of increases in the fuselage length and wingspan. Some basic definitions used in the tables are as follows:

Maximum Design Taxi Weight (MTW): Maximum weight for ground maneuvers as limited by the aircraft structural characteristics and airworthiness requirements. It includes maximum takeoff weight and the fuel needed for start-up.

Maximum Design Landing Weight (MLW): Maximum allowed weight for landing as limited aircraft's structure and airworthiness.

Maximum Design Takeoff Weight (MTOW): Maximum weight at the start of the takeoff run.

Operating Empty Weight (OEW): Briefly, it is the weight excluding the usable fuel and the payload weight. More specifically, it includes the structure, engines, personnel, unusable fuel and other propulsion liquids and equipment that are considered an integrated part of the aircraft configuration.

Maximum Design Zero Fuel Weight (MZFW): Maximum weight just before the usable weight is loaded into the aircraft.

Maximum Payload: Maximum Design Zero Fuel Weight minus Operational Empty Weight.

Maximum Cargo Volume: Maximum space available for cargo.

Usable Fuel: Fuel available for propulsion.

Table 2-5 gives basic dimensions of Boeing 767-400ER including modified cabin floor area and volume. Estimations of those specifications will be explained in the volume analysis section of Chapter 3. Most of the dimensions are available at *http//www.boeing.com* and *Jane's All the World's Aircraft*, *2001-2002*. However, the items that are not clearly defined in the open sources are estimated by utilizing relations between similar types of equipment in the 767 family for which open sources info is available. Estimated data are marked with (*) in the tables. The estimations will be further explained in the related parts of Chapter 3. In the remaining part of this thesis study, those specifications will be considered as the baseline in every calculations and comments.

Dimensions: External Wing Span Overall Length Fuselage Length Fuselage Max Width Tail Height Wing Aspect Ratio	 170 ft 7 in (51.99 m) 201 ft 4 in (61.4 m) 197 ft (60.07 m) 16 ft 16 in (5.03 m) 55 ft 4 in (16.8 m) 9.3
Interior(Excluding Flight Deck) Width Length*(from front door to aft door) Height Floor Area* Volume* Bulk Cargo Hold Volume Total Cargo Volume	 15 ft 6 in (4.72 m) 143 ft 6 in(43.80 m) 9 ft 5 in (2.87 m) 2637.2 ft^2 (245 m^2) 18787.4 ft^3 (532 m^3) 345 ft^3 (9.77 m^3) 4905 ft^3 (138.9m^3)
Wing Area	3129 ft^2 (290.70 m^2)[1]

[1] Modified by the writer

Table 2-5: Technical Characteristics of Boeing 767-400ER

Table 2-6 is a performance summary of Boeing 767-400ER (http\\www. boeing.com \commercial\767family\767-400ER\characterictics, Nov 2000).

The Auxiliary Power Unit installed onto Boeing 767-400ER is Honeywell 331-400 APU that delivers up to 120kVA. It is more powerful than the ones installed onto the former 767 fleet. Considering that the power supply will be a major concern in MMA concept, some tradeoffs will be implemented in Chapter 3.

Typical Mission Rules		Basic PW4062	Max. PW4062	Basic CF6-80C2B7F1	Max. CF6-80C2B8F
Sea level takeoff thrust/ flat rated temperature	lb/°F lb/°C	63,300/86 63,300/30	63,300/86 63,300/30	62,100/86 62,100/30	63,500/86 63,500/30
Max. taxi weight	lb kg	401,000 181,890	451,000 201,570	401,000 181,890	451,000 204,570
Max. takeoff weight	lb kg	400,000 181,440	450,000 204,120	400,000 181,440	450,000 204,120
Max. landing weight	lb kg	350,000 158,760	350,000 158,760	350,000 158,760	350,000 158,760
Max. zero fuel weight	lb kg	330,000 149,685	330,000 149,685	330,000 149,685	330,000 149,685
Operating empty weight	lb kg	227,400 103,145	227,400 103,145	227,300 103,100	227,300 103,100
Fuel Capacity	gal. liter	24,140 91,377	24,140 91,377	24,140 91,377	24,140 91,377
Cargo, Pallets/Containers		5/18	5/18	5/18	5/18
Design range, MTOW, full passenger payload	nmi km	4260 7890	5585 10343	4315 7991	5625 10418
Takeoff field length(86°F) (30°C) Initial Cruise altitude (MTOW,ISA+10°C)	ft m ft m	8050 2454 34700 10577	11300 3444 32200 9815	8250 2515 34700 10577	11100 3383 32200 9815
Engine-out alt cap (MTOW,ISA+10°C)	ft m	15200 4633	8700 2650	14600 4450	9600 2926
Landing field length, MLW	ft m	5800 1768	5800 1768	5800 1768	5800 1768
Approach speed MLW (3000-nmi mission)	kn kn	149 136	149 136	149 136	149 136
Fuel burn/seat (3000-nmi mission)	lb kg	294.2 133.4	294.2 133.4	290.6 131.8	291.3 132.1

Table 2-6: Boeing 767-400ER Performance Summary

2.2 Systems Engineering Method and Tools

2.2.1 Hatley/Hruschka/Pirbhai (H/H/P) Methods

H/H/P Methods are basically architecture and requirements methods that have been widely used for almost two decades in system and software development. They are actually updated versions of the H/P methods that were developed in the past by Hatley, and Pirbhai.

The methods provide new approaches for effective development of systems of any size and complexity, especially those for which discrete modes of operation are a primary feature. It applies equally well to all technologies and provides a common language for developers in a wide variety of disciplines. This asset of the methods makes them suitable for our MMA design study of the multiple sensors and their multiple roles of operation.

Another important feature of the approach is the coexistence of the requirements and architecture models. The process keeps those two models separate but it records their continuing interrelationships. Other system development methods mostly automate only the requirements model excluding the architecture model (Hatley, Derek and others, *PSARE*, New York: Dorset House Publishing, 2000)

H/H/P Methods help the Systems Engineers to define the physical structure of their systems with representations of physical interconnects and the material, information, and energy passing through them.

The model considers every system comprising layered subsystems below and supersystems above. This layered arrangement can be utilized both in representing systems and in defining the systems development process. Every system has a set of essential requirements that will satisfy the needs. Systems produce outputs from received inputs in order to meet the needs of the environment. Those definitions could be stated as the principles of the H/H/P Methods.

The developers of the mentioned models explain their main principles of systems development as follows:

> To achieve the dependability and flexibility needed in the development of complex systems, all of the systems artifacts invoked by these principles must be represented separately, but with their relationships and interactions also represented. These artifacts include, at a minimum: the layered system structure and the relationships within it; the subsystems, supersystems, and their relationship; the essential requirements, the physical requirements, and their relationship; the information, material, and energy that travel into and out of the sub- and supersystems; the processing of that information, material and energy, and the links between the information, material, and energy, their processing and the sub- and supersystem.(Hatley and others, 2000)

The developer can transfer the models into a software tool that is prepared for systems development purposes. Several automated tools provide support for many features of the H/H/P methods. TurboCASE/Sys, which is the one used to build the MMA environment in this thesis, and Axiom/Sys could be listed as the two of those tools at the first glance. At this point, let us describe the requirements and architecture methods that form the H/H/P Methods. The bridging between these two models is also introduced in Figure 2-6.

2.2.1.1 The Requirements Method

This method combines the Structured Analysis (SA) method, and finite-state machine theory into a unified whole. Data processing is represented by data flow diagrams (DFDs), and the flow of control information is carried in a parallel structure of control flow diagrams (CFDs). Control specifications (CSPECs), including the finite state (FS) machine structures are introduced between those two flow diagrams. The finite state machines are used to control the behavior of the processes in the DFDs. This adds the model an important aspect missing in basic structured analysis. Besides, timing specifications called TSPECs represent the input-to-output timing relationships, and all the data is defined in a requirements dictionary. (Hatley and Pirbhai, 1987)

2.2.1.2 The Architecture Method

This method is an expansion and formalization of the engineering block diagram. Actually, it models the physical realization of the system. Architecture flow diagrams (AFDs) and architecture interconnect diagrams (AIDs) are used to provide this physical realization. These diagrams represent the physical modules that frame the system, the information flows and physical channels between the modules. The modules, flows, and channels are all meticulously defined in an architecture dictionary in a texture module.

The method includes an architecture template, which is used as a guide in adding derived requirements to the requirements model. The distribution of requirements to the architecture is represented graphically using Superbubbles on enhanced DFDs. Then, it is recorded through Traceability Matrices (Hatley and Pirbhai, 1987).

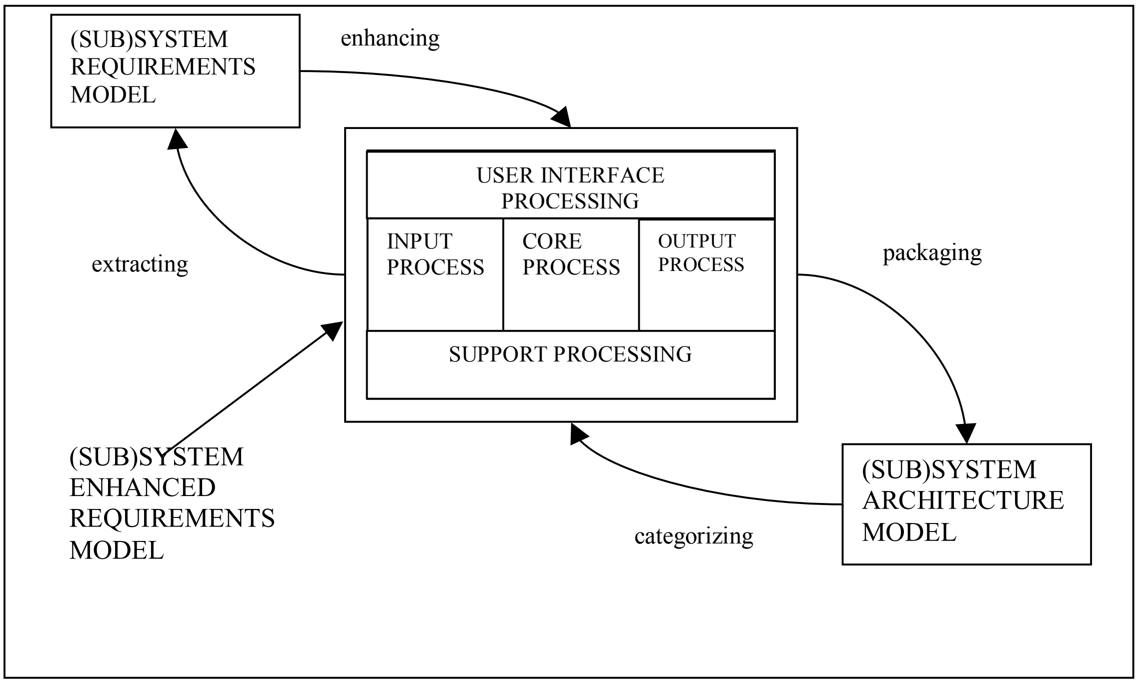


Figure 2-6: The Template Bridging Requirements and Architecture Models

2.2.1 TurboCase/Sys

TurboCASE/Sys is a fully functional system development tool that fully automates the system requirements and architecture methods developed by Derek Hatley and the late Imtiaz Pirbhai, including the latest advances in the methods. TurboCASE/Sys includes the following features:

- Enhanced requirements using the architecture template, supporting interface functions between architecture modules.
- Graphical allocation of requirements to architecture, using superbubbles.
- Requirements/architecture traceability through traceability matrices.
- Automatic creation of submodule requirements diagrams from the higher-level allocations

One can download the trial version of the TurboCASE/Sys™ from www.turbocase.com with a visual demo showing the features of the tool. However, there are some limitations on the trial and the student versions such as saving the program at most three times.

It is easy to use the context-sensitive pop up menus of the TurboCASE/Sys™. Information entered in one view can be used in another view. For instance, you never need to enter a name twice because you can search for it and double click on it to use. Because the tool is totally integrated, you can make changes globally if you want.

Requirements and architecture dictionaries are built in the manner of H/H/P Methods. Information in the dictionary is consistent with the diagrams. Furthermore, you can have the built model checked and make the necessary adjustments in order to ensure the overall consistency with the mother and child models.

The model can be controlled with either state transition diagrams or decision tables. From the requirements model, TurboCASE/Sys can turn it into an enhanced requirements model for the preparation of deciding the architecture of the system.

One can use the superbubbles to allocate architecture modules. The allocated superbubbles are integrated with the architecture modules in the architecture diagrams. It is also possible to model the bus (interconnect) structure using the Architecture Interconnect Diagrams. Type of the interconnections such as radio, LAN, and others could be selected and TurboCASE/Sys™ represents them with different symbols for convenience. For example, throttle linkage is shown as ++++++++. Moreover, TurboCASE/Sys maintains the traceability via traceability matrix for your architecture automatically. (Hatley and others, 2000)

Actually, once you learn the H/H/P Methods from the reference book cited above, you will easily get familiar with the tool. Additionally, real time systems covered in the book with TurboCASE/Sys™ is a great reference for the first time users of the tool.

3 METHODOLOGY

3.1 Systems Engineering Approach

Systems engineering generally focuses on the design of compound platforms that involve many individual subsystems. Systems engineers always have to keep the big picture in mind and should focus on both making sure that everything within a product properly works together and meets the customer's operational and support requirements.

Large-scale systems integration is generally seen as more of an organizational capability while systems engineering is viewed as a skill held by individuals. Consequently, large-scale systems integration entails the ability to manage many tasks that are needed to create a solution meeting the customer's needs. The result of large-scale systems integration can be a multifaceted product such as the MC2A platform, which is our subject.

Systems engineers should follow an elegant systems approach for designing a large-scale system. There are several ways to do this most of which differs in some ways. The most famous one of those is Hall's Methodology for Large Scale Systems that handles the design in seven steps. These seven steps help the systems engineers overcome the difficulties occurring during the design process.

Systems Engineering process is an iterative process utilized until all stakeholder needs are satisfied with a reliable design. Otherwise, further iteration(s) are to be performed by altering the methodology and the set of alternatives with the help of the information gathered on the former iterations.

In this thesis, mostly Hall's methodology will be employed by using some other helpful arguments. What I am going to do is to figure out whether an aircraft is appropriate for a particular set of missions in terms of payload issues. That's why I should also utilize some other processes in order to come up with an answer to those questions.

In spite of some downsides of utilizing Hall's methodology for our case, there are many helpful arguments within those steps. If we come up with that both of the alternatives are good enough to load equipment, or vice versa, then we have to choose the best alternative by fabricating MOEs in order to rank those alternatives. Needless to say, generated importance and weight values might not reflect the official view of the Air Force Staff. However, one could employ the process, which I have created, by using the real numbers and would probably end in reasonable conclusions.

Development of systems is divided into four phases by Hall. These phases comprise analysis and planning, preliminary design, detailed design and test, and production design. The seven steps aforesaid can be iteratively implemented within each four phases. Below, you will see the short descriptions of the Hall's Steps (Sage, 1997). Then the exploitation of these steps will be done beginning with the section 2 of this chapter.

Problem Definition:

Problem definition is the first step in the development of the program-planning phase. This step is very crucial since needs, alterables, constraints, scenario and some other vital descriptions that will shape the rest of the used methodology. The relationships between the products, for example between need and alterables, are visualized by interaction matrices. Actually, problem definition is a group activity held by the systems engineers, decision makers, and other engineers from the relevant disciplines. Documenting in this way makes the process neater helping the systems engineers to produce results that are more reasonable.

Value System Design (VSD)

This is the step in which the objectives are identified and ordered in a hierarchical manner. Additionally, needs, constraints and alterables are made related. A set of measures are defined in order to use in determining the achievability of the objectives. The ordering of those subjects is fulfilled by forming a subordinating matrix.

The set of objectives must serve as the standard by which the alternative solutions are evaluated. Since the established objectives are generally in conflict, some tradeoff studies should be conducted. Those tradeoffs are made on alternative sets of objectives and constraints.

These identified objectives should be validated by the costumer to ensure that the baseline represents what the costumer expects. This validation is attained by means of several activities before jumping to the next step.

System Synthesis

Systems Synthesis is the step performed in order to figure out the answers to the following questions:

- What are the alternative approaches for attaining each objective?
- How is each alternative described?

The answers to these questions are activities and the objectives, the activities and the constraints, and the activities measures and the objectives. Systems Synthesis is the activity in which all the elements are combined in order to convert the functional architecture to the physical architecture. The linkages of objectives, activities, objective measures, and activity measures cover the systems synthesis part of the program planning. Several helpful processes and methods can be used such as H\H\P Methods that are going to be employed in this thesis.

System Modeling and Analysis

The alternative System Models are introduced in this step after the iterations of the former steps. Although there might be several of them at the beginning, the models that are considered could be reduced in accordance with the costumer.

Decision Making

This is the step that the final proposed solution is introduced to the decision maker including the advantages and the disadvantages of the considered models based on certain criteria. Alternative solutions are also presented emphasizing assorted viewpoints.

Planning for Action

This step includes the implementation of the achieved solutions and documenting the process of development. Implementation involves reviewing the results of the iteration and making plans based on the results. After finishing the study, one should document everything possible so that the system could be sustained and the study could provide support for the future improvement studies. This is the step where the decision is made whether additional iterations are to be employed or giving an end to the study. It should also be noted that these two steps are going to be introduced in the Chapter 4 as a conclusion of the conducted analyses.

It is important to say that the intent of this study is to determine the design parameters and to design a tool useful for others to evaluate the different architectures. The writer will be looking at the aircraft as a new NATO aircraft comprised of the basic missions of the current U.S. platforms as the baseline. Overall goal is to provide the end users with a value system in which they can provide the correct measures and determine the best solution. This is due to the desire to accomplish an unclassified study to be used as a systems development educational tool.

3.2 Problem Definition

We need to identify the problem thoroughly in order to define the system satisfactorily under the Systems Engineering approach. The background and the problem statement were introduced in Chapter 1. At this point, needs, constraints, alterables and actors related to aircraft design payload integration should be defined. Short definitions of the statements are also presented next to each subject for a more clear understanding.

3.2.1 Needs

I have assumed that the MMA needs to have following features:

a) Continuous Operations: All weather, 24/7 operations. This implies in-flight refueling capability.

b) Dissemination and Transmission: Outward communication of others and active remote sensing.

c) Command, Control, Communications and Counter Measures (C3CM).

d) ISR Processing and Exploitation: The manipulation and data extraction of the collected data.

e) Receiving and ISR Collection: Inward communication from others and passive or active gathering of remote transmissions for intelligence data.

f) Air and Ground Battle Management (BM): The management and tracking of air and ground assets and adversaries.

g) Air and Ground Command and Control (C2)

h) Long-term Compatibility: It should be designed to integrate easily future technologies along with satisfying the needs of the current situation.

i) Joint Service Interoperability: The platform should be decisively communicating with closely related services.

3.2.2 Alterables

Some alterables, or those items pertaining to the needs that can be changed, could possibly be uncontrollable ones such things as being the state of the art. I determined the alterables of the MMA payload design as following.

a) Constant “c”: The most significant alterable defined within this thesis study is the “c”, which refers to the multiplication constant yielding the total number of selected equipment to be integrated on the proposed MMA. The weight, volume and power characteristics of one unit of a particular equipment have been multiplied by the selected c, which can be chosen from 1 to 5. (Fulghum, David A. “Sigint, Jamming Joined in Single Package”, *Aviation Week & Space Technology*, 23 Dec 2002: 34). Use of c has been explained thoroughly at the beginning of Chapter 4.

b) APU Selection: Rating of the selected APU that is mounted on the aircraft plays a key role in electrical power tradeoff. This issue is discussed in electrical power analysis section of this chapter.

c) Engine Model Selection: Performance characteristics and airframe limits of 767-400ER vary with respect to the selected engine model. So, the model giving the best performance should be selected.

d) Range: Maximum endurance and ranges of MMA alternatives are very important especially for operational consideration.

e) Takeoff Roll Length: It should be within the limits of NATO and national standards. It should be kept in mind that length of any NATO runway must be longer than 8000 feet (Aftergood, 1999).

f) Mission Requirements: The space, weight and power requirements of the missions need to be evaluated. The missions must also perform together.

g) System Architecture: Although a single aircraft is ideal and highly desired, a modular or different tail numbered platform may need to be used if some of the current missions are incompatible, or if the limitations of a single aircraft will not allow so. Therefore, the system architecture will select the airframe based on all of the mission components being consolidated into one permanent platform or into a set of modular platforms.

h) Future Politics/Players/Conflicts/Demands: Each of these future aspects could force the design of the MMA in a completely different direction causing to determine a new set of requirements.

i) CONOPs: How a system is employed affects the multi-mission system compatibility because having multiple missions also means having multiple concerns and goals. A fully outlined training, techniques and procedures (TTP) manual will need to be developed.

3.2.3 Constraints

The constraints under which the needs must be satisfied and range over which the alterables can be varied are defined as follows:

a) Airframe Limits: Each airframe has its space, weight, and range/endurance limits. The airframe must be able to meet the property and loitering requirements of the combined missions.

b) Safety: Information, technology, crew and the aircraft safety will certainly play a key role in determining the optimal architecture. The high number of people onboard may evolve some safety matters. We should keep in mind that most of the systems onboard will be confidential and the crew will include all well-trained and valuable people. Additionally, we should be careful about ensuring the communication safety that could be a major concern because of the magnitude of the complicated electronic systems mounted on the aircraft.

c) Operations Environment: Need for trained personnel, aircraft/human survivability, electromagnetic environment, the overall mission performance and scenario will probably limit the ability of the airframe.

d) Funding: The decision makers have not yet established funding level of the MMA platform. The final LCC could lead us to a conclusion that the former fleet should remain in service if the MMA proves to be non-cost-effective. However, this seems to be not possible because some of the current systems are already outdated.

e) Logistics Supportability: Transportation, labor, supply, environmental impacts, limitations of some bases and rapid turnover time will all limit the logistics and maintenance of the MMA. For example, a very heavy MMA alternative might not take off from a base located at a high altitude just because of the base’s inadequate runway length.

f) Development Time: If the technology is not already in place, it could extend the development time of the airframe. If the development takes too much time, then a future enemy or conflict could cause revision of the requirements, and so the ongoing MMA configuration might become impractical.

g) Classification of the System: Each mission aircraft currently consist of works and reports at different levels of security. Bringing these different levels together and meeting security requirements may increase the difficulty in obtaining the overall integration.

h) Technology Availability: In order to combine missions that currently require their own airframe, technology must be in place to minimize the property needs of the missions. Newly designed transmitters and receivers need to be installed that can conduct the planned missions. On the other hand, existing technology such as air-refueling will be used on the new MMA platform.

i) System Compatibility: Standardization, interoperability and system supportability will all need to be considered.

j) Government Requirements and Policies: International and National level policies and regulations may restrict and even drive some of the decision variables.

k) Performance: Minimal performance in each sensor type will be no less than that of current systems.

3.2.4 Actors and Relevant Disciplines

The key players for the MMA platform could be named as;

- Decision Makers: ACC, AMC, AFSOC, CINCs,
- Owners/Operators: Fighters, bombers and operators of Air Force, Navy and Army,
- Developers: Boeing Company, Raytheon Corporation, Northrop Grumman and others.

The concept map developed to show the interactions between the actors and drivers is presented in Figure 3-1.

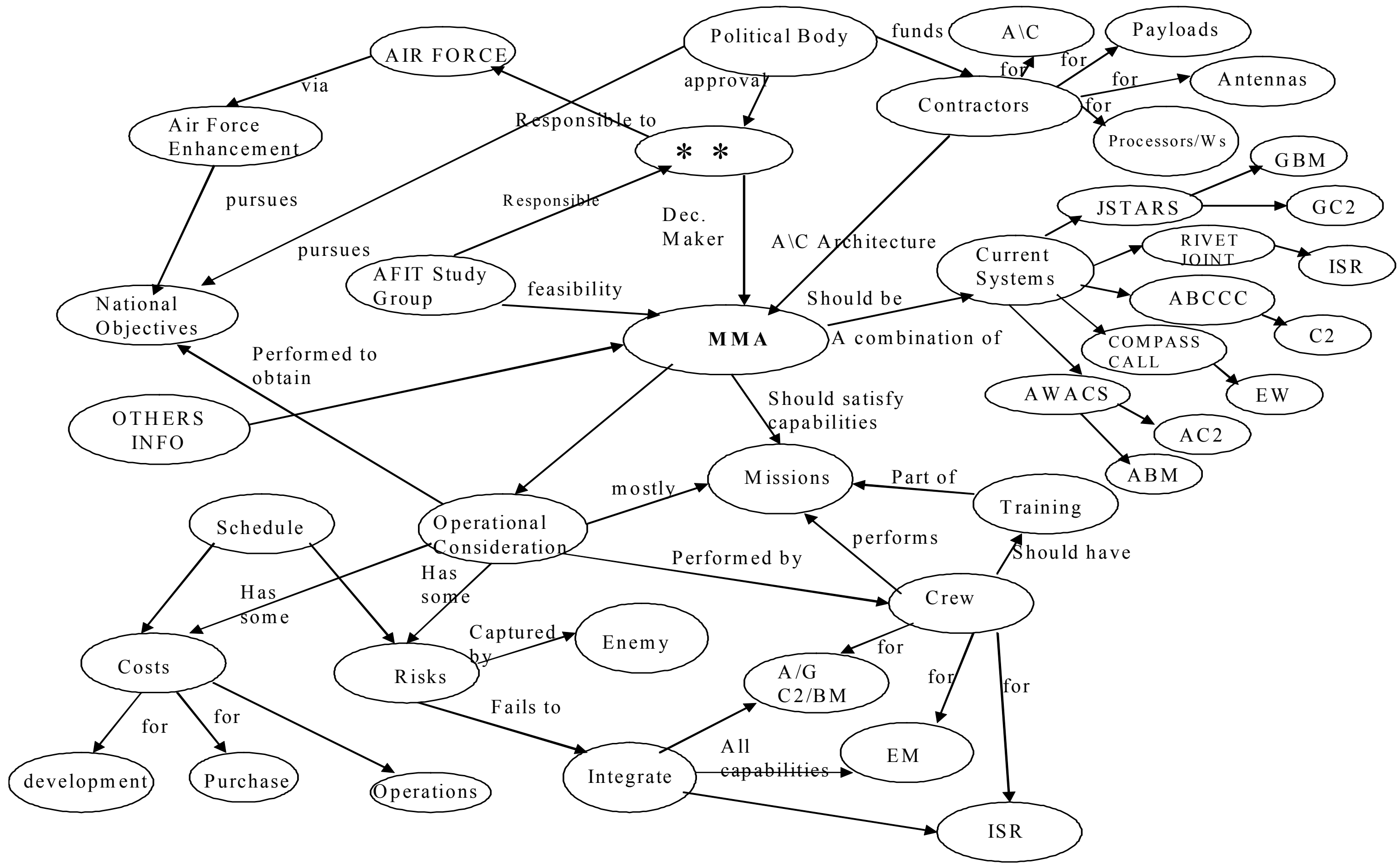


Figure 3-1: Concept Map

Some of the relevant disciplines could be labeled as follows:

- Physics (electromagnetic),
- Logistics,
- Operational Research,
- Acquisition,
- Engineering (mechanical, material, environmental, sensor, transistor, receivers, aeronautics, industrial, systems).

3.3 Value System Design

A chart was developed along with other two systems engineering students at AFIT in order to show visually cross-interactions among the objectives, needs, alterables and constraints. This chart found in Appendix A has been used as a key element to build the system synthesis architecture as they will identify where special or in-depth research will need to be accomplished in order to understand the system design completely. It should be noted that this chart represents the interactions for overall MMA integration rather than payload design only.

Numerical values were assigned to the designated strengths -high, medium, and low- so that the levels of interactions could be identified. Each overall interaction values were calculated with respect to their interactions among the other elements. Every elements of each group of objectives, alterables, constraints and needs are arranged based on those total and natural group interaction levels. The cross-interactions have been categorized by level in Table 3-1.

	HIGH INTERACTION	MEDIUM INTERACTION	LOW INTERACTION
OBJECTIVES	Max Mission Effectiveness Mission Integration & Compatibility	Minimize Risk	Minimize LCC
NEEDS	Air C2 Ground C2 ISR Collect. & Recog. Mission Dissemination & Transmission	ISR Processing & Exploration Air BM Ground BM C3 CM Joint Service Interoperability	Longterm Compatibility All-Weather Capability (24/7)
ALTERABLES	System Architecture	Mission Requirements	Future Politics/Players/… CONOPs
CONSTRAINTS	Operations Environment Tecnnology Availability Development Time System Compatibility	Air Frame Limits Funding Classification of System Logistics Supportability	Safety Gov't regulations & Policies

Table 3-1: Objectives, Needs, Alterables and Constraints Summary by Level of Cross-Interaction

We will need a Value System in order to make any optimization for choosing the best alternative. Therefore, a VSD (Figure 3-2) for payload consideration was developed using basic hierarchy techniques based on the interactions matrix in Appendix A, the concept map (Figure 3-1) and the cross-interactions summary (Table 3-1). Corresponding weights for LCC, A/C Specifications and Risk are set to 0.20, 0.50 and 0.30 successively summing up to 1. A/C specifications issue is thought to have the measure of 0.50 since it is considered as the most important concern during the course of integration. Similarly, the other values are chosen in accordance with the mentioned interaction matrix. Different weights could be assigned to each of those aspects if they are believed to have different importance than those of indicated above.

This objective hierarchy of VSD will be developed into as fine detailed as possible with the given backgrounds and the limitations of research through this chapter. The reader could notice that the VSD, which was generated for the overall MMA, is different from the one in this text. That is quite normal since grading the alternatives and coming up with a result will be based merely on the payload integration issues. That is why any alternative that is robust in terms of payload considerations does not have to be so with regard to EM or Operational views. Obviously, the overall results would be attained by combining those three viewpoints.

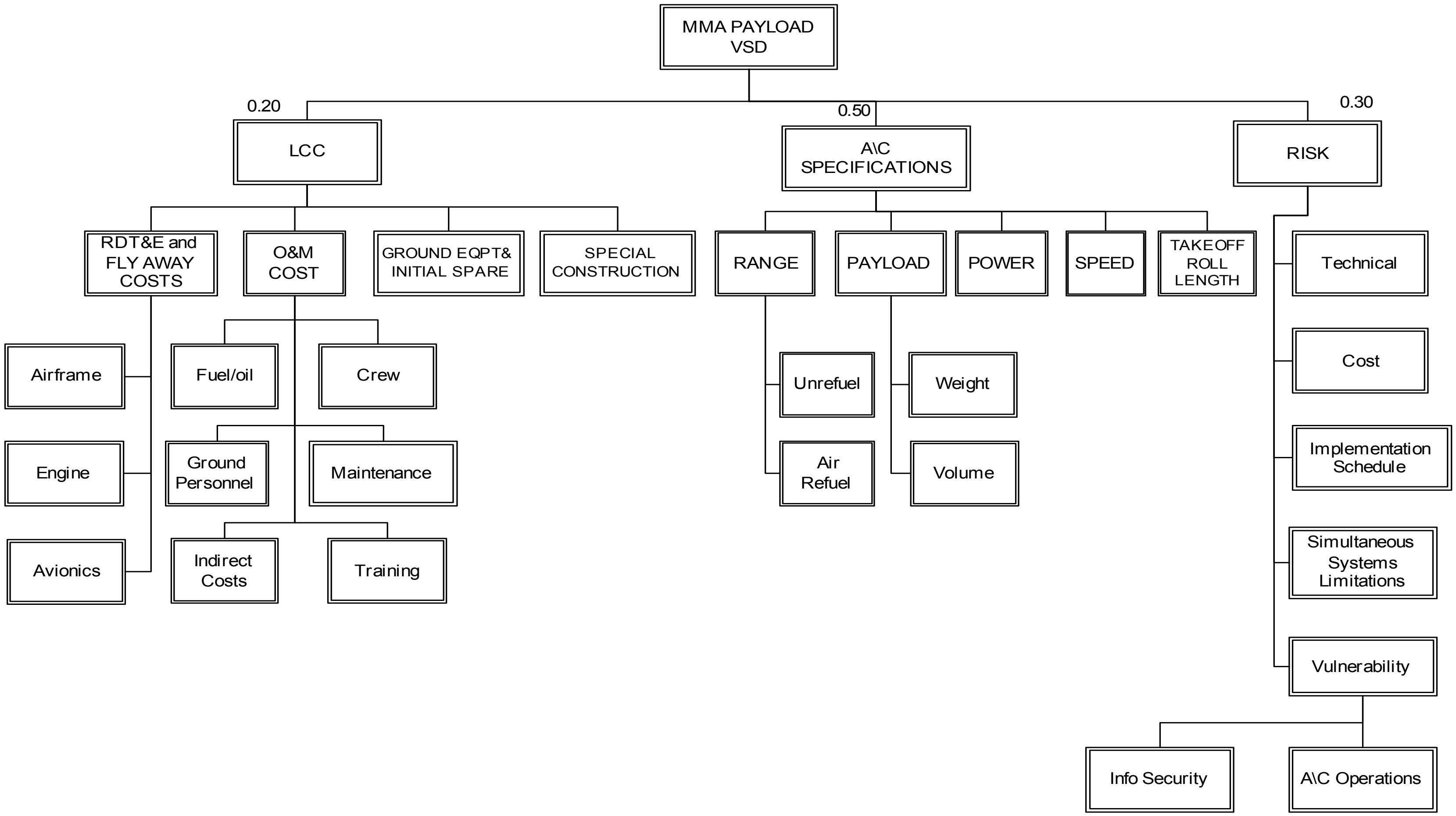


Figure 3-2: VSD for A\C Payload Design

3.4 System Synthesis

Based on the interactions matrix in Appendix A, an interface and flow model was created using techniques defined by Hatley, Hruschka and Pirbhai (H/H/P). These techniques help to stimulate system specifications to generate iteratively a set of system requirements and architecture models. The interface model depicts key requirements and interactions within the MMA design. The flow model was then used to build and track the architectures and some of their variants. The process interface was the centerpiece or driving force behind the iterations. As each architecture was developed, the system requirements were enhanced and fed back into the interface. As the process continues, several architecture variations developed and noted as sub-bullets in the systems architecture model. The tool automatically organizes the requirements you set manually.

3.4.1 H/H/P Model Developed in TurboCASE/Sys™

Initially, environment where the MMA will operate has been pictured in Figure 3-3. Each element in the environment is described with different types of lines. The dark line represents the MMA as a superbubble. The next figure after environment model is Requirements Context Diagram for MMA platform. Then, DFD0, DFD1, selected requirements dictionary entries, PSPECs, enhanced DFD0 and AFCD come in a row. In fact, some other figures available in the generated model are not introduced here because of space concerns in the text. Besides, it is believed that these figures and tables are enough for payload consideration.

