5-2004

Use of Commercial Off the Shelf GPS Technology to Solve Guidance Problems with the Improved Tactical Air Launched Decoy (ITALD)

Scott Kenneth Toppel
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Scott Kenneth Toppel entitled "Use of Commercial Off the Shelf GPS Technology to Solve Guidance Problems with the Improved Tactical Air Launched Decoy (ITALD)." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Aviation Systems.

Ralph D. Kimberlin, Major Professor

We have read this thesis and recommend its acceptance:

Charles TN Paludan, Richard Ranaudo

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council

I am submitting herewith a thesis written by Scott Kenneth Toppel entitled "Use of Commercial Off the Shelf GPS Technology to Solve Guidance Problems with the Improved Tactical Air Launched Decoy (ITALD)." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Aviation Systems.

Ralph D. Kimberlin
Major Professor

We have read this thesis
and recommend its acceptance:

Charles TN Paludan

Richard Ranaudo

Acceptance for the Council:

Anne Mayhew
Vice Chancellor and Dean of
Graduate Studies

(Original signatures are on file with official student records.)

USE OF COMMERCIAL OFF THE SHELF GPS TECHNOLOGY TO SOLVE GUIDANCE PROBLEMS WITH THE IMPROVED TACTICAL AIR LAUNCHED DECOY (ITALD)

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Scott Kenneth Toppel

May 2004

DEDICATION

This thesis is dedicated to my daughter Ella Grace Toppel, God's ultimate gift, my wife Jennifer Toppel and my parents Harold and Carol Toppel whose steadfast support has allowed me to succeed, and to my brothers and sisters serving in the United States Armed Forces who stand the watch to guarantee our freedom.

ACKNOWLEDGEMENTS

I would like to express my sincere appreciation to my replacement as ITALD Project Officer, LCDR Cassidy Norman, whose help made this thesis possible. Mr Eran Shani of Israeli Military Industries who provided the engineering and design insight to resolve the ITALD's navigation problems. CAPT Mark Bathrick, Steve Terando, Yosup Choi, and Bradley Hudson who never let political or fiscal pressure allow a substandard product to end up in the hands of the fleet. I would especially like to thank Ms Betsy Harbin of the University of Tennessee Space Institute whose support has allowed me to finish the program despite two wars and three moves across the country. I would like to thank Dr. Ralph Kimberlin for guiding me through the thesis process. Finally, I thank Dr Charles TN Paludan and Mr Richard Ranaudo for serving on my committee.

ABSTRACT

As the capabilities of threat surface-to-air missile systems increased, the US Navy looked to improve upon the performance of the Tactical Air Launched Decoy (TALD), an air launched glider vehicle with switchblade wings designed to resemble attacking aircraft to confuse and saturate enemy air defenses. In the early 1990's the contractor proposed the Improved Tactical Air Launched Decoy (ITALD), a turbo jet powered air-launched vehicle which tripled the existing range and added a radar altimeter to simulate low level attacks.

In 1998, after several design iterations, the Naval Air Warfare Center at Point Mugu tested the ITALD for suitability in the defense suppression mission and found major deficiencies with the navigation system and product reliability. The contractor resolved the reliability issues; however the navigation system, a simple dead reckoning 2-axis gyro and flight computer, needed improvement. The ITALD navigation system drifted excessively causing the decoy to drift off course and out of field of regard of the intended surface-to-air missile systems.

Incorporating a commercial of the shelf (COTS) global positioning system (GPS) proved to be an effective, expeditious and inexpensive solution to the vehicle's navigational problems. In 2001, the new ITALD-GPS was tested during five flights with mostly satisfactory results.

The opinions, analysis and conclusions expressed in this thesis are those of the author and have not been officially endorsed by the Department of the Navy, Naval Air Systems Command, or Israeli Military Industries, LTD.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

Abbreviations

AGL	Above Ground Level
AMAC	Aircraft Monitor and Control
ARDS	Advanced Range Data System
BD	Brunswick Defense
BRU	Bomb Rack Unit
C.G.	Center of Gravity
CADs	Cartridge Activated Devices
CL	China Lake
COTS	Commercial Off The Self
DT	Development Test
EATS	Extended Area Test System
ECP	Engineering Change Proposal
EMC	Electromagnetic Compatibility
ET	Engineering Test
FAFT	First Article Flight Test
FCA	Flight Computer Assembly
FCP	Flight Control Processor
ft	feet
FTE	Flight Test Engineer
FTS	Flight Termination System
FM	Frequency Modulation
GFE	Government Furnished Equipment
GHz	Giga Hertz
GMT	Greenwich Mean Time
GPS	Global Positioning System
HUD	Heads-Up-Display
HERO	Hazards of Electromagnetic Radiation to Ordnance

IDTP	Improved Decoy Tester Programmer
IMI	Israel Military Industries
ITALD	Improved Tactical Air Launched Decoy
ITER	Improved Triple Ejection Rack
ITL	Intent To Launch
IST	Integrated System Tester
k	Thousands
KCAS	Knots Calibrated Air Speed
KEAS	Knots Equivalent Air Speed
kts	Knots
lbs	Pounds
M	Mach
MHz	Megahertz
MFSO	Missile Flight Safety Officer
MSL	Mean Sea Level
NATOPS	Naval Air Training and Operating Procedures Standardization
NAVAIR	Naval Air (Program Headquarters)
NAWC	Naval Air Warfare Center
NAWCWD PM	Naval Air Warfare Center - Weapons Division, Point Mugu, CA
nm / nmi	Nautical Mile
NP	Navigation Processor
NWTS	Naval Weapons Test Squadron
OPNAV	Office of the Chief Of Naval Operations
ORD	Operational Requirements Document
OTS	Over The Shoulder
PCM	Pulse Code Modulation
PM	Point Mugu
PR	Patuxent River
RADALT	Radar Altimeter
RAM	Random Access Memory

RF	Radio Frequency
RPM	Revolutions Per Minute
SAM	Surface-to-air Missile
s	s
SOF	Safety of Flight
STR	Sea Test Range
TACMAN	Tactical Manual
TALD	Tactical Air Launched Decoy
TEMP	Test and Evaluation Master Plan
TER	Triple Ejection Rack
TM	Telemetry
TSPI	Time, Space, and Position Information
UHF	Ultra-High Frequency
VDC	Volts Direct Current
VMC	Visual Meteorological Conditions
Wypt	Waypoint

Glossary

Chaff Decoy consisting of small metal fragments cut to produce a reflection when exposed to RADAR energy.

Ephemeris A set of parameters, broadcast by the satellite that describes its orbit very accurately for use by the receiver to compute satellite position.

CHAPTER I

INTRODUCTION AND BACKGROUND

Background

The need for decoys dates thousands of years ago when the North American Native Americans fashioned floating decoys out of cattail leaves, bulrush and tule reeds. These were used to lure waterfowl into areas where they could be hunted by bow and arrow or spear or snared using nets [1]. Figure 1-1 shows some examples of typical duck decoys. These decoys were not only effective in luring waterfowl, but could be used to attract other animals into a snare as shown in Figure 1-2.

This tradition has progressed to modern aerial strike warfare with the invention of the air launched decoys to counter the threat of surface-to-air missile systems. Over the past forty years the US Air Force and US Navy have pursued programs to minimize the vulnerability of strike aircraft to these systems. The purpose of the decoy is to confuse and saturate enemy air defense systems by providing a realistic simulation of a strike aircraft to the system operator, thereby masking the ingress of the strike package.

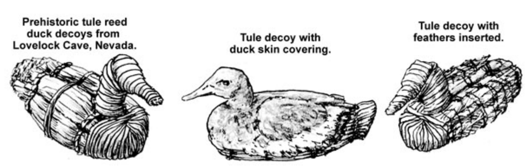


Figure 1-1: Ancient Duck Decoys

Source: Prindle, Tara. *NativeTech History and Background of Duck Decoys.* Native American Technology and Art; 2000. (www.nativetech.org/decoy/DUCKDECOYS.htm)

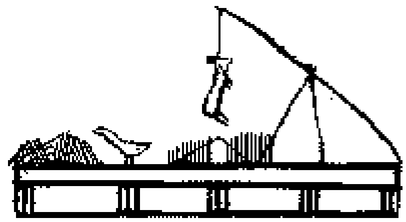


Figure 1-2: Decoy Lures Rabbit into Snare

Source: Prindle, Tara. *NativeTech History and Background of Duck Decoys*. Native American Technology and Art; 2000. (www.nativetech.org/decoy/DUCKDECOYS.htm)

In the 1960's the Brunswick Defense Corporation of Costa Mesa, CA had developed the "Model 150", a non powered glide air launched decoy weighed approximately 130 pounds with pop-out "switchblade" wings. Two of them could be carried on a single under-wing stores pylon of an attacking aircraft. The Model 150 evolved into the Model 300, which weighed approximately 400 pounds and could glide for approximately 68 nm at 250 kts [2].

During the Yom Kippur War of 1973, the Israeli Air Force lost far too many aircraft to Arab air defense systems and decided to purchase air launched decoys to enhance their survivability. Brunswick sold them the Sampson decoy, shown below in Figure 1-3, which was a version of the Model 300 [2]. Incorporated into their tactical arsenal, the Israeli Air Force used Sampson against the Syrian air defense forces over the Bekaa Valley during their conflict with Lebanon in 1982 with outstanding results. Not one aircraft was lost to surface-to-air missile systems.

Figure 1-3: Sampson Air Launched Decoy

Source: URL: www.israeli-weapons.com/weapons/missile_systems/
air_missiles/itald/TALD

The US Navy, however, was not as fortunate during the US intervention in Lebanon following the 1983 terrorist bombing of the marine barracks. Three A-6 Intruder attack aircraft were shot down by Syrian surface-to-air missile systems. The US Navy decided to follow the Israeli example and contracted the Brunswick Corporation to produce the ADM-141A Tactical Air Launched Decoy (TALD). The TALD, Figure 1-4, an improved version of the Sampson, entered service in 1987 and weighed 397 to 450 lbs depending on the payload [3].

Both Brunswick and Israeli Military Industries had concurrent license to produce two versions of the TALD, RF and chaff. The RF payload could actively simulate the electronic emissions of a modern strike aircraft and/or passively reflect RADAR energy to enhance the radar cross section to the surface-to-air missile system operator. The chaff option allows the decoy to dispense chaff, small metal fragments designed to reflect radar energy back toward its source.

The F/A-18 Hornet is the primary US Navy tactical aircraft for employing TALD using the ITERs (Improved Triple Ejector Racks) or MERs (Multiple Ejector Racks). One Hornet can carry up to 20 decoys. Figure 1-5 shows a TALD being dropped from an F/A-18 Hornet during flight testing. During the 1991 Persian Gulf War, the US Navy expended over 100 TALD to confuse and saturate Iraqi air defenses with great success.

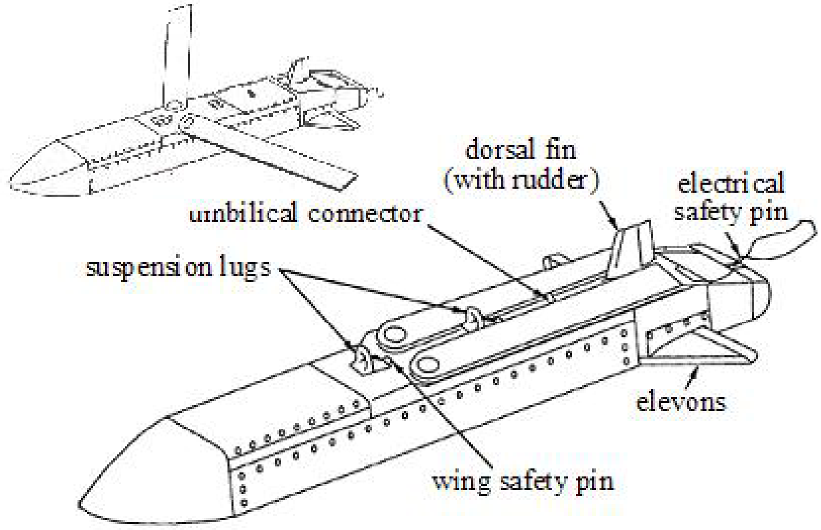


Figure 1-4: ADM-141A: Tactical Air Launched Decoy (TALD)

Source: Norman, Cassidy LCDR. *Low Cost Modification of the TALD*. Point Mugu, CA. Naval Air Warfare Center, Point Mugu. March 2002

Figure 1-5: F/A-18 Hornet Dropping TALD

Source: *ADM-141A Tactical Air-Launched Decoy (TALD), ADM-141C Improved TALD (ITALD)*. Washington DC: Federation of American Scientists Military Analysis Network, 1999.
URL: http://www.fas.org/man/dod-101/sys/ac/equip/tald.htm

The Iraqi military wasted many of their surface-to-air missiles and no US aircraft were lost due to SAMs [2].

In the early 1990s, Brunswick began development of the Improved Tactical Air Launched Decoy (ITALD) or ADM-141C, which was powered by a Teledyne CAE Model 312 turbojet engine. The ITALD was created in response to the increased range and fidelity of modern surface-to-air missile systems. A Teledyne turbo jet engine with a rated thrust of 150 pounds powered the decoy using JP-10 jet fuel contained in the 6.0 gallon (47 lbs) fuel bladder [5]. The jet engine increased the maximum range of the decoy to 160 nm and could better simulate an attacking aircraft by a sustained airspeed of over 0.8 Mach at high altitude. A pyrotechnic-activated battery and main battery, both designed to function for 20 minutes, powered the ITALD's electrical system. The main battery supplied power for the engine ignition, payload operation and programmed flight functions. The ITALD also incorporated a radar altimeter (RADALT), which allowed the decoy to fly a terrain avoidance profile similar to strike aircraft penetrating air defenses at low level. The radar augmentation system contained in the nose of the vehicle consisted of a passive, high band device (Luneberg Lens) and two active RF emitters which could simulate electronic emissions of attacking aircraft.

The ITALD was designed to support the Defense Suppression Mission. The purpose of the ITALD can be summarized by the following statement and Figure 1-6.

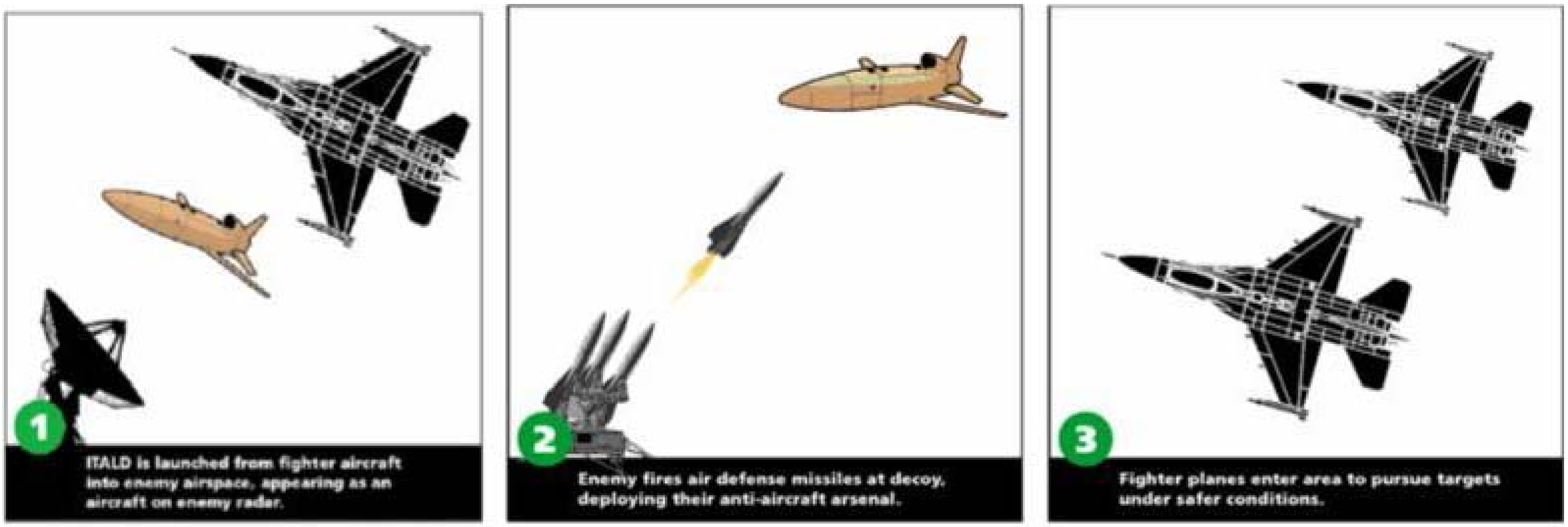


Figure 1-6: ITALD Use in Tactical Strike

1. ITALD is launched from aircraft
2. Enemy surface-to-air missile operators engage ITALD decoys
3. Strike Package proceeds to target unimpeded

Source: www.israeli-weapons.com/weapons/missile_systems/air_missiles/itald/ITALD

The Improved Tactical Air Launched Decoy (ITALD) was developed to meet the requirements of the ORD [Operational Requirements Document] for the purpose of replacing the Tactical Air Launched Decoy (TALD). ***"The ITALD vehicle will be used to improve strike aircraft survivability by misdirecting air defenses, shielding strike aircraft, bringing up enemy radars for anti-radiation missile attack, depleting air defense ordnance assets and aiding electronic intelligence surveillance, thereby enhancing the air superiority mission [6]."***

The conversion from TALD to ITALD was initially undertaken by Brunswick, and then transferred to Israeli Military Industries after Brunswick withdrew from the industry in 1995. The upgrade was sold to the US Navy as an Engineering Change Proposal (ECP) vice a brand new system in order not to highlight the program by minimizing fiscal scrutiny. The ITALD was supposed to be a quick, easy improvement to make the decoy more realistic in the eyes of the enemy surface-to-air radar operator. Table 1-1 is a comparison of the capabilities compared between TALD and ITALD.

Table 1-1: TALD vs ITALD Comparison

Parameter	**TALD**	**ITALD**
Range	~60 nm	~160 nm
Payload	Chaff, Passive/Active RF	Passive/Active RF
Profile	Glide, one turn	High/low altitude, one turn or offset maneuver
Unit Cost	~$24,000	~$120,000

Source: Norman, Cassidy LCDR. *Low Cost Modification of the TALD*. Point Mugu, CA. Naval Air Warfare Center, Point Mugu. March 2002

Initial Testing Results

The ITALD went through several series of tests starting in 1993. The planned simple incorporation of a turbojet engine and radar altimeter proved to be much more complicated.

In September 1993 the US Navy planned 12 separation tests at Naval Air Warfare Center, Aircraft Division (NAWCAD) Patuxent River from F/A-18C aircraft. The tests were halted due to the decoy becoming unstable shortly after separating from the aircraft. Brunswick made modifications to the ventricle and dorsal fins as well as the control augmentation logic. The new design was deemed to be stable via simulation. However, in 1994, another test of the revised ITALD was performed at NAWCAD Patuxent River from an F/A-18C aircraft. The ITALD, which was released from station 2, left ITER shoulder station at 23,000 ft MSL and 0.9 M, immediately went unstable. A team composed of Brunswick, IMI, Applied Physics Laboratory (APL), and Systems Technology Incorporated (STI) was established to audit the ITALD aerodynamic data, simulations, and assist in designing a robust autopilot.

In March 1995, the US Navy conducted a flight to validate the new design during a separation flight known as ET-1 with full telemetry on the aircraft and the ITALD test vehicle. Again, the ITALD went unstable after umbilical separation and came within 10 feet of striking the launch aircraft. Brunswick made additional hardware and software changes to the ITALD by moving the fins and increasing their surface area as well as modifications to the autopilot [7].

Rather than risk embarrassment with the US Navy, Brunswick contracted an Avtel

F-4D Phantom to conduct the next series of tests at Yuma Proving Grounds in Arizona using 5 ITALDs in August 1995. Four of the five ITALD separations were successful, so Brunswick decided to continue with a re-test of ET-1 referred to as ET-1R. In September 1995, the US Navy and Brunswick conducted ET-1R using the Avtel F-4D Phantom at NAWCWD Point Mugu. The telemetry configured ITALD was launched at 17500 ft MSL, 0.8M [7]. This was the first US Navy documented successful separation and free flight of the ITALD.

In January 1996, the US Navy conducted separation testing at NAWCAD Patuxent River and free flight demonstration launched at NAWCWD Point Mugu using the F/A-18C aircraft. Five Engineering Design Model (EDM) ITALDs were tested at Patuxent River to validate the simulation results. Four of the five separated successfully with the one inadvertent separation attributed to pilot error. Five of the six First Article Flight Test (FAFT) ITALDs, which were telemetry equipped, flew successfully off the coast of Point Mugu. The one failure was caused by post launch engine failure. The ITALD complied with the military specifications (excluding the engine failure); however, there were no qualified test pilots or flight test engineers assigned to the test team to evaluate the ITALD's mission effectiveness and suitability as an air defense suppression tool [7].

Developmental testing DT-IIIE commenced in the fall of 1998 at NAWCWD Point Mugu with a properly trained test team, with dramatically different results. The test consisted of ground testing as well as air launches of nine FAFT ITALDs from F/A-18C/D aircraft. The captive carriage and separation characteristics were satisfactory however ITALD free flight performance was severely deficient in two categories: navigational performance and product reliability. Excessive navigational drift rate, heading change errors and lateral offset inaccuracies prevented the ITALD from guiding to within the effective region of the electronic payload. The ITALD also experienced several mechanical failures on the ground and in flight. Only six of ten ITALDs were suitable for loading out of the container due to production irregularities. Of the six that were flown without contractor repair, two experienced in-flight failures – a gyro failure causing the ITALD to fail to release from the aircraft and an engine failure post launch. In total, the test team identified eight serious (Part I) deficiencies and one moderate (Part II) deficiency [8]. See Appendix A for a complete description of deficiency classifications used by the Naval Air Warfare Center. The report concluded the ITALD was not suitable for the defense suppression mission and it recommended that the Part I the navigational and reliability deficiencies be corrected prior to progressing from developmental to operational testing [8].

CHAPTER II

SCOPE OF THESIS

This thesis will only focus on the three navigational deficiencies reported in the DT-IIIE Report of Test Results. Israeli Military Industries solved the reliability deficiencies after a thorough review of their assembly and design procedures. The solution of the navigational deficiencies was particularly controversial because it represented a case where the air vehicle could meet a design specification, but not be suitable for the mission. This thesis will review the navigational performance analysis of the DT-IIIE flight test results, briefly discuss several solution options and report the results of the option the program managers chose to solve the navigation problems.

ITALD Mission Need Statement

The ITALD specification states:

> *"The ITALD vehicle will be used to improve strike aircraft survivability by misdirecting air defenses, shielding strike aircraft, bringing up enemy radars for anti-radiation missile attack, depleting air defense ordnance assets and aiding electronic intelligence surveillance, thereby enhancing the air superiority mission* [6]*."*

The specification also states that:

> *The ITALD is designed to be air launched from* ***outside the enemy threat envelop*** *and execute a preprogrammed flight profile* ***into the objective area*** *in order* ***to confuse enemy air defenses*** [6]*."*
>
> *"The baseline version will be a powered decoy used to saturate enemy IADS* ***to divert attention from attacking aircraft*** [6]*."*

Mission Need Statement: *An air launched tactical decoy which is capable of closely replicating manned strike aircraft is needed to cause enemy air defense systems to treat the decoy as a threat. The greatest potential threat that the ITALD must counter will probably remain the threat posed by the former Soviet Union* [9].

The ITALD must be seen by the intended victim radar system within the RF augmentation payload field of regard and must present a realistic target to that system with its engagement zone. The ITALD was not designed as a weapon, but an expendable decoy. Therefore, it only had to navigate to within the field of regard and the weapon engagement zone of the enemy surface-to-air radar system. The ITALD navigation system tested during DT-IIIE was not accurate enough to satisfy that mission requirement.

ITALD Navigational Performance - DT-IIIE Test Results

FAFT ITALD General Description

The ADM-141C First Article Flight Test (FAFT) ITALDs, used in the DT-IIIE flight tests, weighed a nominal 375 pounds, were 92 (L), by 15 (H) by 10 (W) inches in size, and were non recoverable. Figures 2-1 and 2-2 are schematics showing the internal and external configurations. The wings were folded for carriage on the aircraft and opened 3 s after launch ensuring the ITALD was safely separated from the launch aircraft [8].

Two elevons and a rudder provided aerodynamic control via electrically driven actuators controlled by the flight computer. Flight sensors included a 2-axis attitude gyro, rate sensors, accelerometers, a barometric pressure sensor and a radar altimeter for low altitude terrain following. Thermal batteries provide the electrical power for all of the ITALD's components.

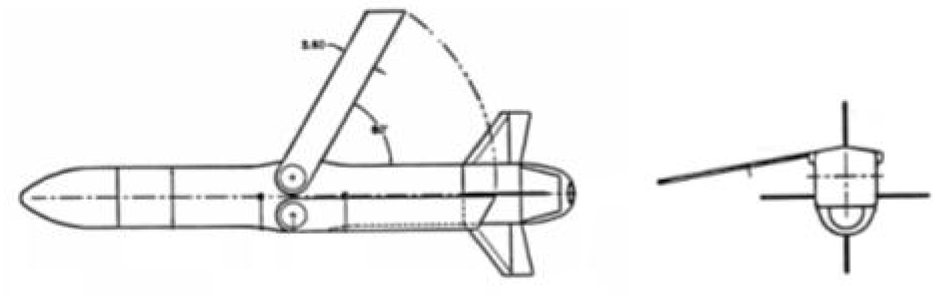


Figure 2-1: ITALD Top and Back Views

Source: *ITALD Mission Planning Document BC Document No 43-212*. Costa Mesa CA: Brunswick Defense Corporation, January 1996.

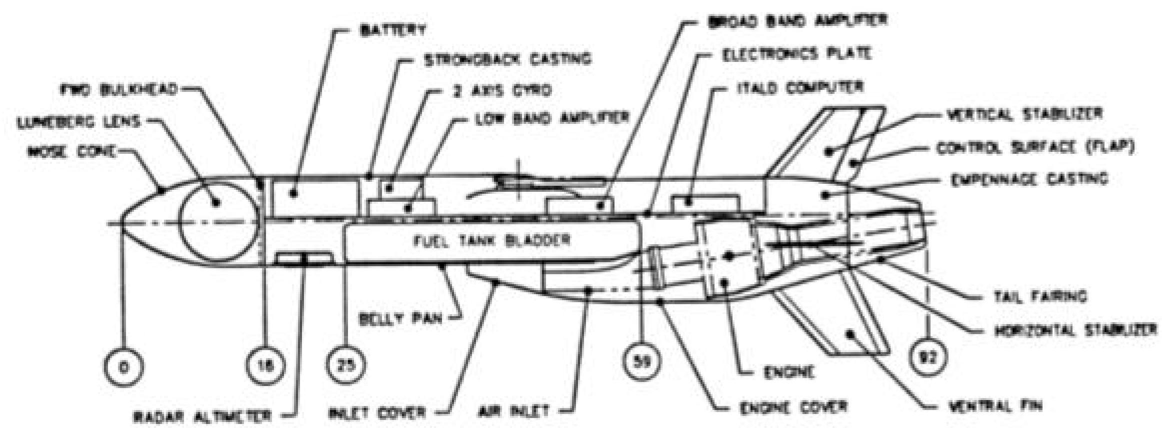


Figure 2-2: ITALD Side View Showing Internal Components

Source: *ITALD Mission Planning Document BC Document No 43-212*. Costa Mesa CA: Brunswick Defense Corporation, January 1996.

The active and passive RF augmentation systems were removed for flight testing and replaced with telemetry equipment. The weight and balance equaled that of the operational ITALD.

FAFT ITALD Navigation System Description

The FAFT ITALD navigation system was rudimentary, incorporating most of the properties of its predecessor, the TALD. The ITALD computer was responsible for taking the inputs from the various sensors and translating them into control inputs via the autopilot. The 2-axis attitude gyro controlled roll and heading and the rate sensors were responsible for pitch and yaw. The ITALD also used normal and lateral accelerometers for flight stability. The pressure altitude sensor and radar altimeter are both used for altitude control at high and low altitude respectively. Most importantly, the ITALD navigation system did not keep track of the vehicle's position in space, but used a dead reckoning technique to fly one of the profiles listed in Figure 2-3. The ITALD could be pre-programmed to fly straight ahead, execute one 30 or 45 degree turn in either direction or perform a lateral offset from one to four nautical miles. The ITALD navigation system used only time and roll commands to fly the profile since it did not have a way of calculating heading.

Since the navigation system could not compute the vehicles location in space nor determine its heading, the ITALD required the aircraft to point accurately at the intended victim radar site and correct for wind drift by varying the launch heading, similar to Kentucky Windage when shooting a rifle at a long range target. Kentucky Windage requires the shooter to adjust the point of aim to compensate for wind [10].