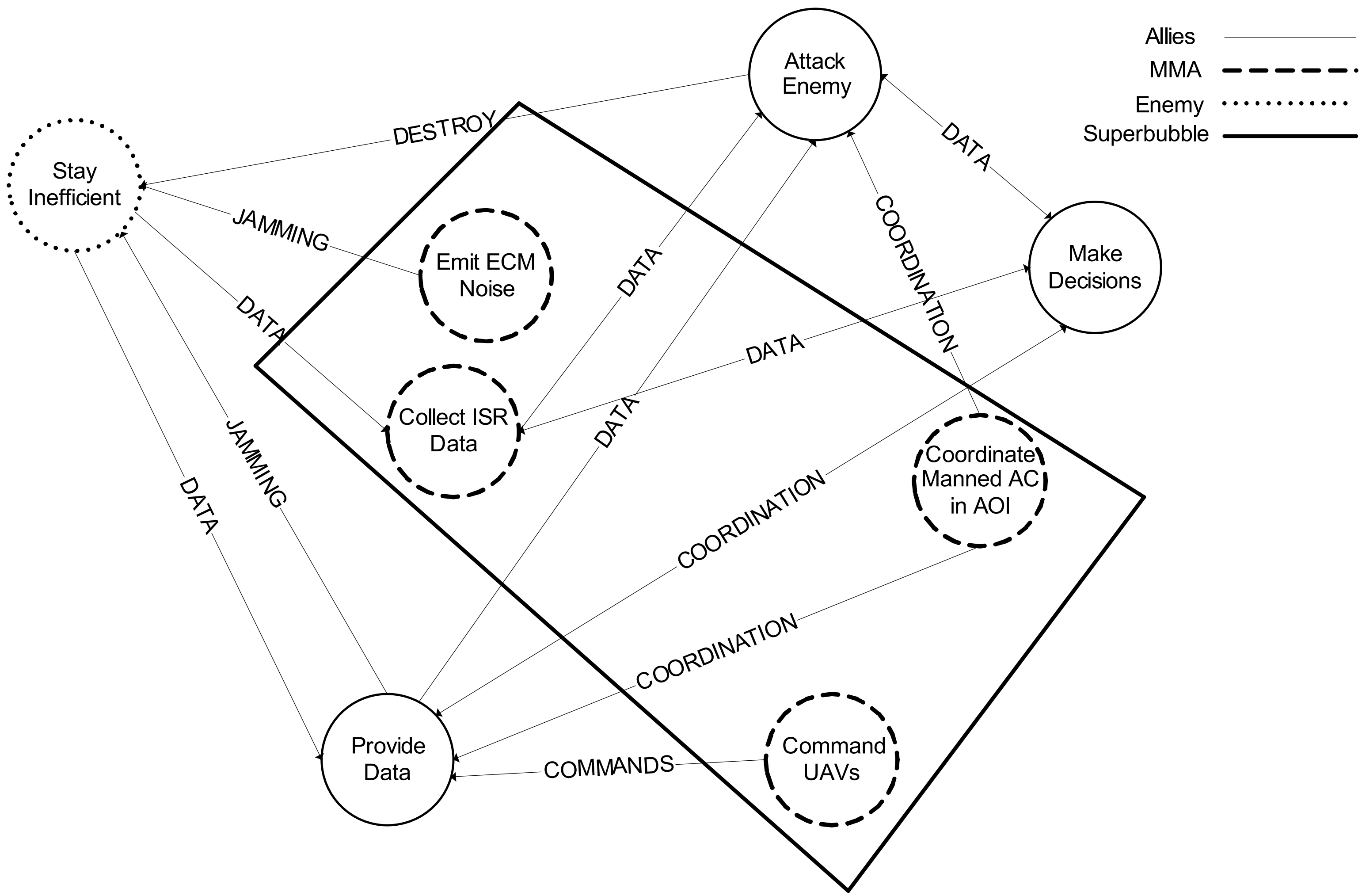


Figure 3-3: Environment Model for MMA

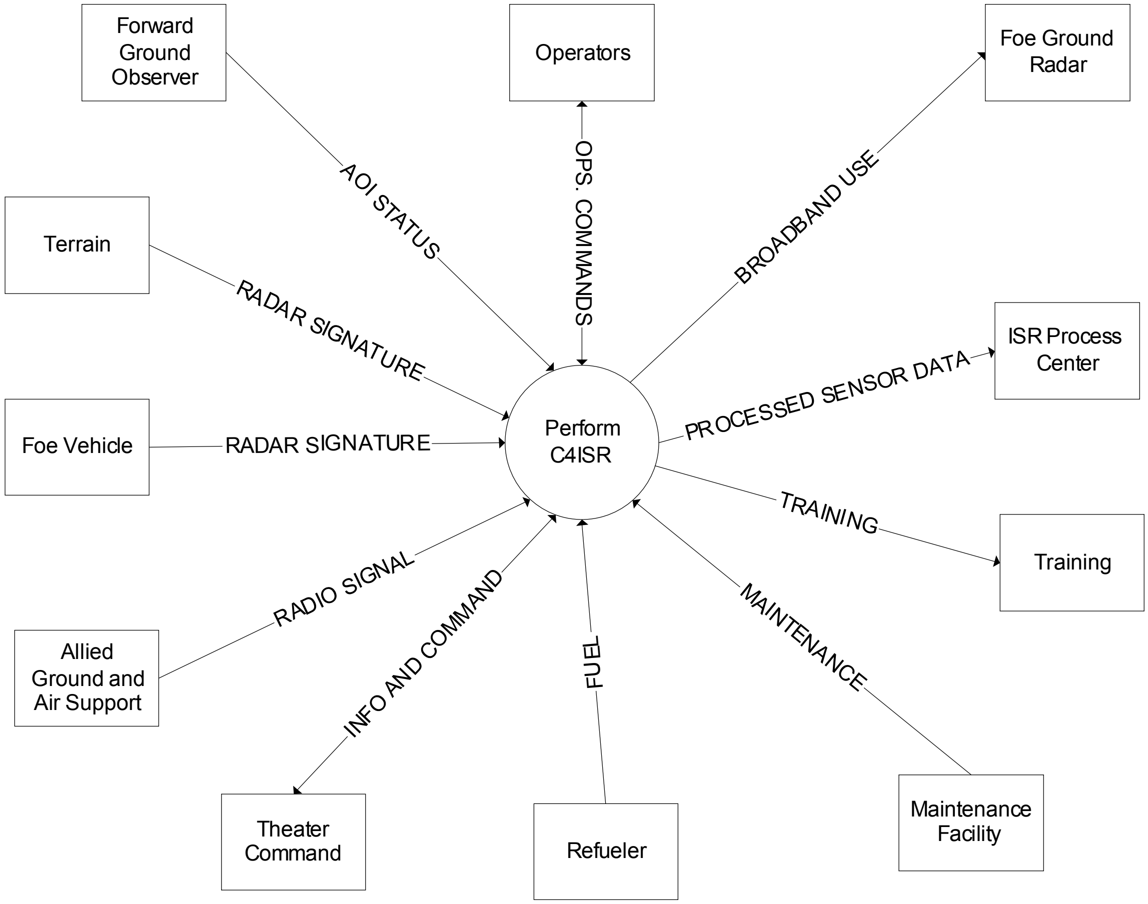


Figure 3-4: Requirements Context Diagram for MMA

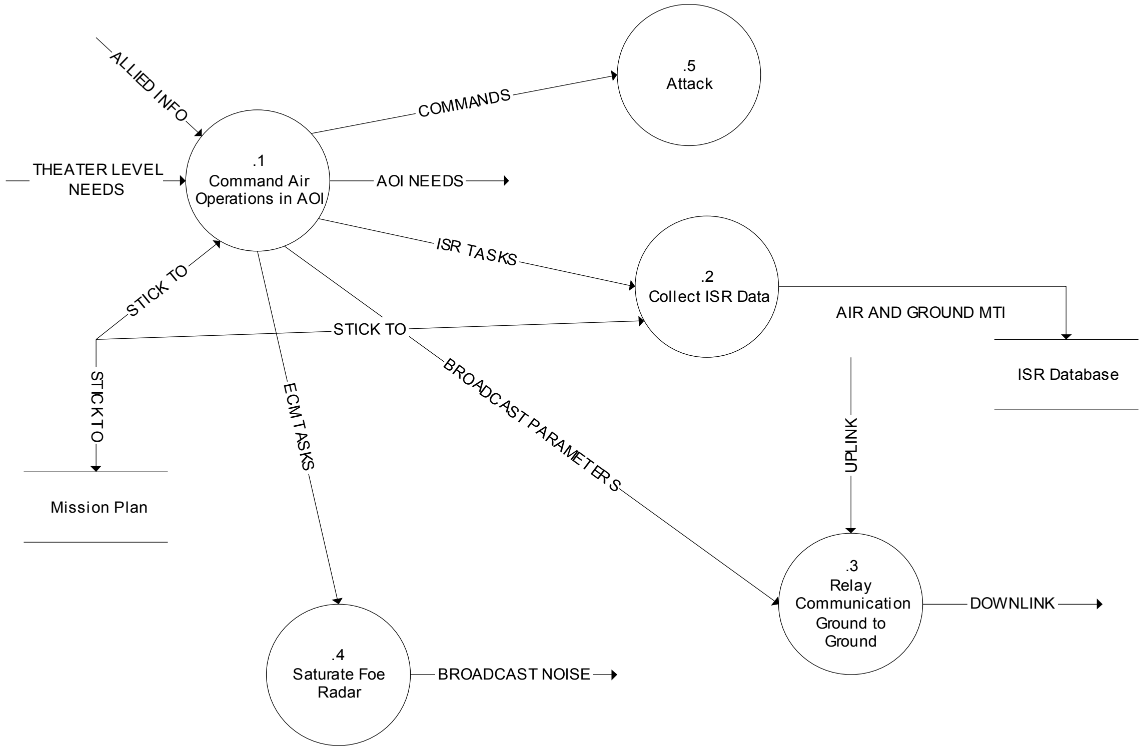


Figure 3-5 : DFD0

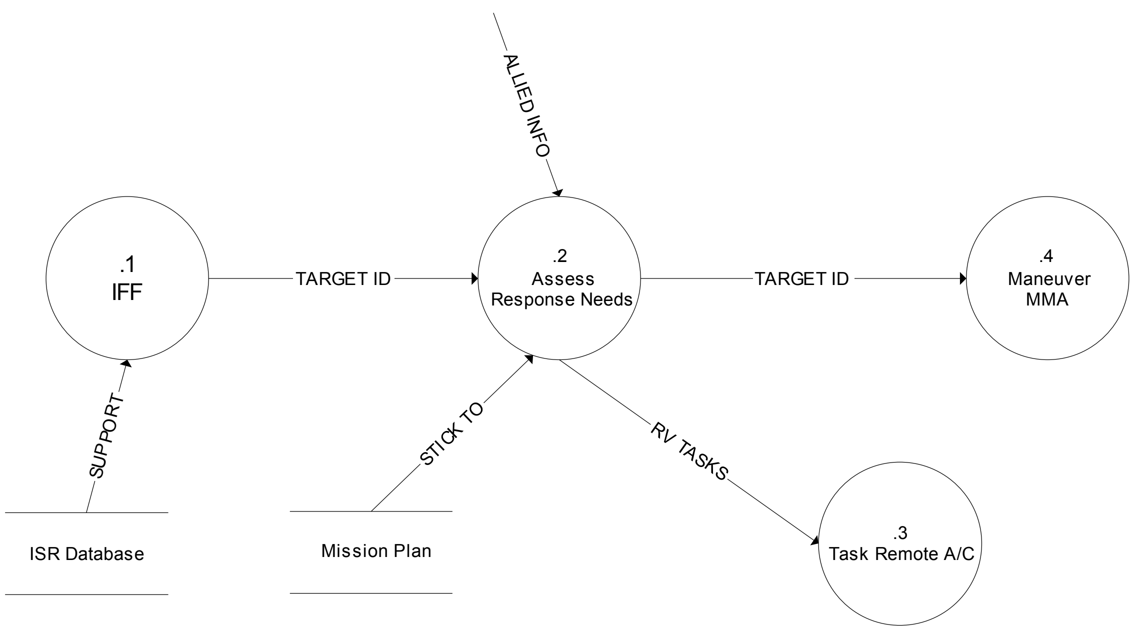


Figure 3-6 : DFD1

Name	Composed of	Type
ALLIED INFO	ISR INFO + IFF ID	DATA
COMMANDS	HOLD + ATTACK	CONTROL
BROADCAST NOISE	JAMMING SIGNAL	DATA
ISR TASKS	INTELLIGENCE + SURVEILLANCE + RECONNAISSANCE	DATA

Table 3-2: Selected Requirements Dictionary Entries for Flows on DFD0

PSPEC1: According to the mission plan, Command ISR and ECM TASKS with the help of info gathered from the allies in order to meet the THEATER LEVEL NEEDS and AOI NEEDS.
PSPEC2: Collect ISR data by sticking to the mission plan and send Air and Ground MTI info to the ISR database.
PSPEC3: According to set broadcast parameters, relay ground-to-ground uplink and downlink communication.
PSPEC4: Saturate foe radar by broadcasting noise.

Table 3-3: Process Specifications (PSPECs) for Processes in DFD0

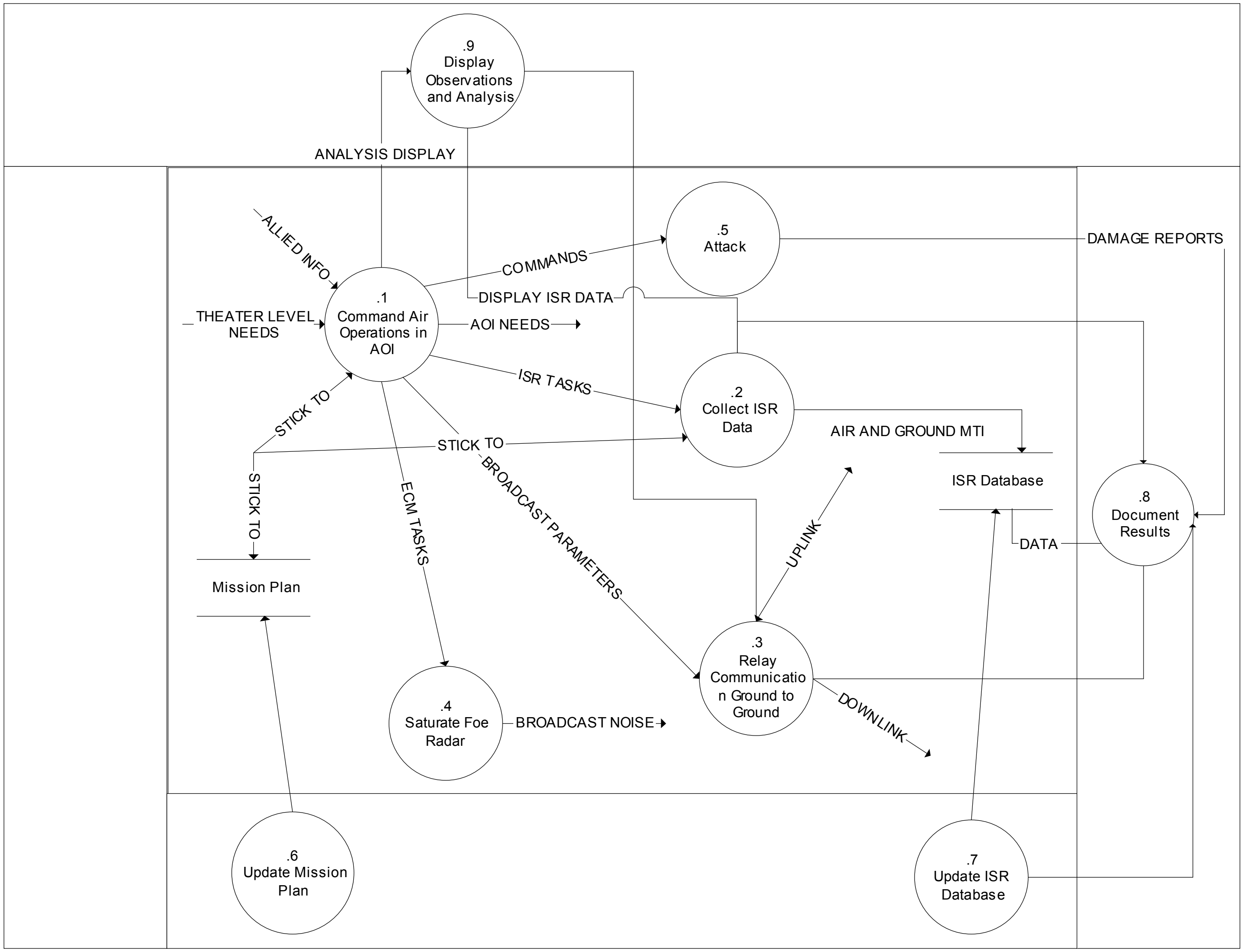


Figure 3-7 : Enhanced DFD0

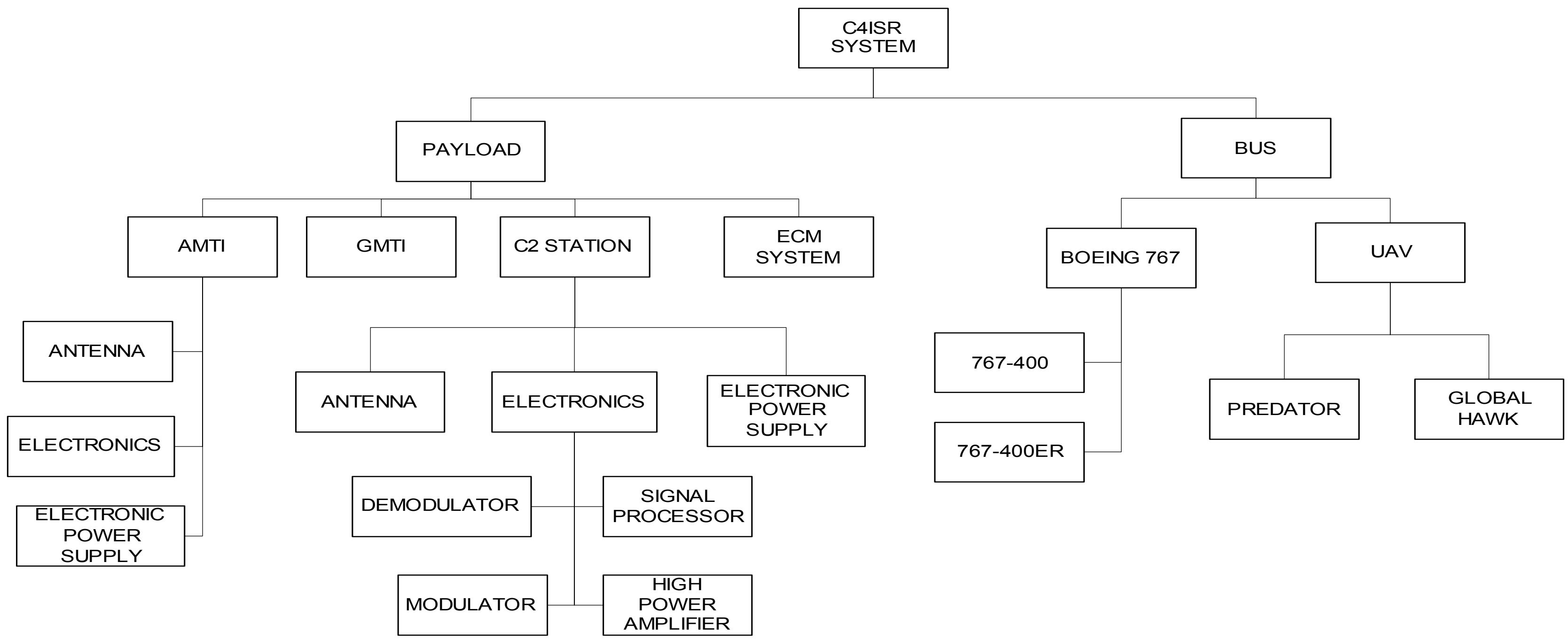


Figure 3-8: AFCD

3.5 System Modeling

System models were developed after several iterations. These models include but are not limited to the following:

a) Baseline: The status of each mission without future improvements. That is, current situation.

b) Legacy Improvements/ Standard Acquisition Process: Follows the traditional method followed by DOD in replacing aircraft. Under the Legacy concept, each weapon system will be replaced by a similar upgraded system. Legacy replacement results in system architecture almost identical to that of today. In spite of widely different schedules, budgets and technical risk, it still remains a feasible alternative.

c) One Tail Number (OTN): This would involve consolidation of multiple missions under a single airframe. This is the desired outcome from decision makers as it is expected to reduce the life cycle cost, and increase the ability to combine data and information.

d) Different Tail Number (DTN): Each aircraft would consist of sets of compatible missions. For example, tail number A1 may consist of Battle Management, C2 and IFF; tail number A2 may consist of C3CM, GMTI, IFF; tail number A3 may consist of C3CM and ISR; etc.

e) RTC: The architecture consists of a suite of three types of aircraft missions. This concept centers on separating the three basic functions of systems described earlier into transmitting platforms, receiving and processing platforms, and separate command and control platforms. More than three aircraft could be used in the architecture but would be limited to one of the three primary missions.

f) Sensor Craft: This is a long dwelling, real estate unlimited aircraft that could accomplish all potential missions under one aircraft. Sensor Craft is an envisioned platform mounted on a state of the art aircraft. Diamond shaped platform is shown in Figure 3-9.

Figure 3-9: Imaginary Picture of Sensor Craft Aircraft

g) Modular: The aircraft would have a compartment or module that could be inserted based on the mission. Each module would be outfitted with different hardware and software specific to the missions' needs.

Only the OTN and DTN architectures will be considered in this thesis because the OTN is the preference of the customer and the DTN seems to be the one closest to the desires of the customer according to the literature review I have made. Although the form of the OTN is obvious, the DTN alternative can be created as a combination of several variants. Therefore, four different types of DTN each of which consists of two subordinate variants have been established despite the fact that more options could be generated by changing the configurations. Those specific DTN architectures are generated by considering time limitations and importance of two major fleets, AWACS and JSTARS.

The overall feasibility of any DTN architecture will be considered as the combination of those two secondary DTNs. Table 3-4 is the list of MMA alternatives that will be examined in this thesis.

<table>
<tr><th>ALTERNATIVE</th><th colspan="2">TITLE</th><th>CONFIGURATION</th></tr>
<tr><td>One Tail Number</td><td colspan="2">OTN</td><td>JSTARS-AWACS-RJ-COMPASS CALL-ABCCC</td></tr>
<tr><td rowspan="8">Different Tail Numbers</td><td rowspan="2">DTN1</td><td>DTN11</td><td>AWACS-JSTARS</td></tr>
<tr><td>DTN12</td><td>RJ-ABCCC-COMPASS CALL</td></tr>
<tr><td rowspan="2">DTN2</td><td>DTN21</td><td>AWACS-ABCCC</td></tr>
<tr><td>DTN22</td><td>JSTARS-RJ-COMPASS CALL</td></tr>
<tr><td rowspan="2">DTN3</td><td>DTN31</td><td>AWACS-RJ</td></tr>
<tr><td>DTN32</td><td>JSTARS-COMPASS CALL-ABCCC</td></tr>
<tr><td rowspan="2">DTN4</td><td>DTN41</td><td>AWACS-COMPASS CALL</td></tr>
<tr><td>DTN42</td><td>JSTARS-RJ-ABCCC</td></tr>
</table>

Table 3-4: MMA Alternatives

3.6 System Analysis

In any system, many variables could influence the overall performance, cost, or design of the detailed components. I will primarily present those factors and then I will try to find out their effects on previously identified alternative models.

3.6.1 Weight Analysis

It is apparent that one of the major concerns of the integration is going to be the weight. We should carefully make the necessary tradeoffs between weight of fuel and payload that are directly affecting range and endurance. The weight of an aircraft is categorized into the same several portions in most of the aircraft design books. I have defined them in chapter 2 of this thesis under the title of Boeing 767-400ER. Now, let me introduce the basic aircraft weight equation:

$$W_o = W_{payload} + W_{empty} + W_{fuel} \qquad \text{Equation 3-1}$$

where W_o is total takeoff gross weight. $W_{payload}$ is the weight of flight and mission crew, consoles, and special equipment related to the mission of the aircraft. Many kinds of radars, antennas and sensors can be named under special equipment related to the mission type. W_{fuel} is the weight of the fuel required for performing the mission, and W_{empty} is the empty weight of the aircraft that includes the structure, engines, landing gear, instruments, fixed equipment and anything else not considered as the part of payload (Raymer, 1999).

To simplify the calculations, both W_{empty} and W_{fuel} can be written as the fraction of W_o such as W_{empty}/W_o and W_{fuel}/W_o. In this way, some necessary tradeoffs could be easily done between fuel and payload weights. Finally, Equation 3.1 could be expressed as follows:

$$W_0 = \frac{W_{Payload}}{1 - (W_{empty}/W_0) - (W_{fuel}/W_0)} \qquad \text{Equation 3-2}$$

Although it is possible that the Boeing Company will implement changes to W_o, I am assuming that it will be unchanged during the development study. That means we have got other three variables left in the formula that can be altered. On the other hand, there are two different engine selections and two variations, which are basic and maximum, of each engine types of Boeing 767-400ER. Besides, selecting basic or maximum model causes big differences in the performance of the aircraft. Nevertheless, both Pratt Whitney and General Electric *maximum model engines* have similar performance values. Therefore, I assume the General Electric CF6-80C2B8F *maximum model engine* with the W_o of 450,000 lb is mounted on the aircraft allowing us to load more weight than the *basic model engine.* For additional data on 767-400ER engine characteristics, the reader should consult Table 2-6 and Table 3-5.

On the other hand, W_{empty} seems to be somewhat alterable by removing some basic furnishings in the passenger cabin provided in the commercial version of 767-400ER. The furnishings contain seats for flight-deck crew, cabin crew and passengers, lavatory and water compartment, food providers, cabin windows and miscellaneous. Weight of furnishings in pounds for a commercial aircraft is formulated as follows (Roskam, 1999):

W_{fur} = flight-deck crew seats + passenger seats + cabin-crew seats + (lavatories and water) + food providers +cabin windows +miscellaneous,

Or:

$$W_{fur} = 55N_{fdc} + 32N_{pax} + 15N_{cc} + K_{lav}(N_{pax})^{1.33} + K_{buf}(N_{pax})^{1.12} + 109\{N_{pax}(1+P_c)/100\}^{0.505} + 0.771(W_o/1{,}000) \qquad \text{Equation 3-3}$$

where K_{lav} = 1.11 and K_{buf} = 5.68 for long range aircraft. P_c refers to design ultimate cabin pressure in psi whose value depends on the design altitude for the pressure cabin. P_c has been selected as 6.7 assuming the aircraft's maximum flight altitude is 50000 ft (http://www.tpub.com/ase2/75.htm). Actually, P_c is fixed to 6.7 for the altitudes greater than 40000 ft in the cited reference. Additionally, estimations are based on the *three-class arrangement* with 243 passenger seats (http\\www.boeing.com).

In fact, seats for the flight-deck crew will remain in the aircraft. Therefore, we should not include them in the furniture that will be taken out from the commercial 767-400ER. Additionally, it is assumed that the cabin windows will be removed from the aircraft, those gaps being filled with probably aluminum monocoque skin. So, based on the density difference of glass and aluminum, the weight gained from window removal will be assumed as the half of the formula estimate for the type of glass required for that altitude.

According to the estimations made by the formula introduced above, eliminating those 243 passenger and 10 cabin crew seats along with other redundant furnishings including screens, galley equipment, lavatory, video control center and closets will provide us;

W_{fur}= 0 + 7926 + 150 + 1652.64 + 2668.25 + (478.448/2) + 346.95 = 12983 lb (5889 kg)

It should be noted that seats for each flight crew, cabin crew, and passenger are considered as 55 lb, 15 lb and 32 lb respectively according to the Equation 3.3.

Eventually, those estimations will reduce W_{empty} by 12983 lb to 214,317 lb (97,212 kg) while the weight assigned for payload will increase by 12983 lb to 115,683 lb (52,473 kg).

If JP-8 with the density of 6.7 lb\gal is chosen as the fuel to fly the aircraft, the maximum usable fuel weighs around 161,738 lb. However, we cannot load the aircraft with more than 120,000 lb of fuel on the ground if we have to use up all the payload capacity because of the magnitude of the mission equipment. Nevertheless, we can use all the capacity in case of an in-flight refueling remembering that the maximum landing weight should be less than 350,000 lb. Numbers of refueling will be determined in accordance with the operational aspects. Associated ranges vs. weight plots obtained from www.boeing.com are available in the Appendix B. They will be used in the text if needed. Table 3-5 shows the basic weight characteristics of Boeing 767-400ER after the adjustments explained above.

		Basic	Maximum
Maximum taxi weight		401,000 lb (181,890 kg)	451,000 lb (204,570 kg)
Maximum takeoff weight		400,000 lb(181,440 kg)	450,000 lb(204,120 kg)
Maximum landing weight		350,000 lb (158,760 kg)	350,000 lb (158,760 kg)
Maximum zero fuel weight		330,000 lb (149,685 kg)	330,000 lb (149,685 kg)
Operating empty weight		214,417 lb (97,296 kg)	214,317 lb (97,212 kg)
Maximum payload weight		115,583 lb (52,429 kg)	115,683 lb (52,473 kg)
Usable Fuel	US Gal.	24140	24140
	Lt	91380	91380
	lb[2]	161738	161738
	kg	73363	73363
Max. fuel at takeoff	lb	70,000	120,000
	kg	31,751	54,431

[2] JP-8 with the density of 6.7 lb/gal

Table 3-5: Adjusted Weight Characteristics of Boeing 767-400ER

Now that we cannot play with the W_o and W_{empty} in the estimations, we need to optimize the weight of fuel and payload according to the mission the platform will perform. Obviously, weight is directly related to the density of the fuel that means different types of gasoline will load different weights to the aircraft to carry during the flight. We know that military aircraft consume JP-8 that has a greater density than Aviation Gasoline. At present, we do not know if the MMA platform has a serious weight concern. However, the idea of fueling with Aviation Gas instead of JP-8 can be suggested as a last resort although this transformation could possibly change aircraft's aerodynamic performances. Following Table 3-6 summarizes commercial and military fuel densities:

	Average Actual Density		
	0°F	100°F	Mil-spec density
Aviation Gasoline	6.1{.73}	5.7{.68}	6.0{.72}
JP-4	6.7{.80}	6.4{.77}	6.5{.78}
JP-5	7.2{.86}	6.8{.82}	6.8{.82}
JP-8/JETA1	—	—	6.7{.80}

Table 3-6: Fuel Densities (lb\gal or kg\liter) (Raymer, 1999)

Range is estimated by using the Breguet range equation:

$$R = \frac{V}{SFC}\frac{L}{D}\ln\frac{W_{i-1}}{W_i} \quad \text{or} \quad \frac{W_{i-1}}{W_i} = \exp\left[-\left(\frac{R * SFC}{V * (L/D)}\right)\right] \qquad \text{Equation 3-4}$$

where

R = Range (ft or m)

SFC = Specific Fuel Consumption (1/s)

V = Velocity (ft/s or m/s)

L/D = Lift-to-Drag Ratio

W_{i-1} / W_i = Phase Mission Weight Fraction

Fuel consumption rate varies according to the phase of the flight, which are typically takeoff, climb, cruise, loitering and landing. Additionally, the overall range and fuel needed are estimated as a function of all those phases. In the range trade, we will possibly need for the Specific Fuel Consumption (SFC) values during the cruise and takeoff. Although range can be directly found out from available tables, we need to be able to estimate them from the formulas for operational issues. The SFC constants can be calculated by using the formulas below (Raymer, 1999):

$$SFC_{cruise}=0.88e^{(-0.05BPR)} \quad \text{Equation 3-5}$$

$$SFC_{maxT}=0.67e^{(-0.12BPR)} \quad \text{Equation 3-6}$$

where BPR is the bypass-ratio. The formulas above are for subsonic non-afterburning engines such as found on commercial transports, and cover a bypass ratio range from zero to six. Table 3-7 displays the engine specifications including BPR values for each type of engines that could be mounted onto Boeing 767-400ER.

	CF6-80C2	PW4062
Air Flow (kg/s)	802	816
BPR	5.05	4.8
Dry Weight (kg)	4309	4179
Max.Takeoff Thrust (lb)	63500	63300

Table 3-7: Engine Characteristics of Boeing 767-400ER (Jane's All the World's Aircraft, 2001-2002, 2001)

These equations would yield SFC_{cruise} as 0.684 and SFC_{maxT} as 0.365 for the associated BPR for CF6-80C2 engine. Lift to drag (L/D) ratio of Boeing 767-400ER can be considered as 17 by using the historical data tables available in the aircraft design books (Raymer, 1999). Those tables give the L\D ratio as a combination of the wing aspect ratio and maximum thrust of selected engine.

Now, we are ready to do any estimation if we are given the total weight of the payload loaded. However, here comes the most important question: What will be the total weight of the payload needed for the missions? It certainly depends on the selection of the alternative, whether OTN or DTN. I will present those estimates in Chapter 4 by using the historical data available in the C4I sources and latest company catalogs from the internet.

3.6.2 Volume Analysis

As indicated in the Chapter 2, cabin floor area and volume values of Boeing 767-400ER are not available in the open literature. However, they are very important to know for any estimation in payload design. Thus, the historical data of other versions of 767 family (200, 200ER, 300, and 300ER) were examined in JMP IN which is a widely used statistical tool. Both linear and quadratic fit correlation models have been established in order to have the least biased estimate of the historical data. The codes that have the highest R^2 values were selected. By using the codes gathered after this effort, the cabin volume and floor area have been estimated.

However, these estimates are based on the length from front door to the aft door for 767-400ER. When we look at the drawings of the aircraft, there is an extra space beyond the doors that is approximately equal to the flight deck volume. Thus, 13.5 m^3 of volume and 5 m^2 of area are added to the value found after estimations.

Moreover, that volume estimate reflects the cabin volume excluding the passenger stow bins replaced at the top of the seats. Now that our new aircraft will not fulfill commercial transportation, we can easily discard them for extra storage. Each outboard bin on the Boeing 767-400ER can accommodate two Air Transport Association (ATA) carry-on bags (9-by 17-by 23.75 inch) stowed diagonally yielding to a 0.1191 m^3 volume each. Assuming *Three Class Arrangement*, which is for 243 passengers, and one outboard bin for every rows of seat, there could be around 150 bins. By eliminating those compartments, we will gain at least 150 x 0.1191 = 17.865 m^3 extra storage volume.

Another confirmation for estimated overhead storage volume could be made by making a comparison with the 767-300 version. It is stated that overhead stowage for carry-on baggage is 0.08 m3 (3.0 cu ft) per passenger assuming 767-300 accommodation for 269 passengers. That configuration gives 269 x 0.08 m^3 = 21.52 m^3 space for storage confirming our assumption of 17.865 m^3 cabin volume (Jane's All the World's Aircraft, 2001-2002, 2001).

After all those assumptions and calculations, the final rounded estimates are as follows:

Cabin Floor Area= $245m^2 + 5m^2 = 250m^2$ ($2691ft^2$)

Cabin Volume= $532m^3 + 13.5m^3 + 17.865\ m^3 = 563.4m^3$ ($19896\ ft^3$)

If we divide the cabin volume to the length, we will get 12.863 m^3, which is the approximate volume of space sitting on a 1-meter length. This estimate can be used in volume trade in the optimization section. It should be also noted that the flight deck is not included in the estimations since it is believed not to have so much impact on the indoor layout design of the aircraft. I am also aware that there is a risk of having biased estimates because the sample size is too small, which is 4. However, the procedure for the small sample sizes were exactly used assuming that the data is normally distributed. We should have a sample size greater than 30 in order to get rid of the normality assumption. However, necessary tests are performed in order to check the normality of the distribution (Devore, 2000).

I could have assumed a rough estimate of cabin volume just by inspecting other Boeing transport without doing any calculations. However, I wanted to have some reasonable numbers rather than thrown up values.

Boeing 767-400ER has a bulk cargo hold volume capacity of 9.77 m^3 (345 ft^3) and a total cargo volume capacity of 138.9 m^3 (4905 ft^3). These values will be real estate limitations for settling the payload need to be installed inside the aircraft. Figures 3-10 and 3-11 display the cabin and lower deck layout of Boeing 767-400ER while Table 3-8 provides a comparison between 767-400ER and 707, the aircraft at which the JSTARS and AWACS platforms are currently housed.

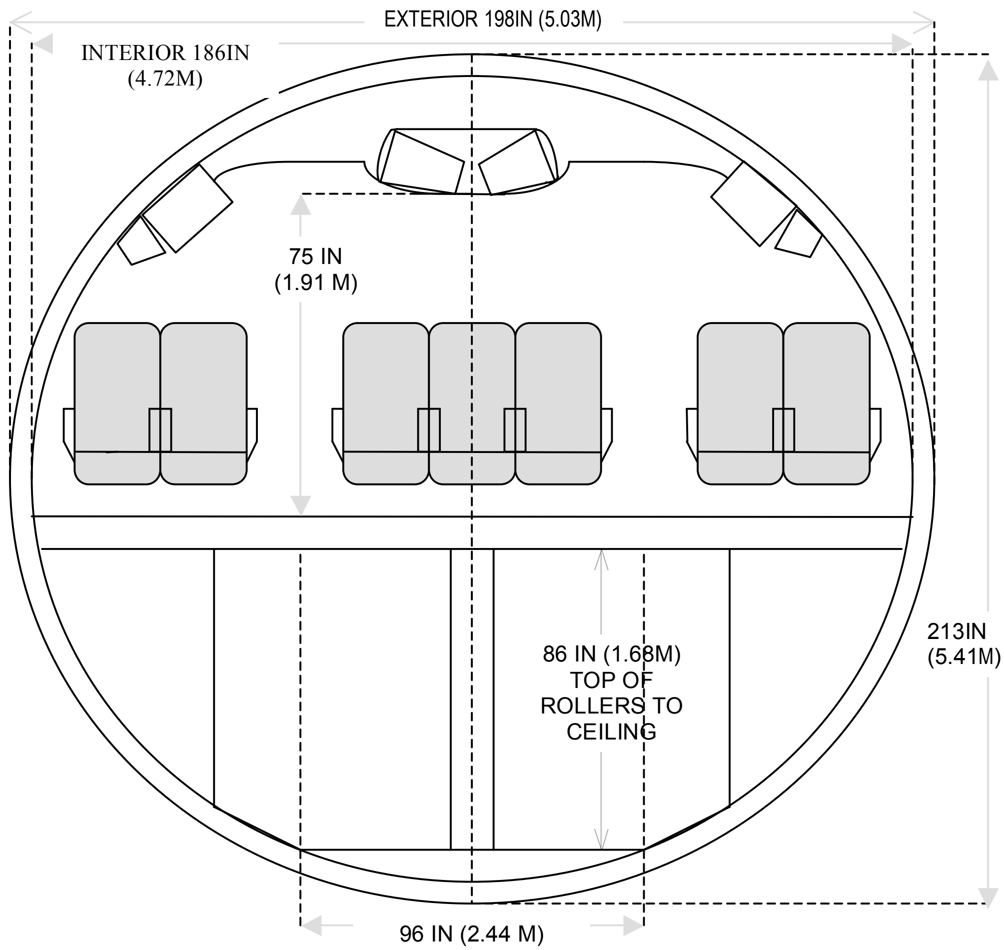


Figure 3-10 Interior Layout of Boeing 767-400ER

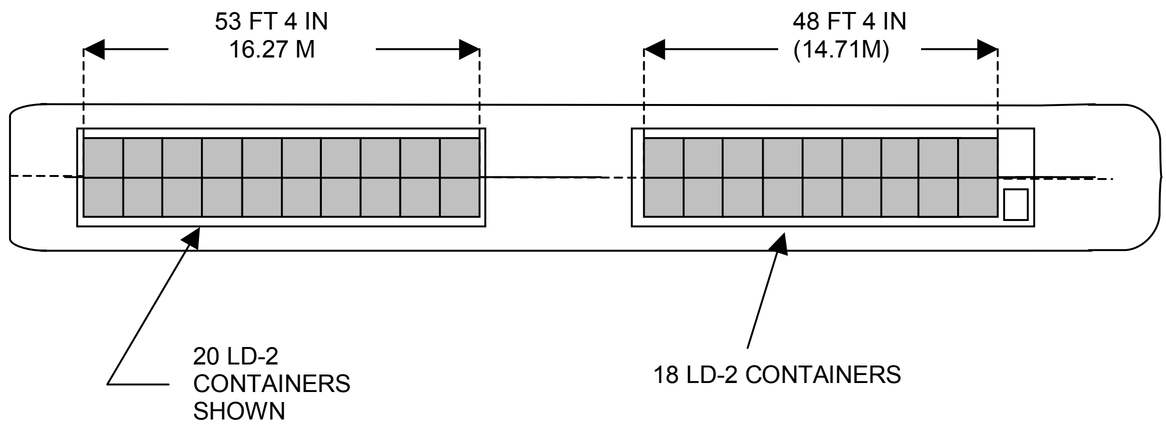


Figure 3-11: Lower Deck Cargo Layout of Boeing 767-400ER

	707	767-400ER	Ratio
Lower Deck Cargo Dimensions			
Forward	24.49	67.97	2.775
Aft	25.63	61.17	2.386
Bulk Cargo	NA	9.77	-
Total	50.12	138.91	2.772
Cabin Dimensions (m)			
Length	29.94	43.80	1.463
Width	3.54	4.72	1.333
Max Height	2.192	2.87	1.309
Interior Wetted Volume (m^3)	226.5	563.4	2.487

Table 3-8: Dimension and Volume Comparison of 707-320B vs. 767-400ER (http\\www.boeing.com)

It is noticeable that newly selected aircraft has at least two times greater volume capacity than the old one. This difference will certainly provide a freedom to the designers in spite of the fact that it is not known yet whether that much space is big enough or not.

3.6.3 Electrical Power Analysis

Electrical power to the avionics, hydraulics, environmental-control, lighting, and other subsystems is provided by the electrical system in an aircraft. The electrical system consists of batteries or generators (engine generator and APU), transformers, electrical controls, circuit breakers and cables.

Generators commonly produce AC power that is converted to DC by the transformers. Boeing 767-400ER has two engine driven 120kVA Integrated Drive Generators (IDG) supplying 115/200 V, 400 Hz, three phase AC power and has another 120kVA generator attached to the APU. Actually, the 767-400ER has one of the most powerful generators available in the market.

All large-scale aircraft including the commercial transport and military applications are completely dependent upon the hydraulic system for flight control. If the hydraulic pumps stop running, an emergency hydraulic power will be needed as well as an electrical power until the engines can be restarted. There are several forms of emergency power available in the aviation industry. Most commercial transports and military aircraft are accommodated with jet-powered APUs.

Usually, an APU is designed to provide ground power for air conditioning, cabin lighting, and engine starting. In some cases, the APU is run continuously in-flight for additional hydraulic or electrical power.

The APU is actually another jet engine, and its installation requires detailed care during the initial design layout. The APU needs its own inlet, exhaust pipes, and it must be covered by a firewall. Ground access is very important since it requires frequent maintenance. The APU is generally mounted inside the tailcone of a transport aircraft so that the noise can be isolated. The APU can also be located inside the landing gear pods of some military transport aircraft whose landing gears are located in fuselage-mounted pods.

It should be also remembered that the exhaust from the APU is extremely hot and noisy. Therefore, aircraft structure and obviously any human being should not be imposed to it. I introduce specifications of some APUs available in the market in Table 3-9 believing that it could enlighten the issue.

The dry weight seen in the table represents only the uninstalled APU weight. Obviously, the installed APU will be heavier than the uninstalled one because of the firewalls and other additional material. That's why the uninstalled APU weight value should be multiplied by 2.2 in order to get the real weight loaded on the aircraft (Raymer, 1999).

APU Type	Startup Ceiling (ft)	Dry Weight (lb)	Ground Power (kVA)
Honeywell 331-350	41,000	560	115
Honeywell 331-500	43,000	730	120
Honeywell 700	25,000	650	100
PW901	25000	835	180

Table 3-9: Auxiliary Power Units (Jane's All the World's Aircraft 2001-2002, 2001)

As of November 2002, the statistics of Honeywell 331-400, which is the APU on Boeing 767-400ER, were not available on the open sources. However, the information about Honeywell 331-500 could be used instead since it has also 120-kVA ground power. As seen on the table above, Pratt & Whitney (Canada) PW901 provides 180kVA power that is half as much as the one on the Boeing 767-400ER. The first iteration will be done based on the APU that is currently installed on the Boeing 767-400ER. If more power is needed, the P&W generator installation will be considered and the results will be stated. It should be also noted that selecting the P&W brand APU would load an additional 105 lb (47.62 kg) weight on the aircraft. This weight addition will be also kept in mind during the estimations. I should also express that both kVA and kW can be used as the unit of power because of the fact that watts is the product of Volt and Ampere.

Now, let me dig into more. Is the most powerful APU available in the market going to be good enough to satisfy the need for the high power demand? In order to answer this question, we should examine thoroughly each subsystem that will be mounted on the aircraft and identify the overall power demand. Actually, it is not a piece of cake. To do this rigorously requires "component weights, geometries, and power and cooling requirements will have to be estimated by the avionics experts, but that will take six months to a year" (Raymer,1999:303). So, a simpler procedure will be used here.

While each alternatives are being examined, a list of mission equipment will be listed along with the weight and volume characteristics and power needs. The required specifications have been collected from several sources -mostly Jane's avionics, radar, C4I and aircraft systems books. These sources are numbered with the reference numbers of 16, 27, 35 and 40 in the bibliography. In most cases, power consumption and volume values have been estimated by using the formulas available in the aircraft design books. The reader should refer to Appendix D to see a tabular list of the formulas giving the power and volume characteristics of different avionic systems for a given weight. Some reductions to the formula results could be applied because of the technological enhancements in the electronic systems over the years. This approach is similar to that employed in the Space Mission Analysis and Design (SMAD) methodology, which is used in conceptual satellite design (Wertz and Larson, 1999). Explanations that are more detailed will be introduced while those values are being estimated through the text.

After the test-flights performed with Paul Revere platform, it is revealed that the MMA concept will need for high amount of electric power because of its extended avionic systems. Therefore, the idea of installing additional powerful APUs onto the aircraft could be considered in order to increase the power supply.

This discussion brings up the question whether we can install more than one APU to meet the power requirements or not. The physical realities of the APU installation stated above make us think that adding an extra APU does not make sense, or a very detailed design should be implemented to locate that equipment. Additionally, I have not run into any aircraft having multiple APUs on the available literature. Thus, the idea of installing more than one APU onto an alternative is disregarded.

3.6.4 Avionics Analysis

Avionics is the abbreviation of “aviation electronics” that includes radios, radars, flight instruments, flight control computers, infrared detectors, navigational aids and other equipment. Today’s avionics are the integral part of the design process with the approximate cost of approaching a third of total costs for some military aircraft (Raymer, 1999). We can envision that the MMA’s avionics will also cost a lot.

Avionics could be classified as Communication\Navigation (Com\Nav), Mission Equipment, and Vehicle Management (Raymer, 1999). Now that a commercial transport aircraft that is currently available in the market has been chosen for the MMA concept, the Com\Nav and Vehicle Management subsystems are going to come inherently with the baseline architecture. Thus, our main concern should be on the Mission Equipment.

As electronics progressed, military aircraft began to be dependent on the onboard electronics for the fulfillment of the mission. Mission equipment now includes air-to air and air-to ground radar, electronic countermeasures, infrared seekers and sensors, IFF, gun and missile aiming, terrain following autopilots (i.e. Lantern system), active electronic stealth techniques and host of other mission-specific systems. These systems also require a lot of onboard computing power.

The location of the avionics is very important. They should be close to the crew to have short cables. They must be supplied with enough power and cooling air. They are very sensitive to vibration and heat.

The interconnectivity of airborne electronics is called *architecture* and it mainly includes six aspects; displays, controls, computation, data buses, safety partitioning and environment (Kayton, 1997). That means we have to allocate some room for all of these six aspects inside or on the surface of the aircraft.

For the sophisticated aircraft, design of the avionics system requires integrated teamwork done with the aircraft designers and avionics experts. Besides, it is a very time consuming and tedious work to do, as I stated before. For a military aircraft, most of the avionics equipment will be new and it will be very hard to make the exact drawings since the avionic components most probably have not been designed yet.

However, for the initial design, the historical data of the current systems could be used in the weight, volume and the performance trade. The required data can be delivered from the manufacturers. However, the manufacturers generally do not release the latest data to anyone who is not a potential costumer for them. In this case, there is no option than using the data, which is sometimes very old, available on the open sources.

There is a trend toward miniaturizing and integrating the avionics systems such as the active phased arrays that are providing a better performance and up to 30% reduction in space and weight. Those arrays even let the antennas be mounted on the skin of the aircraft during the manufacturing phase.

Although a specific technological improvement factor can be employed in the estimations, there is a strange contradiction in design of some kind of avionics components. Those avionics are getting better in performance not in dimension. That's why we can assume the similar weight and volume characteristics of the current systems with not so much potential weight reduction due to the technological developments. For this reason, it is chosen as zero in my estimations. Raymer gives a rule of thumb expressing that the avionics has a density of around 30-45 lb/ft^3 or 480-720kg/m^3. This will be used in Appendix D in order to estimate the volume in case a suitable formula cannot be fit to particular avionics equipment.

The transport aircraft have quite small radar with respect to the bombers in their nose. This radar is generally used for weather avoidance. Figure 3-12 shows the antenna layout of both commercial and military aircraft. It is seen that there are many antennas distributed all over the fuselage, wings and tail. They are easily identified on a close shot picture of a commercial jet as tens of sticks attached on the fuselage. Keeping in mind that these are the antennas needed only for basic communication purposes, other special purpose surveillance and intelligence sensors will take a lot of space on the body of the aircraft. They would certainly require detailed engineering and laboring.

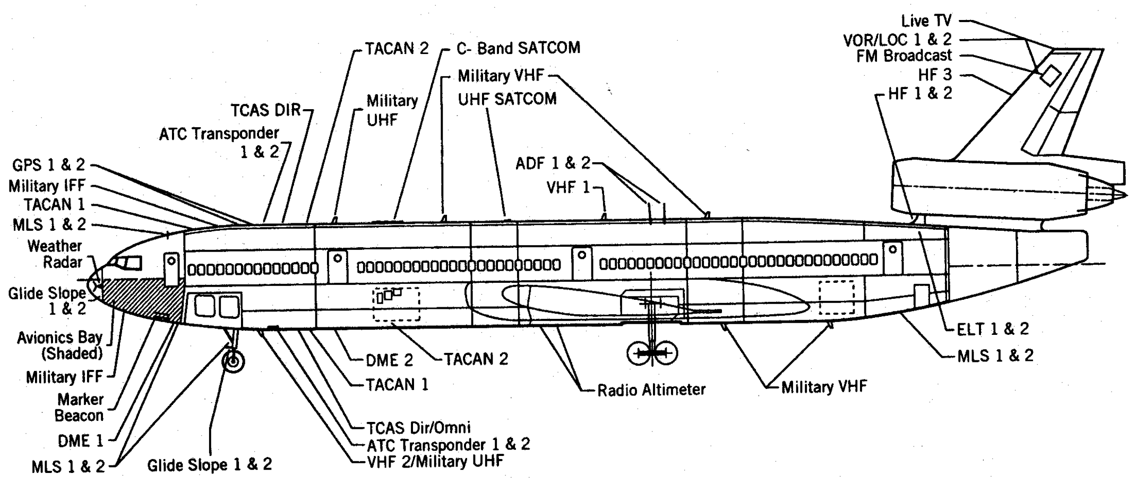


Figure 3-12: Avionics Placement on Multi-purpose Transport and Military Aircraft (Kayton, 1997)

The avionics systems that are to be installed on the new MMA platform need to be identified. For this reason, I ought to name every subsystem, especially the C4I systems, on the current aircraft. I have already listed all known subsystems of the current fleet in several tables in the Chapter 2. Besides, Table 3-10 summarizes the equipment mounted onboard the current airframes.

	AWACS	JSTARS	Rivet Joint	ABCCC	Compass Call
INS	1	1	1	1	1
TACAN	1	1	1	1	1
ESM	1				
RCMP	x				
Radar Synchronizer	x				
STALO	x				
AR	x				
MP	x				
DDP	x				
RDC	x				
Consoles	14	18	x	15	x

	AWACS	JSTARS	Rivet Joint	ABCCC	Compass Call
Air Data Computer	1				
Interface Adaptor	1				
PCE	x				
AA(transmitter, IFF\SSR)	x				
MR	x				
HVPS w\ transformer, filter, regulators	x				
Transmit Electronics	x				
RC	x				
Digital Processor		18			
Supermini Computers		x			
Signal Processors		3	x		
High-speed Processors		15			
Printers	x	x	x	x	x
Workstations		18			
JTIDS Terminals	x	2	x	x	
UHF Radios	x	12	x	Totally 23 Radios	3
VHF Radios	x	3	x		1
HF Radios	x	2	x		2
SINCGARS		1		x	
SATCOM	x	x	x		1
INTERCOM	x	Multiple	x	x	x
SCDL Air Data Terminal		1			
TADIL	1	x	x		
JTT with a constant source		1			
Integrated Terminal Group Radios			4		
Track Management Processor			x		
Common Data and Retrieval Sys			x		
Comms. Emitter Location Sys			Multiple		
Background Search Sys.			x		
Beamformer Processor			x		
Search Database Processor			x		
ACIDS				1	
CS				1	
TBMS				1	
AMS				1	
Blink Jammer					1
Radar Warning and Homing	x	x	x	x	x
Countrmeasr. Dispensing Set					1
Countrmeasr. Receiving Set					1

	AWACS	JSTARS	Rivet Joint	ABCCC	Compass Call
Terrain Following Radar	x	x	x	x	x
Crypto Equip.	x	19	x	x	x
ECM Sys.					1

Table 3-10: Equipment Mounted on the Current Airframes

Generally, the sources from which I have gathered the data about systems do not mention about how many of them are mounted on the related airframe. For example, *Jane's All the World's Aircraft* states that there are supermini computers installed on the JSTARS. However, the total number of those computers is not clearly stated. This forced me to assume some fabricated configurations for those equipment.

System enclosures mechanically mount computer modules to a backplane module within an aircraft. Traditionally, Air Transport Tracking (ATR) units are the standard enclosure formats (Newport, 1994). The ATR system enclosure formats are shown in Table 3-11. One would need for this conversion table a lot since dimensions of the avionics systems are defined in ATR units in some sources.

	Width (in)	Height (in)	Length (in)
1 ½ ATR	15.29	7.64	12.52
1 ATR	10.09	7.64	12.52
¾ ATR	7.50	7.64	12.52
½ ATR	4.88	7.64	12.76
⅜ ATR	3.56	7.64	12.76
¼ ATR	2.29	7.64	12.76

Table 3-11: Standard Enclosure Dimensions (Taken from MIL-STD-1788)

A new technology called network-centric environment is intended to employ in data transfer between the MC2A and other aerial platforms. Under current technologies, a crew aboard the MC2A would have to put data about targets into a data link that connects to a fighter aircraft. The fighter pilot would have to look at the data and translate it into something he finds on his radarscope while still flying his plane. It is not the case in network-centric environment such that information can move directly from one platform to another without requiring human intervention. In a network-centric environment, the data would move straight from the MC2A's computers to the fighter's control system. Such applications eliminate steps that are non–value added that take time and that can introduce error.

There are also several ongoing studies about integrating the intelligence and jamming equipment into one payload or system such as the Adaptive Joint C4ISR Node (AJCN). This system is designed to relay communications, listen to the advisories' conversations, or jam enemy's communications all at the same time. It can be applicable to almost any type of platforms since it is modular. Although this integration used to seem unattainable several years ago, the latest developments made it possible. The basic package contains two currently used subsystems, the Signal Intelligence (SIGINT) software and the Joint Tactical Radio System (JTRS). JTRS is designed to receive signals from different sensors and convert them into a common language that can be transmitted throughout a network. These two capabilities will be combined with the jamming function. The system can switch to another task whenever needed. For example, it can shift to jam the foe's communication systems while it was providing long-range communication to the friendly forces. Actually, this is a big milestone in multimission aircraft concept. This development could solve many problems in integration in terms of volume and power considerations. The project is planned to be in use by the year 2007 after a 5-year test and evaluation period (Fulghum, David A. "Sigint, Jamming Joined in Single Package", *Aviation Week & Space Technology*, 23 Dec 2002: 34).

It is known that JSTARS, AWACS and RJ are equiped with JTIDS. However, there are some similarities and redundancies in the computations performed with separate JTIDS, GPS, INS and Relative Navigation (RelNav) units. That is, the same data is gathered independently by each of those subsystems. So, a fully integrated navigation system called Multifunctional Information and Distribution System (MIDS) having lower cost, weight, volume and power requirements than the mentioned subsystems will be considered as an alternative in the estimations performed in Chapter 4. The MIDS will integrate all the functions of aforesaid subsystems within a one-unit air-data computer. Moreover, it will also provide the optimum combination of the measurements from those multiple sensors.

Jan Roskam gives a quick formula (Equation 3.7) in order to estimate the weight of the instrumentation, avionics and electronics of an aircraft in his book *Airplane Design, Part V: Component Weight Estimation, 1999.* The results are remarkably close to the real values of the several commercial airplanes:

$$W_{iae} = 0.575 \times (W_{empty})^{0.556} \times (R)^{0.25} \qquad \text{Equation 3-7}$$

where W_{iae} is the weight of instrumentation, avionics and electronics, R is the maximum range, which is 5626 nmi for Boeing 767-400ER. Given values yield to an approximate weight of 4738 lb (2149 kg) for the previously mentioned subsystems.

3.6.5 Life Cycle Cost (LCC)

Life cycle cost has become one of the major concerns in preliminary aircraft design. Commercial and military aircraft LCC consist of different segments. The elements that make up aircraft LCC are shown in Figure 3-13. The sizes of the boxes also represent roughly the relative magnitude of the cost involved.

Research, Development, Test and Evaluation (RDT&E) cost includes the costs associated with the airworthiness, mission capability, and compliance with Mil-Specs. RTD&E costs are actually nonrecurring irrespective of how many aircraft are produced. It is typically less than 10% of the overall LCC (Raymer, 1999).

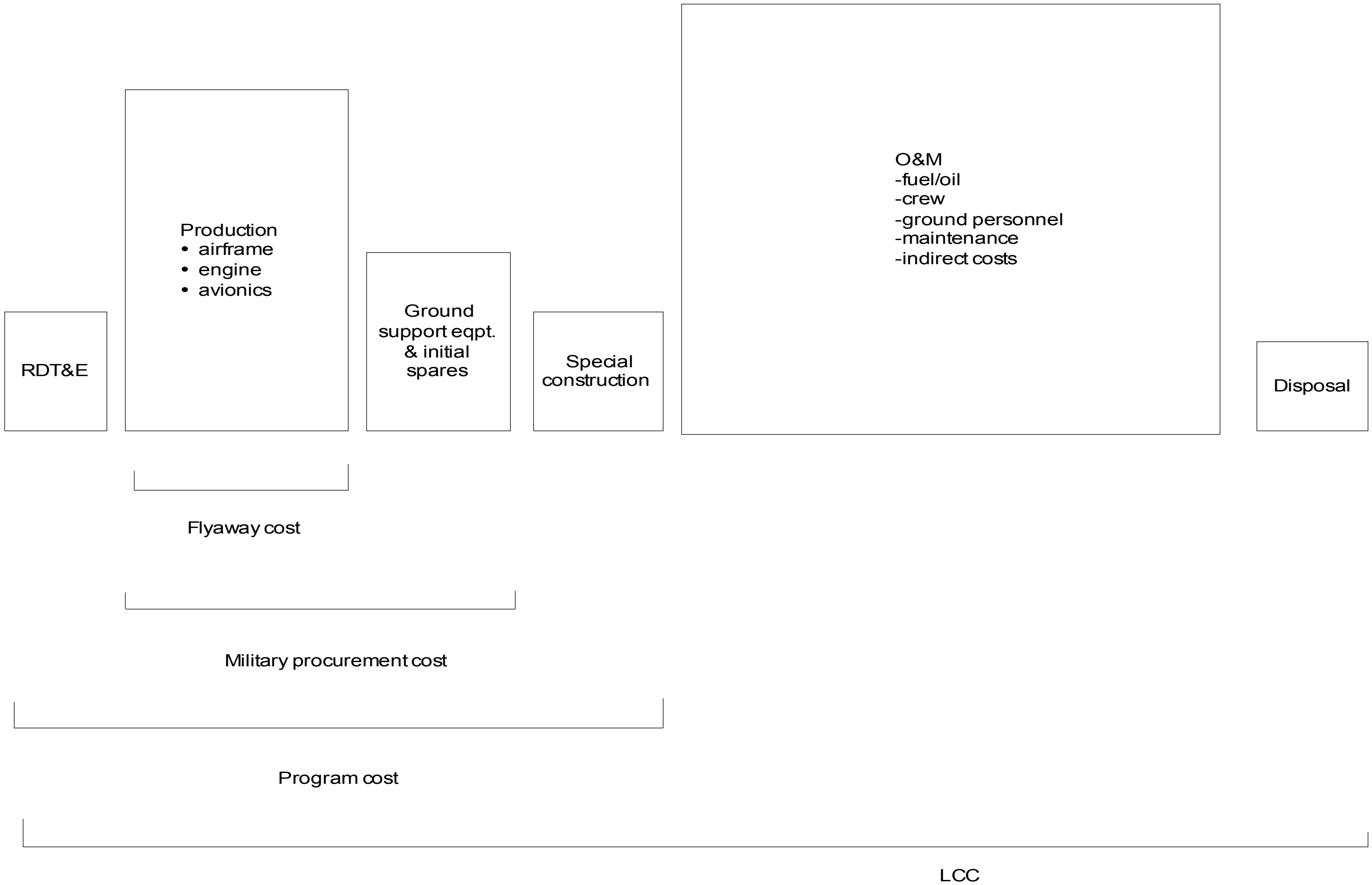


Figure 3-13: Elements of LCC (Raymer, 1999)

The flyaway cost covers the labor and material costs to produce the aircraft including airframe, engines and avionics. It is directly related to the number of aircraft manufactured. However, the cost of every new aircraft gets smaller because of the learning curve effect. For the military aircraft, flyaway cost is approximately half of the total LCC (Raymer, 1999). Actually, it is very difficult to distinguish the RTD&E and flyaway costs. So, they will be estimated under the same title in this thesis.

Modified DAPCA IV Cost Model is used in order to estimate the RTD&E and flyaway costs. For convenience, the formulas in mks units, which are typically kg, meter, second, km/hr, are selected. It should be remembered that costs are in constant 1999 US dollars (Raymer, 1999).

Following are the formulas used in LCC estimation.

$$H_E = 7.53\ W_{empty}^{0.777}\ V^{0.894}\ Q^{0.163}$$ Equation 3-8

$$H_T = 10.5\ W_{empty}^{0.777}\ V^{0.696}\ Q^{0.263}$$ Equation 3-9

$$H_M = 15.2\ W_{empty}^{0.82}\ V^{0.484}\ Q^{0.641}$$ Equation 3-10

$H_Q = 0.076\ H_M$ if cargo A\C

$H_Q = 0.133\ H_M$ otherwise Equation 3-11

$C_D = 48.7\ W_{empty}^{0.630}\ V^{1.3}$ Equation 3-12

$C_F = 1408\ W_{empty}^{0.325}\ V^{0.822}\ FTA^{1.21}$ Equation 3-13

$C_M = 22.6\ W_{empty}^{0.921}\ V^{0.621}\ Q^{0.799}$ Equation 3-14

$C_{eng} = 2251\ [9.66\ T_{max} + 243.25\ M_{max}$

$+ 1.74\ T_{turbine\ inlet} - 2228]$ Equation 3-15

$RTD\&E + \text{flyaway costs} = H_E\ R_E + H_T\ R_T + H_M\ R_M + H_Q\ R_Q + C_D$

$+ C_F + C_M + C_{eng}\ N_{eng} + C_{avionics}$ Equation 3-16

where

H_E = Engineering Hours

H_T = Tooling Hours

H_M = Manufacturing Hours

H_Q = Quality Control Hours

C_D = Development Support Cost

C_F = Flight Test Cost

C_M = Manufacturing Materials Cost

C_{eng} = Engineering Production Cost

$C_{avionics}$ = Avionics Cost

V = Maximum Velocity (km\hr)

Q = Lesser of production quantity or number to be produced in 5 years

FTA = Number of flight test A\C

N_{eng} = Total production quantity times number of engines per A\C

T_{max} = Engine maximum thrust (kN)

M_{max} = Engine maximum Mach number

$T_{turbine\ inlet}$ = Turbine inlet temperature (K)

It should be also noted that the hours estimated by DAPCA are based upon the design and fabrication of an aluminum aircraft. The hours estimated with this model are multiplied by the appropriate hourly rates, called *wrap rates*, in order to calculate the labor costs. Following wrap rates, which are adjusted to 2003 by assuming 5% compound interest rate, are used in those estimations (Raymer, 1999):

R_E = Engineering = \$104.53

R_T = Tooling = \$106.96

R_Q = Quality Control = \$98.46

R_M = Manufacturing = \$88.73

Unfortunately, DAPCA does not estimate avionics weight. However, avionics cost can be approximated as \$8.5 – \$15.8 per gram in 2003 dollars. So, an average of \$12 per gram is assumed as the unit avionics cost (Raymer, 1999).

Analogously, there are not any formulas used to calculate the interior accommodations such as seats, lavatories, and similar items. Nevertheless, Roskam suggests that cost per aircraft be increased by approximately \$3000 per passenger for jet transport (adjusted to 2003 dollars). Additionally, initial spares will add possibly 10 to 15% to an aircraft's purchase price (Raymer, 1999).

Military procurement or acquisition cost includes the production cost and the ground support equipment cost such as simulators and test equipment. One of the latest trends in military aircraft manufacturing is called "cost sharing", which means that the military officials invite the manufacturer to share some of the RDT&E costs expecting the manufacturers recovering them during the production. However, it is somewhat related to the future decision makers' permission to the full cost recovery.

Program cost includes the total cost to deploy the aircraft into the military inventory. Some aircraft require special ground facilities such that an aircraft having a wide wingspan requires building larger hangars that causes a special construction cost.

O&M costs are typically equal to the development and production costs for the military aircraft. O&M costs cover fuel, oil, maintenance, and other indirect costs. The disposal cost for military aircraft can be ignored in LCC estimation since it is generally assumed that they have no market value after lifetime has ended. Storage cost after disposing the aircraft is not a big deal (Raymer, 1999).

We need to know the yearly fuel usage of a single A\C in order calculate the fuel and oil costs. To do this, a typical mission profile is selected and the total duration and fuel burned are used to determine the average fuel burned per hour. This is multiplied by the average yearly flight hours per A\C, which must be assumed based upon typical data for that class of aircraft. Table 3-12 gives some rough guidelines for some LCC parameters for military and civil transport aircraft.

A/C Class	FH/YR/AC	Crew Ratio	MMH/FH
Military Transport	700-1400	1.5 if FH/YR < 1200 2.5 if 1200 < FH/YR < 2400 3.5 if 2400 < FH/YR	20-40
Civil Transport	2500-4500	-	5-15

Table 3-12: LCC Parameter Approximation (Raymer, 1999)

Then, the total amount of fuel burned per year of operations is multiplied by the fuel price as obtained from the vendors. Although fuel prices can change always, they were around 80 cents per gallon as of December 2002 (http://www.eia.doe.gov, Dec 2002). Raymer also suggests the same price. It should be also noted that the oil costs average less than half a percent of the fuel costs and can be ignored.

Maintenance cost is calculated by multiplying the MMH/YR times maintenance labor cost. In the absence of better data, the maintenance labor cost can be approximated by the manufacturing wrap rate, which is $88.73. Materials, parts and supplies used for maintenance will approximately equal the labor costs for military aircraft (Raymer, 1999).

Consumer Price Index information provided by United States Bureau of Labor Statistics is used as an approximate economic escalation-factor. The average salary per crewmember can be assumed as typically $48000 per year or $4000 per month.

3.6.6 Takeoff Roll Length Analysis

Takeoff roll length of an aircraft is directly related to W_o and the altitude of the airport from sea level. Namely, required runway length increases as takeoff weight and altitude of the airport get higher.

As a NATO aircraft, MMA has to comply with the regulations of the NATO as well. Most importantly, length of a NATO runway must be longer than 8000 feet (Aftergood, 1999). It is certain that this limitation directly affects the amount of loadable fuel before takeoff. In some cases, the aircraft might not take off because it cannot be loaded with enough amount of fuel due to its huge gross weight. Alternatively, an immediate in-flight refueling just after the takeoff might be unavoidable. It is also apparent that this issue will affect the range of the aircraft and the timing of first air refueling after takeoff.

Besides, aircraft need more runway length in order to take off from higher altitudes. Related tradeoffs have been introduced in Chapter 4 by using two runway length plots of 767-400ER, which are available in Appendix B.

3.6.7 Assessment of Risk

Every implementation contains some risk to an extent whose magnitude may vary with respect to many factors. Therefore, every decision along with investment should be made by considering risk. Risks that MMA integration involves have been examined under five categories.

3.6.7.1 Technical Risk

Integrating big numbers of electronic systems into one airframe could cause several technical problems. Most specifically, physical limitations of the aircraft may not be sufficient for required amount of equipment. If selected aircraft has any problems with meeting those requirements, then another aircraft should be selected or the requirements set at the beginning should be modified. For example, if 767-400ER is not big enough to load all avionics that the OTN alternative needs, then a bigger aircraft must be considered or a suitable DTN alternative should be employed.

There is a rapid increase in the required computer programming before an aircraft can enter the operation. This computerization makes almost everything easier for the crew. However, the aircraft could be so relied on those systems that you might have to reactivate the aircraft if they stop working. In short, it could be too difficult to recover any failure in a system that is highly dependent on computerization while that problem could be instantly solved without any severe damage in less sophisticated systems.

3.6.7.2 Cost

In many cases, implementation of a project or investment might be cancelled only because of the magnitude of its cost. Cost has been considered as a major concern although it used to be believed trivial for military applications. Therefore, the cost estimation accuracy has to be ensured in order to prevent further inconsistencies. Insufficient number of similar investments in a specific type of area could cause a risk or uncertainty for cost assessments. Besides, changes in external economic environment are always a threat to making right decisions. In other words, past information is often valuable while there is a risk in using it directly without adjustments for expected future conditions. Additionally, biased data and estimations should be recognized through analysis review procedures.

3.6.7.3 Implementation Schedule

Opposite relationship between available budget and implementation schedule compels analysts and decision makers to make some necessary tradeoffs in terms of many aspects of the project. More specifically, development and test period for some kind of equipment might extend the delivery time of an aircraft. Therefore, decision makers sometimes should decide whether an aircraft should have a better performance or should be in use earlier.

3.6.7.4 Simultaneous Systems Limitations

The fact that different types of systems have to work simultaneously in order to run an integrated system is a huge problem standing in front of MMA integration. For example, the aircraft might not be performing two different types of missions at the same time when two different sensors do not cover the same area of interest. Analogously, altitude or air speed necessary for specific equipment might not work for another crucial sensor that is also needed for simultaneous operations.

Another simultaneous system operability problem is certainly the interference between conflicting systems. It does not make any sense to construct a self-jamming aircraft in spite of the fact that it meets all of the physical requirements. Hence, it is very important to conduct fundamental consistency tests before letting the aircraft enter the operation.

3.6.7.5 Vulnerability

Risk of loosing so many precious equipment and crew in case of a crashing should be taken into account before determining the type of MMA to be produced. It is obvious that OTN alternative is more risky than others in terms of information security issues. It should be also remembered that the same risk for DTN alternatives could not be ignored either.

Additionally, the incident that the airframe is captured by the adversaries is also a risk that must be always kept in mind. However, this small probability is never a preventive reason to create such architecture. OTN is again more risky than DTN regarding to the risk of possession by the adversary.

The issues that are considered important in the problem definition part have been examined so far. Now it is time to reveal which alternative, either OTN or DTN, meets the requirements with the help of the spreadsheets available in Appendix E and F. This study will be presented in Chapter 4.

4 RESULTS

4.1 Assessments of the MMA Alternatives

In this chapter, the payload characteristics of each type of MMA will be assessed based on the established methodology. The MMA will obviously consist of the common equipment, which are necessary to fly an aircraft, and mission equipment, which are necessary to perform the tasks of current airframes desired to be integrated on the MMA.

For this reason, an Excel spreadsheet, which is available in Appendix E, has been prepared calculating the power and volume characteristics of selected equipment by using the formulas presented in Appendix D. The spreadsheet also estimates the required rest area, lavatory and galley measurements for indicated number of crew.