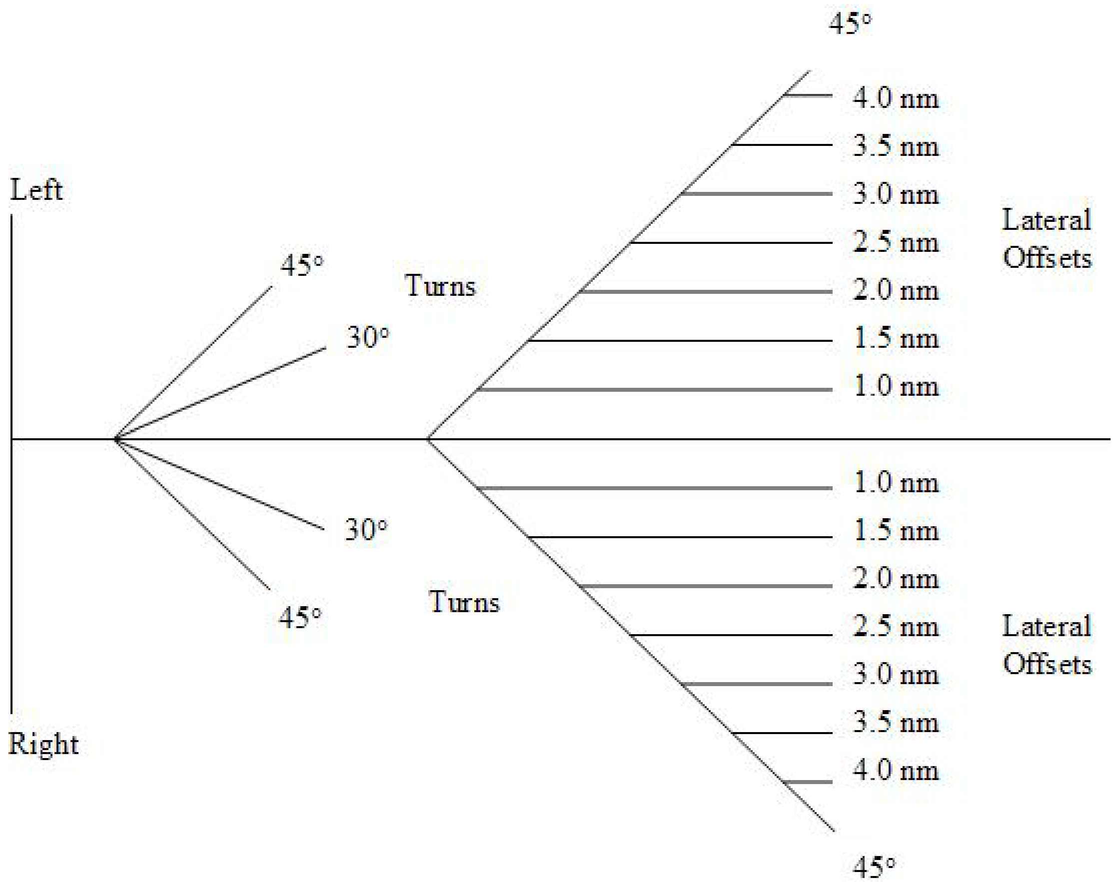


Figure 2-3: ITALD Programmed Maneuvers

Source: *ITALD Mission Planning Document BC Document No 43-212*. Costa Mesa CA: Brunswick Defense Corporation, January 1996.

The ITALD mission planning document stated that the principle source of crossrange flight dispersion was gyro drift, particularly for longer flight times [11]. The 2-axis gyro was the same gyro used in the TALD, a glider, whose flight time was about one third that of the ITALD. Likewise, the specification for the ITALD gyro drift rate mirrored that the TALD, 2 degrees per minute [6,9]. The mission planning document also specified typical and maximum gyro drift rate values, shown in Table 2-1, which varied depending upon the ITER rack launch station, center or left or right should station. When released from the shoulder station, the ITALD had to roll 45 deg to achieve wings level, increasing the gyro drift rate. Figure 2-4 shows the ITALD mounted on the ITER shoulder station. A complete description of the Improved Triple Ejector Rack is provided in Chapter 3.

Table 2-1: Estimated ITALD Gyro Drift Rates

Parameter	Center Station	Shoulder Station
Typical Gyro Drift Value	0.50	0.75
Maximum Gyro Drift Value	1.00	1.50

Source: *ITALD Mission Planning Document BC Document No 43-212*. Costa Mesa CA: Brunswick Defense Corporation, January 1996.

Figure 2-4: ITALD Mounted on ITER Shoulder Station

Source: Photos from the DT-IIIE Terrain Following Evaluation, October 2000.

FAFT ITALD Navigational Deficiencies

The NAWCWD, Point Mugu test team reported two Part I and one Part II deficiencies with the ITALD Navigation System during DT-IIIE testing; excessive gyro drift rate (I), excessive heading change (I) and excessive lateral offset errors (II) [8]. Table 2-2 is a summary of the DT-IIIE flight test results. Figures 2-5 through 2-11 are plots of the each of the flights used for navigational performance analysis. Profile 5 is excluded because the ITALD impacted the ground 25 s after launch. The excessive gryo drift rate caused the ITALD to deviate significantly from the planned course and not be engaged by the intended victim radar site. When programmed to execute a 45 degree heading change, the ITALD turned 61 degrees, rendering the active RF payload useless, since it had an effective operation envelope only within +/-15 degrees of the ITALD heading. Thus, the enemy surface-to-air radar operator would not see ITALD's RF emissions and would dismiss it as a decoy.

Table 2-2: ITALD DT-IIIE Flight Profiles and Results

ITALD DT-IIIE Flight Profiles and Results										
	Profile Description		Launch Conditions			Performance Results				
Profile No.	**Lateral Maneuver**	**Vertical Maneuver**	**Altitude (FT MSL)**	**Airspeed (IMN)**	**ITER Station**	**Flight Time (min:s)**	**Total Distance[1] (nm)**	**Flightpath Deviation[2] (nm)**	**Drift Rate (deg/min)**	**Notes**
1	30° Left Turn @ 5 min	Climb to 25k MSL @ 9 min	13.5k	0.45	Left	19:14	137.6 / 143.4	25	2.16 left[6,7]	1, 2
2	30° Right Turn @ 3 min	Dive to 500 ft AGL @ 1 min	3.3k	0.63	Left	13:08	95.8 / 97.8[3]	4	0.17 right[8]	1, 2, 3,
3	45° Left Turn @ 5 min	Climb to 25k ft MSL @ 15 min	23k	0.89	Left	13:09	97.4 / 102.4[4]	18	1.28 left[8]	1, 2, 4
4	4 nm Left Offset @ 7 min	None	23k	0.90	Center	20:10	134.6 / 143.7	7	0.25 left[8]	1, 2
5	1 nm Left Offset @ 1 min	Dive to 500 ft AGL @ 1 min	3.2k (1.0k AGL)	0.64	Left	0:25	Note 5	Note 5	Note 5	1, 2, 5
6	None	None	20k	0.80	Left	19:24	154.5 / 161.3	29	1.21 right[8]	1, 2
7A	4 nm Right Offset @ 12 min	Dive to 15k ft MSL @ 5 min	40k	0.80	Left	20:49	157.1 / 157.4	10	0.80 left[8]	1, 2
7B	1.5 nm Right Offset @ 1 min	Dive to 500 ft AGL @ 2 min	23k	0.83	Left	15:36	124.0/ 127.9	14	1.62 left[8]	1, 2

1. Upper number is the measured Total Flight Path Range and the lower number is the Total Flight Path Range corrected for headwind
2. Deviation taken from wind corrected track compared with ideal flight path. Distances estimated from measurements on Excel plots.
3. Low altitude dash
4. Early termination due to excessive drift
5. Vehicle prematurely impacted ground
6. Profile 1. Initial drift rate of 2.25 deg/min right was measured from 30 s to 4 min 30 . Post turn 2.16 deg/min drift rate measured from 7 min 37 s to 17 min 02 s
7. Exceeded Gryo Drift Rate specification of 2 deg/min
8. Met Gryo Drift Rate specification of 2 deg/min

Source: Choi, Yosup. *ITALD Drift Rate Analysis Project*. Point Mugu, CA. Naval Air Warfare Center, Weapons Division, 2000.

Figure 2-5: Flight Profile 1; 30 deg Left Heading Change
Drift Analysis: The ITALD drifted 25 nm left of the intended flight path. Gyro Drift Rate of 2.16 deg/min left exceeded the specification.

Source: Choi, Yosup. *ITALD Drift Rate Analysis Project*. Point Mugu, CA. Naval Air Warfare Center, Weapons Division, 2000.

Launch Conditions
Altitude: 13.47k ft Baro / 13.9k ft Radar
Airspeed: 0.45 IMN
Heading: 314 deg T
ITER Station: Left

Flight Profile 1

Profile Description:
30 deg left turn at 5 min
Climb to 25k ft 9 min

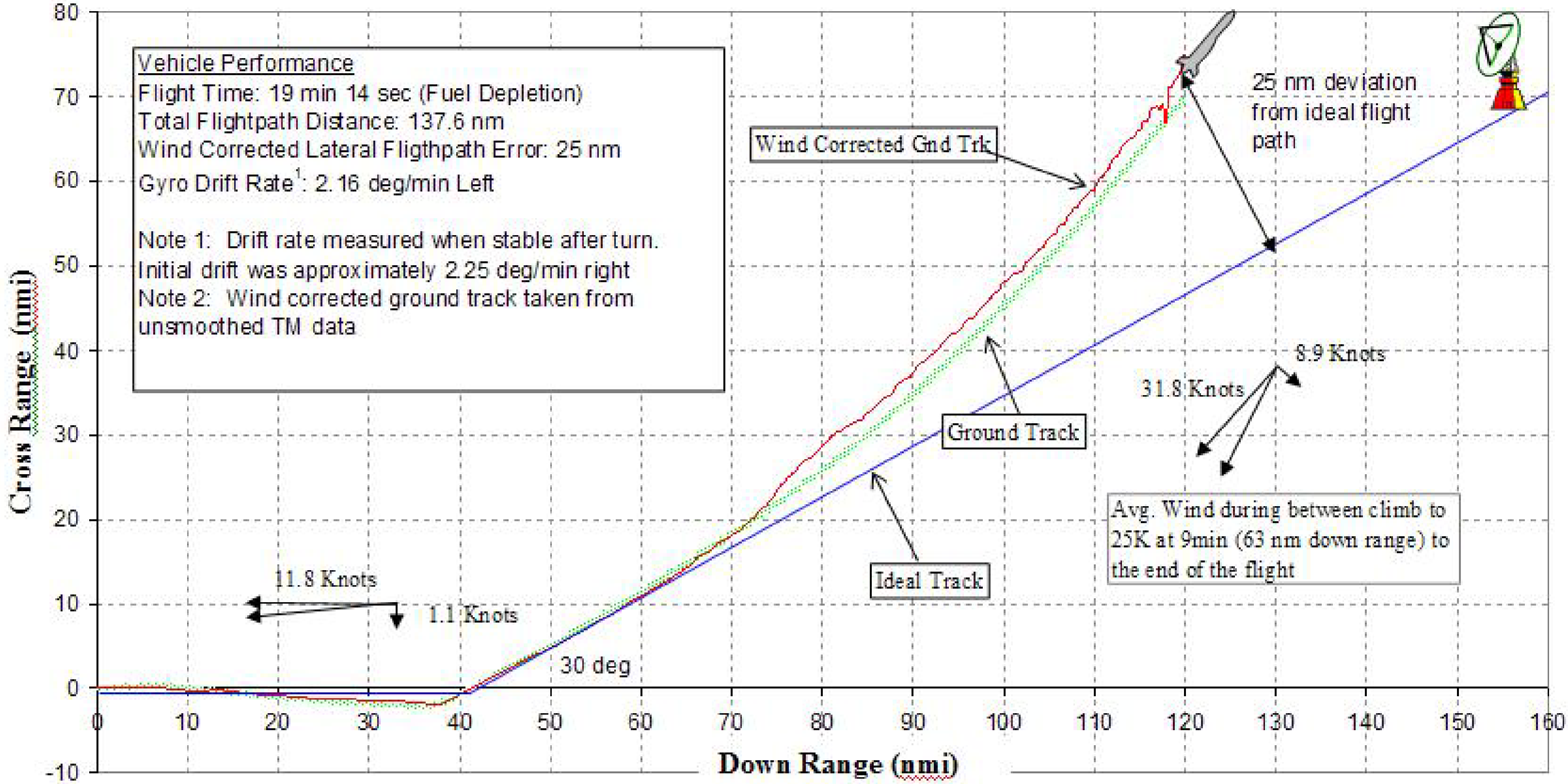


Figure 2-6: Flight Profile 2; 30 deg Right Heading Change Drift Analysis: The ITALD drifted 4 nm right of the intended flight path. Gyro Drift Rate of 0.17 deg/min right met the specification.

Source: Choi, Yosup. *ITALD Drift Rate Analysis Project*. Point Mugu, CA. Naval Air Warfare Center, Weapons Division, 2000.

Launch Conditions
Altitude: 3.27k Kft Baro / 3.37k ft Radar
Airspeed: 0.64 IMN
Heading: 279 deg T
ITER Station: Left

Flight Profile 2

Profile Description: Low altitude dash
Dive to 500 ft AGL at 1 min
30 deg right turn at 3 min

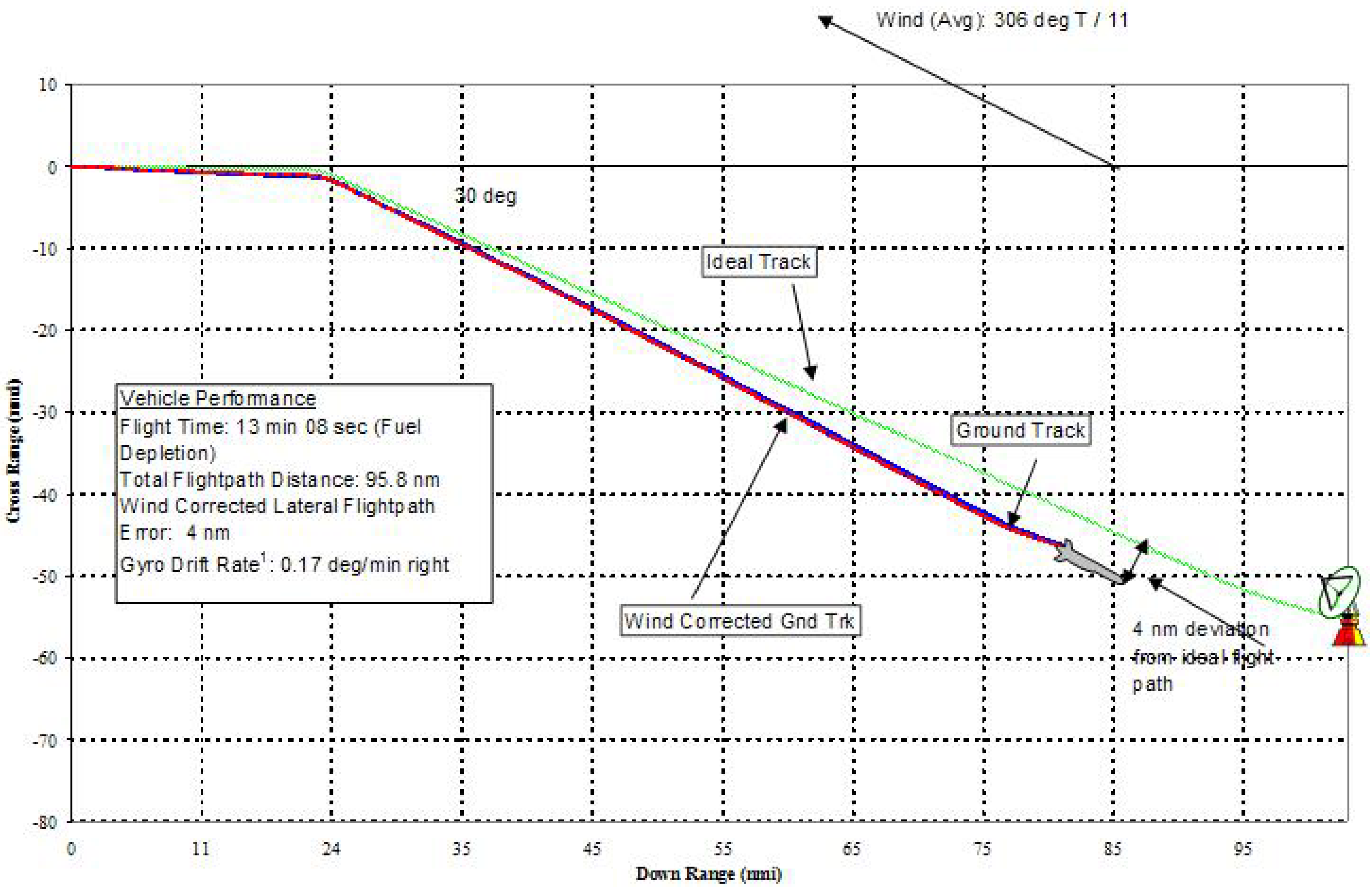


Figure 2-7: Flight Profile 3; 45 deg Left Heading Change Drift Analysis: The ITALD drifted 18 nm left of the intended flight path. The Gyro Drift Rate of 1.28 deg/min left met the specification.