Once you insert the weight of any particular avionics system in kilograms, the spreadsheet calculates the weight in pounds, needed volume in ft^3, m^3 and in^3 and power in watts. A specified technology enhancement can be also applied to the ultimate estimations considering that technological improvements have increased the performance of the avionics equipment since the time the formulas were prepared. However, I have chosen that enhancement rate as 0% for this study because of the reasons stated in section 3.6.4 and more. One could change the initially inserted weight, enhancement percentage and crew numbers by plugging different values into the assigned cells in the spreadsheet.

In the quantity column of the spreadsheet, the known quantities of related equipment available in a single current airframe have been inserted. For example, the reader would see 12 in the quantity cell for UHF radio which is the total number of associated radio available in the JSTARS.

Constant c for each equipment, which was defined in section 3.2.2, has been selected by inspecting the number of regarding equipment currently mounted on the current fleet. For example; if you are dealing with integrating, let's say, AWACS and JSTARS, c has been chosen as 1.5 that indicates that 12 x 1.5 = 18 UHF Radios are considered on the DTN11 architecture. Similarly, choosing c as zero means that related equipment is not needed on that particular MMA. It is very important to state that the common equipment available on each airframe is not multiplied by the constant c in the calculations. In other words, c for the common equipment is always 1. Common equipment in question are listed at the very beginning of estimations with the same title.

Even though c could be chosen up to five in theory, it would never be so high for any type of integration. For example, c for VHF Radio of OTN alternative has been chosen as 3.5 instead of 5. Although OTN is an integration of 5 current fleet, required number of those radios will be less than the sum of radios needed individually. In other words, the main idea is 1 + 1 < 2.

The equipment are categorized with respect to the site they are positioned. These sites are interior cabin, below front cabin, below rear cabin and on the outer surface of the fuselage. Hence, not only any violation of overall space limitations but also the ones regarding to any specific region of the aircraft have been checked. I should also express that there is no need to set such a categorization for weight and power issues. Following is the list of arguments used as the baseline of the spreadsheet:

- Each crew seat weighs 14.5 kg (32 lb) luckily needing no power to run. The room they occupy will be considered along with the operational consoles. Additionally, each crew is assumed to weigh 81.65 kg (180 lb) (Roskam, 1999).

- The layout of the operational consoles mounted on the AWACS is chosen as the baseline. Each console will be placed back to back along the corridor leaving a 60 cm walkway between the processors located adjacent to the other side of the cabin. Each console will host 6 operators with displays and computers. Every set of consoles will occupy $7.2679 m^2$ area and $13.88175 m^3$ space including the clearance between the sets of consoles. The space between the top of a console and ceiling is also included in the total volume of a console since that part of the cabin couldn't be allocated for any other equipment. The clearance between two sets of consoles is assumed as 60 cm. Analogously, each set of consoles are assumed to weigh 90 kg including the computers and displays. Figure 4.1 depicts the proposed console from a three dimensional view.

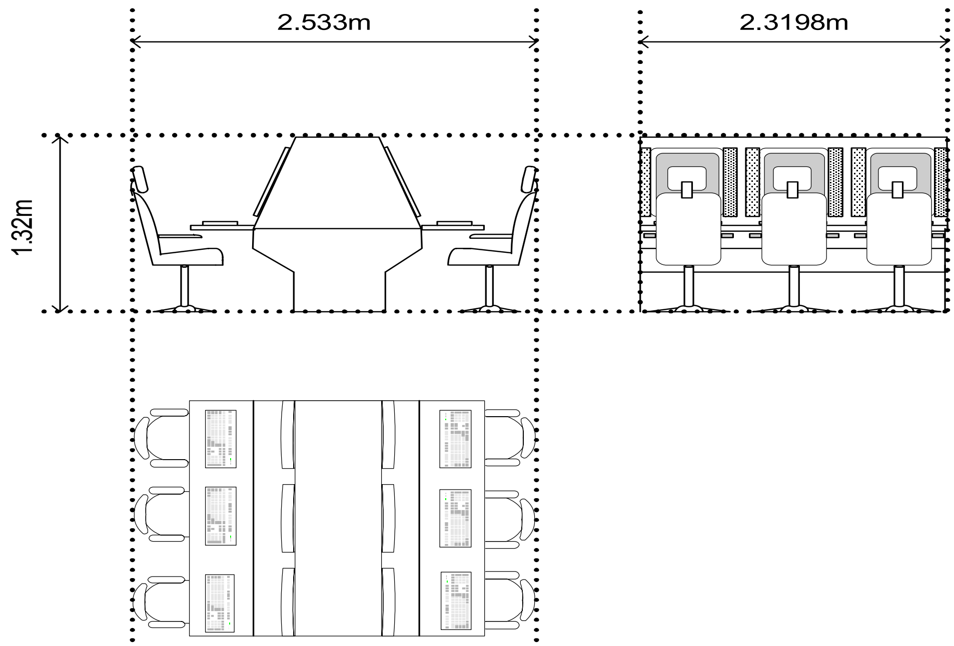


Figure 4-1 : Imaginary 3-D view of an Operational Console

- A rest area is located under the cabin near to the flight deck having double decker bunk beds positioned longitududally. Total number of beds will be the one third of the crew onboard. Each bed can host 2 crew at a time and has dimensions of 1m x 1.68m x 1.9m. At most 8 bunks can be located longitudinally on one side of the corridor because of the length limitation (the length of the lower cabin is 16.27m). A-44 cm walkway is allowed between the beds located on each side of the corridor. This would cause a 12.027 m^3 lose in the available volume. That some processors and avionics may also be located at the same place is going to be a threat to the full satisfaction of the resting crew. Noise and radiation from the equipment could possibly cause fatigue and insomnia on the crew. Actually, this is a bigger problem than expected since the rest area could not be big enough for a large number of mission crew needed for a 24 hour mission. A standard power need of 500Watts is considered for any size of the rest area. That power will be used in order to illumine the location.

- Now that the OTN needs to be in-flight refuel capable, some extra equipment has to be installed at the top of the fuselage near to the nose. Following equation is utilized in order to calculate the weight of the in-flight refuel system (Nicolai, 1988):

$$W_{in\text{-}flight} = 13.64\ (W_{fuel} \times 10^{-2})^{0.392} \qquad \text{Equation 4-1}$$

where W_{fuel} is the maximum usable fuel in gallons. This formula gives the weight of mentioned subsystem as 117.18 lb (53.15 kg).

- Weights of lavatories and galley are estimated by using Equation 3-3. Required space and power are calculated according to the size of the crew. Power need for the galley would be considerably high because of the devices such as microwave ovens and refrigerators etc.
- A key assumption in the estimations is that the APU can be utilized as a continous source of power like other two engine driven generators (Raymer, 1999: 299).
- It is certain that some of the equipment available on the airframes are not listed in this thesis. They might be either classified or not mentioned in the open sources.

For this reason, those equipment are considered as 5% of the total interior equipment and added to the estimations.

- The weights gathered from the sources are for the uninstalled avionics. We should keep in mind that extra joining and covering material will be used in the installation. Following formula gives W_{TRON}, which is the total installed avionics weight:

$$W_{TRON} = 2.117\ (W_{AU})^{0.933} \qquad \text{Equation 4-2}$$

  where W_{AU} is the uninstalled avionics equipment weight (Nicolai, 1988).

- Generators are considered having 84% power efficiency. That is, 84% of the generated power is usable.

- Crew numbers for each sensor combinations have been obtained from the member of Systems Engineering Design Team dealing with the operational environment issue. Mission of each person onboard has been also examined by her.

- Range and endurance estimates are based upon a takeoff from a 8000 feet long runway.

The imaginary antenna layout of OTN is drawn in Figure 4-2 and Figure 4-3. The antennas are placed at approximately the same places where they used to be on the related current airframe.

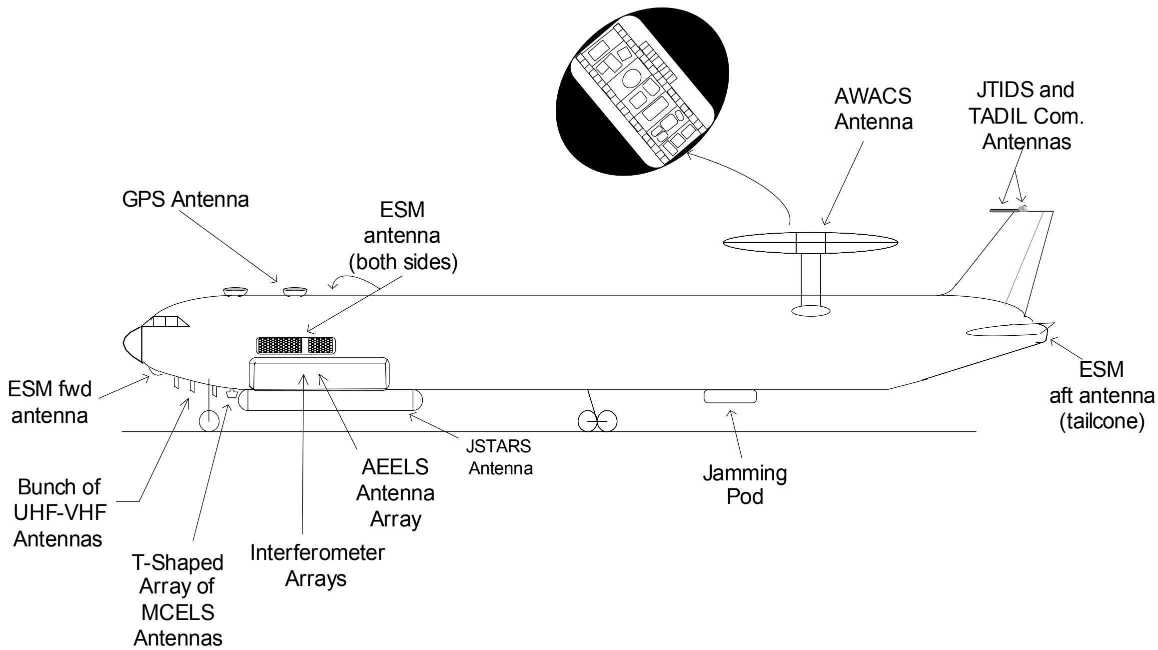


Figure 4-2: OTN Antenna Placement (Side view)

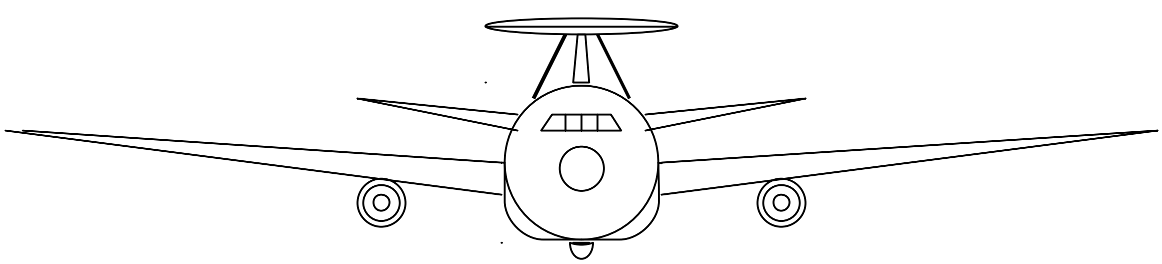


Figure 4-3: OTN Antenna Placement (Front view)

AWACS radar is positioned at the top of the fuselage in front of the tail. JSTARS radar is mounted on the belly while RJ sensors are located on the cheek just below the ESM antennas on each side of the fuselage.

Besides, COMPASS CALL jamming pod has been placed under the belly between the landing gears and tailcone. It is certain that there are dozens of other communication and navigation antennas as shown in Figure 3-5.

The interference between those antenna arrays were inspected by the AFIT EM representative of the MMA study. She envisioned that both AWACS and JSTARS sensors will have harmonic and spurious interference with RJ antennas. Time management is recommended as an option for compatibility. This interpretation makes OTN alternative unattainable in terms of electromagnetic considerations. Although other alternatives have also some interferences between each other, this problem can be overcome with the help of available techniques and technologies. So, other MMA alternatives are considered as practical with reapect to electromagnetic considerations.

Notional placement of the operational consoles, processors, computers, lavatory and galley inside the OTN is shown in Figure 4-4. It is seen that 57 consoles are located on the right side of the cabin while the processors reside on the opposite side. Lavatories are arbitrarily positioned in the front cabin entrance and at the end of the consoles. Galley equipment is at the end of the corridor just like the ones on commercial aircraft.

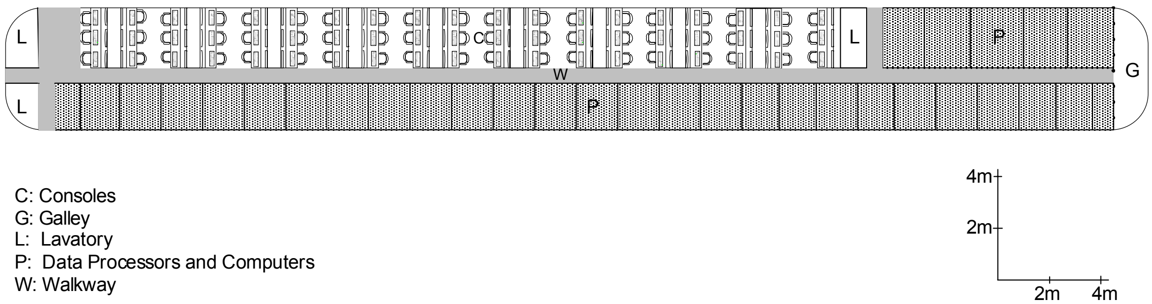


Figure 4-4: Notional Interior Layout of OTN

Now let's examine what we can mount onto Boeing 767-400ER without violating the weight, volume and power limitations. Table 4-1 summarizes the limitations of Boeing 767-400ER.

	Weight (kg)	Volume (m^3)	Power (Watts)
Interior	-	563.4	-
Below front Cabin	-	67.97	-
Below Rear Cabin	-	61.17	-
Bulk Cargo	-	9.77	-
Engine	-	-	240,000
APU	-	-	120,000/180,000
TOTAL	52,473	702.31	*302,400/352,800

* with 84% power efficiency

Table 4-1: Summary of Limitations of 767-400ER

Alternatives listed in system modeling section of Chapter 3 have been examined. Required weight, volume and power values have been calculated by assigning suitable c values to the subsystems. The writer selected the c constants by inspecting the airframes that form the related alternative. A team of avionics experts could determine more suitable values representing the selected MMA for more accurate results. Table 4-2 summarizes the results gathered for alternatives in question. The meanings of configuration symbols can be seen from Table 3-2. Moreover, the reader can find the detailed lists of equipment and assigned c constants for every alternative from Appendix E.

The power requirements that are not violating the aircraft's boundaries are written in boldface so that they can be easily identified. The power comparison has been made with respect to different type of generator considerations. The first column of the power title assumes that APU can't be utilized as a major electric supply.

The next two columns make the comparison when 120kVA and 180kVA APUs are respectively used as a major power source along with the engine driven generators. The last column named "Enhanced" refers to the configurations installed with the PW901 APU and new MIDS instead of JTIDS knowing that the MIDS can be installed without waiting for any development period.

		No APU Use	120kVA APU	180kVA APU	Enhanced 180kVA APU
Limitations	Weight(kg)	52473	52473	52473	52473
	Volume(m3)	702.31	702.31	702.31	702.31
	Power(Watts)	201600	302400	352800	352800
OTN	Weight(kg)	42024	42024	42129	40905
	Volume(m3)	527.45	527.45	530.15	529.28
	Power(Watts)	789260	789260	789260	760245
DTN11	Weight(kg)	22557.07	22557.07	22661.85	21845.83
	Volume(m3)	363.08	363.08	365.78	365.21
	Power(Watts)	373425.32	373425.32	373425.32	354082.48
DTN12	Weight(kg)	23923.15	23923.15	24027.93	23415.91
	Volume(m3)	357.24	357.24	359.94	359.51
	Power(Watts)	459924.85	459924.85	459924.85	445417.71
DTN21	Weight(kg)	15916.18	15916.18	16020.96	15286.54
	Volume(m3)	345.78	345.78	348.48	347.96
	Power(Watts)	235707.29	**235707.29**	**235707.29**	**218298.73**
DTN22	Weight(kg)	32384.06	32384.06	32488.84	31672.81
	Volume(m3)	409.03	409.03	411.73	411.16
	Power(Watts)	608295.01	608295.01	608295.01	588952.17
DTN31	Weight(kg)	25603.15	25603.15	25707.93	24973.51
	Volume(m3)	401.74	401.74	404.44	403.92
	Power(Watts)	397702.60	397702.60	397702.60	380294.05
DTN32	Weight(kg)	32714.12	32714.12	32818.90	31798.87
	Volume(m3)	391.08	391.08	393.78	393.06
	Power(Watts)	623543.92	623543.92	623543.92	599365.36
DTN41	Weight(kg)	21128.84	21128.84	21233.62	20825.61
	Volume(m3)	355.44	355.44	358.14	357.86
	Power(Watts)	426973.44	426973.44	426973.44	417302.02
DTN42	Weight(kg)	30269.63	30269.63	30374.41	29354.38
	Volume(m3)	401.46	401.46	404.16	403.44
	Power(Watts)	478212.18	478212.18	478212.18	454033.63

Table 4-2: Summary of Characteristics of MMA Alternatives

At this point, let me explain from where the numbers in Table 4-2 came. For example, let's pick OTN alternative. Estimations for this alternative architecture begin on page E-2 of Appendix E. At the top of that page, limitations of Boeing 767-400ER are presented. After those limitations, common equipment available on every alternative are listed. Then comes mission equipment starting with the ones located in the cabin of the aircraft.

Now, let me explain every cell in a single row, say, of HF Radio. There is 2 in the quantity cell representing the HF radio. This means that 2 HF radios are needed in a single existing airframe. 3.5 next to 2 indicates that OTN architecture will need 3.5 times as many HF radios as the current airframe. 35.17 is the unit uninsatalled weight in kilograms obtained from dependable sources that were stated in section 3.6.3. The number in the installed weight cell, which is 58.654, is calculated by using Equation 4-2.

Then, volume and power values, which are 0.0469 m^3 and 4850.15 Watts respectively,are estimated by using the most suitable formula introduced in Appendix D. Volume results are presented in three different units since some of those formulas give results in ft^3 and others in in^3. Total weight of the HF radios to be mounted on OTN is the product of 2, 3.5 and 58.654. Total volume and power have been estimated in the same way.

This process has been utilized for every equipment listed on pages E-2, E-3, and E-4. The spreadsheet at the top of page E-5 estimates the necessary measurements of crew, seats, galley and lavatory for a total number of 61 crew members. It should be noted that rest area is examined under the title of *Below Front Cabin* on page E-4. It is envisioned that 10 double-decker and 1 single beds will be necessary for selected number crew members.

Table at the bottom of the same page summarizes the results of OTN alternative. The last row of that table shows the sum of everything mounted on OTN. You will see that 40905 kg, 529.28 m^3 and 760245 Watts on Table 4-2 are the same as the ones in the last row of the table on page E-5. "OVERLOAD" at the bottom of total power is an alert indicating that 760245 Watts is greater than the maximum available power, which is 352800 Watts, on Boeing 767-400ER.

It should be also remembered that the estimations presented on pages from E-2 to E-5 are only for the "Enhanced 180kVA APU" configuration, which is going to be described below. Detailed estimations for other configurations are not included in Appendix E because of space concerns.

Results on Table 4-2 reveal that Boeing 767-400ER has no problem with meeting the weight and volume requirements of any combinations of the MMA. Even the OTN, which will supposedly have the greatest amount of avionics onboard, can be carried by 767-400ER. On the other hand, a serious electric power problem instantly draws attention.

"No APU use" assumption won't let any of the alternatives be feasible. That is, if the APUs work only as the ground starting or emergency power supply, then 767-400ER doesn't have enough electric power in order to carry any kind of MMA.

Actually, the opposite approach wouldn't change the situation a lot. More specifically, none of the configurations except for DTN21 can be handled with currently mounted generators along with the APU. Even the selection of PW901 wouldn't do any help to meet the power requirements.

However, we should pay attention to the result of DTN11 after the enhancements. It is obvious that making only one or two c value adjustments would directly draw it under the threshold. For example, if we decreased the number of crew only by 1, the power consumption would become 350403 kVA, which is evidently less than 352800. This is a significant result indeed since DTN11 refers to AWACS-JSTARS integration.

However, such a decrease will not affect the other alternatives so much. Only the power consumption of DTN31 could be drawn to 352645 kVA by decreasing the number of crew by 7. This possibility should be examined by considering the overlapping specialitites of the crew onboard. Now, let's take a look at the results when c is assumed to be 1 for every sort of integration. Results are introduced in Table 4-3.

Configuration	Enhanced Power (Watts)
OTN	578254.5
DTN11	313839.9
DTN12	369812.1
DTN21	175535.5
DTN22	476972.7
DTN31	341413
DTN32	440126.4
DTN41	380465.8
DTN42	351353

Table 4-3: Power Requirements for c=1

It is seen that alternatives DTN11, DTN21, DTN31 and DTN42 become feasible in terms of power requirements when c is applied as 1. However, this enhancement seems unattainable until proposed AJCN technology improvement is available. This requires that related MMA integrations have to be delayed until 2007. AJCN technology was discussed in Avionics Analysis section of Chapter 3.

Actually, the proposed AJCN technology will provide better volume and power characteristics than the case c is equal to1. AJCN equipment will combine, say, five different payloads that have to be installed separately at present. This development is equivelant to the case that those five payloads have the c value of 0.2 each. I have not examined this case because it is not definite which of those existing payloads will be integrated into the proposed AJCN equipment.

Assuming a higher power efficiency rate for the generators also needs to be considered. Figure 4-5 displays the power supply change with respect to the accompanied efficiency rates. If we had a 100% efficient PW901 APU installed, then we would have 420000kVA power which lets the DTN11, DTN21, DTN31 and DTN41 become feasible.

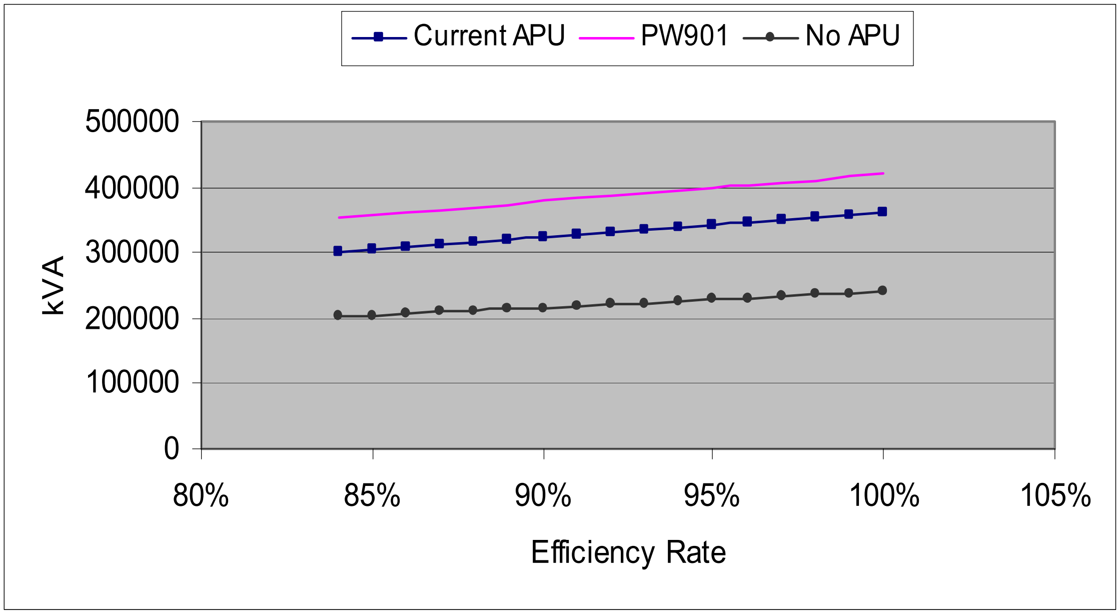


Figure 4-5: Generator Power Efficiency Trade

As a result, these estimations show that the current aging fleet can not be put together into one Boeing 767-400ER by using existing technology. Another significant result of those argument stated above is that different selections and assumptions, and detailed engineering could turn any slightly infeasible configuration into a practical alternative. For this reason, extending the time of delivery could be considered in order to employ future developments in SIGINT technology.

Now that we have figured out the weights, we can get into another issue and look at the weight vs range and endurance trade. We need to know the maximum endurance and range so that one can utilize them in the operational consideration. Besides, takeoff roll length of an aircraft depends on the altitude of the airport it takes off. Table 4-4 shows the maximum takeoff gross weights that a Boeing 767-400ER aircraft can have at different altitudes in order to take off from a 8000 feet long runway.

Airport Altitude	Maximum Wo	
feet	lb	kg
0	410000	178350
2000	390000	169650
4000	370000	160950
6000	350000	152250
8000	328000	142680

Table 4-4: Airport Altitude vs. Maximum W_o for 8000ft Runway Length (Based on Appendix B)

Table 4-5 displays loadable fuel before takeoff, time of first refueling after takeoff, endurance and range values of alternative MMAs given an airport at sea level with the runway length of 8000 feet. The ranges and the runway characteristics of the alternatives are gathered from Appendix B for given estimated payload weights. The similar tables for other base altitudes can be obtained from Appendix G.

	$W_{payload}$	W_{fuel}	Wo	Range				Endurance		Total Number of In-flight Refueling
				After Takeoff		After First Refuel		After Takeoff	After First Refuel	
	kg	kg	kg	nmi	km	nmi	km	hr	hr	times
OTN	40905	40233	178350	2600	4815.2	4250	7871	5.66494118	9.26	2
DTN11	21,846	59,292	178350	4,550	8426.6	5550	10279	9.91364706	12.09294118	2
DTN12	23923.15	57,215	178350	4,300	7963.6	5420	10038	9.36894118	11.80941176	2
DTN21	15286.54	65,851	178350	5200	9630.4	5750	10649	11.3298824	12.52823529	2
DTN22	31672.81	49,465	178350	3500	6482	5300	9816	7.62588235	11.54823529	2
DTN31	24973.51	56,164	178350	4200	7778.4	5470	10130	9.15105882	11.91764706	2
DTN32	31798.87	49,339	178350	3400	6296.8	5150	9538	7.408	11.22117647	2
DTN41	20825.61	60,312	178350	4650	8611.8	5700	10556	10.1315294	12.41882353	2
DTN42	29354.38	51,784	178350	3750	6945	5350	9908	8.17058824	11.65647059	2

Table 4-5: Weight vs. Range and Endurance Trade at Sea Level Altitude

One significant result that these range tables reveal that the OTN alternative can not take off from an airport located at an altitude of 8000 feet from sea level since it cannot be loaded with enough fuel for takeoff. This is because of its huge weight and the runway requirement at that altitude. At the same altitude, you should refuel DTN32 and DTN 22 alternatives at most 26 and 39 minutes later than takeoff respectively.

Analogously, OTN has to be refueled at most 32 minutes later than takeoff at a 6000 feet altitude. This worst case scenario reveals that although 767-400ER is confirmed to carry all kinds of MMA alternatives, weight issue could cause some problems with respect to takeoff consideration.

Additionally, it is appearant that all of the DTN alternatives have an after-first-refuel-endurance time around 12 hours. Although 3% reserve fuel is allowed in the estimations, the endurances of DTN11, DTN 21 and DTN41 alternatives seem critical since they are barely greater than 12 hours. This point should be considered while the operational issues are being inspected. If the refuelings are to be done earlier than suggested maximum endurance times, then these DTNs in question should be refueled three times for reliability of the mission. Besides, the amount of fuel to be loaded at the final refueling should be carefully selected so that the aircraft won't weigh heavier than 158,760 kg when it comes to landing.

4.2 Decision Making

Several variations producing different results have been introduced so far. It is recommended that one should start the decision making phase after selecting one of the aforementioned combinations. Actually, it is obvious that the answer will change according to the considered configuration. It is possible that choosing different number of crew, APU and etc. would end in different ranking although none of the alternatives seems good enough to meet the requirements. Besides, there is a very important point that should be taken into account which is the fact that both of two subordinate DTNs have to be feasible in order that we can confidently say the DTN in question is feasible. For instance, the DTN1 can be considered practical only if both DTN11 and DTN12 are feasible at the same time. The case that DTN11 meeting all of the reqiurements doesn't allow the DTN1 to be feasible unless DTN12 is also viable.

There are certainly many ways to make a decision among several options. I will employ an approach in which previously defined issues are given importance according to the interaction matrix mentioned before. Each issue will be multiplied by related Measure of Effectiveness (MOE) factors. The addition of these products will yield the overall grade of that specific alternative. The one having the highest grade will be selected as the best choice.

This methodology is actually the one that should be employed in case of all of the alternatives meeting all the requirements. Now that none of the alternatives are good enough, the process should be stopped here. Actually, my major intent is just to display the way of decision-making employed in this thesis rather than dictating a result as the final decision. It should be remembered that the final decision is always up to the decision maker.

Therefore, OTN and DTN1 have been compared assuming that other alternatives are proved to be infeasible. Detailed calculations can be viewed from Appendix F. Necessary MOEs have been generated by making comparisons between maximum loadable weight, volume and power, and the ones regarding alternatives have.

The decision making has been performed assuming that:

- 2 engine driven 120kVA generators and 1 PW901 APU provide power.
- MIDS improvement has been utilized,
- The power efficiency of the generators is 84%,
- All of the MMAs are in-flight capable,
- A total number of 55 Boeing 767-400ER will be purchased,
- All MMA alternatives will take off from an air force base stationed at sea level and having a runway length of 8000feet.

I want to introduce the estimated cost of each alternative before getting started the grading process. The methodology introduced in the LCC section of this thesis gives the cost of any MMA as shown in Table 4-6. The total corrected cost is calculated by multiplying the total cost by a technology factor, which is assumed to be 1.75. It should be also noted that the costs are Net Present Value of FY2003 in US$. Each portion forming the overall LCC can be viewed from Appendix F.

	TOTAL COST	TOTAL COST CORRECTED
OTN	$60,992,711,733.54	$106,737,245,533.69
DTN1	$49,856,406,614.06	$87,248,711,574.60
DTN2	$50,065,132,159.77	$87,613,981,279.59
DTN3	$53,923,024,705.57	$94,365,293,234.74
DTN4	$51,522,238,705.38	$90,163,917,734.42

Table 4-6: LCC of MMA Alternatives

It is appearent that OTN has the highest LCC. Life cycle costs of all DTN alternatives vary from $87 billion and $94 billion. If cost were the only criteria of selection, then DTN1 having the lowest LCC should have been selected.

Overall scores of both alternatives have been shown in Table 4-7 below. It is appearent that DTN1 having a 68% grade out of 100% is better than OTN. The huge difference between those scores indicates the robustness of the DTN1 over OTN. These scores are relative and only indicates the best of two considered alternatives. Having a positive score wouldn't mean to be feasible. This scoring has been performed in order to show the methodology followed in this thesis. Details behind the resulting cells can be viewed from Appendix F.

	PAYLOAD VSD			
Importance	0.2	0.5	0.3	
Alternative	LCC	A\C SPECIFICATIONS	RISK	OVERALL GRADE
OTN	0.594736617	0.16227972	0.66	0.398087183
DTN1	0.712964919	0.556799298	0.87	0.681992633

Table 4-7: MMA Decision Table

It is seen that the A\C Specifications score of OTN has a big impact on its relatively low overall grade. Under these conditions, there is no doubt that the DTN1 is the better of two cited alternatives. However, it is possible that the results could change because of any changes in the importance factor. Therefore, a sensitivity analysis has been conducted in order to reveal the changes in case of assigning different importance values to the major issues. The results are introduced in Figure 4-6, 4-7 and 4-8.

As seen from the introduced sensitivity analysis charts, OTN never becomes robust. Although the overall grade of OTN gets higher as the importance of LCC increases, it cannot exceed the grade of DTN1. When it comes to aircraft specifications issue, the situation gets even worse. That is, the difference between those scores becomes larger as the assigned importance factor increases. Similarly, the results do not change when the same adjustment has been implemented for risk.

It is determined to stop the process at this point because it is revealed that integration seems unattainable by means of existing technology.