Source: Choi, Yosup. *ITALD Drift Rate Analysis Project*. Point Mugu, CA. Naval Air Warfare Center, Weapons Division, 2000.

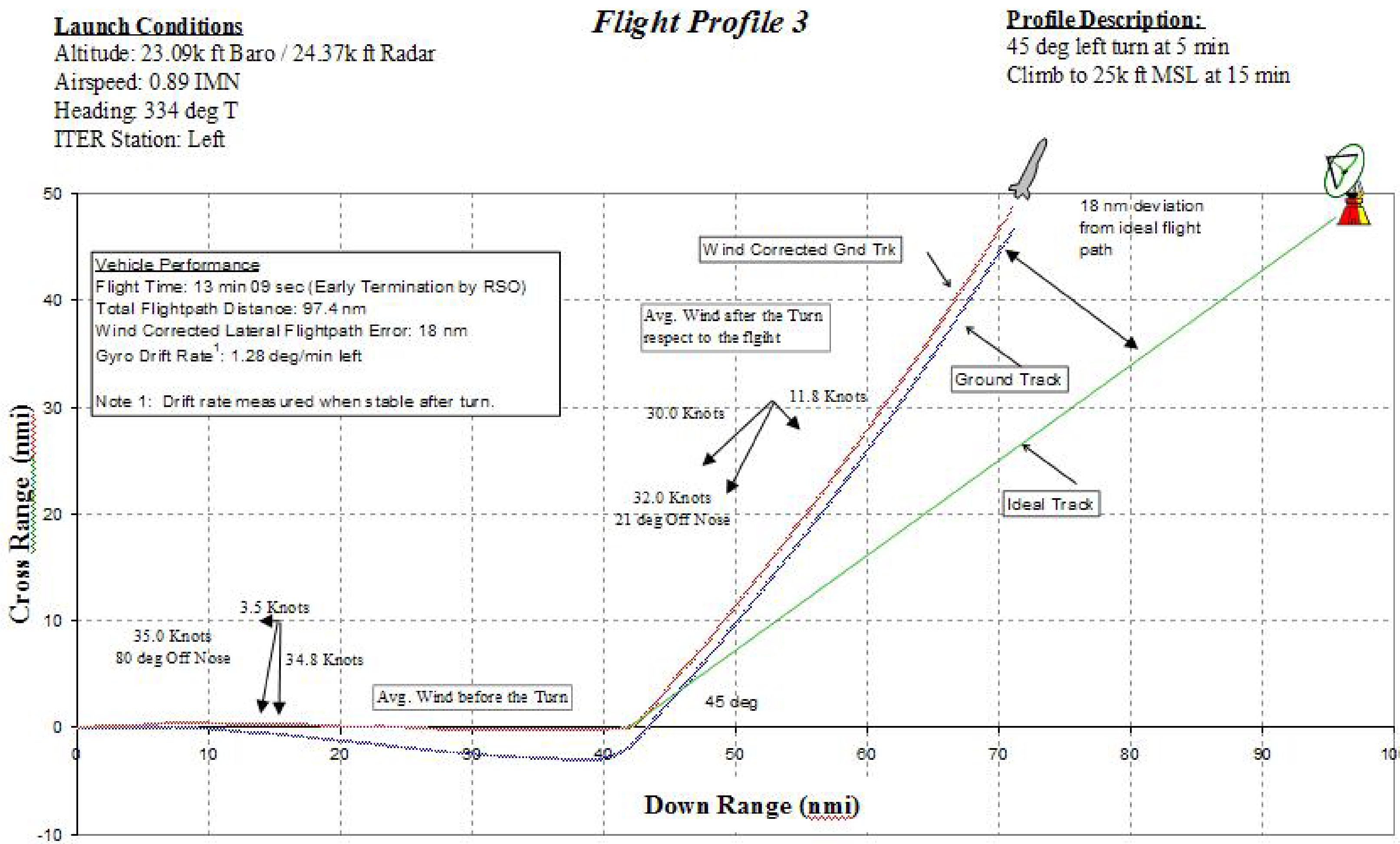

Launch Conditions
Altitude: 23.09k ft Baro / 24.37k ft Radar
Airspeed: 0.89 IMN
Heading: 334 deg T
ITER Station: Left
Flight Profile 3
Profile Description:
45 deg left turn at 5 min
Climb to 25k ft MSL at 15 min
Vehicle Performance
Flight Time: 13 min 09 sec (Early Termination by RSO)
Total Flightpath Distance: 97.4 nm
Wind Corrected Lateral Flightpath Error: 18 nm
Gyro Drift Rate[1]: 1.28 deg/min left
Note 1: Drift rate measured when stable after turn.
Wind Corrected Gnd Trk
18 nm deviation from ideal flight path
Avg. Wind after the Turn respect to the flight
Ground Track
11.8 Knots
30.0 Knots
32.0 Knots
21 deg Off Nose
Ideal Track
3.5 Knots
35.0 Knots
80 deg Off Nose
34.8 Knots
Avg. Wind before the Turn
45 deg
Cross Range (nmi)
Down Range (nmi)
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
100

Figure 2-8: Flight Profile 4; 4 nm Left Offset
Offset Results: ITALD offset 11 nm left
Drift Analysis: The ITALD drifted 7 nm left of the intended flight path. Gyro Drift Rate of 0.25 deg/min left met the specification.

Source: Choi, Yosup. *ITALD Drift Rate Analysis Project*. Point Mugu, CA. Naval Air Warfare Center, Weapons Division, 2000.

Launch Conditions
Altitude: 23.04k ft Baro / 24.15k ft Radar
Airspeed: 0.89 IMN
Heading: 309 deg T
ITER Station: Center

Flight Profile 4

Profile Description:
4 nm left offset at 7 min

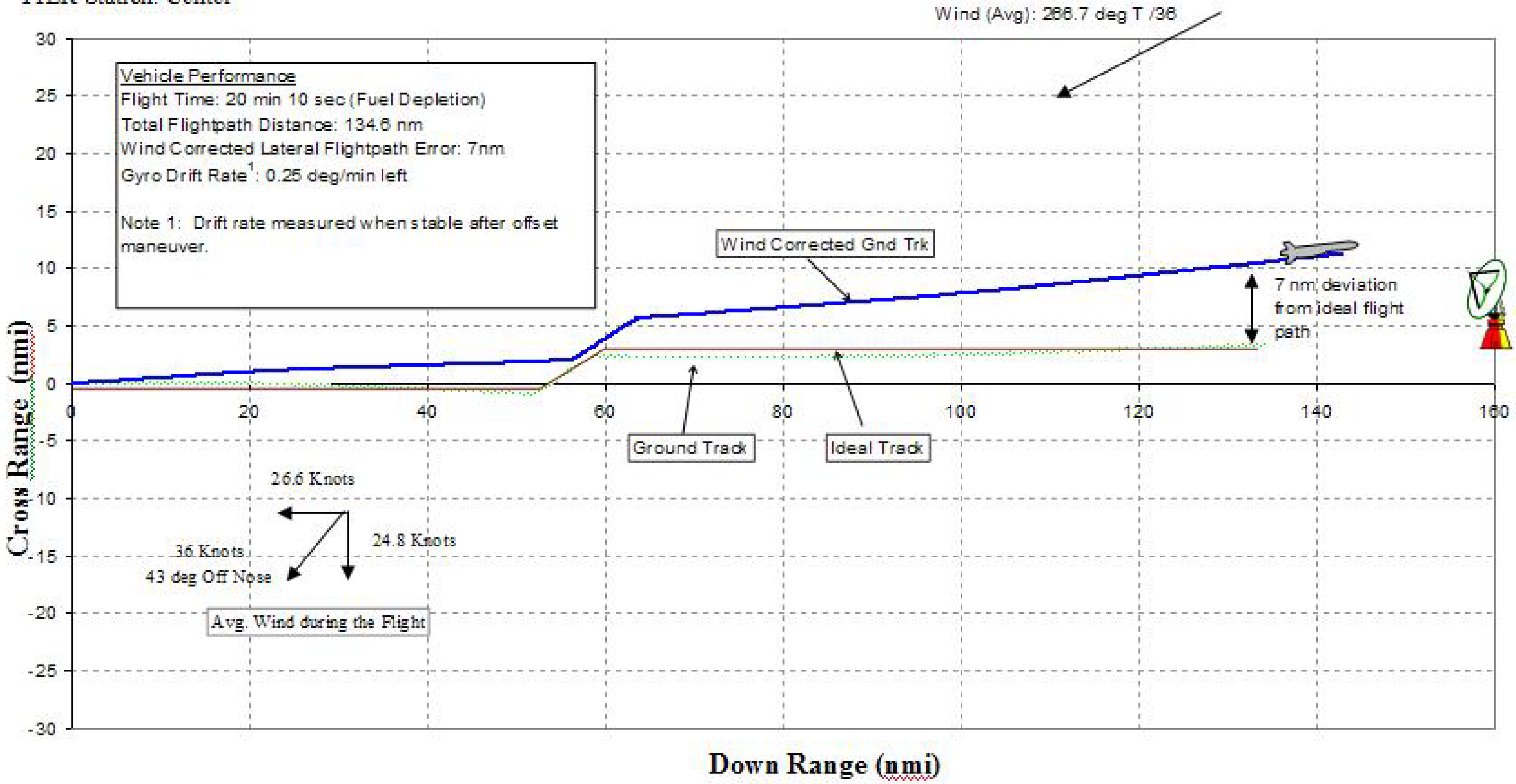


Figure 2-9: Flight Profile 6; No Maneuver
Drift Analysis: The ITALD drifted 29 nm right of the intended flight path. Gyro Drift Rate of 1.21 deg/min right met the specification.

Source: Choi, Yosup. *ITALD Drift Rate Analysis Project*. Point Mugu, CA. Naval Air Warfare Center, Weapons Division, 2000.

Flight Profile 6

Launch Conditions
Altitude: 20.02 Kft Baro / 20.99 Kft Radar
Airspeed: 0.778 IMN
Heading: 307 Deg T
ITER Station: Left

Profile Description: Max Range Verfication
No planned altitude or heading changes

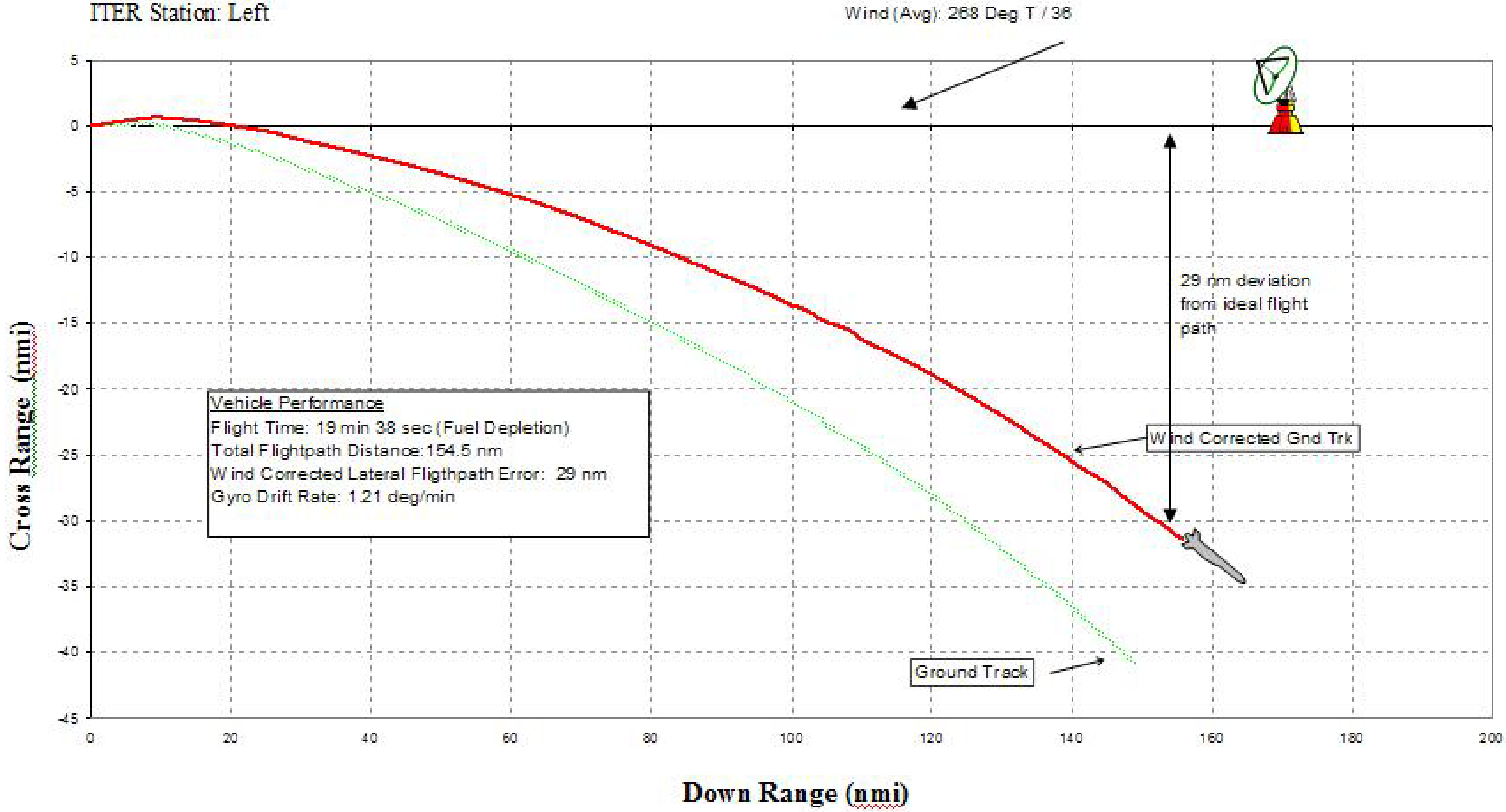


Figure 2-10: Flight Profile 7A; 4 nm Right Offset
Offset Results: ITALD offset 6 nm left
Drift Analysis: The ITALD drifted 10 nm left of the intended flight path. Gyro Drift Rate of 0.80 deg/min left met the specification.

Source: Choi, Yosup. *ITALD Drift Rate Analysis Project*. Point Mugu, CA. Naval Air Warfare Center, Weapons Division, 2000.

Launch Conditions
Altitude: 39.9k ft Baro / 40.7k ft Radar
Airspeed: 0.78 IMN
Heading: 308 deg T
ITER Station: Left

Flight Profile 7A

Profile Description- High Altitude launch
4 nm right offset at 12 min

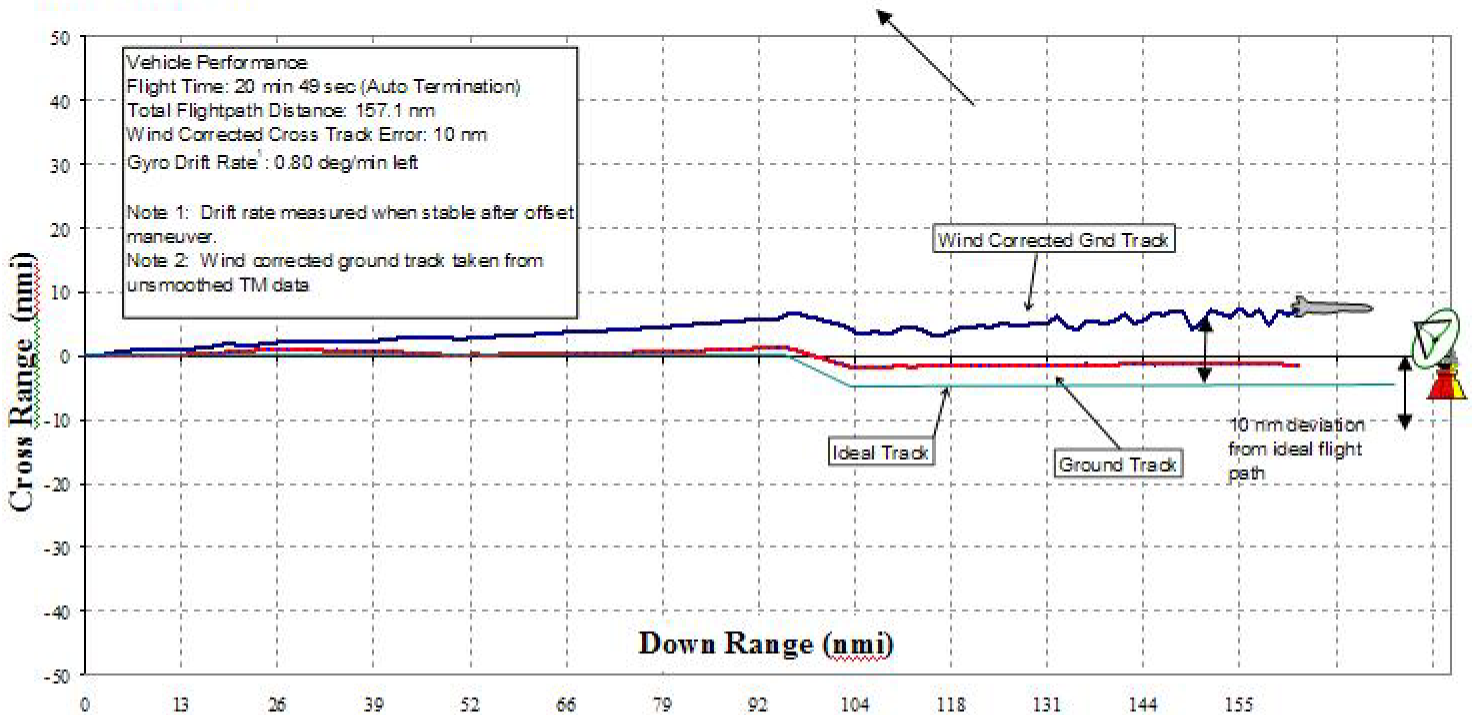


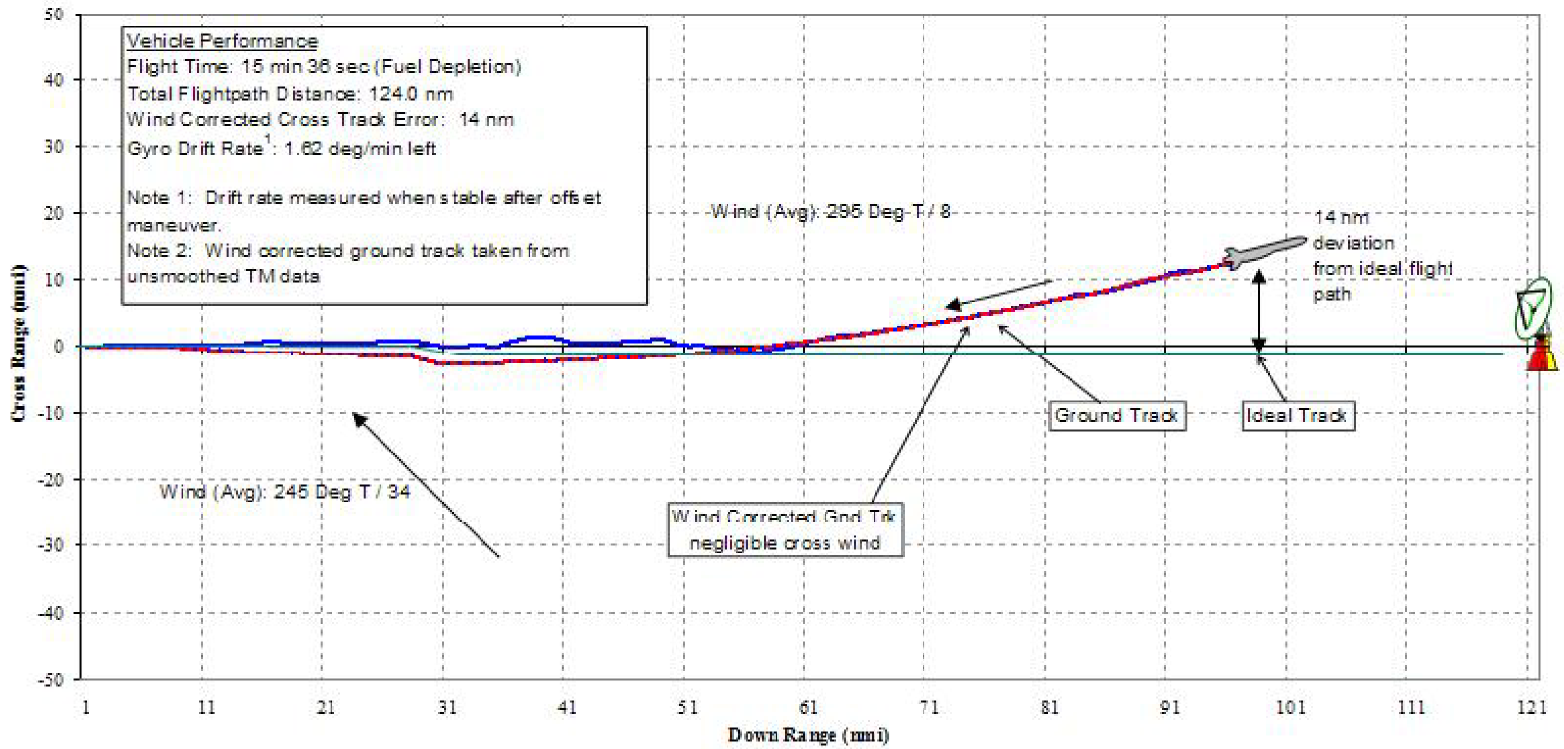
Figure 2-11: Flight Profile 7B; 1.5 nm Right Offset
Offset Results: ITALD offset 12.5 nm left
Drift Analysis: The ITALD drifted 14 nm left of the intended flight path. Gyro Drift Rate of 1.62 deg/min left met the specification.

Source: Choi, Yosup. *ITALD Drift Rate Analysis Project*. Point Mugu, CA. Naval Air Warfare Center, Weapons Division, 2000.

Launch Conditions
Altitude: 22.95k ft Baro / 24.14k ft Radar
Airspeed: 0.83 IMN
Heading: 313 deg T / 295 deg T (TF portion)
ITER Station: Left

Flight Profile 7B

Profile Description
1.5 Nmi right offset at 1 min
Dive to Terrain Following Altitude at 5 min 14 sec
Low altitude dash at 10 min 12 sec



ITALD Drift Rate Analysis

By estimating the gyro drift rate, the ITALD cross range could be calculated using the following formula [11]:

XR = R(GDR) t/(114.6)

where,

XR = Crossrange (nm)
R = Range (nm)
GDR = Gyro Drift Rate (deg/min) from Table 2-1
t = Flight Time (min)

The drift rate for a typical 150 nm flight (R) with a flight time (t) of 15 minutes varied between the best case of 9.8 nm and the worst case of 29.5 nm. The pilot could not compensate for gyro drift using the same Kentucky Windage technique because neither the magnitude nor the direction was predictable.

The DT-IIIE test results mirrored that of the mission planning document. The gyro drift rate was unpredictable in both magnitude and direction. When directed to fly straight ahead, the ITALD deviated almost 30 nm from its intended flight path. In two of the three lateral offset flights, the gyro drift caused the ITALD to offset opposite to the planned direction.

Proposed Solutions to Navigational Deficiencies

Do Nothing

During the 1996 flight test, the ITALD was deemed “satisfactory” because it met the design specifications delineated in the Operational Requirements Document. As stated earlier, no mission relation analysis was performed during those flight tests.

However, the DT-IIIE developmental tests resulted in three navigational deficiencies. Both the ITALD program managers and the contractors at Israeli Military Industries were not convinced that the navigational deficiencies merited correction. The program was already over budget and behind schedule and a redesign of the navigation system could prove costly and delay the program even further. They did not understand the concept of mission relation with regard to flight testing. The Naval Air Warfare Center Report Writing Guide for Flight Test and Engineering Group Reports states:

> *Mission Relation. This is probably the most important part of the evaluation in that it justifies the conclusion and the recommendations. It is the test team's opinion, based upon their experience with the intended mission, of the degree to which the characteristic under evaluation will enable the equipment to fulfill its mission. It should be a clear statement regarding safety of flight, operational suitability, or operational effectiveness of the aircraft or system with respect to its primary or secondary missions* [13].

Their solution to the problem was to employ more decoys in the hopes that more would find their way to the target area. However, a haphazard pattern of decoys with a dispersion of over 50 miles would not resemble a formation of attacking aircraft, thus it would be very easy for the victim radar site to dismiss the oncoming ITALD as decoys and not engage them.

Two figures were used to convince the program managers that the ITALD navigation was unsuitable for the mission. Figure 2-12 compares the flight paths of TALD and ITALD graphically depicting why the ORD threshold gyro drift rate of 2 deg/min was unsuitable for the ITALD. TALD, a glider, was typically launched approximately 50 nm from the intended victim radar site.

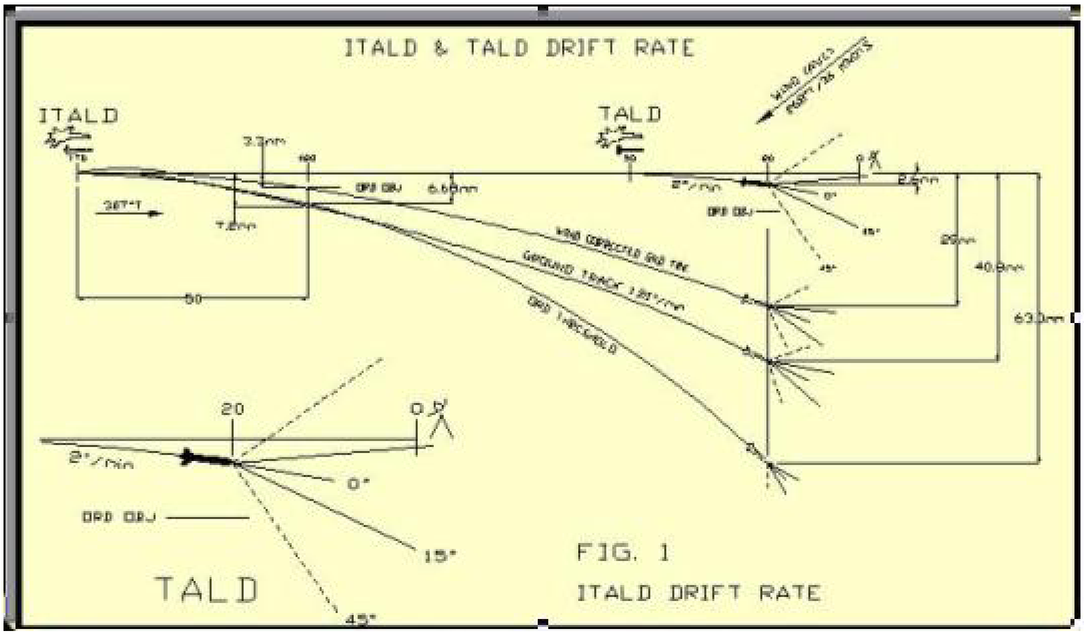


Figure 2-12: ITALD and TALD Drift Rate

Source: Bathrick, Mark CDR. *ITALD Video Teleconference Brief to N880* (Washington DC). Point Mugu, CA. Naval Air Warfare Center, Weapons Division, 24 June 99

Even if subjected to the maximum gyro drift rate, the TALD would arrive at the engagement range (20 nm in the figure) with the site barely within the effective envelope of the active RF augmenter (+/-15 deg of the nose) and well within the envelope of the passive reflective lens (+/- 45 deg of the nose).

Figure 2-13 depicts the real world consequences of excessive gyro drift. The conflict in Bosnia involved penetrating an extremely sophisticated air defense network. If ITALD were used in the conflict with the same navigational system, the decoy not only would have bypassed the intended radar sites, but would have crash landed in Albania. The political consequences of the United States appearing to attack a neighboring country by mistake would have been disastrous.

New Gyro Design

Replacing the gyro would require starting from square one of the design process since it affected the ITALD's flight characteristics. It took over two years before the ITALD flew successfully after being launched from an aircraft. A new gyro would have to be proven flight worthy, a time and cost intensive process. Also, the new gyro would not guarantee sufficient accuracy because the navigation system would still not be able to compensate for wind. The risks associated with a gyro re-design were too great to a program on the verge of cancellation.