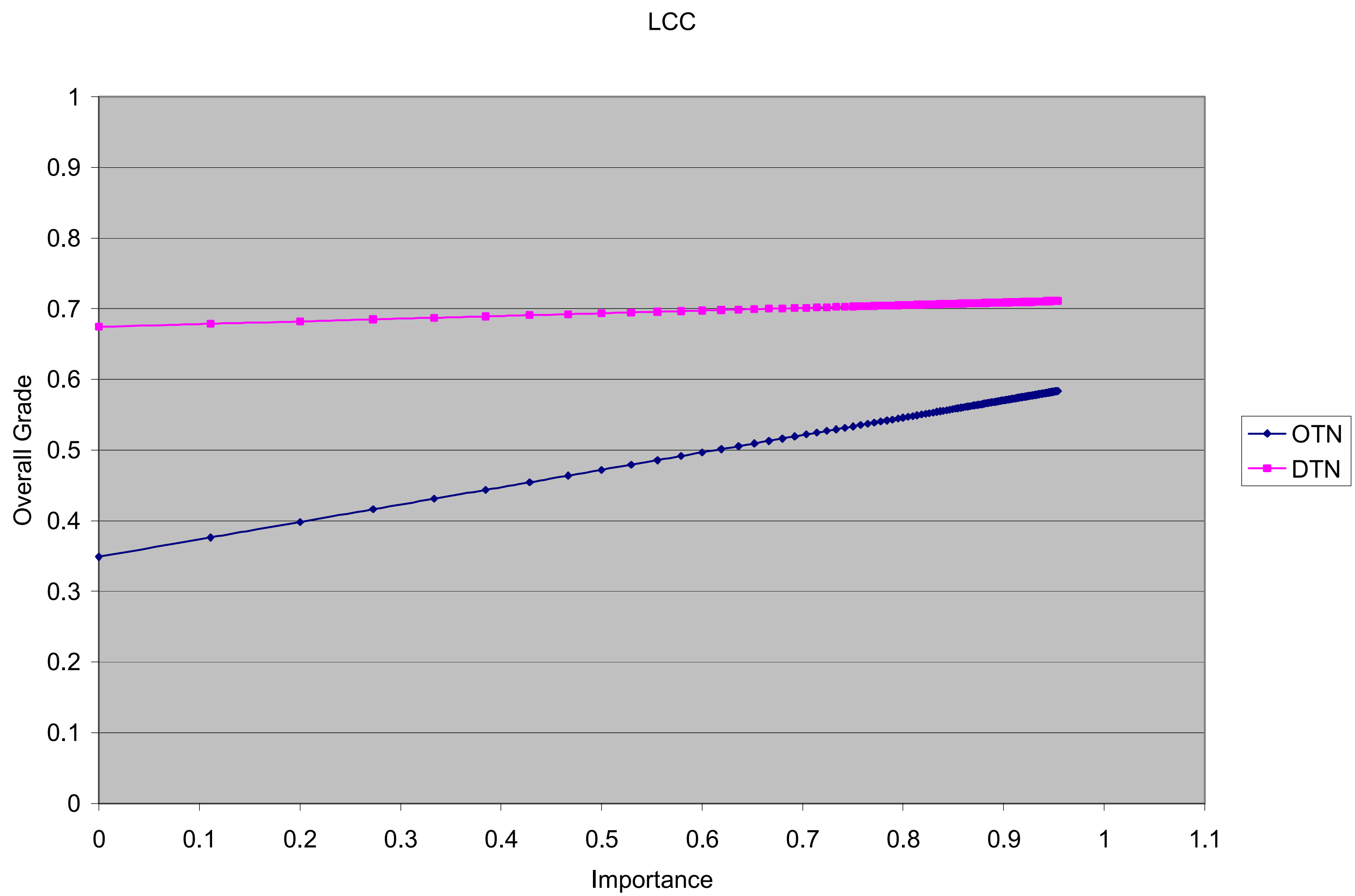


Figure 4-6 : LCC Sensitivity Analysis Chart

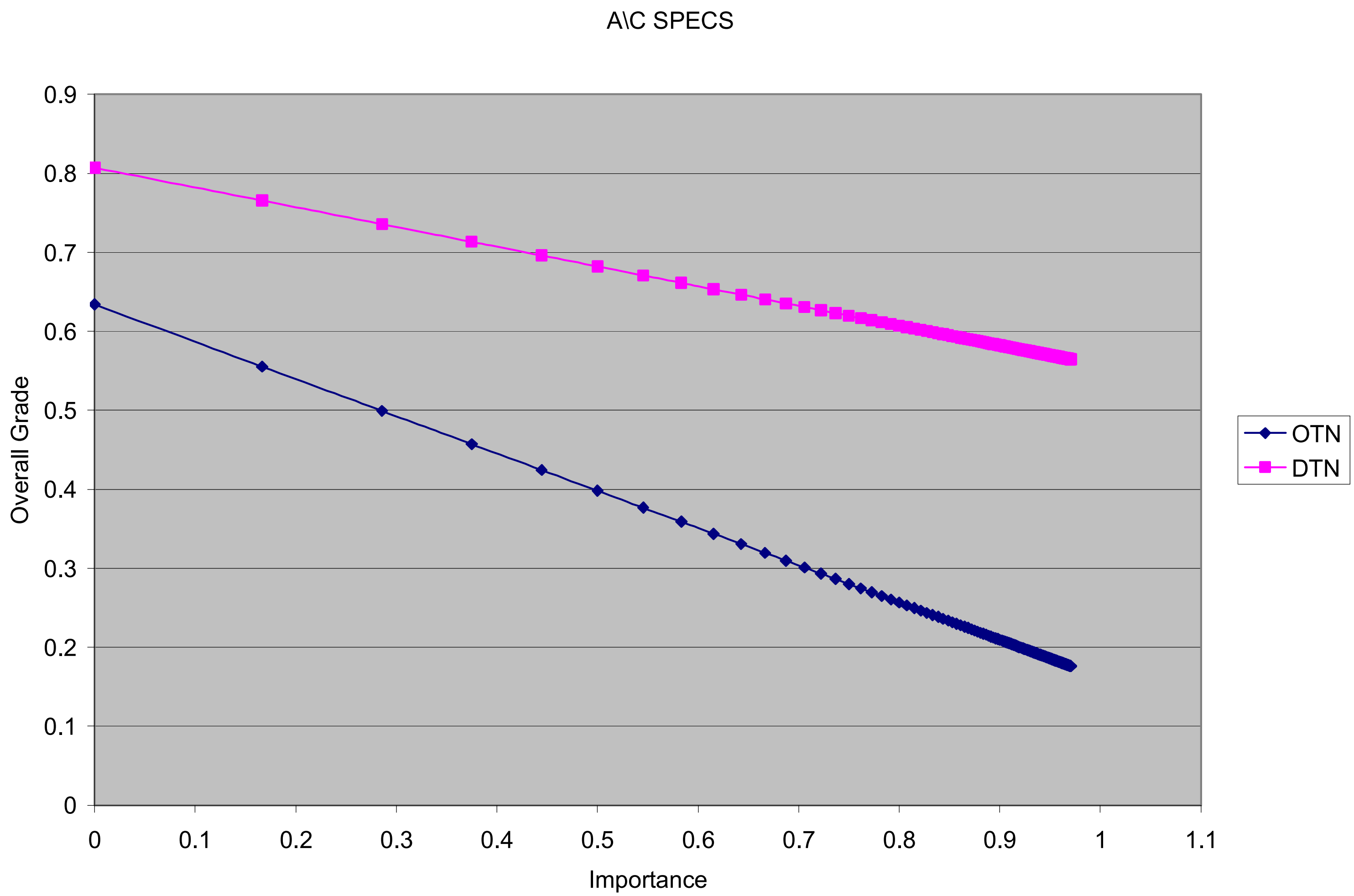


Figure 4-7: Aircraft Specifications Sensitivity Analysis Chart

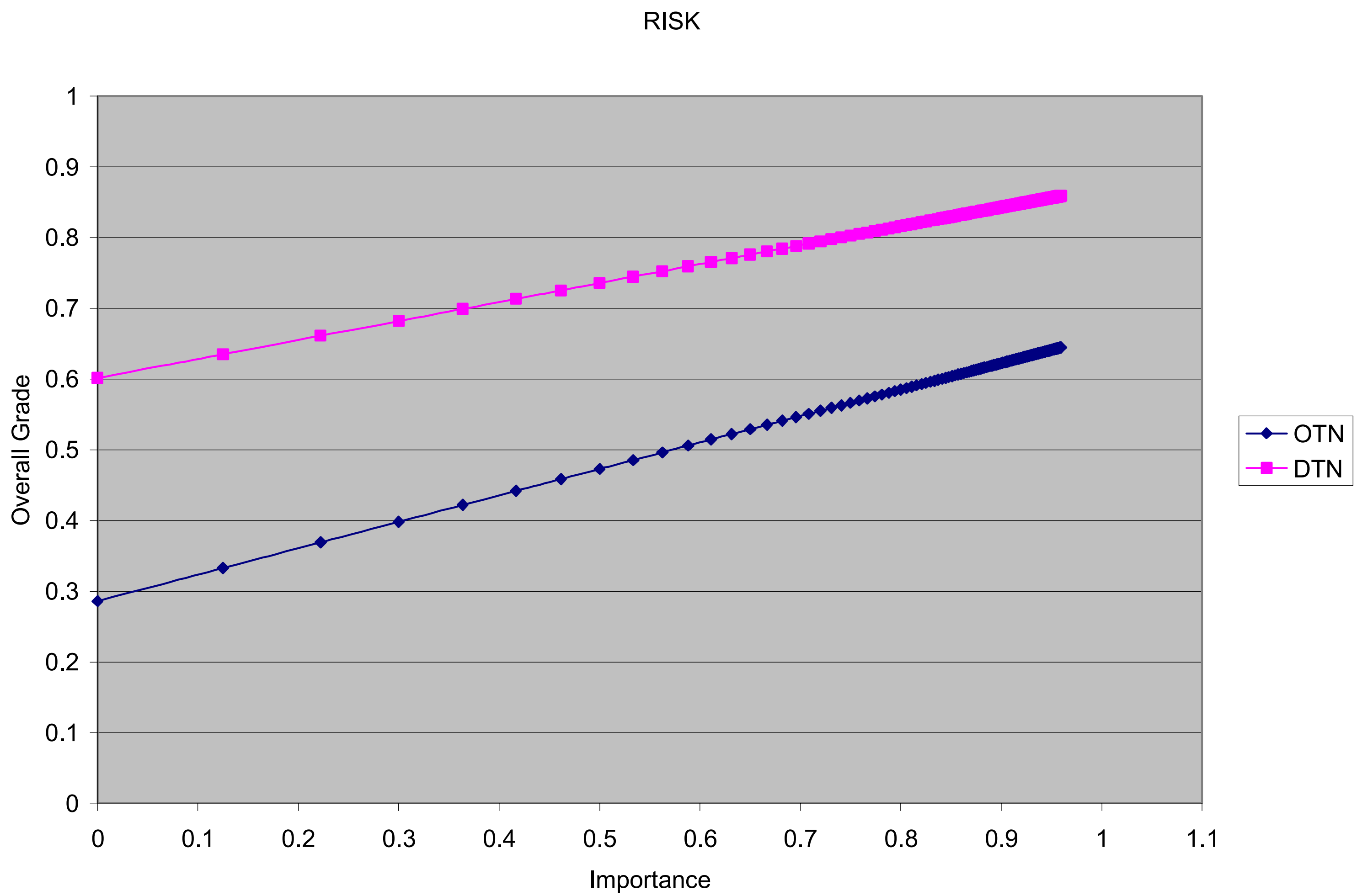


Figure 4-8: Risk Sensitivity Analysis Chart

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

In previous chapter, nine different configurations of MMA have been created with the help of the methodology introduced beforehand. Estimated characteristics of those alternatives have been compared to those of 767-400ER. As a result, it is envisioned that none of the alternatives is feasible using existing technology.

Actually, the major problem seems to be the power requirements to run the equipment onboard. It is surprising that even combination of two existing fleet seems infeasible except for AWACS-ABCCC integration. However, as a result of a couple of improvements including a more powerful APU installation and MIDS selection, some of the alternatives have become practicable. But, any particular alternative couldn't be determined to be the best of all since none of them meets the requirements completely. Because of this, it is recommended that the requirements set at the beginning should be updated or the project should be delayed until necessary SIGINT technology is available on the market.

Moreover, it is seen that power consumption is not the only problem standing in front of the MMA concept. Although the weight characteristics of the alternatives are all below the limitations, it is envisioned that OTN and maybe DTN22 and DTN32 might meet with some severe problems in terms of takeoff. However, it is believed that the producer of the aircraft could recover this problem by either increasing the maximum engine thrust or installing a more powerful couple of engines.

That OTN alternative is not feasible in terms of both payload and electromagnetic considerations is the most significant conclusion achieved by this study. It is important because OTN was the alternative that the sponsor desired.

Finally, it should be remembered that estimations in this thesis have been performed by ignoring possible electromagnetic interferences between the sensors installed on the MMA alternatives inspected.

5.2 RECOMMENDATIONS FOR FUTURE RESEARCH

This thesis represents the first payload design study of integrating the current C4ISR fleets into one or more MMA architecture. It is recommended that further studies be shaped according to the feedback that will be gotten from the decision makers. It is the reader's belief that further research performed by the process introduced within this text would give results that are more satisfactory if real input data could be used in accordance with the relevant section of the AFRL.

It is also recommended that further researchers should create and examine more DTN configurations than the ones generated in this study in order to figure out a pair of feasible DTN architecture.

Besides, layout of the equipment and antennas couldn’t be examined in detail because of time limitations. It is suggested that layout studies should be performed by means of design software, which is generally called CAD.

It is also believed that establishing a design team from relevant specialties such as avionics and mechanical engineering under the command of a systems engineer could provide valuable results. In this way, the overall results and interactions could be introduced within one thesis study.

APPENDIX A: System Interaction Matrix

Objectives Interaction Matrices

X	/	/	Min.LCC
X	/	Max.Mission Eff	
X	Min. Risk		
Mission Integration & Compatibility			

Constraints – Objectives

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Min.LCC		/		/		X	/			X
Max.Mission Eff	/				X	X	X	/	/	
Min. Risk			/	X			X		X	/
Mission Integration & Compatibility	/			X		/	X	X	X	/

Alterables – Objectives

	A1	A2	A3	A4
Min.LCC	X			X
Max.Mission Eff	X	X	X	X
Min. Risk		/		X
Mission Integration & Compatibility		/	/	X

Needs – Objectives

	N1	N2	N3	N4	N5	N6	N7	N8	N9	N 10	N 11
Min.LCC	/		/	/	/	/	/			/	/
Max.Mission Eff	/	X	/	X	X	X	X	X	X	X	X
Min. Risk				/	X	/	X	/	/	X	X
Mission Integration & Compatibility	X		/	X	X	X	X	X	X	X	X

Constraints Interaction Matrices

	C1	C2	C3	C4	C5	C6	C7	C8	C9
Funding **(C10)**				X		X	X		
System Compability **(C9)**	/				/	/	X	X	
Air Frame Limits **(C8)**			/		X	/	X		
Technology Availibility **(C7)**				X					
Logistics Supportibility **(C6)**		X	/		X				
Operations Environment **(C5)**	/	X	X						
Devolopment Time **(C4)**			/						
Safety **(C3)**		X							
Gov't Regulations & Policies **(C2)**	X								
Classification of System **(C1)**									

Alterables – Constraints

	A1	A2	A3	A4
C10	X			X
C9	/	/	/	/
C8	X	X	/	X
C7		X	/	X
C6	/		/	X
C5	X		X	X
C4		?		X
C3			/	/
C2	X	/		/
C1	/		/	/

Needs – Constraints

	N1	N2	N3	N4	N5	N6	N7	N8	N9	N 10	N 11
C10	/		/	/	/	/	/			/	/
C9	X		/	X	X	X	X	/	/	/	/
C8				X	/	/	X	/	/	/	/
C7	X			X		/	X	/	/	X	X
C6	/		/							X	X
C5		X	X	X	X	X	X	X	X	X	X
C4	/		/	X	/	X	X	/	/	X	X
C3		/								X	X
C2			/								
C1				X	/	X	X	/	/	/	/

Alterables Interaction Matrices

	A1	A2	A3
System Architec. **(A4)**	X	X	X
CONOPS **(A3)**	X	/	
Mission Requirements **(A2)**	X		
Future Politics/Players/conflicts /Demands **(A1)**			

Needs – Alterables

	N1	N2	N3	N4	N5	N6	N7	N8	N9	N 10	N 11
A4		/		X	/		X			X	X
A3		X	/	X	X	X	X	/	/	X	X
A2	/	X	/	X	X	X	X	X	X	X	X
A1	X		X	X		X	X			X	X

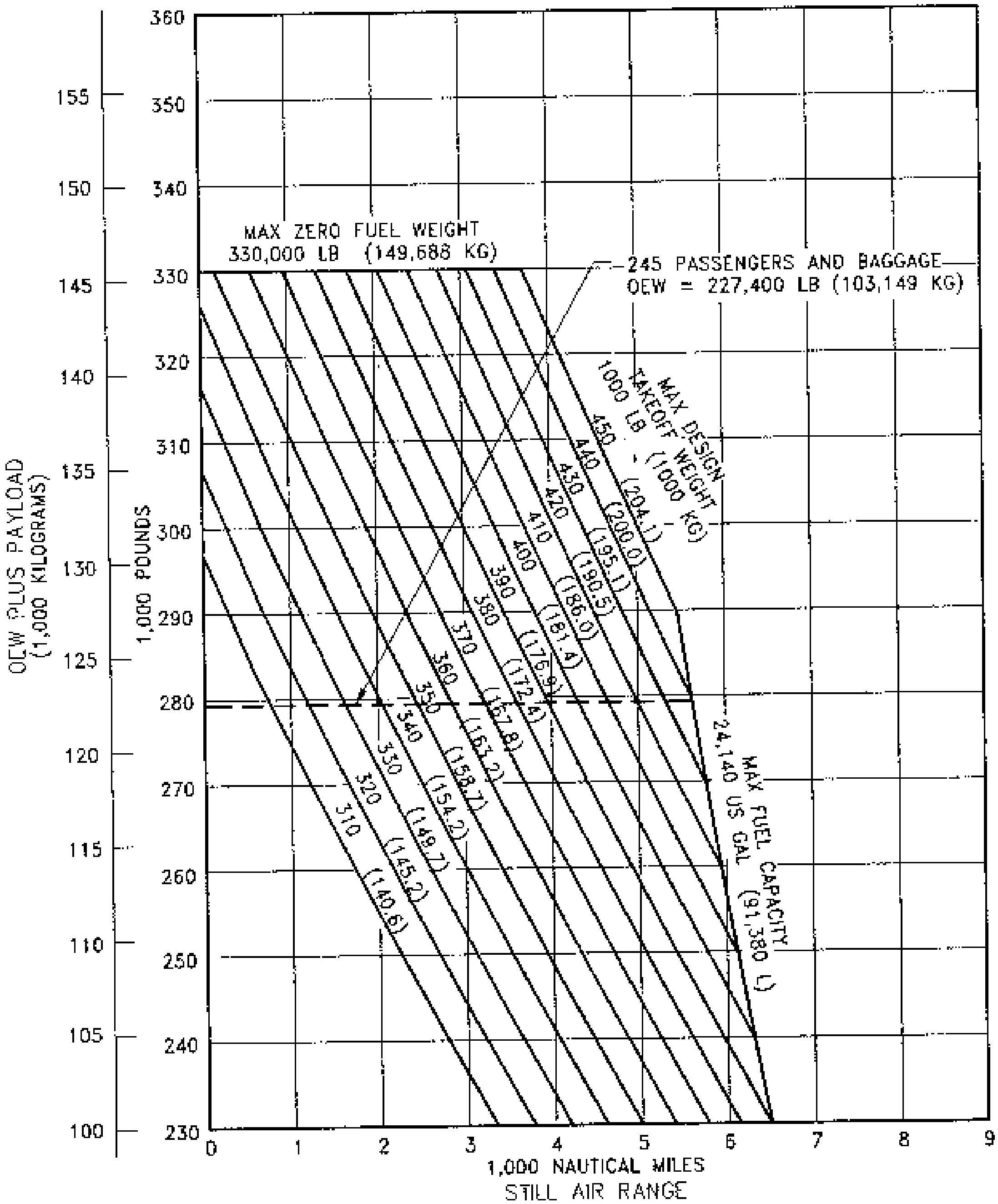
Needs Interaction Matrices

	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10
Air C2 **(N11**	/	X	/	X	X		X	/	X	X
Ground C2 **(N1**	/	X	/	X	/			X	/	
Air BM **(N90)**	/		X		X	X	/	/		
Ground BM **(N8)**	/		X			X	/			
ISR Coll.& Rec. Mis. **(N7)**	/	X		/	X	X				
ISR Process.& Expl. **(N6)**	/			X						
C3 CM **(N5)**	/	/		X						
Dissem. & Transm. **(N4)**	/	X	/							
Joint Service Interoperability **(N3)**	/									
All-Weather Capability (24/7) **(N2)**										
Longterm Compatibility **(N1)**										

X	:	HIGH INTERACTION
/	:	MEDIUM INTERACTION
	:	LOW INTERACTION

APPENDIX B:

WEIGHT vs. RANGE and RUNWAY LENGTH PLOTS OF 767-400ER

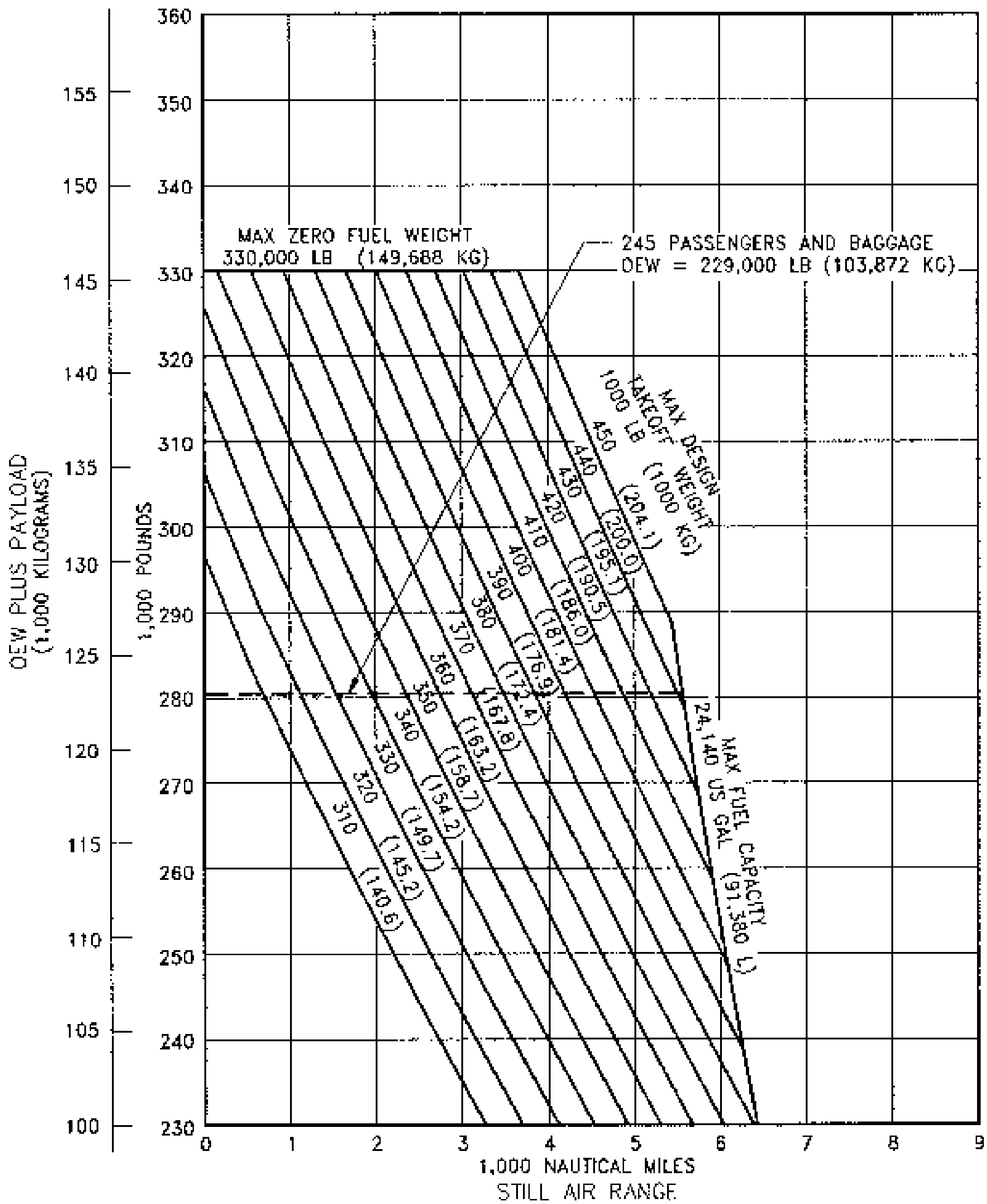


NOTES:

* CF6-80C2B8F ENGINES
* CRUISE MACH = 0.80
* STANDARD DAY

APPENDIX B:

WEIGHT vs. RANGE and RUNWAY LENGTH PLOTS OF 767-400ER

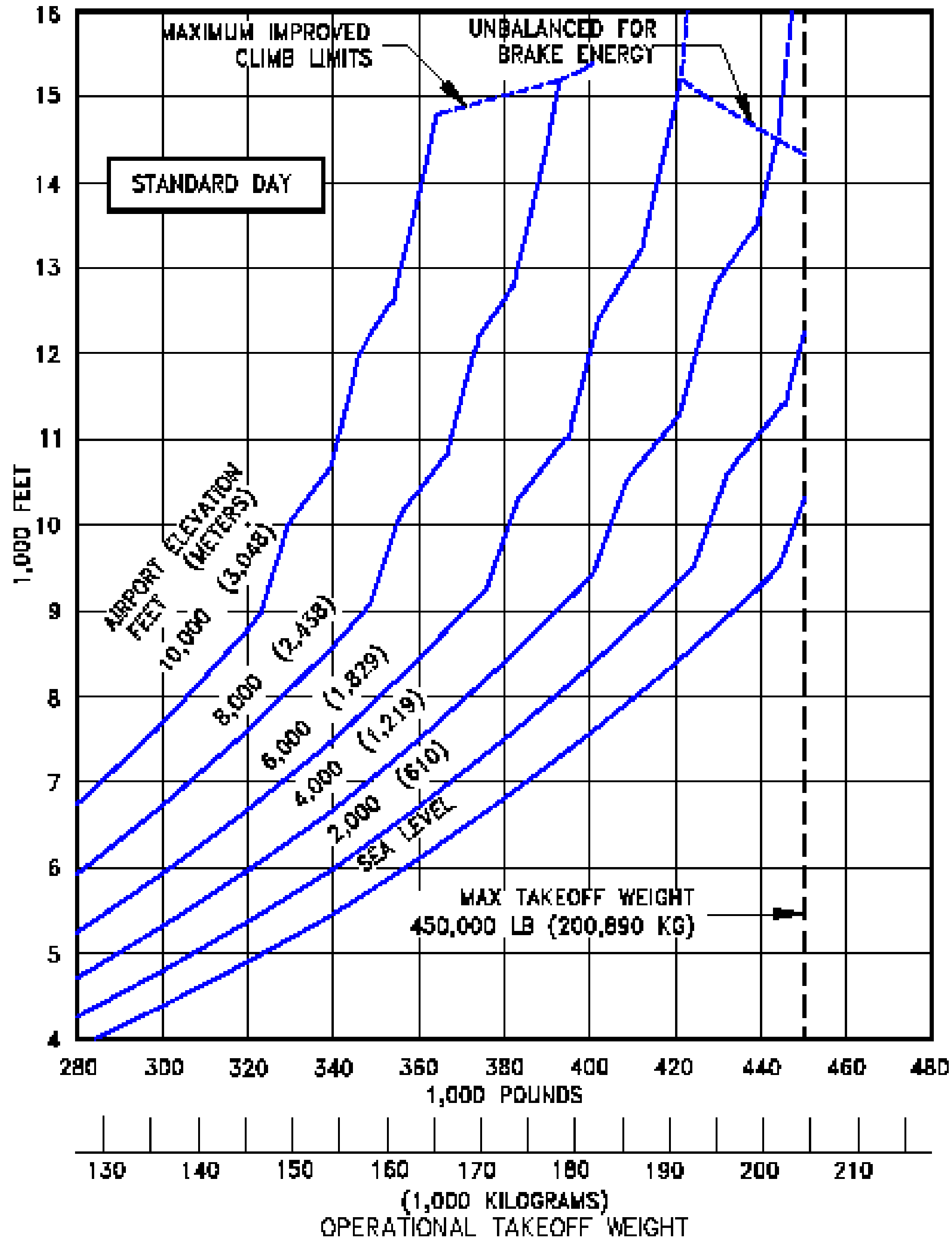


NOTES:

* PW4062 ENGINES
* CRUISE MACH = 0.80
* STANDARD DAY

APPENDIX B:

WEIGHT vs. RANGE and RUNWAY LENGTH PLOTS OF 767-400ER

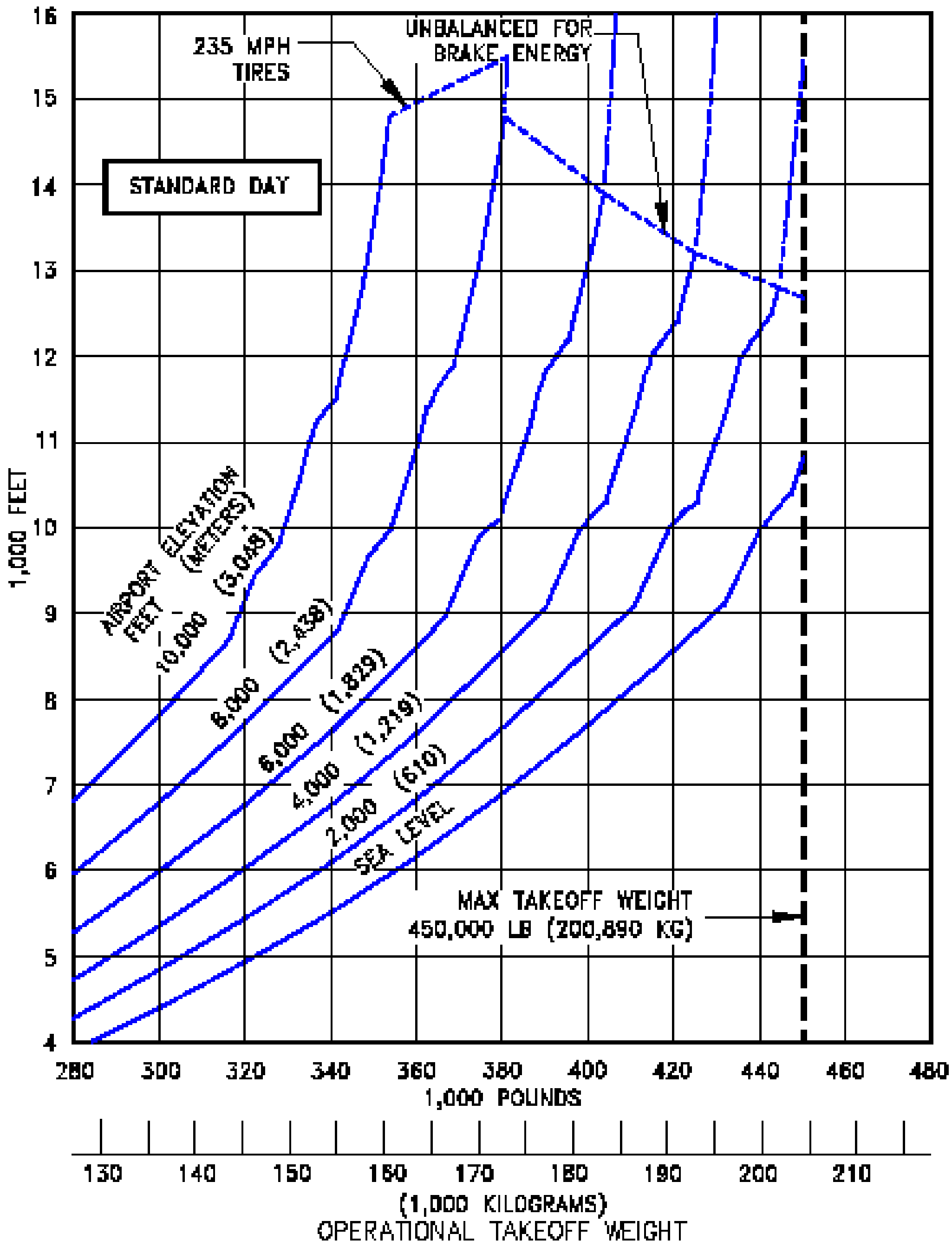


NOTES:

* CF6-80C2B8F ENGINES
* STANDARD DAY, DRY RUNWAY SURFACE

APPENDIX B:

WEIGHT vs. RANGE and RUNWAY LENGTH PLOTS OF 767-400ER



NOTES:

* PW4062 ENGINES
* STANDARD DAY, DRY RUNWAY SURFACE

APPENDIX C:

767-400ER CABIN AREA AND VOLUME ESTIMATION BASED ON HISTORICAL DATA

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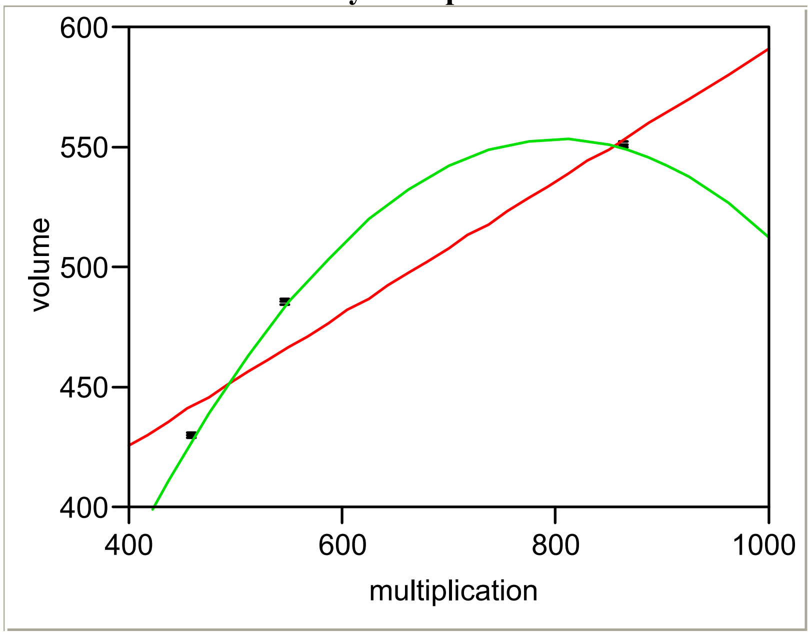
Bivariate Fit of volume By multiplication



Linear Fit

volume = 315.38885 + 0.2757509 multiplication

Summary of Fit

RSquare	0.929568
RSquare Adj	0.859137
Root Mean Square Error	22.88458
Mean of Response	487.3667
Observations (or Sum Wgts)	3

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	6911.9428	6911.94	13.1982
Error	1	523.7039	523.70	Prob > F
C. Total	2	7435.6467		**0.1710**

Polynomial Fit Degree=2

volume = 280.97088 + 0.3827033 multiplication - 0.0010655 (multiplication-623.671)^2

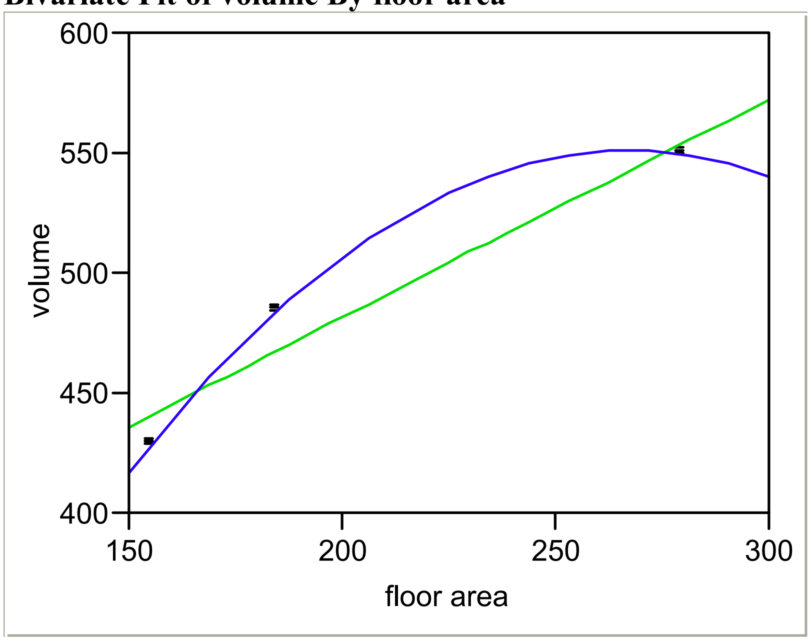
Summary of Fit

RSquare	1
RSquare Adj	.
Root Mean Square Error	.
Mean of Response	487.3667
Observations (or Sum Wgts)	3

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	7435.6467	3717.82	.
Error	0	0.0000	.	Prob > F
C. Total	2	7435.6467		.

Bivariate Fit of volume By floor area



Linear Fit

volume = 299.93465 + 0.9098642 floor area

Summary of Fit

RSquare	0.939542
RSquare Adj	0.879084
Root Mean Square Error	21.20249
Mean of Response	487.3667

Observations (or Sum Wgts)	3

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	6986.1009	6986.10	15.5404
Error	1	449.5458	449.55	Prob > F
C. Total	2	7435.6467		**0.1582**

Polynomial Fit Degree=2

volume = 268.47465 + 1.1966078 floor area - 0.0098151 (floor area-206)^2

Summary of Fit

RSquare	1
RSquare Adj	.
Root Mean Square Error	.
Mean of Response	487.3667
Observations (or Sum Wgts)	3

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	7435.6467	3717.82	.
Error	0	0.0000	.	Prob > F
C. Total	2	7435.6467		.

APPENDIX D:

FORMULAS FOR AVIONICS VOLUME AND POWER ESTIMATION

Following are the formulas used in estimating volume and power consumption values of the avionics equipment mounted on the MMA alternatives. The formulas are obtained from *Fundamentals of Aircraft Design,* Leland M Nicolai, 1988. The most suitable formulas have been chosen for the systems not included in the formulas. Some adjustments have been implemented to the formulas when the achieved results were extremely different from what they were believed to be.

<u>Radar Systems:</u>

$\text{Weight} = 0.431\ (\text{Power})^{0.777}$

$\text{Weight} = 38.21\ (\text{Volume})^{0.873}$

for the radar weight(less antenna) in pounds, power required in watts and volume required (less antenna) in cubic feet.

<u>Doppler Navigation Systems:</u>

$\text{Weight} = 0.408\ (\text{Power})^{0.868}$

$\text{Weight} = 29.67\ (\text{Volume})^{0.662}$

for the Doppler system weight in pounds, power required in watts and volume required in cubic feet.

Inertial Navigation Systems:

$$Weight = 0.465\ (Power)^{0.848}$$

$$Weight = 51.85\ (Volume)^{0.738}$$

for the Inertial Navigation Systems weight in pounds, power required in watts and volume required in cubic feet.