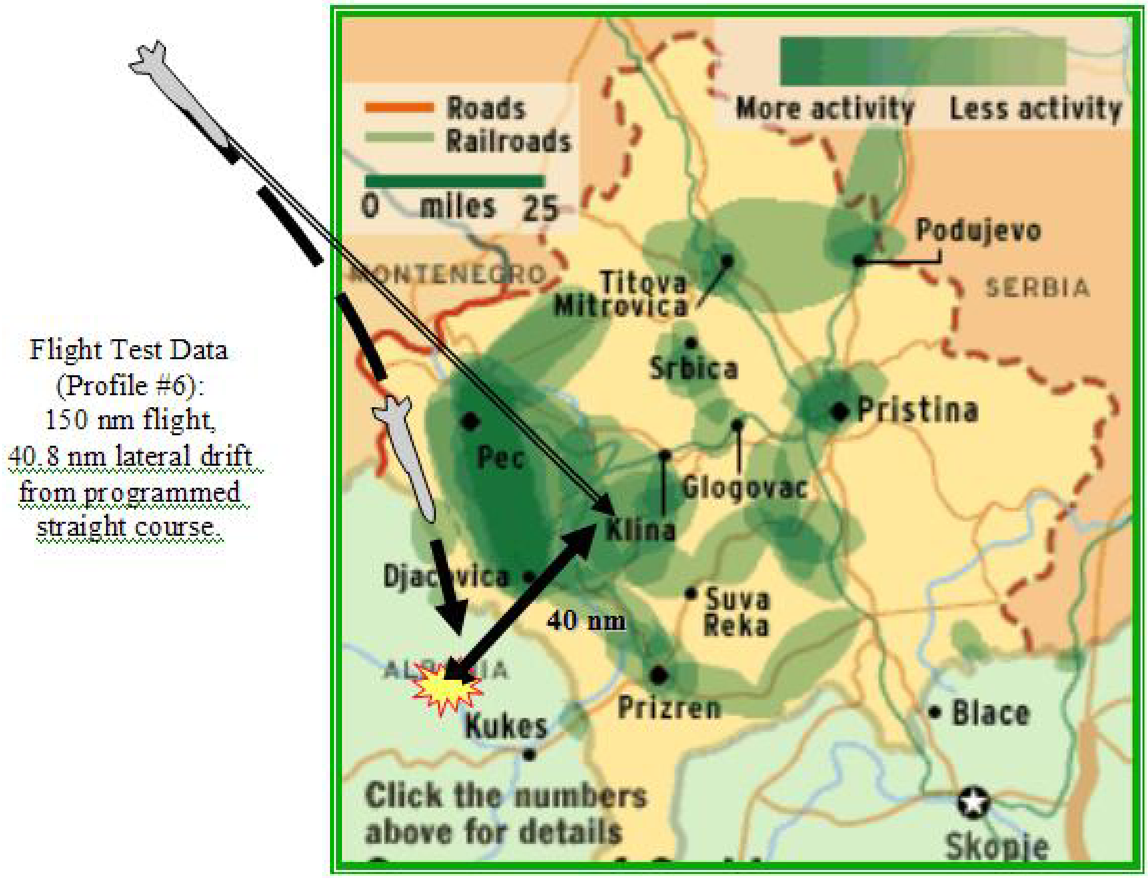


Figure 2-13: Mission Consequences of ITALD Drift Rate

Source: Bathrick, Mark CDR. *ITALD Video Teleconference Brief to N880* (Washington DC). Point Mugu, CA. Naval Air Warfare Center, Weapons Division, 24 June 99

Commercial Off the Shelf (COTS) GPS Incorporation

The solution that was ultimately chosen was to add a commercial GPS system to work in concert with the legacy navigation system. A commercial off the shelf (COTS) GPS was desired because it had proven reliability and accuracy. The benefit of using GPS was twofold. First, the system would guarantee sufficient endpoint accuracy and second, by the nature of programmed waypoints vice turns and offsets depicted in Figure 2-3, would render the inaccurate heading change and lateral offset deficiencies moot. With some modifications, the GPS receiver could easily be incorporated as another input to the flight control computer. Not only would the incorporation of a COTS GPS system solve the navigational problems, but it would add capability to the ITALD by allowing it to fly a preprogrammed route vice just a series of turns, increasing the resemblance of the decoy to strike aircraft. The cost penalty incorporating a COTS GPS into the navigation system was only $10k per ITALD; raising the projected price from $120k to $130k per production decoy [3].

The only limitation was the gyro gimbal limits restricted the angle of bank to 35 deg or less and heading changes to within 45 deg of the initial launch heading, both inherited from the previous ITALD navigation system. The ITALD could execute a 45 deg turn in one direction, then a maximum of 90 deg in the opposite direction as shown in Figure 2-14.

In terms of performance, risk and cost, the COTS GPS system proved to be the best option available.

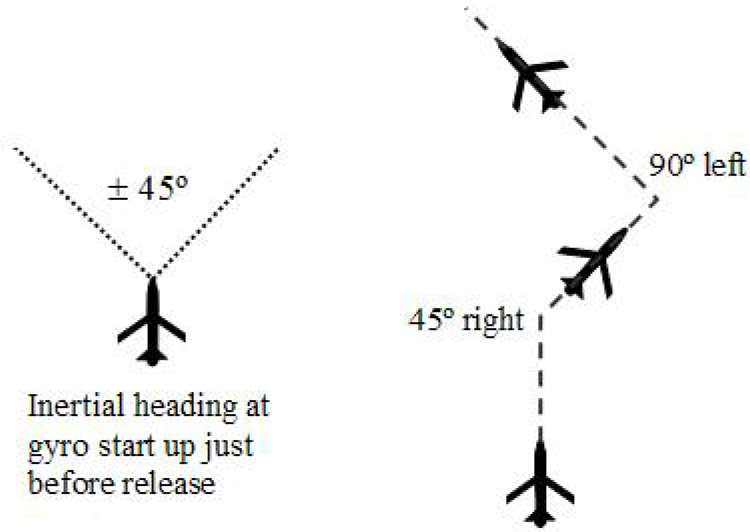


Figure 2-14: ITALD Turn Limitations

Source: Norman, Cassidy LCDR. *Low Cost Modification of the TALD*. Point Mugu, CA. Naval Air Warfare Center, Point Mugu. March 2002

CHAPTER III

TEST ARTICLE AND AIRCRAFT DESCRIPTION

ITALD-GPS Vehicle Description

General Description

The ITALD-GPS, shown schematically in Figure 3-1, retained the majority of the characteristics as the FAFT ITALD used in the DT-IIIE testing. Aerodynamically, the weight and balance had to remain the same or the vehicle would have to start the flight testing process from the beginning. The dimensions and weight were 92 (L) by 15 (H) by 10 (W) inches in size and nomial weight of 375 pounds respectively. The three control surfaces, twin elevons and dorsal rudder, and fixed ventral fin still provided aerodynamic control. The same two batteries, pyrotechnic-activated pilot battery and main battery, powered the electrical system. The ITALD-GPS was carried with the wings in a folded position and launched from an F/A-18 Hornet aircraft carrying an Improved Triple Ejector Rack (ITER) in the same manner as the previous ITALD design.

To create the ITALD-GPS, IMI modified the ITALD to include the GPS receiver, GPS antenna, a Navigation Processor (NP), a modified Flight Control Assembly (FCA) A3 board, a new wire harness for the GPS unit and modifications to two existing harnesses. The GPS unit was mounted to the Strongback on the top of the vehicle using shock absorbers to minimize dynamic effects and grounded by a dedicated shielding cable to the ITALD chassis.

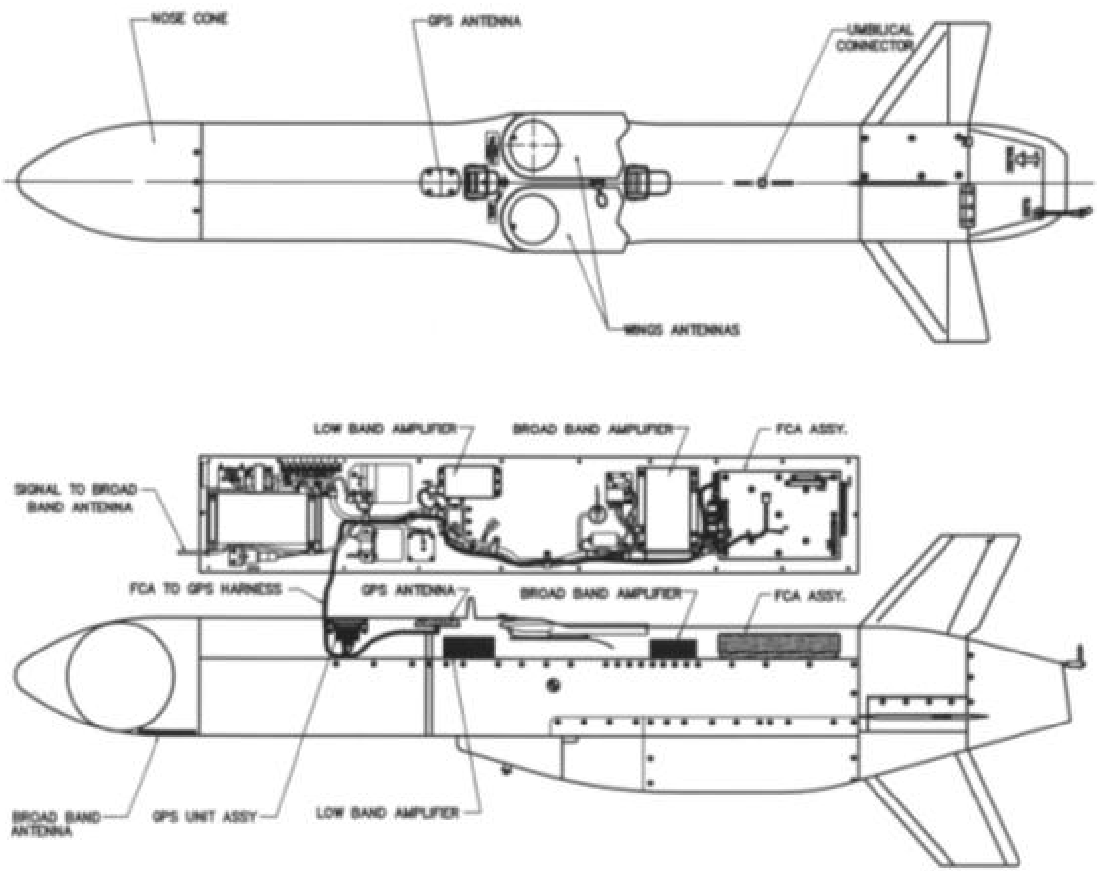


Figure 3-1: ITALD-GPS Schematic

Source: *ITALD Final Design Review*. Israel: Israeli Military Industries LTD., June 2001

The GPS antenna was mounted in the upper part of the Strongback in front of the forward attachment point (to the ITER). The antenna was mounted flush to the surface and sealed with an "O" ring to provide an environmental seal [16]. The relative positions of the GPS components are depicted in Figure 3-1.

GPS System

Israeli Military Industries chose the 8 channel Lassen SK II GPS receiver manufactured by Trimble designed specifically for embedded applications due to its modular format. The designers chose this particular system because of its proven reliability, accuracy and fast GPS satellite acquisition post cold start. Because the ITALD-GPS was not powered until post launch, the designer required rapid GPS power up and satellite acquisition in order for the system to successfully provide useful navigational information. The Lassen SK II was also very compact in size and optimized for battery operated devices due to its low power consumption and minimal heat dissipation requirements [17, 19].

Since the ITALD was not designed as a weapon, the navigation system only required the commercial accuracy of 100 meters and 0.5m/s provided by the coarse acquisition (C/A) code available with the Standard Positioning Service (SPS). The Lassen II received C/A code on the L1 frequency (1575.42 MHz) and used the Trimble Standard Interface Protocol (TSIP), which supported over 40 commands and their associated response packets, for I/O communication with the receiver to provide control over operation, self-test and GPS configuration via the serial port [19].

To minimize the time to acquire a positional fix on startup, the GPS stored the almanac and ephemeris data, a real-time clock and last position in RAM using backup power provided by the SAFT lithium battery (Part Number LS-14500). The ITALD GPS used a 1 pulse-per-second (PPS) timing for reporting position, velocity and data accuracy.

GPS Incorporation

The old ITALD navigation system was modified to incorporate the computed GPS derived heading and altitude errors into the control loop. The new ITALD-GPS navigation system still relied on the legacy 2-axis gyro for attitude stabilization and open loop heading control. Figure 3-2 is a block diagram of the Flight Control System.

To incorporate the GPS into the flight control system, a Navigation Processor (NP) was added to one of the three PC Boards (A3) of the Flight Control Assembly (FCA) to process GPS data and provide correction commands to the Flight Control Processor (FCP), located on the A1 board. A Dual Port RAM (DPR) provided the communication between the two processors [16].

GPS Programming – Improved Decoy Tester Programmer

The Improved Decoy Tester Programmer (IDTP) combined the functions of the Integrated System Tester and Decoy Tester Programmer used on the previous versions of the ITALD into a battery operated test and programming set, which tested the ITALD-GPS electronics, servos, and subsystems (DEC, sensors, radar altimeter). A fault in any system generated an error code displayed on the IDTP via English fault messages.

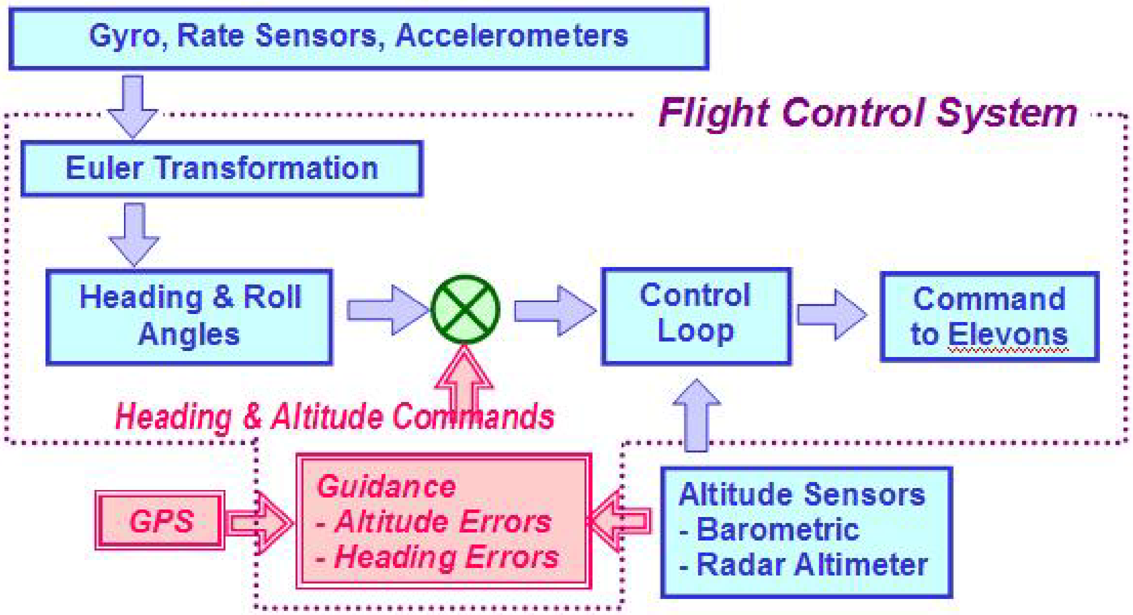


Figure 3-2: ITALD-GPS Flight Control System

Source: Norman, Cassidy LCDR. *Low Cost Modification of the TALD*. Point Mugu, CA. Naval Air Warfare Center, Point Mugu. March 2002

The IDTP was also used to program the ITALD-GPS FCA and NP using a compact flash card memory [16].