TACAN Systems:

$$Weight = 13.61 + 0.104(Power)$$

$$Weight = 0.311\ (Volume)^{0.704}$$

for the TACAN Systems weight in pounds, power required in watts and volume required in cubic inches.

Receiver Systems:

$$Weight = 6.3 + 0.17(Power)$$

$$Weight = 44.5\ (Volume)^{0.737}$$

for the Receiver Systems weight in pounds, power required in watts and volume required in cubic feet.

Transmitter Systems:

$$Weight = 0.73\ (Power)^{0.610}$$

$$Weight = 6.4 + 40.2\ (Volume)$$

for the Transmitter System weight in pounds, power required in watts and volume required in cubic feet.

Identification Systems:

$$\text{Weight} = 0.607\ (\text{Power})^{0.724}$$

$$\text{Weight} = 0.069\ (\text{Volume})^{0.868}$$

for the Identification Systems weight in pounds, power required in watts and volume required in cubic inches.

Computers:

$$\text{Weight} = 2.246\ (\text{Power})^{0.630}$$

$$\text{Weight} = 0.123\ (\text{Volume})^{0.817}$$

for the Computer weight required in pounds, power required in watts and volume required in cubic inches.

Electronic Counter Measures (ECM):

$$\text{Weight} = 0.429\ (\text{Power})^{0.771}$$

$$\text{Weight} = 0.055\ (\text{Volume})^{0.912}$$

for the ECM Systems weight required in pounds, power required in watts and volume required in cubic inches.

APPENDIX E:
VOLUME-POWER ESTIMATION SPREADSHEET
SUMMARY

In this Appendix, estimations for "Enhanced 180kVA APU" configuration that was described in section 4.1 are presented. The overall results including other APU selections have been summarized in the table below.

		No APU Use	120kVA APU	180kVA APU	Enhanced 180kVA APU
Limitations	Weight(kg)	52473	52473	52473	52473
	Volume(m3)	702.31	702.31	702.31	702.31
	Power(Watts)	201600	302400	352800	352800
OTN	Weight(kg)	42024	42024	42129	40905
	Volume(m3)	527.45	527.45	530.15	529.28
	Power(Watts)	789260	789260	789260	760245
DTN11	Weight(kg)	22557.07	22557.07	22661.85	21845.83
	Volume(m3)	363.08	363.08	365.78	365.21
	Power(Watts)	373425.32	373425.32	373425.32	354082.48
DTN12	Weight(kg)	23923.15	23923.15	24027.93	23415.91
	Volume(m3)	357.24	357.24	359.94	359.51
	Power(Watts)	459924.85	459924.85	459924.85	445417.71
DTN21	Weight(kg)	15916.18	15916.18	16020.96	15286.54
	Volume(m3)	345.78	345.78	348.48	347.96
	Power(Watts)	235707.29	**235707.29**	**235707.29**	**218298.73**
DTN22	Weight(kg)	32384.06	32384.06	32488.84	31672.81
	Volume(m3)	409.03	409.03	411.73	411.16
	Power(Watts)	608295.01	608295.01	608295.01	588952.17
DTN31	Weight(kg)	25603.15	25603.15	25707.93	24973.51
	Volume(m3)	401.74	401.74	404.44	403.92
	Power(Watts)	397702.60	397702.60	397702.60	380294.05
DTN32	Weight(kg)	32714.12	32714.12	32818.90	31798.87
	Volume(m3)	391.08	391.08	393.78	393.06
	Power(Watts)	623543.92	623543.92	623543.92	599365.36
DTN41	Weight(kg)	21128.84	21128.84	21233.62	20825.61
	Volume(m3)	355.44	355.44	358.14	357.86
	Power(Watts)	426973.44	426973.44	426973.44	417302.02
DTN42	Weight(kg)	30269.63	30269.63	30374.41	29354.38
	Volume(m3)	401.46	401.46	404.16	403.44
	Power(Watts)	478212.18	478212.18	478212.18	454033.63

APPENDIX E:

VOLUME-POWER ESTIMATION SPREADSHEET

OTN

	Interior	Below Front Cabin	Below Rear Cabin	Bulk Cargo	TOTAL
Max. Volume(m3)	563.4	67.97	61.17	9.77	702.31

Generators assumed 84% efficient

Max. Payload Weight (kg)	52473

	Engine	APU	TOTAL
Max. Power (Watts)	240000	120000	302400
	240000	180000	352800

	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
Common Equipment	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
ILS-VOR	1	1	5.5	12.12541	10.38674	22.8988	0.30734	531.08	0.0087	25
Gyro Compass	1	1	3.81	8.399602	7.3743519	16.2576	0.21	362.88	0.0059	58.5744
Autopilot System	1	1	76	167.5511	120.37047	265.371	1.1336	1958.86	0.0321	1523.95
Radar Altimeter	1	1	2.1	4.629702	4.230108	9.32578	0.08913	154.019	0.0025	52.2895
Range only Radar	1	1	11.34	25.00039	20.402098	44.9789	0.61513	1062.95	0.0174	396.143
Flight Deck Instrument	1	1	115	253.5313	177.1544	390.558	In the Flight Deck			3597.44
Flight Data Recorder	2	1	7.07	15.58666	13.128925	28.9443	0.60028	1037.28	0.017	57.8293
Weather Radar	1	1	45.5	100.3102	74.583969	164.429	3.0194	5217.53	0.0855	2100.86
Mission Equipment	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
In the Cabin	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
Intercom System	2	3.8	13.16	29.0128	23.441565	51.6797	0.53436	923.383	0.0151	266.94
UHF Radio	12	2.5	8.8	19.40066	16.103608	35.5023	0.3882	670.801	0.011	582.728
VHF Radio	3	3.5	3.1	6.834322	6.0836093	13.412	0.04499	77.7503	0.0013	118.144
HF Radio	2	3.5	35.17	77.53649	58.654276	129.31	1.65509	2860	0.0469	4850.15
IFF	1	1	2.962	6.530084	5.8305525	12.8542	0.55	950.4	0.0156	67.8096
TACAN	1	1	20.86525	45.99995	36.036539	79.4469	1.65	2851.2	0.0467	633.047
Embedded GPS\INS	1	1	20.4	44.97425	35.286274	77.7928	0.31193	539.023	0.0088	418.828
Radar Warning&Homing	1	3	92.53284	203.9997	144.63551	318.866	1.40636	2430.19	0.0398	4926.92
ECM Equipment	1	1	2300	5070.626	2898.7645	6390.67	172.124	297430	4.874	258564
Countermeas. Dispensing Set	1	1	53.1	117.0653	86.145788	189.919	2.75287	4756.96	0.078	9107.89
Countermeas. Receiving Set	1	1	42.65	94.02704	70.215876	154.799	2.75951	4768.43	0.0781	873.525
Terrain Following Radar	1	0	112.95	249.0118	174.20624	384.059	8.55985	14791.4	0.2424	6259.66

APPENDIX E:

VOLUME-POWER ESTIMATION SPREADSHEET

OTN

Mission Equipment	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
In the Cabin	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
MIDS	2	3	23.18	51.10309	39.753163	87.6406	0.43405	750.034	0.0123	991.815
Crypto Equipment	57	1	1.42	3.13056	2.9363369	6.47351	0.02804	48.4528	0.0008	5.36698
TADIL SYSTEM	1	2.5	20	44.0924	34.640316	76.3687	0.41516	717.396	0.0118	350
Operational Consoles	57	1	15	33.0693	26.485855	58.3912	81.7049	141186	2.3136	176.171
SATCOM	2	3.8	8.3	18.29835	15.248275	33.6167	0.27687	478.426	0.0078	532.855
Signal Processors	3	3.8	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Air Data Terminals	15	3.8	22.5	49.60395	38.664033	85.2395	52.972	91535.6	1.5	642.312
Air Data Computer	2	3.8	7.48	16.49056	13.837927	30.5074	0.5	864	0.0142	125.729
RCMP	1	1	3.98	8.774388	7.6808939	16.9335	0.16004	276.55	0.0045	35.8
Radar Synchronizer	3	3.8	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
STALO	1	1	4.79	10.56013	9.1300655	20.1283	0.13737	237.382	0.0039	64.9789
AR	1	1	99.79	219.999	155.1919	342.139	15.961	27582.7	0.452	1975.52
MP	1	1	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
DDP	2	1	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
RDC	1	1	7.07	15.58666	13.128925	28.9443	0.30014	518.641	0.0085	57.8293
Interface Adaptor	2	3.8	1.57	3.461253	3.2247439	7.10933	0.02804	48.4528	0.0008	6.22754
Digital Processor	57	1	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Supermini Computers	5	2	7.48	16.49056	13.837927	30.5074	0.5	864	0.0142	125.729
High-speed Processors	15	2	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Printers	5	3.5	8	17.63696	14.733428	32.4816	0.71512	1235.73	0.0203	138.887
SINCGARS	1	1	3.1	6.834322	6.0836093	13.412	0.0517	89.3388	0.0015	10
SCDL Terminal	2	1	20	44.0924	34.640316	76.3687	0.54975	949.965	0.0156	750
JTT with a constant source	1	1	53.4	117.7267	86.599792	190.92	1.11706	1930.27	0.0316	1155.06
Integrated Terminal Group Radios	4	1	3.1	6.834322	6.0836093	13.412	0.04499	77.7503	0.0013	118.144
Track Management Processor	2	1	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Beamformer Processor	1	1	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Search Database Processor	1	1	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
ACIDS	1	1	11.34	25.00039	20.402098	44.9789	0.46047	795.685	0.013	135

APPENDIX E:
VOLUME-POWER ESTIMATION SPREADSHEET
OTN

Mission Equipment	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
In the Cabin	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
In-flight Refuel System	1	1	53.15	117.1756	86.221467	190.086	0	0	0	1147.06
JTIDS Terminal	2	0	155	341.7161	234.04552	515.981	5.2972	9153.56	0.15	5597.26
ESM SYSTEM	1	1	100	220.462	155.49659	342.811	563.727	974120	15.963	1000
TADIL DATA TERMINAL	2	3	4.6	10.14125	8.7917214	19.3824	0.01243	21.4823	0.0004	28
TADIL SDLT	1	3	4.6	10.14125	8.7917214	19.3824	0.01243	21.4823	0.0004	15
Common Data Retrivial Sys	1	1	2.52	5.555642	5.0144992	11.0551	0.27531	475.734	0.0078	18
Comms. Emitter Location Sys.	1	1	2.52	5.555642	5.0144992	11.0551	0.27531	475.734	0.0078	18
Background Search sys.	1	1	53.4	117.7267	86.599792	190.92	1.11706	1930.27	0.0316	1155.06
In the Rotodome										
PCE	1	1	100	182.5365	136.48661	300.901	1.65509	2860	0.0469	4850.15
AA(transmitter, IFF\SSR)	1	1	18.762	41.36308	33.632033	74.1459	1.0478	1810.59	0.0297	267.81
MR	1	1	99.79	219.999	155.1919	342.139	15.961	27582.7	0.452	1975.52
SLR Antenna	1	1	29.5	65.03629	49.781136	109.748	15.961	27582.7	0.452	4000
BLINK JAMMER	1	1	9	19.84158	16.44482	36.2546	1.58916	2746.07	0.045	4000
Below Front Cabin										
Rest Area	61				326.58653	720	676.347	1168727	19.152	500
Below Rear Cabin										
HVPS with	1	NA	NA	NA	Totally 1210 kg	NA	NA	NA	Totally 25.63 m3	NA
Transmit Electronics	1	NA	NA	NA		NA	NA	NA		NA
RC	1	NA	NA	NA		NA	NA	NA		NA
APU	1	1	47.62725	105	104.77995	231	95.3496	164764	2.7	0

*AWACS Equip. plus APU occupy 25.63 m3 space in the below rear cabin(according to Boeing 707 data)

*AWACS Equip. in the dome weighs 1210 kg which is 1/3 of total AWACS equipment

Each Terminal 1m*1m*1.5m

APPENDIX E:

VOLUME-POWER ESTIMATION SPREADSHEET

OTN

Insert Number of crew onboard

OTHER	Crew	Weight		Adjusted Volume			Power
	People	kg	lb	ft3	in3	m3	Watts
Crew	61	4980.44	10980	0	0	0	0
Seats	61	14.515	32	Considered with consoles			0
Galley	61	257.385	567.4365	1412.587	2440949.6	40	6000
Lavatory	61	119.255	262.9125	1112.412	1922247.8	31.5	2100
	TOTAL	391.155	862.349	2524.999	4363197.4	71.5	8100

10.5

BUNK BEDS

Note: 0% technology improvement is applied to the estimated volume and power values

Each Crew weighs 180 lb,Each Seat weighs 32 lb

	Total Weight		Total Volume		Total Power
	kg	lb	ft3	m3	Watts
COMMON EQUIPMENT	440.76	971.708	6.575165	0.186188	7869.9099
TOTAL INTERIOR EQUIPMENT	36611	80712.7	15379.9	435.5103	658573.34
ROTODOME EQUIPMENT	391.54	863.189	434.5981	12.30645	15093.482
BELOW FRONT CABIN EQUIPMENT	326.59	719.999	1101.068	31.17878	500
BELOW REAR CABIN EQUIPMENT	1304.8	2876.54	1000.465	28.33	45280.447
CLASSIFIED EQUIPMENT	1830.5	4035.64	768.995	21.77551	32928.667
GRAND TOTAL	40905	90179.8	18691.6	529.2872	760245.85

OVERLOAD

CLASSIFIED EQUIPMENT CONSIDERED AS THE 5% OF THE INTERIOR EQUIPMENT

APPENDIX E:

VOLUME-POWER ESTIMATION SPREADSHEET

DTN11

	Interior	Below Front Cabin	Below Rear Cabin	Bulk Cargo	TOTAL
Max. Volume(m3)	563.4	67.97	61.17	9.77	702.31

Generators assumed 84% efficient

Max. Payload Weight (kg)	52473

	Engine	APU	TOTAL
Max. Power (Watts)	240000	120000	302400
	240000	180000	352800

	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
Common Equipment	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
ILS-VOR	1	1	5.5	12.12541	10.38674	22.8988	0.3073	531.08	0.0087	25
Gyro Compass	1	1	3.81	8.399602	7.3743519	16.2576	0.21	362.88	0.0059	58.5744
Autopilot System	1	1	76	167.5511	120.37047	265.371	1.1336	1958.86	0.0321	1523.95
Radar Altimeter	1	1	2.1	4.629702	4.230108	9.32578	0.0891	154.019	0.0025	52.2895
Range only Radar	1	1	11.34	25.00039	20.402098	44.9789	0.6151	1062.95	0.0174	396.143
Flight Deck Instrument	1	1	115	253.5313	177.1544	390.558	In the Flight Deck			3597.44
Flight Data Recorder	2	1	7.07	15.58666	13.128925	28.9443	0.6003	1037.28	0.017	57.8293
Weather Radar	1	1	45.5	100.3102	74.583969	164.429	3.0194	5217.53	0.0855	2100.86
Mission Equipment	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
In the Cabin	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
Intercom System	2	1.8	13.16	29.0128	23.441565	51.6797	0.5344	923.383	0.0151	266.94
UHF Radio	12	1.5	8.8	19.40066	16.103608	35.5023	0.3882	670.801	0.011	582.728
VHF Radio	3	1.8	3.1	6.834322	6.0836093	13.412	0.045	77.7503	0.0013	118.144
HF Radio	2	1.8	35.17	77.53649	58.654276	129.31	1.6551	2860	0.0469	4850.15
IFF	1	1	2.962	6.530084	5.8305525	12.8542	0.55	950.4	0.0156	67.8096
TACAN	1	1	20.86525	45.99995	36.036539	79.4469	1.65	2851.2	0.0467	633.047
Embedded GPS\INS	1	1	20.4	44.97425	35.286274	77.7928	0.3119	539.023	0.0088	418.828
Radar Warning&Homing	1	1.5	92.53284	203.9997	144.63551	318.866	1.4064	2430.19	0.0398	4926.92
ECM Equipment	1	0	2300	5070.626	2898.7645	6390.67	172.12	297430	4.874	258564
Countermeas. Dispensing Set	1	0	53.1	117.0653	86.145788	189.919	2.7529	4756.96	0.078	9107.89
Countermeas. Receiving Set	1	0	42.65	94.02704	70.215876	154.799	2.7595	4768.43	0.0781	873.525

APPENDIX E:
VOLUME-POWER ESTIMATION SPREADSHEET
DTN11

Mission Equipment	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
In the Cabin	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
Terrain Following Radar	1	1	112.95	249.0118	174.20624	384.059	8.5598	14791.4	0.2424	6259.66
MIDS	2	2	23.18	51.10309	39.753163	87.6406	0.434	750.034	0.0123	991.815
Crypto Equipment	32	1	1.42	3.13056	2.9363369	6.47351	0.028	48.4528	0.0008	5.36698
TADIL SYSTEM	1	1.5	20	44.0924	34.640316	76.3687	0.4152	717.396	0.0118	350
Operational Consoles	32	1	15	33.0693	26.485855	58.3912	81.705	141186	2.3136	176.171
SATCOM	2	1.8	8.3	18.29835	15.248275	33.6167	0.2769	478.426	0.0078	532.855
Signal Processors	3	1.8	109	240.3036	168.51547	371.513	8.6681	14978.4	0.2455	3323
Air Data Terminals	15	1.8	22.5	49.60395	38.664033	85.2395	52.972	91535.6	1.5	642.312
Air Data Computer	2	1.8	7.48	16.49056	13.837927	30.5074	0.5	864	0.0142	125.729
RCMP	1	1	3.98	8.774388	7.6808939	16.9335	0.16	276.55	0.0045	35.8
Radar Synchronizer	3	1.8	109	240.3036	168.51547	371.513	8.6681	14978.4	0.2455	3323
STALO	1	1	4.79	10.56013	9.1300655	20.1283	0.1374	237.382	0.0039	64.9789
AR	1	1	99.79	219.999	155.1919	342.139	15.961	27582.7	0.452	1975.52
MP	1	1	109	240.3036	168.51547	371.513	8.6681	14978.4	0.2455	3323
DDP	2	1	109	240.3036	168.51547	371.513	8.6681	14978.4	0.2455	3323
RDC	1	1	7.07	15.58666	13.128925	28.9443	0.3001	518.641	0.0085	57.8293
Interface Adaptor	2	1.8	1.57	3.461253	3.2247439	7.10933	0.028	48.4528	0.0008	6.22754
Digital Processor	32	1	109	240.3036	168.51547	371.513	8.6681	14978.4	0.2455	3323
Supermini Computers	5	1	7.48	16.49056	13.837927	30.5074	0.5	864	0.0142	125.729
High-speed Processors	15	1	109	240.3036	168.51547	371.513	8.6681	14978.4	0.2455	3323
Printers	5	1.8	8	17.63696	14.733428	32.4816	0.7151	1235.73	0.0203	138.887
SINCGARS	1	1	3.1	6.834322	6.0836093	13.412	0.0517	89.3388	0.0015	10
SCDL Terminal	2	1	20	44.0924	34.640316	76.3687	0.5497	949.965	0.0156	750
JTT with a constant source	1	1	53.4	117.7267	86.599792	190.92	1.1171	1930.27	0.0316	1155.06
Integrated Terminal Group Radios	3	0	3.1	6.834322	6.0836093	13.412	0.045	77.7503	0.0013	118.144
Track Management Processor	2	0	109	240.3036	168.51547	371.513	8.6681	14978.4	0.2455	3323
Beamformer Processor	1	0	109	240.3036	168.51547	371.513	8.6681	14978.4	0.2455	3323
Search Database Processor	1	0	109	240.3036	168.51547	371.513	8.6681	14978.4	0.2455	3323

APPENDIX E:

VOLUME-POWER ESTIMATION SPREADSHEET

DTN11

Mission Equipment	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
In the Cabin	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
ACIDS	1	0	11.34	25.00039	20.402098	44.9789	0.4605	795.685	0.013	135
In-flight Refuel System	1	1	53.15	117.1756	86.221467	190.086	0	0	0	1147.06
JTIDS Terminal	2	0	155	341.7161	234.04552	515.981	5.2972	9153.56	0.15	5597.26
ESM SYSTEM	1	1	100	220.462	155.49659	342.811	563.73	974120	15.963	1000
TADIL DATA TERMINAL	2	1.5	4.6	10.14125	8.7917214	19.3824	0.0124	21.4823	0.0004	28
TADIL SDLT	1	1.5	4.6	10.14125	8.7917214	19.3824	0.0124	21.4823	0.0004	15
In the Rotodome										
PCE	1	1	100	182.5365	136.48661	300.901	1.6551	2860	0.0469	4850.15
AA(transmitter, IFF\SSR)	1	1	18.762	41.36308	33.632033	74.1459	1.0478	1810.59	0.0297	267.81
MR	1	1	99.79	219.999	155.1919	342.139	15.961	27582.7	0.452	1975.52
SLR Antenna	1	1	29.5	65.03629	49.781136	109.748	15.961	27582.7	0.452	4000
Below Front Cabin										
Rest Area	36				326.58653	720	676.35	1168727	19.152	500
Below Rear Cabin										
HVPS with	1	NA	NA	NA	Totally 1210 kg	NA	NA	NA	Totally 25.63 m3	NA
Transmit Electronics	1	NA	NA	NA		NA	NA	NA		NA
RC	1	NA	NA	NA		NA	NA	NA		NA
APU	1	1	47.62725	105	104.77995	231	95.35	164764	2.7	0

*AWACS Equip. plus APU occupy 25.63 m3 space in the below rear cabin(according to Boeing 707 data)

*AWACS Equip. in the dome weighs 1210 kg which is 1/3 of total AWACS equipment

Each Terminal 1m*1m*1.5m

APPENDIX E:

VOLUME-POWER ESTIMATION SPREADSHEET

DTN11

Insert Number of crew onboard

OTHER	Crew	Weight		Adjusted Volume			Power
	People	kg	lb	ft3	in3	m3	Watts
Crew	36	2939.28	6480	0	0	0	0
Seats	36	14.515	32	Considered with consoles			0
Galley	36	142.585	314.3451	706.2934	1220474.8	20	3000
Lavatory	36	59.1386	130.3782	635.6641	1098427.3	18	1200
	TOTAL	216.238	476.7232	1341.957	2318902.1	38	4200

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BUNK BEDS

Note: 0% technology improvement is applied to the estimated volume and power values

Each Crew weighs 180 lb,Each Seat weighs 32 lb

	Total Weight		Total Volume		Total Power
	kg	lb	ft3	m3	Watts
COMMON EQUIPMENT	440.76	971.708	6.575165	0.186188	7869.9099
TOTAL INTERIOR EQUIPMENT	18465	40709.1	9879.679	279.7613	286989.18
ROTODOME EQUIPMENT	375.09	826.935	415.5282	11.76645	11093.482
BELOW FRONT CABIN EQUIPMENT	326.59	719.999	1101.068	31.17878	500
BELOW REAR CABIN EQUIPMENT	1314.8	2898.59	1000.465	28.33	33280.447
CLASSIFIED EQUIPMENT	923.27	2035.45	493.9839	13.98807	14349.459
GRAND TOTAL	21846	48161.7	12897.3	365.2108	354082.48

OVERLOAD

CLASSIFIED EQUIPMENT CONSIDERED AS THE 5% OF THE INTERIOR EQUIPMENT

APPENDIX E:

VOLUME-POWER ESTIMATION SPREADSHEET

DTN12

	Interior	Below Front Cabin	Below Rear Cabin	Bulk Cargo	TOTAL
Max. Volume(m3)	563.4	67.97	61.17	9.77	702.31

Generators assumed 84% efficient

Max. Payload Weight (kg)	52473

	Engine	APU	TOTAL
Max. Power (Watts)	240000	120000	302400
	240000	180000	352800

	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
Common Equipment	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
ILS-VOR	1	1	5.5	12.12541	10.38674	22.8988	0.30734	531.08	0.0087	25
Gyro Compass	1	1	3.81	8.399602	7.3743519	16.2576	0.21	362.88	0.0059	58.5744
Autopilot System	1	1	76	167.5511	120.37047	265.371	1.1336	1958.86	0.0321	1523.95
Radar Altimeter	1	1	2.1	4.629702	4.230108	9.32578	0.08913	154.019	0.0025	52.2895
Range only Radar	1	1	11.34	25.00039	20.402098	44.9789	0.61513	1062.95	0.0174	396.143
Flight Deck Instrument	1	1	115	253.5313	177.1544	390.558	In the Flight Deck			3597.44
Flight Data Recorder	2	1	7.07	15.58666	13.128925	28.9443	0.60028	1037.28	0.017	57.8293
Weather Radar	1	1	45.5	100.3102	74.583969	164.429	3.0194	5217.53	0.0855	2100.86
Mission Equipment	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
In the Cabin	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
Intercom System	2	2.8	13.16	29.0128	23.441565	51.6797	0.53436	923.383	0.0151	266.94
UHF Radio	12	1.6	8.8	19.40066	16.103608	35.5023	0.3882	670.801	0.011	582.728
VHF Radio	3	2.8	3.1	6.834322	6.0836093	13.412	0.04499	77.7503	0.0013	118.144
HF Radio	2	2.8	35.17	77.53649	58.654276	129.31	1.65509	2860	0.0469	4850.15
IFF	1	1	2.962	6.530084	5.8305525	12.8542	0.55	950.4	0.0156	67.8096
TACAN	1	1	20.86525	45.99995	36.036539	79.4469	1.65	2851.2	0.0467	633.047
Embedded GPS\INS	1	1	20.4	44.97425	35.286274	77.7928	0.31193	539.023	0.0088	418.828
Radar Warning&Homing	1	2	92.53284	203.9997	144.63551	318.866	1.40636	2430.19	0.0398	4926.92
ECM Equipment	1	1	2300	5070.626	2898.7645	6390.67	172.124	297430	4.874	258564
Countermeas. Dispensing Set	1	1	53.1	117.0653	86.145788	189.919	2.75287	4756.96	0.078	9107.89
Countermeas. Receiving Set	1	1	42.65	94.02704	70.215876	154.799	2.75951	4768.43	0.0781	873.525

APPENDIX E:

VOLUME-POWER ESTIMATION SPREADSHEET

DTN12

Mission Equipment	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
In the Cabin	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
Terrain Following Radar	1	0	112.95	249.0118	174.20624	384.059	8.55985	14791.4	0.2424	6259.66
MIDS	2	1.5	23.18	51.10309	39.753163	87.6406	0.43405	750.034	0.0123	991.815
Crypto Equipment	37	1	1.42	3.13056	2.9363369	6.47351	0.02804	48.4528	0.0008	5.36698
TADIL SYSTEM	1	1	20	44.0924	34.640316	76.3687	0.41516	717.396	0.0118	350
Operational Consoles	37	1	15	33.0693	26.485855	58.3912	81.7049	141186	2.3136	176.171
SATCOM	2	2.5	8.3	18.29835	15.248275	33.6167	0.27687	478.426	0.0078	532.855
Signal Processors	3	2.5	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Air Data Terminals	15	2.5	22.5	49.60395	38.664033	85.2395	52.972	91535.6	1.5	642.312
Air Data Computer	2	2.5	7.48	16.49056	13.837927	30.5074	0.5	864	0.0142	125.729
RCMP	1	0	3.98	8.774388	7.6808939	16.9335	0.16004	276.55	0.0045	35.8
Radar Synchronizer	3	2.5	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
STALO	1	0	4.79	10.56013	9.1300655	20.1283	0.13737	237.382	0.0039	64.9789
AR	1	0	99.79	219.999	155.1919	342.139	15.961	27582.7	0.452	1975.52
MP	1	0	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
DDP	2	0	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
RDC	1	0	7.07	15.58666	13.128925	28.9443	0.30014	518.641	0.0085	57.8293
Interface Adaptor	2	2.5	1.57	3.461253	3.2247439	7.10933	0.02804	48.4528	0.0008	6.22754
Digital Processor	37	1	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Supermini Computers	5	0	7.48	16.49056	13.837927	30.5074	0.5	864	0.0142	125.729
High-speed Processors	15	0	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Printers	5	2.5	8	17.63696	14.733428	32.4816	0.71512	1235.73	0.0203	138.887
SINCGARS	1	0	3.1	6.834322	6.0836093	13.412	0.0517	89.3388	0.0015	10
SCDL Terminal	2	0	20	44.0924	34.640316	76.3687	0.54975	949.965	0.0156	750
JTT with a constant source	1	0	53.4	117.7267	86.599792	190.92	1.11706	1930.27	0.0316	1155.06
Integrated Terminal Group Radios	4	1	3.1	6.834322	6.0836093	13.412	0.04499	77.7503	0.0013	118.144
Track Management Processor	2	1	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Beamformer Processor	1	1	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Search Database Processor	1	1	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323

APPENDIX E:
VOLUME-POWER ESTIMATION SPREADSHEET
DTN12

Mission Equipment	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
In the Cabin	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
ACIDS	1	0	11.34	25.00039	20.402098	44.9789	0.46047	795.685	0.013	135
In-flight Refuel System	1	1	53.15	117.1756	86.221467	190.086	0	0	0	1147.06
JTIDS Terminal	2	0	155	341.7161	234.04552	515.981	5.2972	9153.56	0.15	5597.26
ESM SYSTEM	1	0	100	220.462	155.49659	342.811	563.727	974120	15.963	1000
TADIL DATA TERMINAL	2	1	4.6	10.14125	8.7917214	19.3824	0.01243	21.4823	0.0004	28
TADIL SDLT	1	1	4.6	10.14125	8.7917214	19.3824	0.01243	21.4823	0.0004	15
Common Data Retrivial Sys	1	1	2.52	5.555642	5.0144992	11.0551	0.27531	475.734	0.0078	18
Comms. Emitter Location Sys.	1	1	2.52	5.555642	5.0144992	11.0551	0.27531	475.734	0.0078	18
Background Search sys.	1	1	53.4	117.7267	86.599792	190.92	1.11706	1930.27	0.0316	1155.06
In the Rotodome										
PCE	1	0	100	182.5365	136.48661	300.901	1.65509	2860	0.0469	4850.15
AA(transmitter, IFF\SSR)	1	0	18.762	41.36308	33.632033	74.1459	1.0478	1810.59	0.0297	267.81
MR	1	0	99.79	219.999	155.1919	342.139	15.961	27582.7	0.452	1975.52
SLR Antenna	1	0	29.5	65.03629	49.781136	109.748	15.961	27582.7	0.452	4000
BLINK JAMMER	1	1	9	19.84158	16.44482	36.2546	1.58916	2746.07	0.045	4000
Below Front Cabin										
Rest Area	41				326.58653	720	676.347	1168727	19.152	500
Below Rear Cabin										
HVPS with	1	NA	NA	NA	Totally 1210 kg	NA	NA	NA	Totally 25.63 m3	NA
Transmit Electronics	1	NA	NA	NA		NA	NA	NA		NA
RC	1	NA	NA	NA		NA	NA	NA		NA
APU	1	1	47.62725	105	104.77995	231	95.3496	164764	2.7	0

*AWACS Equip. plus APU occupy 25.63 m3 space in the below rear cabin(according to Boeing 707 data)

*AWACS Equip. in the dome weighs 1210 kg which is 1/3 of total AWACS equipment

Each Terminal 1m*1m*1.5m

APPENDIX E:
VOLUME-POWER ESTIMATION SPREADSHEET
DTN12

Insert Number of crew onboard

OTHER	Crew	Weight		Adjusted Volume			Power
	People	kg	lb	ft3	in3	m3	Watts
Crew	41	3347.51	7380	0	0	0	0
Seats	41	14.515	32	Considered with consoles			0
Galley	41	164.942	363.6351	1059.44	1830712.2	30	4500
Lavatory	41	70.3058	154.9976	794.5801	1373034.2	22.5	1500
	TOTAL	249.763	550.6327	1854.02	3203746.4	52.5	6000

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BUNK BEDS

Note: 0% technology improvement is applied to the estimated volume and power values

Each Crew weighs 180 lb,Each Seat weighs 32 lb

	Total Weight		Total Volume		Total Power
	kg	lb	ft3	m3	Watts
COMMON EQUIPMENT	440.76	971.708	6.575165	0.186188	7869.9099
TOTAL INTERIOR EQUIPMENT	21455	47299.3	10909.53	308.9234	412426.48
ROTODOME EQUIPMENT	16.445	36.2546	38.13984	1.08	4000
BELOW FRONT CABIN EQUIPMENT	326.59	719.999	1101.068	31.17878	500
BELOW REAR CABIN EQUIPMENT	104.78	231	95.34961	2.7	0
CLASSIFIED EQUIPMENT	1072.7	2364.96	545.4764	15.44617	20621.324
GRAND TOTAL	23416	51623.2	12696.14	359.5145	445417.71

OVERLOAD

CLASSIFIED EQUIPMENT CONSIDERED AS THE 5% OF THE INTERIOR EQUIPMENT

APPENDIX E:

VOLUME-POWER ESTIMATION SPREADSHEET

DTN21

	Interior	Below Front Cabin	Below Rear Cabin	Bulk Cargo	TOTAL
Max. Volume(m3)	563.4	67.97	61.17	9.77	702.31

Generators assumed 84% efficient

Max. Payload Weight (kg)	52473

	Engine	APU	TOTAL
Max. Power (Watts)	240000	120000	302400
	240000	180000	352800

	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
Common Equipment	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
ILS-VOR	1	1	5.5	12.12541	10.38674	22.8988	0.30734	531.08	0.0087	25
Gyro Compass	1	1	3.81	8.399602	7.3743519	16.2576	0.21	362.88	0.0059	58.5744
Autopilot System	1	1	76	167.5511	120.37047	265.371	1.1336	1958.86	0.0321	1523.95
Radar Altimeter	1	1	2.1	4.629702	4.230108	9.32578	0.08913	154.019	0.0025	52.2895
Range only Radar	1	1	11.34	25.00039	20.402098	44.9789	0.61513	1062.95	0.0174	396.143
Flight Deck Instrument	1	1	115	253.5313	177.1544	390.558	In the Flight Deck			3597.44
Flight Data Recorder	2	1	7.07	15.58666	13.128925	28.9443	0.60028	1037.28	0.017	57.8293
Weather Radar	1	1	45.5	100.3102	74.583969	164.429	3.0194	5217.53	0.0855	2100.86
Mission Equipment	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
In the Cabin	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
Intercom System	2	1.8	13.16	29.0128	23.441565	51.6797	0.53436	923.383	0.0151	266.94
UHF Radio	12	2	8.8	19.40066	16.103608	35.5023	0.3882	670.801	0.011	582.728
VHF Radio	3	2.2	3.1	6.834322	6.0836093	13.412	0.04499	77.7503	0.0013	118.144
HF Radio	2	2.2	35.17	77.53649	58.654276	129.31	1.65509	2860	0.0469	4850.15
IFF	1	1	2.962	6.530084	5.8305525	12.8542	0.55	950.4	0.0156	67.8096
TACAN	1	1	20.86525	45.99995	36.036539	79.4469	1.65	2851.2	0.0467	633.047
Embedded GPS\INS	1	1	20.4	44.97425	35.286274	77.7928	0.31193	539.023	0.0088	418.828
Radar Warning&Homing	1	1	92.53284	203.9997	144.63551	318.866	1.40636	2430.19	0.0398	4926.92
ECM Equipment	1	0	2300	5070.626	2898.7645	6390.67	172.124	297430	4.874	258564
Countermeas. Dispensing Set	1	0	53.1	117.0653	86.145788	189.919	2.75287	4756.96	0.078	9107.89
Countermeas. Receiving Set	1	0	42.65	94.02704	70.215876	154.799	2.75951	4768.43	0.0781	873.525