Using the existing Portable Flight Planning System (PFPS), the standard for the US Navy, the user could program a mission and download it to the compact flash card, which was then inserted into the Improved Decoy Tester Programmer (IDTP). Figure 3-3 illustrates an example PFPS mission. The PFPS output consisted of a nine-page mission code file. Page 1 specified the launch date, mission code serial number and launch point date (altitude, latitude and longitude). Page 2 listed the number of waypoints (1 to 7) and the termination time in minutes (16 in Figure 3-3). Pages 3 through 9 contained the information for each of the subsequent waypoints. For each waypoint, the user could specify the waypoint location, altitude, engine thrust (Low, Medium, High) and payload ON/OFF. GPS almanac data could also be transferred to the flash memory card from PFPS [18].

Prior to flight, the IDTP was hooked up to the aft access panel as shown in Figure 3-4 and the launch point, waypoint and GPS almanac data downloaded to the ITALD FCA using the Trimble Standard Interface Protocol (TSIP). Because the GPS almanac provided information to predict the flight path of the GPS satellites, the initial GPS fix was quickest when the FCA contained the most current almanac; therefore the IDTP was also equipped with a GPS receiver and antenna so that the most current almanac could be uploaded directly as long as the IDTP was in direct view of the significant portion of the sky.

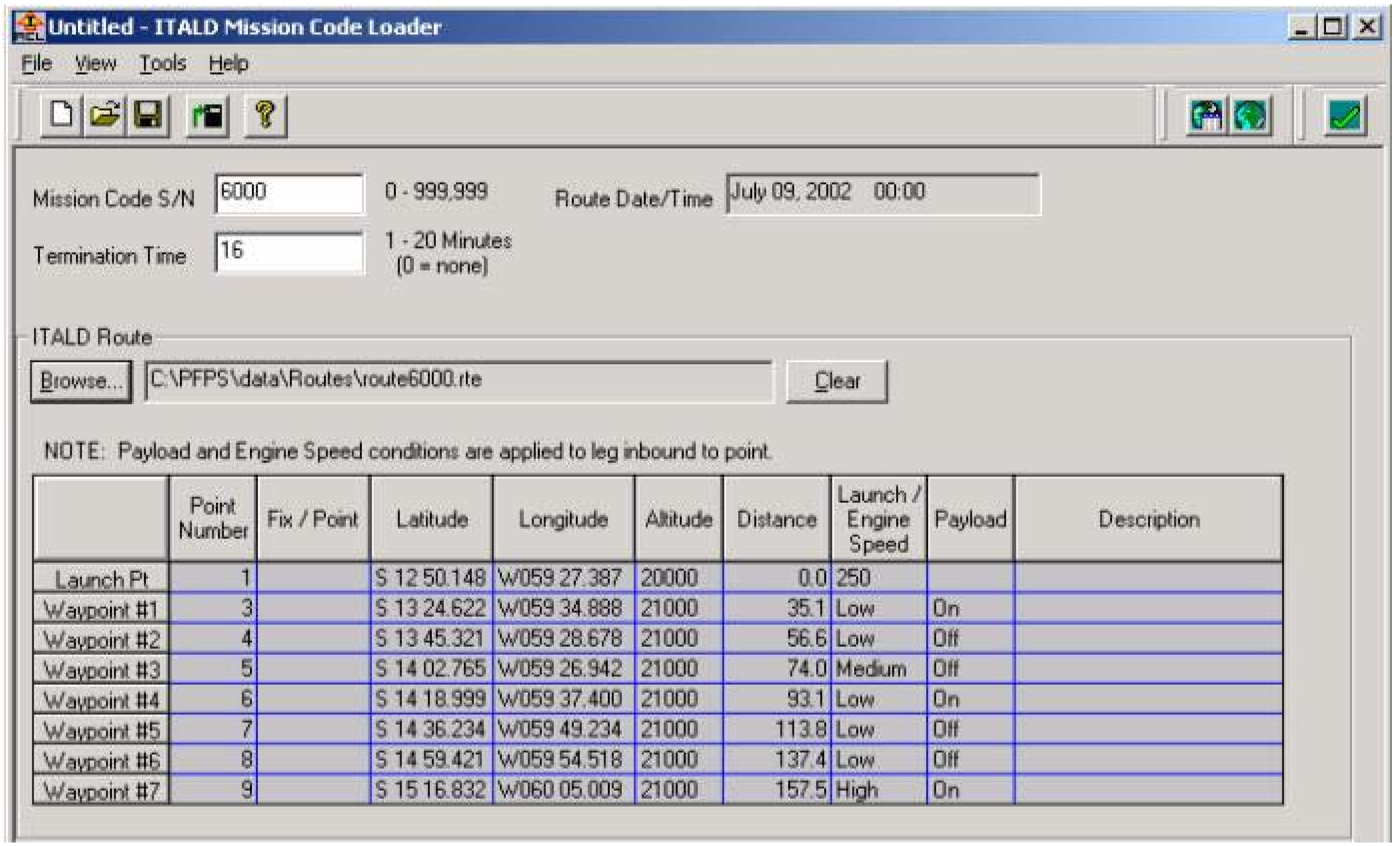


Figure 3-3: ITALD-GPS PFPS Mission Planning Page

Source: Terando, Steve. *ITALD Mission Programming Brief.* Point Mugu, CA: Naval Air Warfare Center, Weapons Division, 2002.

Figure 3-4: Improved Decoy Tester Programmer (IDTP) Hooked to ITALD

Source: Norman, Cassidy LCDR. *Low Cost Modification of the TALD*. Point Mugu, CA. Naval Air Warfare Center, Point Mugu. March 2002

Once disconnected from the IDTP, the aircrew would not be able to communicate to the ITALD-GPS, which prevented any alteration of the mission in flight. A workaround for this limitation was the use of the “launch basket” concept discussed in the next section.

Operational Concept – Navigation Modes

The ITALD-GPS navigation system was designed to function in two main modes, Waypoint and Target of Opportunity (TOO). The Waypoint mode had two sub-modes Pre-Planned Route (7 waypoints maximum) and Direct to Last Waypoint. If GPS service were unavailable, then the ITALD-GPS would default to the dead reckoning mode using the gyro only.

The ITALD-GPS launch sequence, pictured in Figure 3-5, remained the same as the previous design with the exception that the GPS system would power up after launch and acquire a fix within 60 s. From that position, the ITALD-GPS would establish its launch position based on current position and time of flight. The ITALD-GPS established the Launch Reference Altitude (LRA) at wing opening and initiated a windmill engine start below 15,000 ft MSL and above 0.55 Mach [15].

In order for it to be able to navigate the entire Pre-Planned Route, the ITALD-GPS had to be released within a constrained Launch Basket, defined in Table 3-1, due to the turn and angle of bank limitations of the gyro. The ITALD-GPS had to extrapolate its launch position based upon the first GPS fix and the time of flight.

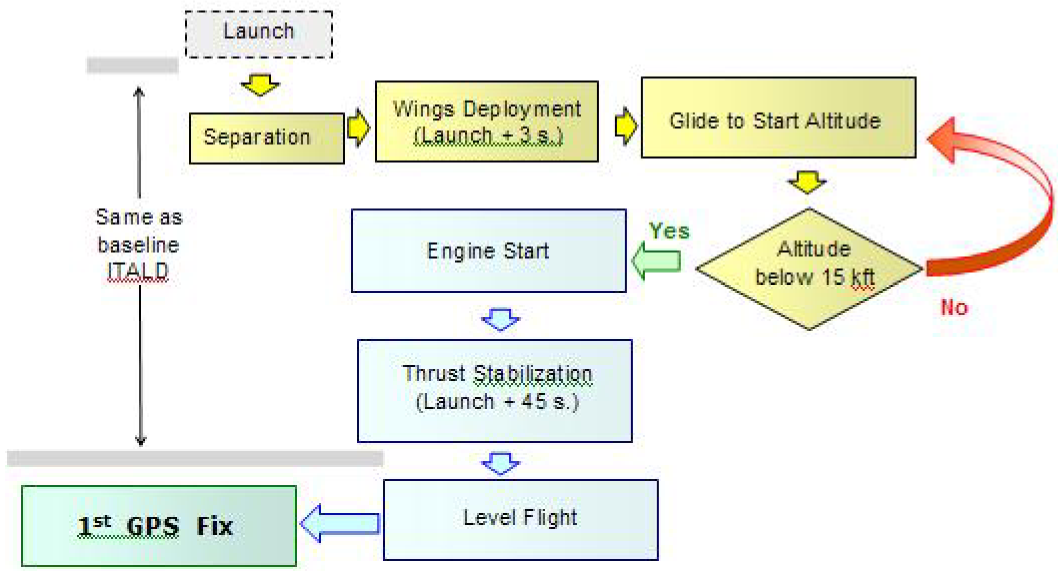


Figure 3-5: ITALD-GPS Launch Logic

Source: *ITALD-GPS Final Design Review*. Israel: Israeli Military Industries, LTD, June 2001.

Table 3-1: Launch Basket - Requirements for Pre-Planned Route

1	Launch Point Altitude Error	Within ± 5,000 feet
2	Angle between launch direction and bearing from the launch point to the last waypoint	Within ± 45°
3	Launch Point Down Range Error	Within ± 10 NM
4	Launch Point Cross Range Error	Within ± 5 NM
5	Launch Point Course Error	Within ± 5°

Source: Report of Test Results, Improved Tactical Air Launced Decoy DT-IIIF GPS Upgrade Evaluation, NAWCWD Point Mugu, February 2002

If conditions 1 or 2 in Table 3-1 were exceeded then the ITALD-GPS would invoke Target of Opportunity Mode, TOO. With TOO selected, the ITALD-GPS would climb back to the launch reference altitude (LRA) or 20,000 ft MSL, whichever was less, and fly in a straight line with engine thrust set to HIGH and the payload set to ON. This allowed the aircrew to engage a different target from the one loaded during preflight. If conditions 3, 4 or 5 were exceeded, then the ITALD-GPS would navigate Direct to Last Waypoint. Figure 3-6 is a graphic depiction of the navigation mode logic [15].

Test Item Modifications

Five ITALD-GPS decoys, modified by Israeli Military Industries for flight test, were designated Engineering Test (ET) Vehicles, costing approximately $150,000 each. The RF payload was replaced with two telemetry (TM) systems (Primary and Secondary) complete with antennas operating at 2,222.5 MHz and 2,250.0 MHz, respectively and a Flight Termination System (FTS) for safety.

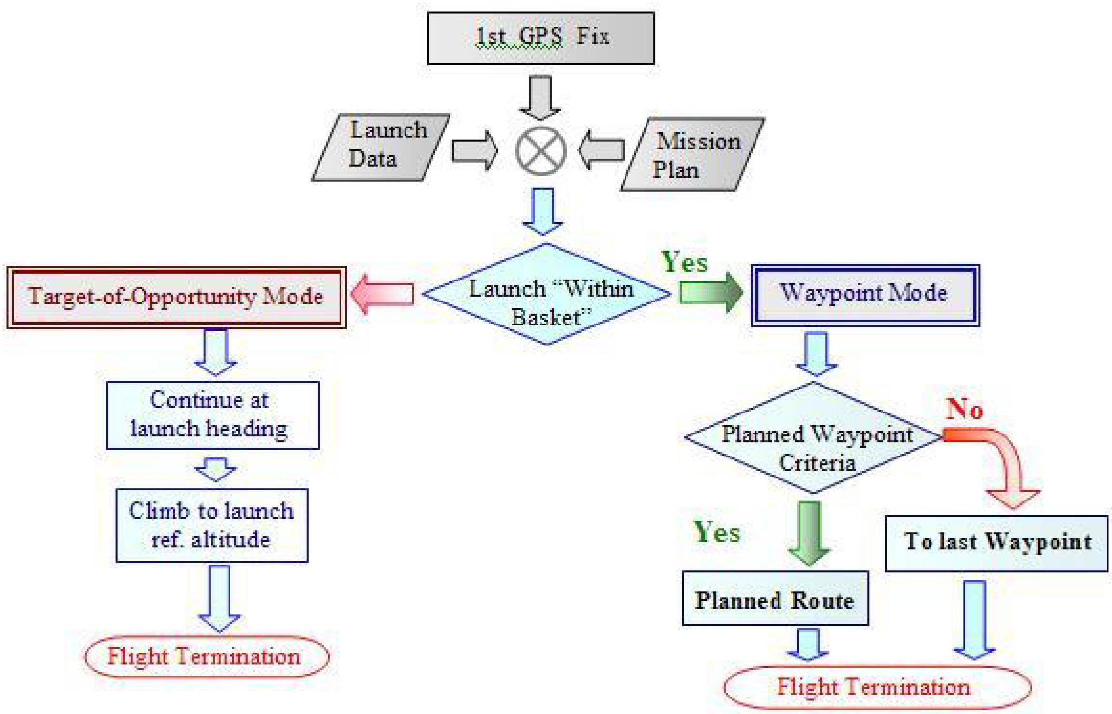


Figure 3-6: ITALD-GPS Navigation Mode Logic

Source: *ITALD-GPS Final Design Review*. Israel: Israeli Military Industries, LTD, June 2001.

The Primary telemetry system was exactly the same as the one used in the DT-IIIE testing providing the data from all the aerodynamic sensors, the FTS and Digital Engine Controller (DEC). The Secondary system was added to monitor GPS position and velocity data as well as internal computations from the FCA. The Flight Termination System, which transmitted at 425 MHz, was the same one used in the DT-IIIE testing with the replacement of an obsolete power divider. The FTS, powered by both an internal battery and the ITALD main battery, shut down the fuel pump and commanded the flight controls to maximum opposite directions. The decoys were ballasted to maintain the same operational weight, center of gravity (cg) and inertial properties. Finally, the ITALD-GPS was finished with a highly visible orange paint to enhance visual observation. Despite these modifications, the ITALD-GPS ET vehicles were considered production representative for flight test purposes [16, 22].

F/A-18C Aircraft

The F/A-18C/D Hornets used for the flight tests were twin-engine fighter/attack aircraft built by the Boeing Aircraft Company. The Hornet, the US Navy's first strike fighter aircraft, was capable of employing both air-to-air and air-to-surface weapons including the latest "smart" weapons that are GPS guided. Two General Electric F404-GE-400/402 turbofan afterburning engines powered the aircraft. Figure 3-7 is a multi angle illustration of the Hornet. The F/A-18C model was a single seat aircraft while the D model had dual tandem seating. The basic gross weight of the test aircraft was approximately 25,000 pounds, which included test-specific instrumentation [20].