APPENDIX E:
VOLUME-POWER ESTIMATION SPREADSHEET

DTN21

Mission Equipment	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
In the Cabin	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
Terrain Following Radar	1	0	112.95	249.0118	174.20624	384.059	8.55985	14791.4	0.2424	6259.66
MIDS	2	1.8	23.18	51.10309	39.753163	87.6406	0.43405	750.034	0.0123	991.815
Crypto Equipment	28	1	1.42	3.13056	2.9363369	6.47351	0.02804	48.4528	0.0008	5.36698
TADIL SYSTEM	1	1.2	20	44.0924	34.640316	76.3687	0.41516	717.396	0.0118	350
Operational Consoles	28	1	15	33.0693	26.485855	58.3912	81.7049	141186	2.3136	176.171
SATCOM	2	1.8	8.3	18.29835	15.248275	33.6167	0.27687	478.426	0.0078	532.855
Signal Processors	3	1.8	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Air Data Terminals	15	1.8	22.5	49.60395	38.664033	85.2395	52.972	91535.6	1.5	642.312
Air Data Computer	2	1.8	7.48	16.49056	13.837927	30.5074	0.5	864	0.0142	125.729
RCMP	1	1	3.98	8.774388	7.6808939	16.9335	0.16004	276.55	0.0045	35.8
Radar Synchronizer	3	1.8	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
STALO	1	1	4.79	10.56013	9.1300655	20.1283	0.13737	237.382	0.0039	64.9789
AR	1	1	99.79	219.999	155.1919	342.139	15.961	27582.7	0.452	1975.52
MP	1	1	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
DDP	2	1.2	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
RDC	1	1	7.07	15.58666	13.128925	28.9443	0.30014	518.641	0.0085	57.8293
Interface Adaptor	2	1.8	1.57	3.461253	3.2247439	7.10933	0.02804	48.4528	0.0008	6.22754
Digital Processor	28	0	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Supermini Computers	5	0	7.48	16.49056	13.837927	30.5074	0.5	864	0.0142	125.729
High-speed Processors	15	1	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Printers	5	1.8	8	17.63696	14.733428	32.4816	0.71512	1235.73	0.0203	138.887
SINCGARS	1	0	3.1	6.834322	6.0836093	13.412	0.0517	89.3388	0.0015	10
SCDL Terminal	2	0	20	44.0924	34.640316	76.3687	0.54975	949.965	0.0156	750
JTT with a constant source	1	0	53.4	117.7267	86.599792	190.92	1.11706	1930.27	0.0316	1155.06
Integrated Terminal Group Radios	4	0	3.1	6.834322	6.0836093	13.412	0.04499	77.7503	0.0013	118.144
Track Management Processor	2	0	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Beamformer Processor	1	0	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Search Database Processor	1	0	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323

APPENDIX E:
VOLUME-POWER ESTIMATION SPREADSHEET
DTN21

Mission Equipment	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
In the Cabin	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
ACIDS	1	1	11.34	25.00039	20.402098	44.9789	0.46047	795.685	0.013	135
In-flight Refuel System	1	1	53.15	117.1756	86.221467	190.086	0	0	0	1147.06
JTIDS Terminal	2	0	155	341.7161	234.04552	515.981	5.2972	9153.56	0.15	5597.26
ESM SYSTEM	1	1	100	220.462	155.49659	342.811	563.727	974120	15.963	1000
TADIL DATA TERMINAL	2	1	4.6	10.14125	8.7917214	19.3824	0.01243	21.4823	0.0004	28
TADIL SDLT	1	1	4.6	10.14125	8.7917214	19.3824	0.01243	21.4823	0.0004	15
Common Data Retrivial Sys	1	0	2.52	5.555642	5.0144992	11.0551	0.27531	475.734	0.0078	18
Comms. Emitter Location Sys.	1	0	2.52	5.555642	5.0144992	11.0551	0.27531	475.734	0.0078	18
Background Search sys.	1	0	53.4	117.7267	86.599792	190.92	1.11706	1930.27	0.0316	1155.06
In the Rotodome										
PCE	1	1	100	182.5365	136.48661	300.901	1.65509	2860	0.0469	4850.15
AA(transmitter, IFF\SSR)	1	1	18.762	41.36308	33.632033	74.1459	1.0478	1810.59	0.0297	267.81
MR	1	1	99.79	219.999	155.1919	342.139	15.961	27582.7	0.452	1975.52
SLR Antenna	1	0	29.5	65.03629	49.781136	109.748	15.961	27582.7	0.452	4000
BLINK JAMMER	1	0	9	19.84158	16.44482	36.2546	1.58916	2746.07	0.045	4000
Below Front Cabin										
Rest Area	32				326.58653	720	676.347	1168727	19.152	500
Below Rear Cabin										
HVPS with	1	NA	NA	NA	Totally	NA	NA	NA	Totally	NA
Transmit Electronics	1	NA	NA	NA	1210 kg	NA	NA	NA	25.63	NA
RC	1	NA	NA	NA		NA	NA	NA	m3	NA
APU	1	1	47.62725	105	104.77995	231	95.3496	164764	2.7	0

*AWACS Equip. plus APU occupy 25.63 m3 space in the below rear cabin(according to Boeing 707 data)

*AWACS Equip. in the dome weighs 1210 kg which is 1/3 of total AWACS equipment

Each Terminal 1m*1m*1.5m

APPENDIX E:
VOLUME-POWER ESTIMATION SPREADSHEET
DTN21

Insert Number of crew onboard

OTHER	Crew	Weight		Adjusted Volume			Power
	People	kg	lb	ft3	in3	m3	Watts
Crew	32	2612.69	5760	0	0	0	0
Seats	32	14.515	32	Considered with consoles			0
Galley	32	124.963	275.4963	706.2934	1220474.8	20	3000
Lavatory	32	50.5636	111.4736	635.6641	1098427.3	18	1200
	TOTAL	190.042	418.9699	1341.957	2318902.1	38	4200

5.5

BUNK BEDS

Note: 0% technology improvement is applied to the estimated volume and power values

Each Crew weighs 180 lb,Each Seat weighs 32 lb

	Total Weight		Total Volume		Total Power
	kg	lb	ft3	m3	Watts
COMMON EQUIPMENT	440.76	971.708	6.575165	0.186188	7869.9099
TOTAL INTERIOR EQUIPMENT	12266	27041.4	9268.655	262.4591	172909.42
ROTODOME EQUIPMENT	325.31	717.186	447.9629	12.68489	7093.4824
BELOW FRONT CABIN EQUIPMENT	326.59	719.999	1101.068	31.17878	500
BELOW REAR CABIN EQUIPMENT	1314.8	2898.59	1000.465	28.33	21280.447
CLASSIFIED EQUIPMENT	613.29	1352.07	463.4328	13.12295	8645.4711
GRAND TOTAL	15287	33701	12288.16	347.9619	218298.73

CLASSIFIED EQUIPMENT CONSIDERED AS THE 5% OF THE INTERIOR EQUIPMENT

APPENDIX E:

VOLUME-POWER ESTIMATION SPREADSHEET

DTN22

	Interior	Below Front Cabin	Below Rear Cabin	Bulk Cargo	TOTAL
Max. Volume(m3)	563.4	67.97	61.17	9.77	702.31

Generators assumed 84% efficient

Max. Payload Weight (kg)	52473

	Engine	APU	TOTAL
Max. Power (Watts)	240000	120000	302400
	240000	180000	352800

	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume		
Common Equipment	piece	c	kg	lb	kg	lb	ft3	in3	m3
ILS-VOR	1	1	5.5	12.12541	10.38674	22.8988	0.30734	531.08	0.0087
Gyro Compass	1	1	3.81	8.399602	7.3743519	16.2576	0.21	362.88	0.0059
Autopilot System	1	1	76	167.5511	120.37047	265.371	1.1336	1958.86	0.0321
Radar Altimeter	1	1	2.1	4.629702	4.230108	9.32578	0.08913	154.019	0.0025
Range only Radar	1	1	11.34	25.00039	20.402098	44.9789	0.61513	1062.95	0.0174
Flight Deck Instrument	1	1	115	253.5313	177.1544	390.558	In the Flight Deck		
Flight Data Recorder	2	1	7.07	15.58666	13.128925	28.9443	0.60028	1037.28	0.017
Weather Radar	1	1	45.5	100.3102	74.583969	164.429	3.0194	5217.53	0.0855
Mission Equipment	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume		
In the Cabin	piece	c	kg	lb	kg	lb	ft3	in3	m3
Intercom System	2	3	13.16	29.0128	23.441565	51.6797	0.53436	923.383	0.0151
UHF Radio	12	1.6	8.8	19.40066	16.103608	35.5023	0.3882	670.801	0.011
VHF Radio	3	2.8	3.1	6.834322	6.0836093	13.412	0.04499	77.7503	0.0013
HF Radio	2	3	35.17	77.53649	58.654276	129.31	1.65509	2860	0.0469
IFF	1	1	2.962	6.530084	5.8305525	12.8542	0.55	950.4	0.0156
TACAN	1	1	20.86525	45.99995	36.036539	79.4469	1.65	2851.2	0.0467
Embedded GPS\INS	1	1	20.4	44.97425	35.286274	77.7928	0.31193	539.023	0.0088
Radar Warning&Homing	1	2	92.53284	203.9997	144.63551	318.866	1.40636	2430.19	0.0398
ECM Equipment	1	1	2300	5070.626	2898.7645	6390.67	172.124	297430	4.874
Countermeas. Dispensing Set	1	1	53.1	117.0653	86.145788	189.919	2.75287	4756.96	0.078
Countermeas. Receiving Set	1	1	42.65	94.02704	70.215876	154.799	2.75951	4768.43	0.0781

APPENDIX E:
VOLUME-POWER ESTIMATION SPREADSHEET
DTN22

Mission Equipment	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume		
In the Cabin	piece	c	kg	lb	kg	lb	ft3	in3	m3
Terrain Following Radar	1	2	112.95	249.0118	174.20624	384.059	8.55985	14791.4	0.2424
MIDS	2	2	23.18	51.10309	39.753163	87.6406	0.43405	750.034	0.0123
Crypto Equipment	48	1	1.42	3.13056	2.9363369	6.47351	0.02804	48.4528	0.0008
TADIL SYSTEM	1	2	20	44.0924	34.640316	76.3687	0.41516	717.396	0.0118
Operational Consoles	48	1	15	33.0693	26.485855	58.3912	81.7049	141186	2.3136
SATCOM	2	2.5	8.3	18.29835	15.248275	33.6167	0.27687	478.426	0.0078
Signal Processors	3	2.5	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455
Air Data Terminals	15	2.5	22.5	49.60395	38.664033	85.2395	52.972	91535.6	1.5
Air Data Computer	2	2.5	7.48	16.49056	13.837927	30.5074	0.5	864	0.0142
RCMP	1	0	3.98	8.774388	7.6808939	16.9335	0.16004	276.55	0.0045
Radar Synchronizer	3	2.5	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455
STALO	1	0	4.79	10.56013	9.1300655	20.1283	0.13737	237.382	0.0039
AR	1	0	99.79	219.999	155.1919	342.139	15.961	27582.7	0.452
MP	1	0	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455
DDP	2	0	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455
RDC	1	0	7.07	15.58666	13.128925	28.9443	0.30014	518.641	0.0085
Interface Adaptor	2	2.5	1.57	3.461253	3.2247439	7.10933	0.02804	48.4528	0.0008
Digital Processor	48	1	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455
Supermini Computers	5	1	7.48	16.49056	13.837927	30.5074	0.5	864	0.0142
High-speed Processors	15	1.5	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455
Printers	5	2.5	8	17.63696	14.733428	32.4816	0.71512	1235.73	0.0203
SINCGARS	1	1	3.1	6.834322	6.0836093	13.412	0.0517	89.3388	0.0015
SCDL Terminal	2	1	20	44.0924	34.640316	76.3687	0.54975	949.965	0.0156
JTT with a constant source	1	1	53.4	117.7267	86.599792	190.92	1.11706	1930.27	0.0316
Integrated Terminal Group Radios	4	1	3.1	6.834322	6.0836093	13.412	0.04499	77.7503	0.0013
Track Management Processor	2	1	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455
Beamformer Processor	1	1	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455
Search Database Processor	1	1	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455

APPENDIX E:
VOLUME-POWER ESTIMATION SPREADSHEET
DTN22

Mission Equipment	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume		
In the Cabin	piece	c	kg	lb	kg	lb	ft3	in3	m3
ACIDS	1	0	11.34	25.00039	20.402098	44.9789	0.46047	795.685	0.013
In-flight Refuel System	1	1	53.15	117.1756	86.221467	190.086	0	0	0
JTIDS Terminal	2	0	155	341.7161	234.04552	515.981	5.2972	9153.56	0.15
ESM SYSTEM	1	0	100	220.462	155.49659	342.811	563.727	974120	15.963
TADIL DATA TERMINAL	2	2	4.6	10.14125	8.7917214	19.3824	0.01243	21.4823	0.0004
TADIL SDLT	1	2	4.6	10.14125	8.7917214	19.3824	0.01243	21.4823	0.0004
Common Data Retrivial Sys	1	1	2.52	5.555642	5.0144992	11.0551	0.27531	475.734	0.0078
Comms. Emitter Location Sys.	1	1	2.52	5.555642	5.0144992	11.0551	0.27531	475.734	0.0078
Background Search sys.	1	1	53.4	117.7267	86.599792	190.92	1.11706	1930.27	0.0316
In the Rotodome									
PCE	1	0	100	182.5365	136.48661	300.901	1.65509	2860	0.0469
AA(transmitter, IFF\SSR)	1	0	18.762	41.36308	33.632033	74.1459	1.0478	1810.59	0.0297
MR	1	0	99.79	219.999	155.1919	342.139	15.961	27582.7	0.452
SLR Antenna	1	1	29.5	65.03629	49.781136	109.748	15.961	27582.7	0.452
BLINK JAMMER	1	1	9	19.84158	16.44482	36.2546	1.58916	2746.07	0.045
Below Front Cabin									
Rest Area	52				326.58653	720	676.347	1168727	19.152
Below Rear Cabin									
HVPS with	1	NA	NA	NA	Totally 1210 kg	NA	NA	NA	Totally 25.63 m3
Transmit Electronics	1	NA	NA	NA		NA	NA	NA	
RC	1	NA	NA	NA		NA	NA	NA	
APU	1	1	47.62725	105	104.77995	231	95.3496	164764	2.7

*AWACS Equip. plus APU occupy 25.63 m3 space in the below rear cabin(according to Boeing 707 data)
*AWACS Equip. in the dome weighs 1210 kg which is 1/3 of total AWACS equipment
Each Terminal 1m*1m*1.5m

APPENDIX E:
VOLUME-POWER ESTIMATION SPREADSHEET
DTN22

Insert Number of crew onboard

OTHER	Crew	Weight		Adjusted Volume			Power
	People	kg	lb	ft3	in3	m3	Watts
Crew	52	4245.62	9360	0	0	0	0
Seats	52	14.515	32	Considered with consoles			0
Galley	52	215.247	474.5387	1059.44	1830712.2	30	4500
Lavatory	52	96.4436	212.6214	953.4961	1647641	27	1800
	TOTAL	326.206	719.16	2012.936	3478353.2	57	6300

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BUNK BEDS

Note: 0% technology improvement is applied to the estimated volume and power values

Each Crew weighs 180 lb, Each Seat weighs 32 lb

	Total Weight		Total Volume		Total Power
	kg	lb	ft3	m3	Watts
COMMON EQUIPMENT	440.76	971.708	6.575165	0.186188	7869.9099
TOTAL INTERIOR EQUIPMENT	29271	64531.2	12281.54	347.7744	545316.44
ROTODOME EQUIPMENT	66.226	146.003	421.2334	11.928	8000
BELOW FRONT CABIN EQUIPMENT	326.59	719.999	1101.068	31.17878	500
BELOW REAR CABIN EQUIPMENT	104.78	231	95.34961	2.7	0
CLASSIFIED EQUIPMENT	1463.5	3226.56	614.0768	17.38872	27265.822
GRAND TOTAL	31673	69826.5	14519.84	411.1561	588952.17

OVERLOAD

CLASSIFIED EQUIPMENT CONSIDERED AS THE 5% OF THE INTERIOR EQUIPMENT

APPENDIX E:

VOLUME-POWER ESTIMATION SPREADSHEET

DTN31

	Interior	Below Front Cabin	Below Rear Cabin	Bulk Cargo	TOTAL
Max. Volume(m3)	563.4	67.97	61.17	9.77	702.31

Generators assumed 84% efficient

Max. Payload Weight (kg)	52473

	Engine	APU	TOTAL
Max. Power (Watts)	240000	120000	302400
	240000	180000	352800

	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
Common Equipment	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
ILS-VOR	1	1	5.5	12.12541	10.38674	22.8988	0.30734	531.08	0.0087	25
Gyro Compass	1	1	3.81	8.399602	7.3743519	16.2576	0.21	362.88	0.0059	58.5744
Autopilot System	1	1	76	167.5511	120.37047	265.371	1.1336	1958.86	0.0321	1523.95
Radar Altimeter	1	1	2.1	4.629702	4.230108	9.32578	0.08913	154.019	0.0025	52.2895
Range only Radar	1	1	11.34	25.00039	20.402098	44.9789	0.61513	1062.95	0.0174	396.143
Flight Deck Instrument	1	1	115	253.5313	177.1544	390.558	In the Flight Deck			3597.44
Flight Data Recorder	2	1	7.07	15.58666	13.128925	28.9443	0.60028	1037.28	0.017	57.8293
Weather Radar	1	1	45.5	100.3102	74.583969	164.429	3.0194	5217.53	0.0855	2100.86
Mission Equipment	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
In the Cabin	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
Intercom System	2	1.8	13.16	29.0128	23.441565	51.6797	0.53436	923.383	0.0151	266.94
UHF Radio	12	1.8	8.8	19.40066	16.103608	35.5023	0.3882	670.801	0.011	582.728
VHF Radio	3	1.8	3.1	6.834322	6.0836093	13.412	0.04499	77.7503	0.0013	118.144
HF Radio	2	1.8	35.17	77.53649	58.654276	129.31	1.65509	2860	0.0469	4850.15
IFF	1	1	2.962	6.530084	5.8305525	12.8542	0.55	950.4	0.0156	67.8096
TACAN	1	1	20.86525	45.99995	36.036539	79.4469	1.65	2851.2	0.0467	633.047
Embedded GPS\INS	1	1	20.4	44.97425	35.286274	77.7928	0.31193	539.023	0.0088	418.828
Radar Warning&Homing	1	1	92.53284	203.9997	144.63551	318.866	1.40636	2430.19	0.0398	4926.92
ECM Equipment	1	0	2300	5070.626	2898.7645	6390.67	172.124	297430	4.874	258564
Countermeas. Dispensing Set	1	0	53.1	117.0653	86.145788	189.919	2.75287	4756.96	0.078	9107.89
Countermeas. Receiving Set	1	0	42.65	94.02704	70.215876	154.799	2.75951	4768.43	0.0781	873.525

APPENDIX E:
VOLUME-POWER ESTIMATION SPREADSHEET
DTN31

Mission Equipment	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
In the Cabin	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
Terrain Following Radar	1	1	112.95	249.0118	174.20624	384.059	8.55985	14791.4	0.2424	6259.66
MIDS	2	1.8	23.18	51.10309	39.753163	87.6406	0.43405	750.034	0.0123	991.815
Crypto Equipment	40	1	1.42	3.13056	2.9363369	6.47351	0.02804	48.4528	0.0008	5.36698
TADIL SYSTEM	1	1.8	20	44.0924	34.640316	76.3687	0.41516	717.396	0.0118	350
Operational Consoles	40	1	15	33.0693	26.485855	58.3912	81.7049	141186	2.3136	176.171
SATCOM	2	1.8	8.3	18.29835	15.248275	33.6167	0.27687	478.426	0.0078	532.855
Signal Processors	3	1.8	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Air Data Terminals	15	1.8	22.5	49.60395	38.664033	85.2395	52.972	91535.6	1.5	642.312
Air Data Computer	2	1.8	7.48	16.49056	13.837927	30.5074	0.5	864	0.0142	125.729
RCMP	1	1	3.98	8.774388	7.6808939	16.9335	0.16004	276.55	0.0045	35.8
Radar Synchronizer	3	1.8	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
STALO	1	1	4.79	10.56013	9.1300655	20.1283	0.13737	237.382	0.0039	64.9789
AR	1	1	99.79	219.999	155.1919	342.139	15.961	27582.7	0.452	1975.52
MP	1	1	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
DDP	2	1.2	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
RDC	1	1	7.07	15.58666	13.128925	28.9443	0.30014	518.641	0.0085	57.8293
Interface Adaptor	2	1.8	1.57	3.461253	3.2247439	7.10933	0.02804	48.4528	0.0008	6.22754
Digital Processor	40	1	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Supermini Computers	5	0	7.48	16.49056	13.837927	30.5074	0.5	864	0.0142	125.729
High-speed Processors	15	1	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Printers	5	1.8	8	17.63696	14.733428	32.4816	0.71512	1235.73	0.0203	138.887
SINCGARS	1	0	3.1	6.834322	6.0836093	13.412	0.0517	89.3388	0.0015	10
SCDL Terminal	2	0	20	44.0924	34.640316	76.3687	0.54975	949.965	0.0156	750
JTT with a constant source	1	0	53.4	117.7267	86.599792	190.92	1.11706	1930.27	0.0316	1155.06
Integrated Terminal Group Radios	4	1	3.1	6.834322	6.0836093	13.412	0.04499	77.7503	0.0013	118.144
Track Management Processor	2	1	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Beamformer Processor	1	1	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Search Database Processor	1	1	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323

APPENDIX E:

VOLUME-POWER ESTIMATION SPREADSHEET

DTN31

Mission Equipment	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
In the Cabin	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
ACIDS	1	0	11.34	25.00039	20.402098	44.9789	0.46047	795.685	0.013	135
In-flight Refuel System	1	1	53.15	117.1756	86.221467	190.086	0	0	0	1147.06
JTIDS Terminal	2	0	155	341.7161	234.04552	515.981	5.2972	9153.56	0.15	5597.26
ESM SYSTEM	1	1	100	220.462	155.49659	342.811	563.727	974120	15.963	1000
TADIL DATA TERMINAL	2	1.8	4.6	10.14125	8.7917214	19.3824	0.01243	21.4823	0.0004	28
TADIL SDLT	1	1.8	4.6	10.14125	8.7917214	19.3824	0.01243	21.4823	0.0004	15
Common Data Retrivial Sys	1	1	2.52	5.555642	5.0144992	11.0551	0.27531	475.734	0.0078	18
Comms. Emitter Location Sys.	1	1	2.52	5.555642	5.0144992	11.0551	0.27531	475.734	0.0078	18
Background Search sys.	1	1	53.4	117.7267	86.599792	190.92	1.11706	1930.27	0.0316	1155.06
In the Rotodome										
PCE	1	1	100	182.5365	136.48661	300.901	1.65509	2860	0.0469	4850.15
AA(transmitter, IFF\SSR)	1	1	18.762	41.36308	33.632033	74.1459	1.0478	1810.59	0.0297	267.81
MR	1	1	99.79	219.999	155.1919	342.139	15.961	27582.7	0.452	1975.52
SLR Antenna	1	0	29.5	65.03629	49.781136	109.748	15.961	27582.7	0.452	4000
BLINK JAMMER	1	0	9	19.84158	16.44482	36.2546	1.58916	2746.07	0.045	4000
Below Front Cabin										
Rest Area	44				326.58653	720	676.347	1168727	19.152	500
Below Rear Cabin										
HVPS with	1	NA	NA	NA	Totally	NA	NA	NA	Totally	NA
Transmit Electronics	1	NA	NA	NA	1210 kg	NA	NA	NA	25.63	NA
RC	1	NA	NA	NA		NA	NA	NA	m3	NA
APU	1	1	47.62725	105	104.77995	231	95.3496	164764	2.7	0

*AWACS Equip. plus APU occupy 25.63 m3 space in the below rear cabin(according to Boeing 707 data)

*AWACS Equip. in the dome weighs 1210 kg which is 1/3 of total AWACS equipment

Each Terminal 1m*1m*1.5m

APPENDIX E:

VOLUME-POWER ESTIMATION SPREADSHEET

DTN31

Insert Number of crew onboard

OTHER	Crew	Weight		Adjusted Volume			Power
	People	kg	lb	ft3	in3	m3	Watts
Crew	44	3592.45	7920	0	0	0	0
Seats	44	14.515	32	Considered with consoles			0
Galley	44	178.518	393.5635	1059.44	1830712.2	30	4500
Lavatory	44	77.2291	170.2608	794.5801	1373034.2	22.5	1500
	TOTAL	270.262	595.8243	1854.02	3203746.4	52.5	6000

7.5

BUNK BEDS

Note: 0% technology improvement is applied to the estimated volume and power values

Each Crew weighs 180 lb,Each Seat weighs 32 lb

	Total Weight		Total Volume		Total Power
	kg	lb	ft3	m3	Watts
COMMON EQUIPMENT	440.76	971.708	6.575165	0.186188	7869.9099
TOTAL INTERIOR EQUIPMENT	21491	47380.6	11150.83	315.7562	327190.67
ROTODOME EQUIPMENT	325.31	717.186	447.9629	12.68489	7093.4824
BELOW FRONT CABIN EQUIPMENT	326.59	719.999	1101.068	31.17878	500
BELOW REAR CABIN EQUIPMENT	1314.8	2898.59	1000.465	28.33	21280.447
CLASSIFIED EQUIPMENT	1074.6	2369.03	557.5413	15.78781	16359.534
GRAND TOTAL	24974	55057.1	14264.44	403.9239	380294.05

OVERLOAD

CLASSIFIED EQUIPMENT CONSIDERED AS THE 5% OF THE INTERIOR EQUIPMENT

APPENDIX E:

VOLUME-POWER ESTIMATION SPREADSHEET

DTN32

	Interior	Below Front Cabin	Below Rear Cabin	Bulk Cargo	TOTAL
Max. Volume(m3)	563.4	67.97	61.17	9.77	702.31

Generators assumed 84% efficient

Max. Payload Weight (kg)	52473

	Engine	APU	TOTAL
Max. Power (Watts)	240000	120000	302400
	240000	180000	352800

	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
Common Equipment	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
ILS-VOR	1	1	5.5	12.12541	10.38674	22.8988	0.30734	531.08	0.0087	25
Gyro Compass	1	1	3.81	8.399602	7.3743519	16.2576	0.21	362.88	0.0059	58.5744
Autopilot System	1	1	76	167.5511	120.37047	265.371	1.1336	1958.86	0.0321	1523.95
Radar Altimeter	1	1	2.1	4.629702	4.230108	9.32578	0.08913	154.019	0.0025	52.2895
Range only Radar	1	1	11.34	25.00039	20.402098	44.9789	0.61513	1062.95	0.0174	396.143
Flight Deck Instrument	1	1	115	253.5313	177.1544	390.558	In the Flight Deck			3597.44
Flight Data Recorder	2	1	7.07	15.58666	13.128925	28.9443	0.60028	1037.28	0.017	57.8293
Weather Radar	1	1	45.5	100.3102	74.583969	164.429	3.0194	5217.53	0.0855	2100.86
Mission Equipment	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
In the Cabin	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
Intercom System	2	3	13.16	29.0128	23.441565	51.6797	0.53436	923.383	0.0151	266.94
UHF Radio	12	2.8	8.8	19.40066	16.103608	35.5023	0.3882	670.801	0.011	582.728
VHF Radio	3	2.8	3.1	6.834322	6.0836093	13.412	0.04499	77.7503	0.0013	118.144
HF Radio	2	3	35.17	77.53649	58.654276	129.31	1.65509	2860	0.0469	4850.15
IFF	1	1	2.962	6.530084	5.8305525	12.8542	0.55	950.4	0.0156	67.8096
TACAN	1	1	20.86525	45.99995	36.036539	79.4469	1.65	2851.2	0.0467	633.047
Embedded GPS\INS	1	1	20.4	44.97425	35.286274	77.7928	0.31193	539.023	0.0088	418.828
Radar Warning&Homing	1	2	92.53284	203.9997	144.63551	318.866	1.40636	2430.19	0.0398	4926.92
ECM Equipment	1	1	2300	5070.626	2898.7645	6390.67	172.124	297430	4.874	258564
Countermeas. Dispensing Set	1	1	53.1	117.0653	86.145788	189.919	2.75287	4756.96	0.078	9107.89
Countermeas. Receiving Set	1	1	42.65	94.02704	70.215876	154.799	2.75951	4768.43	0.0781	873.525

APPENDIX E:
VOLUME-POWER ESTIMATION SPREADSHEET
DTN32

Mission Equipment	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
In the Cabin	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
Terrain Following Radar	1	1	112.95	249.0118	174.20624	384.059	8.55985	14791.4	0.2424	6259.66
MIDS	2	2.5	23.18	51.10309	39.753163	87.6406	0.43405	750.034	0.0123	991.815
Crypto Equipment	42	1	1.42	3.13056	2.9363369	6.47351	0.02804	48.4528	0.0008	5.36698
TADIL SYSTEM	1	2	20	44.0924	34.640316	76.3687	0.41516	717.396	0.0118	350
Operational Consoles	42	1	15	33.0693	26.485855	58.3912	81.7049	141186	2.3136	176.171
SATCOM	2	2.5	8.3	18.29835	15.248275	33.6167	0.27687	478.426	0.0078	532.855
Signal Processors	3	2.5	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Air Data Terminals	15	2.5	22.5	49.60395	38.664033	85.2395	52.972	91535.6	1.5	642.312
Air Data Computer	2	2.5	7.48	16.49056	13.837927	30.5074	0.5	864	0.0142	125.729
RCMP	1	0	3.98	8.774388	7.6808939	16.9335	0.16004	276.55	0.0045	35.8
Radar Synchronizer	3	2.5	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
STALO	1	0	4.79	10.56013	9.1300655	20.1283	0.13737	237.382	0.0039	64.9789
AR	1	0	99.79	219.999	155.1919	342.139	15.961	27582.7	0.452	1975.52
MP	1	0	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
DDP	2	0	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
RDC	1	0	7.07	15.58666	13.128925	28.9443	0.30014	518.641	0.0085	57.8293
Interface Adaptor	2	2.5	1.57	3.461253	3.2247439	7.10933	0.02804	48.4528	0.0008	6.22754
Digital Processor	42	1	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Supermini Computers	5	1	7.48	16.49056	13.837927	30.5074	0.5	864	0.0142	125.729
High-speed Processors	15	2.5	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Printers	5	2.5	8	17.63696	14.733428	32.4816	0.71512	1235.73	0.0203	138.887
SINCGARS	1	1	3.1	6.834322	6.0836093	13.412	0.0517	89.3388	0.0015	10
SCDL Terminal	2	1	20	44.0924	34.640316	76.3687	0.54975	949.965	0.0156	750
JTT with a constant source	1	1	53.4	117.7267	86.599792	190.92	1.11706	1930.27	0.0316	1155.06
Integrated Terminal Group Radios	4	0	3.1	6.834322	6.0836093	13.412	0.04499	77.7503	0.0013	118.144
Track Management Processor	2	0	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Beamformer Processor	1	0	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Search Database Processor	1	0	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323

APPENDIX E:
VOLUME-POWER ESTIMATION SPREADSHEET
DTN32

Mission Equipment	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
In the Cabin	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
ACIDS	1	0	11.34	25.00039	20.402098	44.9789	0.46047	795.685	0.013	135
In-flight Refuel System	1	1	53.15	117.1756	86.221467	190.086	0	0	0	1147.06
JTIDS Terminal	2	0	155	341.7161	234.04552	515.981	5.2972	9153.56	0.15	5597.26
ESM SYSTEM	1	0	100	220.462	155.49659	342.811	563.727	974120	15.963	1000
TADIL DATA TERMINAL	2	2	4.6	10.14125	8.7917214	19.3824	0.01243	21.4823	0.0004	28
TADIL SDLT	1	2	4.6	10.14125	8.7917214	19.3824	0.01243	21.4823	0.0004	15
Common Data Retrivial Sys	1	1	2.52	5.555642	5.0144992	11.0551	0.27531	475.734	0.0078	18
Comms. Emitter Location Sys.	1	1	2.52	5.555642	5.0144992	11.0551	0.27531	475.734	0.0078	18
Background Search sys.	1	1	53.4	117.7267	86.599792	190.92	1.11706	1930.27	0.0316	1155.06
In the Rotodome										
PCE	1	0	100	182.5365	136.48661	300.901	1.65509	2860	0.0469	4850.15
AA(transmitter, IFF\SSR)	1	0	18.762	41.36308	33.632033	74.1459	1.0478	1810.59	0.0297	267.81
MR	1	0	99.79	219.999	155.1919	342.139	15.961	27582.7	0.452	1975.52
SLR Antenna	1	1	29.5	65.03629	49.781136	109.748	15.961	27582.7	0.452	4000
BLINK JAMMER	1	1	9	19.84158	16.44482	36.2546	1.58916	2746.07	0.045	4000
Below Front Cabin										
Rest Area	46				326.58653	720	676.347	1168727	19.152	500
Below Rear Cabin										
HVPS with	1	NA	NA	NA	Totally	NA	NA	NA	Totally	NA
Transmit Electronics	1	NA	NA	NA	1210 kg	NA	NA	NA	25.63	NA
RC	1	NA	NA	NA		NA	NA	NA	m3	NA
APU	1	1	47.62725	105	104.77995	231	95.3496	164764	2.7	0

*AWACS Equip. plus APU occupy 25.63 m3 space in the below rear cabin(according to Boeing 707 data)
*AWACS Equip. in the dome weighs 1210 kg which is 1/3 of total AWACS equipment
Each Terminal 1m*1m*1.5m

APPENDIX E:

VOLUME-POWER ESTIMATION SPREADSHEET

DTN32

Insert Number of crew onboard

OTHER	Crew	Weight		Adjusted Volume			Power
	People	kg	lb	ft3	in3	m3	Watts
Crew	46	3755.75	8280	0	0	0	0
Seats	46	14.515	32	Considered with consoles			0
Galley	46	187.63	413.6534	1059.44	1830712.2	30	4500
Lavatory	46	81.9326	180.6302	794.5801	1373034.2	22.5	1500
	TOTAL	284.078	626.2836	1854.02	3203746.4	52.5	6000

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BUNK BEDS

Note: 0% technology improvement is applied to the estimated volume and power values

Each Crew weighs 180 lb,Each Seat weighs 32 lb

	Total Weight		Total Volume		Total Power
	kg	lb	ft3	m3	Watts
COMMON EQUIPMENT	440.76	971.708	6.575165	0.186188	7869.9099
TOTAL INTERIOR EQUIPMENT	29391	64795.9	11672.85	330.5382	555233.76
ROTODOME EQUIPMENT	66.226	146.003	421.2334	11.928	8000
BELOW FRONT CABIN EQUIPMENT	326.59	719.999	1101.068	31.17878	500
BELOW REAR CABIN EQUIPMENT	104.78	231	95.34961	2.7	0
CLASSIFIED EQUIPMENT	1469.5	3239.8	583.6424	16.52691	27761.688
GRAND TOTAL	31799	70104.4	13880.72	393.0581	599365.36

OVERLOAD

CLASSIFIED EQUIPMENT CONSIDERED AS THE 5% OF THE INTERIOR EQUIPMENT

APPENDIX E:

VOLUME-POWER ESTIMATION SPREADSHEET

DTN41

	Interior	Below Front Cabin	Below Rear Cabin	Bulk Cargo	TOTAL
Max. Volume(m3)	563.4	67.97	61.17	9.77	702.31

Generators assumed 84% efficient

Max. Payload Weight (kg)	52473

	Engine	APU	TOTAL
Max. Power (Watts)	240000	120000	302400
	240000	180000	352800

	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
Common Equipment	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
ILS-VOR	1	1	5.5	12.12541	10.38674	22.8988	0.30734	531.08	0.0087	25
Gyro Compass	1	1	3.81	8.399602	7.3743519	16.2576	0.21	362.88	0.0059	58.5744
Autopilot System	1	1	76	167.5511	120.37047	265.371	1.1336	1958.86	0.0321	1523.95
Radar Altimeter	1	1	2.1	4.629702	4.230108	9.32578	0.08913	154.019	0.0025	52.2895
Range only Radar	1	1	11.34	25.00039	20.402098	44.9789	0.61513	1062.95	0.0174	396.143
Flight Deck Instrument	1	1	115	253.5313	177.1544	390.558	In the Flight Deck			3597.44
Flight Data Recorder	2	1	7.07	15.58666	13.128925	28.9443	0.60028	1037.28	0.017	57.8293
Weather Radar	1	1	45.5	100.3102	74.583969	164.429	3.0194	5217.53	0.0855	2100.86
Mission Equipment	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
In the Cabin	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
Intercom System	2	1.8	13.16	29.0128	23.441565	51.6797	0.53436	923.383	0.0151	266.94
UHF Radio	12	1.5	8.8	19.40066	16.103608	35.5023	0.3882	670.801	0.011	582.728
VHF Radio	3	1.8	3.1	6.834322	6.0836093	13.412	0.04499	77.7503	0.0013	118.144
HF Radio	2	1.8	35.17	77.53649	58.654276	129.31	1.65509	2860	0.0469	4850.15
IFF	1	1	2.962	6.530084	5.8305525	12.8542	0.55	950.4	0.0156	67.8096
TACAN	1	1	20.86525	45.99995	36.036539	79.4469	1.65	2851.2	0.0467	633.047
Embedded GPS\INS	1	1	20.4	44.97425	35.286274	77.7928	0.31193	539.023	0.0088	418.828
Radar Warning&Homing	1	1	92.53284	203.9997	144.63551	318.866	1.40636	2430.19	0.0398	4926.92
ECM Equipment	1	1	2300	5070.626	2898.7645	6390.67	172.124	297430	4.874	258564
Countermeas. Dispensing Set	1	1	53.1	117.0653	86.145788	189.919	2.75287	4756.96	0.078	9107.89
Countermeas. Receiving Set	1	1	42.65	94.02704	70.215876	154.799	2.75951	4768.43	0.0781	873.525

APPENDIX E:

VOLUME-POWER ESTIMATION SPREADSHEET

DTN41

Mission Equipment	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
In the Cabin	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
Terrain Following Radar	1	1	112.95	249.0118	174.20624	384.059	8.55985	14791.4	0.2424	6259.66
MIDS	2	1	23.18	51.10309	39.753163	87.6406	0.43405	750.034	0.0123	991.815
Crypto Equipment	28	1	1.42	3.13056	2.9363369	6.47351	0.02804	48.4528	0.0008	5.36698
TADIL SYSTEM	1	1.2	20	44.0924	34.640316	76.3687	0.41516	717.396	0.0118	350
Operational Consoles	28	1	15	33.0693	26.485855	58.3912	81.7049	141186	2.3136	176.171
SATCOM	2	1.8	8.3	18.29835	15.248275	33.6167	0.27687	478.426	0.0078	532.855
Signal Processors	3	1.8	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Air Data Terminals	15	1.8	22.5	49.60395	38.664033	85.2395	52.972	91535.6	1.5	642.312
Air Data Computer	2	1.8	7.48	16.49056	13.837927	30.5074	0.5	864	0.0142	125.729
RCMP	1	1	3.98	8.774388	7.6808939	16.9335	0.16004	276.55	0.0045	35.8
Radar Synchronizer	3	1.8	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
STALO	1	1	4.79	10.56013	9.1300655	20.1283	0.13737	237.382	0.0039	64.9789
AR	1	1	99.79	219.999	155.1919	342.139	15.961	27582.7	0.452	1975.52
MP	1	1	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
DDP	2	1.2	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
RDC	1	1	7.07	15.58666	13.128925	28.9443	0.30014	518.641	0.0085	57.8293
Interface Adaptor	2	1.8	1.57	3.461253	3.2247439	7.10933	0.02804	48.4528	0.0008	6.22754
Digital Processor	28	1	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Supermini Computers	5	1	7.48	16.49056	13.837927	30.5074	0.5	864	0.0142	125.729
High-speed Processors	15	0	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Printers	5	1.8	8	17.63696	14.733428	32.4816	0.71512	1235.73	0.0203	138.887
SINCGARS	1	0	3.1	6.834322	6.0836093	13.412	0.0517	89.3388	0.0015	10
SCDL Terminal	2	0	20	44.0924	34.640316	76.3687	0.54975	949.965	0.0156	750
JTT with a constant source	1	0	53.4	117.7267	86.599792	190.92	1.11706	1930.27	0.0316	1155.06
Integrated Terminal Group Radios	4	0	3.1	6.834322	6.0836093	13.412	0.04499	77.7503	0.0013	118.144
Track Management Processor	2	0	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Beamformer Processor	1	0	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Search Database Processor	1	0	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323

APPENDIX E:

VOLUME-POWER ESTIMATION SPREADSHEET

DTN41

Mission Equipment	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
In the Cabin	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
ACIDS	1	0	11.34	25.00039	20.402098	44.9789	0.46047	795.685	0.013	135
In-flight Refuel System	1	1	53.15	117.1756	86.221467	190.086	0	0	0	1147.06
JTIDS Terminal	2	0	155	341.7161	234.04552	515.981	5.2972	9153.56	0.15	5597.26
ESM SYSTEM	1	1	100	220.462	155.49659	342.811	563.727	974120	15.963	1000
TADIL DATA TERMINAL	2	1.2	4.6	10.14125	8.7917214	19.3824	0.01243	21.4823	0.0004	28
TADIL SDLT	1	1.2	4.6	10.14125	8.7917214	19.3824	0.01243	21.4823	0.0004	15
Common Data Retrivial Sys	1	0	2.52	5.555642	5.0144992	11.0551	0.27531	475.734	0.0078	18
Comms. Emitter Location Sys.	1	0	2.52	5.555642	5.0144992	11.0551	0.27531	475.734	0.0078	18
Background Search sys.	1	0	53.4	117.7267	86.599792	190.92	1.11706	1930.27	0.0316	1155.06
In the Rotodome										
PCE	1	1	100	182.5365	136.48661	300.901	1.65509	2860	0.0469	4850.15
AA(transmitter, IFF\SSR)	1	1	18.762	41.36308	33.632033	74.1459	1.0478	1810.59	0.0297	267.81
MR	1	1	99.79	219.999	155.1919	342.139	15.961	27582.7	0.452	1975.52
SLR Antenna	1	0	29.5	65.03629	49.781136	109.748	15.961	27582.7	0.452	4000
BLINK JAMMER	1	1	9	19.84158	16.44482	36.2546	1.58916	2746.07	0.045	4000
Below Front Cabin										
Rest Area	32				326.58653	720	676.347	1168727	19.152	500
Below Rear Cabin										
HVPS with	1	NA	NA	NA	Totally 1210 kg	NA	NA	NA	Totally 25.63 m3	NA
Transmit Electronics	1	NA	NA	NA		NA	NA	NA		NA
RC	1	NA	NA	NA		NA	NA	NA		NA
APU	1	1	47.62725	105	104.77995	231	95.3496	164764	2.7	0

*AWACS Equip. plus APU occupy 25.63 m3 space in the below rear cabin(according to Boeing 707 data)

*AWACS Equip. in the dome weighs 1210 kg which is 1/3 of total AWACS equipment

Each Terminal 1m*1m*1.5m

APPENDIX E:
VOLUME-POWER ESTIMATION SPREADSHEET
DTN41

Insert Number of crew onboard

OTHER	Crew	Weight		Adjusted Volume			Power
	People	kg	lb	ft3	in3	m3	Watts
Crew	32	2612.69	5760	0	0	0	0
Seats	32	14.515	32	Considered with consoles			0
Galley	32	124.963	275.4963	706.2934	1220474.8	20	3000
Lavatory	32	50.5636	111.4736	635.6641	1098427.3	18	1200
	TOTAL	190.042	418.9699	1341.957	2318902.1	38	4200

5.5

BUNK BEDS

Note: 0% technology improvement is applied to the estimated volume and power values

Each Crew weighs 180 lb,Each Seat weighs 32 lb

	Total Weight		Total Volume		Total Power
	kg	lb	ft3	m3	Watts
COMMON EQUIPMENT	440.76	971.708	6.575165	0.186188	7869.9099
TOTAL INTERIOR EQUIPMENT	17525	38637	9565.182	270.8558	347198.27
ROTODOME EQUIPMENT	341.76	753.441	486.1027	13.76489	11093.482
BELOW FRONT CABIN EQUIPMENT	326.59	719.999	1101.068	31.17878	500
BELOW REAR CABIN EQUIPMENT	1314.8	2898.59	1000.465	28.33	33280.447
CLASSIFIED EQUIPMENT	876.27	1931.85	478.2591	13.54279	17359.914
GRAND TOTAL	20826	45912.6	12637.65	357.8584	417302.02

OVERLOAD

CLASSIFIED EQUIPMENT CONSIDERED AS THE 5% OF THE INTERIOR EQUIPMENT

APPENDIX E:

VOLUME-POWER ESTIMATION SPREADSHEET

DTN42

	Interior	Below Front Cabin	Below Rear Cabin	Bulk Cargo	TOTAL
Max. Volume(m3)	563.4	67.97	61.17	9.77	702.31

Generators assumed 84% efficient

Max. Payload Weight (kg)	52473			
		Engine	APU	TOTAL
	Max. Power (Watts)	240000	120000	302400
		240000	180000	352800

	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
Common Equipment	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
ILS-VOR	1	1	5.5	12.12541	10.38674	22.8988	0.30734	531.08	0.0087	25
Gyro Compass	1	1	3.81	8.399602	7.3743519	16.2576	0.21	362.88	0.0059	58.5744
Autopilot System	1	1	76	167.5511	120.37047	265.371	1.1336	1958.86	0.0321	1523.95
Radar Altimeter	1	1	2.1	4.629702	4.230108	9.32578	0.08913	154.019	0.0025	52.2895
Range only Radar	1	1	11.34	25.00039	20.402098	44.9789	0.61513	1062.95	0.0174	396.143
Flight Deck Instrument	1	1	115	253.5313	177.1544	390.558	In the Flight Deck			3597.44
Flight Data Recorder	2	1	7.07	15.58666	13.128925	28.9443	0.60028	1037.28	0.017	57.8293
Weather Radar	1	1	45.5	100.3102	74.583969	164.429	3.0194	5217.53	0.0855	2100.86
Mission Equipment	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
In the Cabin	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
Intercom System	2	2.8	13.16	29.0128	23.441565	51.6797	0.53436	923.383	0.0151	266.94
UHF Radio	12	2.5	8.8	19.40066	16.103608	35.5023	0.3882	670.801	0.011	582.728
VHF Radio	3	3	3.1	6.834322	6.0836093	13.412	0.04499	77.7503	0.0013	118.144
HF Radio	2	3	35.17	77.53649	58.654276	129.31	1.65509	2860	0.0469	4850.15
IFF	1	1	2.962	6.530084	5.8305525	12.8542	0.55	950.4	0.0156	67.8096
TACAN	1	1	20.86525	45.99995	36.036539	79.4469	1.65	2851.2	0.0467	633.047
Embedded GPS\INS	1	1	20.4	44.97425	35.286274	77.7928	0.31193	539.023	0.0088	418.828
Radar Warning&Homing	1	2	92.53284	203.9997	144.63551	318.866	1.40636	2430.19	0.0398	4926.92
ECM Equipment	1	0	2300	5070.626	2898.7645	6390.67	172.124	297430	4.874	258564
Countermeas. Dispensing Set	1	0	53.1	117.0653	86.145788	189.919	2.75287	4756.96	0.078	9107.89
Countermeas. Receiving Set	1	0	42.65	94.02704	70.215876	154.799	2.75951	4768.43	0.0781	873.525

APPENDIX E:
VOLUME-POWER ESTIMATION SPREADSHEET
DTN42

Mission Equipment	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
In the Cabin	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
Terrain Following Radar	1	2	112.95	249.0118	174.20624	384.059	8.55985	14791.4	0.2424	6259.66
MIDS	2	2.5	23.18	51.10309	39.753163	87.6406	0.43405	750.034	0.0123	991.815
Crypto Equipment	52	1	1.42	3.13056	2.9363369	6.47351	0.02804	48.4528	0.0008	5.36698
TADIL SYSTEM	1	2.2	20	44.0924	34.640316	76.3687	0.41516	717.396	0.0118	350
Operational Consoles	52	1	15	33.0693	26.485855	58.3912	81.7049	141186	2.3136	176.171
SATCOM	2	2.5	8.3	18.29835	15.248275	33.6167	0.27687	478.426	0.0078	532.855
Signal Processors	3	2.5	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Air Data Terminals	15	2	22.5	49.60395	38.664033	85.2395	52.972	91535.6	1.5	642.312
Air Data Computer	2	2.5	7.48	16.49056	13.837927	30.5074	0.5	864	0.0142	125.729
RCMP	1	0	3.98	8.774388	7.6808939	16.9335	0.16004	276.55	0.0045	35.8
Radar Synchronizer	3	2	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
STALO	1	0	4.79	10.56013	9.1300655	20.1283	0.13737	237.382	0.0039	64.9789
AR	1	0	99.79	219.999	155.1919	342.139	15.961	27582.7	0.452	1975.52
MP	1	0	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
DDP	2	0	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
RDC	1	0	7.07	15.58666	13.128925	28.9443	0.30014	518.641	0.0085	57.8293
Interface Adaptor	2	2	1.57	3.461253	3.2247439	7.10933	0.02804	48.4528	0.0008	6.22754
Digital Processor	52	1	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Supermini Computers	5	1	7.48	16.49056	13.837927	30.5074	0.5	864	0.0142	125.729
High-speed Processors	15	1.5	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Printers	5	2	8	17.63696	14.733428	32.4816	0.71512	1235.73	0.0203	138.887
SINCGARS	1	1	3.1	6.834322	6.0836093	13.412	0.0517	89.3388	0.0015	10
SCDL Terminal	2	1	20	44.0924	34.640316	76.3687	0.54975	949.965	0.0156	750
JTT with a constant source	1	1	53.4	117.7267	86.599792	190.92	1.11706	1930.27	0.0316	1155.06
Integrated Terminal Group Radios	4	1	3.1	6.834322	6.0836093	13.412	0.04499	77.7503	0.0013	118.144
Track Management Processor	2	1	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Beamformer Processor	1	1	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323
Search Database Processor	1	1	109	240.3036	168.51547	371.513	8.66808	14978.4	0.2455	3323

APPENDIX E:

VOLUME-POWER ESTIMATION SPREADSHEET

DTN42

Mission Equipment	Quantity	Constant	Uninstalled Weight		Installed Weight		Adjusted Volume			Power
In the Cabin	piece	c	kg	lb	kg	lb	ft3	in3	m3	Watts
ACIDS	1	1	11.34	25.00039	20.402098	44.9789	0.46047	795.685	0.013	135
In-flight Refuel System	1	1	53.15	117.1756	86.221467	190.086	0	0	0	1147.06
JTIDS Terminal	2	0	155	341.7161	234.04552	515.981	5.2972	9153.56	0.15	5597.26
ESM SYSTEM	1	0	100	220.462	155.49659	342.811	563.727	974120	15.963	1000
TADIL DATA TERMINAL	2	2.2	4.6	10.14125	8.7917214	19.3824	0.01243	21.4823	0.0004	28
TADIL SDLT	1	2.2	4.6	10.14125	8.7917214	19.3824	0.01243	21.4823	0.0004	15
Common Data Retrivial Sys	1	1	2.52	5.555642	5.0144992	11.0551	0.27531	475.734	0.0078	18
Comms. Emitter Location Sys.	1	1	2.52	5.555642	5.0144992	11.0551	0.27531	475.734	0.0078	18
Background Search sys.	1	1	53.4	117.7267	86.599792	190.92	1.11706	1930.27	0.0316	1155.06
In the Rotodome										
PCE	1	0	100	182.5365	136.48661	300.901	1.65509	2860	0.0469	4850.15
AA(transmitter, IFF\SSR)	1	0	18.762	41.36308	33.632033	74.1459	1.0478	1810.59	0.0297	267.81
MR	1	0	99.79	219.999	155.1919	342.139	15.961	27582.7	0.452	1975.52
SLR Antenna	1	1	29.5	65.03629	49.781136	109.748	15.961	27582.7	0.452	4000
BLINK JAMMER	1	0	9	19.84158	16.44482	36.2546	1.58916	2746.07	0.045	4000
Below Front Cabin										
Rest Area	56				326.58653	720	676.347	1168727	19.152	500
Below Rear Cabin										
HVPS with	1	NA	NA	NA	Totally	NA	NA	NA	Totally	NA
Transmit Electronics	1	NA	NA	NA	1210 kg	NA	NA	NA	25.63	NA
RC	1	NA	NA	NA		NA	NA	NA	m3	NA
APU	1	1	47.62725	105	104.77995	231	95.3496	164764	2.7	0

*AWACS Equip. plus APU occupy 25.63 m3 space in the below rear cabin(according to Boeing 707 data)

*AWACS Equip. in the dome weighs 1210 kg which is 1/3 of total AWACS equipment

Each Terminal 1m*1m*1.5m

APPENDIX E:
VOLUME-POWER ESTIMATION SPREADSHEET
DTN42

Insert Number of crew onboard

OTHER	Crew	Weight		Adjusted Volume			Power
	People	kg	lb	ft3	in3	m3	Watts
Crew	56	4572.21	10080	0	0	0	0
Seats	56	14.515	32	Considered with consoles			0
Galley	56	233.875	515.6066	1059.44	1830712.2	30	4500
Lavatory	56	106.434	234.6457	953.4961	1647641	27	1800
	TOTAL	354.824	782.2522	2012.936	3478353.2	57	6300

9.5

BUNK BEDS

Note: 0% technology improvement is applied to the estimated volume and power values

Each Crew weighs 180 lb,Each Seat weighs 32 lb

	Total Weight		Total Volume		Total Power
	kg	lb	ft3	m3	Watts
COMMON EQUIPMENT	440.76	971.708	6.575165	0.186188	7869.9099
TOTAL INTERIOR EQUIPMENT	27079	59697.9	12058.39	341.4555	420632.11
ROTODOME EQUIPMENT	49.781	109.748	383.0935	10.848	4000
BELOW FRONT CABIN EQUIPMENT	326.59	719.999	1101.068	31.17878	500
BELOW REAR CABIN EQUIPMENT	104.78	231	95.34961	2.7	0
CLASSIFIED EQUIPMENT	1353.9	2984.9	602.9194	17.07277	21031.606
GRAND TOTAL	29354	64715.3	14247.39	403.4412	454033.63

OVERLOAD

CLASSIFIED EQUIPMENT CONSIDERED AS THE 5% OF THE INTERIOR EQUIPMENT

APPENDIX F:
LCC ESTIMATION SPREADSHEET

DECISION TABLE

	PAYLOAD DESIGN VSD			
Weight	2	5	3	10
Importance	0.2	0.5	0.3	1

Alternative	LCC	A\C SPECS	RISK	Overall Grade
OTN	0.594736617	0.16227972	0.66	0.398087183
DTN1	0.712964919	0.556799298	0.87	0.681992633

DTN1 IS THE BEST
ALTERNATIVE

APPENDIX F:
LCC ESTIMATION SPREADSHEET

Weight	5	5	5	5	20
Importance	0.25	0.25	0.25	0.25	1
		LCC			
Alternative	RDT&E and Flyaway (	O&M COST	GROUND EQPT	SPEC. CONST.	Overall Grade
OTN	0.51	0.373091934	0.5000	1	0.594736617
DTN1	0.63	0.73	0.5000	1	0.712964919

	RDT&E and FLYAWAY COSTS			
Alternative	Airframe	Engine	Avionics	Grade
OTN	0.61	0.55	0.36	0.51
DTN11	0.39	0.45	0.64	0.49
DTN12	0.71	0.74	0.83	0.76

	O&M COST						
Alternative	Fuel/Oil	Crew	Ground Pers.	Maintenance	Indirect Costs	Training	Grade
OTN	0.389	0.386	0.386	0.347	0.347	0.386	0.37
DTN11	0.611	0.614	0.614	0.653	0.653	0.614	0.63
DTN12	0.823	0.812	0.812	0.842	0.842	0.812	0.82

COST ESTIMATION

Service Life(Years) 25

Note: All costs are base on the Net Present Value (NPV)

Interest Rate= 5.00%

1lb= 6.7Gal

Technology factor assumed 1.75 for corrected total cost

	TOTAL COST	TOTAL COST CORRECTED
OTN	$60,992,711,733.54	$106,737,245,533.69
DTN1	$49,856,406,614.06	$87,248,711,574.60

APPENDIX F:

LCC ESTIMATION SPREADSHEET

	OTN				
RDT&E and Flyaway	Wempty(kg)	Q(piece)	V(km\hr)	FTA	Wavionics(kg)
$43,212,862,651.07	97212	55	850	1	40905
Airframe Cost	He	Hm	Hq	Ht	Ncrew(persons)
$13,510,366,148.76	45168218.28	63853562.47	4852870.748	24730824.99	61
Engine Cost	Re	Rm	Rq	Rt	MMH/YR
$2,705,196,502.31	104.53	88.73	98.46	106.96	66000
Avionics Cost	Cd	Cf	Cm	Ceng	Cavionics
$26,997,300,000.00	434547332.1	15051991.77	1437200596	7439968.927	26997300000
	Tinlet(K)	Tmax(kN)	Mmax	Neng	MMH/FH
	1500	282.4621	0.8	110	30
	Wfuel (kg/HR)	Wfuel (lb/HR)	Vfuel (Gal)	FH\YR\AC	Crew Ratio
	6113.583333	13478.14323	2011.663168	2200	2.5

O&M Cost(PV)
$16,707,349,082.47
O&M Cost(Annual)
$1,185,427,472.36
Fuel/Oil
$194,728,994.67
Crew
$118,944,836.96
Ground Pers.
$223,021,569.30
Maintenance
$306,752,285.71
Indirect(material etc.)
$306,752,285.71
Training
$35,227,500.00

Ground Equipment& Initial Spares Cost(PV)	
$1,072,500,000.00	15% of purchase price

Special Constr. Cost
None

APPENDIX F:

LCC ESTIMATION SPREADSHEET

	DTN11				
RDT&E and Flyaway	Wempty(kg)	Q(piece)	V(km\hr)	FTA	Wavionics(kg)
$20,344,475,161.17	97212	30	850	1	21846
Airframe Cost	He	Hm	Hq	Ht	Ncrew(persons)
$10,698,419,910.13	40918961.75	43295959.87	3290492.95	21086578	36
Engine Cost	Re	Rm	Rq	Rt	MMH/YR
$1,781,495,251.04	104.53	88.73	98.46	106.96	35000
Avionics Cost	Cd	Cf	Cm	Ceng	Cavionics
$7,864,560,000.00	434547332.1	15051991.77	885497791.5	7439968.927	7864560000
	Tinlet(K)	Tmax(kN)	Mmax	Neng	MMH/FH
	1500	282.4621	0.8	60	25
	Wfuel (kg/HR)	Wfuel (lb/HR)	Vfuel (Gal)	FH\YR\AC	Crew Ratio
	6113.583333	13478.14323	2011.663168	1400	2.5

O&M Cost(PV)
$5,165,056,739.68
O&M Cost(Annual)
$366,473,467.77
Fuel/Oil
$67,591,882.45
Crew
$38,289,247.07
Ground Pers.
$71,792,338.26
Maintenance
$88,730,000.00
Indirect(material etc.)
$88,730,000.00
Training
$11,340,000.00

Ground Equipment& Initial Spares Cost(PV)	
$585,000,000.00	15% of purchase price

Special Constr. Cost
None

APPENDIX F:

LCC ESTIMATION SPREADSHEET

	DTN12				
RDT&E and Flyaway	Wempty(kg)	Q(piece)	V(km\hr)	FTA	Wavionics(kg)
$18,772,092,581.44	97212	25	850	1	23923
Airframe Cost	He	Hm	Hq	Ht	Ncrew(persons)
$10,008,136,281.65	39720806.93	38520524.66	2927559.874	20099323.44	41
Engine Cost	Re	Rm	Rq	Rt	MMH/YR
$1,587,056,299.79	104.53	88.73	98.46	106.96	35000
Avionics Cost	Cd	Cf	Cm	Ceng	Cavionics
$7,176,900,000.00	434547332.1	15051991.77	765458529.6	7439968.927	7176900000
	Tinlet(K)	Tmax(kN)	Mmax	Neng	MMH/FH
	1500	282.4621	0.8	50	25
	Wfuel (kg/HR)	Wfuel (lb/HR)	Vfuel (Gal)	FH\YR\AC	Crew Ratio
	6113.583333	13478.14323	2011.663168	1400	2.5

O&M Cost(PV)
$4,502,282,131.76
O&M Cost(Annual)
$319,447,980.70
Fuel/Oil
$56,326,568.70
Crew
$36,339,331.71
Ground Pers.
$68,136,246.96
Maintenance
$73,941,666.67
Indirect(material etc.)
$73,941,666.67
Training
$10,762,500.00

Ground Equipment& Initial Spares Cost(PV)	
$487,500,000.00	15% of purchase price

Special Constr. Cost
None

APPENDIX G:

WEIGHT vs. ENDURANCE TRADE

Takeoff from Sea Level

	Wpayload	Wfuel	Wo	Range				Endurance		Total Number of In-flight Refueling
				After Takeoff		After First Refuel		After Takeoff	After First Refuel	
	kg	kg	kg	nmi	km	nmi	km	hr	hr	times
OTN	40905	40233	178350	2600	4815.2	4250	7871	5.66494118	9.26	2
DTN11	21,846	59,292	178350	4,550	8426.6	5550	10279	9.91364706	12.09294118	2
DTN12	23923.15	57,215	178350	4,300	7963.6	5420	10038	9.36894118	11.80941176	2
DTN21	15286.54	65,851	178350	5200	9630.4	5750	10649	11.3298824	12.52823529	2
DTN22	31672.81	49,465	178350	3500	6482	5300	9816	7.62588235	11.54823529	2
DTN31	24973.51	56,164	178350	4200	7778.4	5470	10130	9.15105882	11.91764706	2
DTN32	31798.87	49,339	178350	3400	6296.8	5150	9538	7.408	11.22117647	2
DTN41	20825.61	60,312	178350	4650	8611.8	5700	10556	10.1315294	12.41882353	2
DTN42	29354.38	51,784	178350	3750	6945	5350	9908	8.17058824	11.65647059	2

Takeoff from 2000 feet

	Wpayload	Wfuel	Wo	Range				Endurance		Total Number of In-flight Refueling
				After Takeoff		After First Refuel		After Takeoff	After First Refuel	
	kg	kg	kg	nmi	km	nmi	km	hr	hr	times
OTN	40905	31533	169650	1800	3333.6	4250	7871	3.92188235	9.26	3
DTN11	21,846	50,592	169650	3,800	7037.6	5,550	10278.6	8.27952941	12.09247059	2
DTN12	23923.15	48,515	169650	3550	6574.6	5,420	10037.8	7.73482353	11.80922353	2
DTN21	15286.54	57,151	169650	4,500	8334	5750	10649	9.80470588	12.52823529	2
DTN22	31672.81	40,765	169650	2700	5000.4	5300	9815.6	5.88282353	11.54776471	2
DTN31	24973.51	47,464	169650	3,450	6389.4	5470	10130.4	7.51694118	11.91816471	2
DTN32	31798.87	40,639	169650	2600	4815.2	5150	9537.8	5.66494118	11.22094118	2
DTN41	20825.61	51,612	169650	3,900	7222.8	5700	10556.4	8.49741176	12.41929412	2
DTN42	29354.38	43,084	169650	3050	5648.6	5350	9908.2	6.64541176	11.65670588	2

APPENDIX G:

WEIGHT vs. ENDURANCE TRADE

Takeoff from 4000 feet

	Wpayload	Wfuel	Wo	Range				Endurance		Total Number of In-flight Refueling
				After Takeoff		After First Refuel		After Takeoff	After First Refuel	
	kg	kg	kg	nmi	km	nmi	km	hr	hr	times
OTN	40905	22833	160950	950	1759.4	4250	7871	2.06988235	9.26	3
DTN11	21,846	41,892	160950	2,900	5370.8	5550	10279	6.31858824	12.09294118	2
DTN12	23923.15	39,815	160950	2,750	5093	5420	10038	5.99176471	11.80941176	2
DTN21	15286.54	48,451	160950	3750	6945	5750	10649	8.17058824	12.52823529	2
DTN22	31672.81	32,065	160950	1900	3518.8	5300	9816	4.13976471	11.54823529	2
DTN31	24973.51	38,764	160950	2600	4815.2	5470	10130	5.66494118	11.91764706	2
DTN32	31798.87	31,939	160950	1800	3333.6	5150	9538	3.92188235	11.22117647	2
DTN41	20825.61	42,912	160950	3000	5556	5700	10556	6.53647059	12.41882353	2
DTN42	29354.38	34,384	160950	2200	4074.4	5350	9908	4.79341176	11.65647059	2

Takeoff from 6000 feet

	Wpayload	Wfuel	Wo	Range				Endurance		Total Number of In-flight Refueling
				After Takeoff		After First Refuel		After Takeoff	After First Refuel	
	kg	kg	kg	nmi	km	nmi	km	hr	hr	times
OTN	40905	14133	152250	250	**463**	4250	7871	**0.54470588**	9.26	3
DTN11	21,846	33,192	152250	2,200	4074.4	5550	10279	4.79341176	12.09294118	2
DTN12	23923.15	31,115	152250	2,000	3704	5420	10038	4.35764706	11.80941176	2
DTN21	15286.54	39,751	152250	3100	5741.2	5750	10649	6.75435294	12.52823529	2
DTN22	31672.81	23,365	152250	1200	2222.4	5300	9816	2.61458824	11.54823529	2
DTN31	24973.51	30,064	152250	1900	3518.8	5470	10130	4.13976471	11.91764706	2
DTN32	31798.87	23,239	152250	1150	2129.8	5150	9538	2.50564706	11.22117647	2
DTN41	20825.61	34,212	152250	2300	4259.6	5700	10556	5.01129412	12.41882353	2
DTN42	29354.38	25,684	152250	1500	2778	5350	9908	3.26823529	11.65647059	2

APPENDIX G:

WEIGHT vs. ENDURANCE TRADE

Takeoff from 8000 feet

	Wpayload	Wfuel	Wo	Range				Endurance		Total Number of
				After Takeoff		After First Refuel		After Takeoff	After First Refuel	In-flight Refueling
	kg	kg	kg	nmi	km	nmi	km	hr	hr	times
OTN	40905	4563	142680	**0**	**0**	4250	7871	**0**	9.26	3
DTN11	21,846	23,622	142680	1,200	2222.4	5550	10279	2.61458824	12.09294118	2
DTN12	23923.15	21,545	142680	1,000	1852	5420	10038	2.17882353	11.80941176	2
DTN21	15286.54	30,181	142680	2150	3981.8	5750	10649	4.68447059	12.52823529	2
DTN22	31672.81	13,795	142680	**300**	555.6	5300	9816	**0.65364706**	11.54823529	3
DTN31	24973.51	20,494	142680	850	1574.2	5470	10130	1.852	11.91764706	2
DTN32	31798.87	13,669	142680	**200**	370.4	5150	9538	**0.43576471**	11.22117647	3
DTN41	20825.61	24,642	142680	1400	2592.8	5700	10556	3.05035294	12.41882353	2
DTN42	29354.38	16,114	142680	650	1203.8	5350	9908	1.41623529	11.65647059	2

APPENDIX H:

LIST OF ASSUMPTIONS

Assumptions made in this thesis can be grouped under four titles:

1. Weight and Volume Assumptions:

- Three-class arrangement with 243 passenger seats is assumed in order to figure out the furnishing to be discarded from the commercial version of 767-400ER.
- K_{lav} = 1.11, K_{buf}= 5.68, P_c = 6.7 and maximum flight altitude = 50000 ft.
- Flight crew, cabin crew, and passenger seats are considered as 55 lb, 15 lb and 32 lb respectively.
- Installed APU weight is 2.22 times greater than uninstalled APU.
- AWACS equipment plus APU occupy 25.63-m3 space in the lower rear cabin.
- AWACS equipment in the dome weighs 1210 kg that is 1/3 of total AWACS equipment.
- Each crewmember weighs 180lb.
- 1 bed for each 3 crew will be located inside the front cargo cabin. Dimension of a bunk bed is 1m x 1.68m x 1.9m. There is a 44 cm walkway between two sets of beds. Power needed for illuminating the rest are is 500W.
- Classified equipment is 5% of the total interior equipment.
- Dimension of an operational console is 2.53m x 2.32m x 1.32m.
- There is a 60 cm walkway between the corridors and processors.

2. Airframe Assumptions:

- Boeing 767-400ER is the aircraft selected for the MMA platform.
- General Electric CF6-80C2B8F maximum model engine is mounted on the aircraft.
- APU is assumed as a main power supply along with other two engine driven generators.
- Power efficiency of an electric generator is 84%.
- The engine by-pass ratio is 5.05.
- JP-8 fuel is used for propulsion.
- MMA's cruise and loitering speeds are both 850 km/hr.
- MMA's Lift to Drag ratio is 17.
- Cabin length of the 767-400ER is 43.80m.
- All of the MMAs are in-flight capable.

3. Cost Assumptions:

- Wrap rates for engineering, tooling, quality control and manufacturing are $104.53, $106.96, $98.46, and $88.73 respectively.
- Cost estimations are in NPV of FY 2003 with an interest rate of 5% per year.
- Avionics cost is $12 per gram.
- Initial Spares will add 15% to an aircraft's purchase price.
- Purchase price of one Boeing 767-400ER is $130,000,000.
- Interior accommodation cost is $3000 per passenger.

- Some LCC parameter approximations are listed in Table 3-12.
- The average salary per crewmember is $48000 per year or $4000 per month.
- Maintenance wrap rate is equal to manufacturing wrap rate.
- Technology factor applied to Total Corrected Cost is 1.75.
- A total number of 55 MMA will be produced.

4. Others:

- Total power consumption value of any MMA architecture has been estimated assuming that all of the equipment is running concurrently.
- The generated VSD consists of LCC, A/C Specifications and Risk. Their importance factors are 0.2, 0.50 and 0.30 respectively.
- All MMA alternatives will take off from an air force base stationed at sea level and having a runway length of 8000 feet.
- Electromagnetic interference between the installed avionics is ignored.
- MIDS improvement has been utilized.
- Other assumptions made in the estimations can be obtained by clicking on the related cells of the spreadsheet available in Appendix E.

APPENDIX I:

MEMORANDUM OF THESIS TOPIC PROPOSAL

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

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VITA

1st Lieutenant Ahmet Kahraman was born in Manisa. He graduated from Kuleli Military High School in 1993 and entered undergraduate studies at the Turkish Air Force Academy in Istanbul, Turkey. He graduated with a Military of Science degree in Industrial Engineering in August 1997. Upon graduation, he was commissioned as a 2nd Lieutenant in Turkish Air Force.

His first assignment was at 2nd Main Jet Base, Izmir Turkey as a student in Undergraduate Pilot Training in August 1997. His second assignment was at Technical Training Base as a student in Supply Training School, Izmir Turkey. He was assigned to the 6th Main Jet Base, Bandirma Turkey where he served as a Supply officer. In August 2001, he began his studies in Systems Engineering at the Air Force Institute of Technology.

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14. ABSTRACT

It is proposed that a Multi-Mission Aircraft (MMA) be prepared to combine some or all the functions of the aging AWACS, JSTARS, RIVET JOINT, COMPASS CALL, and ABCCC fleet. Three different thesis studies have been developed by three Air Force Institute of Technology GSE students to show the feasibility of replacing the current aging fleet with one or more MMA platforms. This is the thesis in which the *payload issues* have been examined. Within this thesis, two different alternative architectures, which are One Tail Number and Different Tail Numbers including nine different configurations, have been considered. Estimated payload characteristics of these alternatives have been compared to those of Boeing 767-400ER, which is the aircraft selected as the baseline for MMA platform. Reduced life cycle cost, increased measure of aircraft specifications, and minimum risk are the main objectives pursued by means of several systems engineering and aircraft design methodologies.

15. SUBJECT TERMS

Aircraft Design, Preliminary Design, Hall's Methodology, HHP Methods, Optimization

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