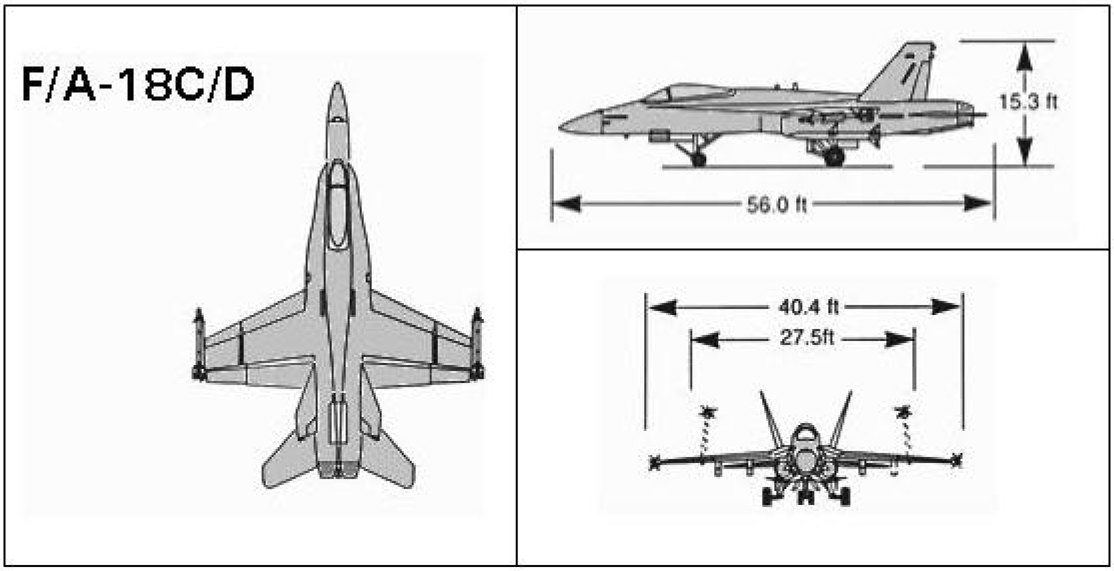


Figure 3-7: F/A-18C/D Hornet Illustration

Source: *F/A-18 Hornet*. Washington DC: Federation of American Scientists Military Analysis Network, 25 April 2000.
URL: www.fas.org/man/dod-101/sys/ac/equip/tald.htm

The F/A-18C/D had nine weapons stations numbered 1 through 9 starting from the left wing tip station. Stations 1 and 9 were normally for the AIM-9 sidewinder, but could also be loaded with a tracking pod that provides time, space and position information (TSPI). The four wing stations 2, 3, 7 and 8 were designed to carry the majority of the ordnance using pylons that contain the BRU-32 ejector rack. The wing stations were capable of carrying the Improved Triple Ejector Rack, ITER which was used to carry and deliver the ITALD. The centerline station was used primarily for an external fuel tank. For simplicity, the station loadings will be depicted as if looking forward from the rear of the aircraft, shown in Figure 3-8 [15].

Test Modification / Instrumentation

The F/A-18C, used for the ITALD-GPS DT-IIIF flight tests was bureau number 163429, assigned to Naval Weapons Test Squadron, China Lake (NWTS-CL). The ITALD instrumentation control box was installed in the cockpit and three video cameras, two Over-the-Shoulder (OTS) and one Heads-Up-Display (HUD), recorded the cockpit displays onto 8mm tapes. The aircraft was equipped with Aircraft Monitor and Control (AMAC) wiring to allow the pilot to power the ITALD-GPS on the ITER using the ITALD Instrument Control Box [22].

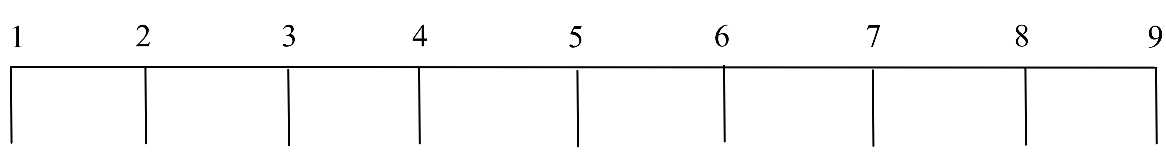


Figure 3-8: F/A-18C/D Hornet Station Diagram

Source: Author

ITALD Instrument Control Box

The ITALD Instrument Control Box, Figure 3-9, was installed on the right cockpit console and used the Aircraft Monitor and Control (AMAC) wiring installed in the pylon to power the ITALD mounted via an ITER on aircraft stations 2 or 8. The control box contained four lights; master power light, instrumentation power light, and two aircraft station lights. Using the Instrument Control Box, the pilot could power the instrumentation package installed with either internal battery or aircraft power. The ITALD-GPS instrumentation package contained two batteries, which supplied power to the FTS, TM system and C-band locator beacon. To ensure successful tracking and data capture, the pilot used the ITALD Instrumentation Control Box to power the FTS, TM system and C-band locator beacon prior to launch [15].

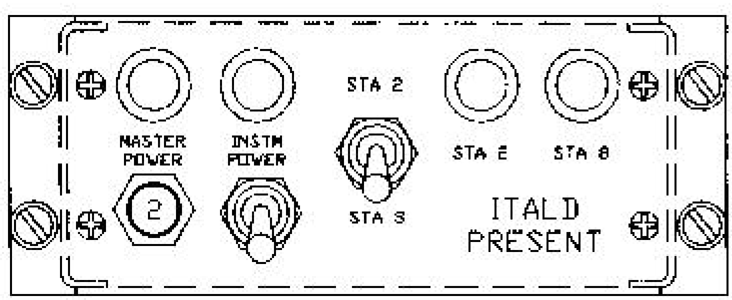


Figure 3-9: ITALD Instrument Control Box

Source: *Improved Tactical Air Launched Decoy (DT-IIIF) Flight Test Plan GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, September 2001.

Improved Triple Ejector Rack

The Improved Triple Ejection Rack (ITER), BRU-42A, consisted of an adapter assembly with three ejector units. Each ejector unit had two suspension hooks spaced 14 inches apart. During weapon release, a cartridge detonation opened the suspension hooks and forcibly ejected the stores with a single ejector foot. The ITER attached to the F/A-18 pylon via the BRU-32 ejector rack. The ITER was not jettisonable and the BRU-32 was not configured with Cartridge Activated Devices (CADs). The ITALD-GPS vehicles were loaded on one or both of aircraft stations 2 and 8, with only a single vehicle per aircraft station. The ITALD-GPS vehicle could be loaded on either the left or right side of the ITER (cannot launch from ITER centerline on stations 2 and 8), as shown in Figure 3-10 [15].

Figure 3-10: ITALD Mounted on ITER Shoulder Station

Source: Photos from the DT-IIIE Terrain Following Evaluation, October 2000.

CHAPTER IV

ITALD-GPS METHOD OF TEST

Scope of the Test

Israeli Military Industries produced five ITALD-GPS Engineering Test (ET) vehicles to be used for the DT-IIIF evaluation on the NAWC-WD Sea Test Range (STR) off the coast of NAS Point Mugu, CA. The five missions evaluated the navigation system as well as reliability. This discussion will address the flight planning associated with the testing of the GPS based navigation system. The test objectives were derived from the classified Operational Requirements Document (ORD) [9] the Test and Evaluation Master Plan (TEMP) and the ITALD System Specification [6].

Preflight Preparation

After completion of ITER electrical checks, the ITALD-GPS ET vehicles were loaded onto the ITER “shoulder” stations as shown in the loading diagram Figure 4-1. Engineers from NAWC-WD and IMI performed an aircraft compatibility test which verified the aircraft’s capability to successfully launch the ITALD-GPS. They also performed a full diagnostic of the ITALD-GPS with the Improved Decoy Tester Programmer (IDTP), testing all the circuits for continuity including autopilot functions and firing circuits. In addition to the GO/NO-GO tests, the engineers loaded the mission flight profile and GPS almanac data into the FCA and NP using the IDTP.

Station*	1	2	3	4	5	6	7	8	9
Flight 1 (5)	□	●▽	○				○	▽◌	□
Flight 2 (2)	□	▽●			○			▽	□
Flight 3 (3)	□	▽			○			▽●	□
Flight 4 (1)	□	●▽			○			▽	□
Flight 5 (4)	□	▽	○				○	●▽	□

Figure 4-1: DT-IIIF Store Loading Diagram

Notes: * Number in Parentheses is the Profile Number

▽ BRU-42A ○ Fuel Tanks □ ARDS Pod

● Launch ITALD-GPS Primary

◌ Dashed lines indicate secondary ITALD-GPS loading

Source: *Report of Test Results, Improved Tactical Air Launched Decoy (DT-IIIF) GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, June 2002.

The IDTP GPS almanac was checked for currency prior to loading it into the decoy's memory. The engineers removed and replaced the nose cone to fully charge the Flight Termination System (FTS) and Telemetry (TM) batteries. Electromagnetic Compatibility (EMC) Safety of Flight (SOF) tests ground and airborne test were conducted prior to the first test flight [22].

ITALD-GPS Launch Profiles

Profile 1: Typical Strike Profile

The objective of Profile 1, described in Table 4-1 and Figure 4-2, was to simulate a standard strike route with an offset turn to simulate Doppler radar acquisition of the target, then direct to the target for a dive weapons delivery profile. The launch parameters were planned for 35k ft MSL with a release speed of 265 KCAS. This profile validated the accuracy of the GPS waypoint system and tested the turn performance of the 2-axis gyro with 45 and 90 degree turns [15].

Table 4-1: Profile 1 Program– Typical Strike

Wypt	**RANGE [NM]**	**ALTITUDE [ft – MSL]**	**TURN [degrees]**	**ENGINE SETTING**	**PAYLOAD**
Launch	0	35,000	N/A	N/A	N/A
1.	90	30,000	Right 45	HIGH	OFF
2.	25	30,000	Left 90	HIGH	ON
3.	30	15,000	N/A	HIGH	ON

Source: *Improved Tactical Air Launched Decoy (DT-IIIF) Flight Test Plan GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, September 2001.

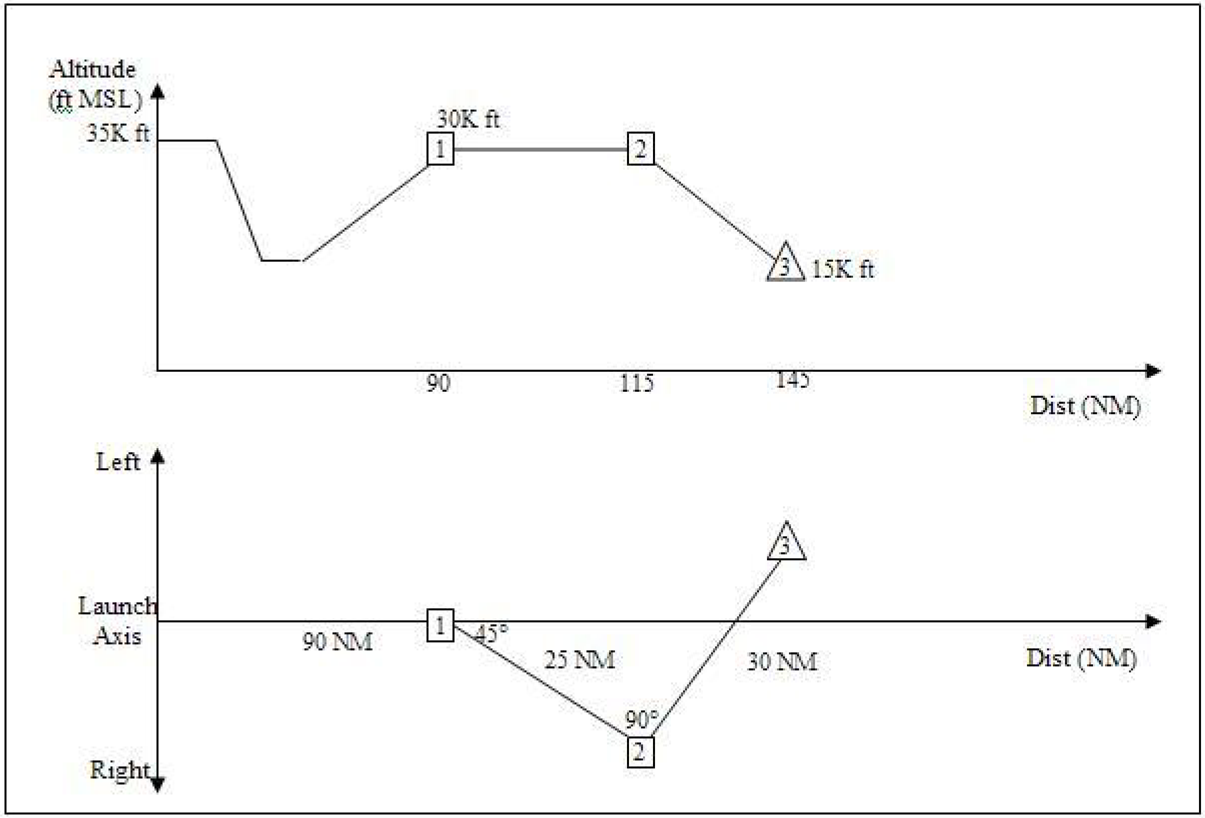


Figure 4-2: Profile 1 Route - Typical Strike Profile

Source: *Improved Tactical Air Launched Decoy (DT-IIIF) Flight Test Plan GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, September 2001.

Profile 2: Target of Opportunity Mode

The objective of Profile 2, described in Table 4-2 and Figure 4-3, was to test the Target of Opportunity (TOO) mode of the ITALD-GPS navigation system. The planned launch parameters, indicated by dashed lines in Figure 4-3, were 12k ft MSL, 350 KEAS and a Termination Time of 10 minutes. The ITALD-GPS would then be launched at 20k ft MLS at 365 KCAS (350 KEAS) and within 30° of the planned launch heading. The ITALD-GPS should then invoke the TOO mode, flying in a straight line at 20k ft with the payload commanded to ON, due to the launch altitude exceeding that specified by the launch basket [15].

Table 4-2: Profile 2 Program – Target of Opportunity Mode

Wypt	**RANGE [NM]**	**ALTITUDE [ft – MSL]**	**TURN [degrees]**	**ENGINE SETTING**	**PAYLOAD**
Launch	0	20,000	N/A	N/A	N/A
1.	30	20,000	Right 30	HIGH	OFF
2.	30	20,000	Left 30	HIGH	OFF
3.	20	20,000	0	HIGH	ON
4.	30	25,000	N/A	HIGH	ON

Source: *Improved Tactical Air Launched Decoy (DT-IIIF) Flight Test Plan GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, September 2001.

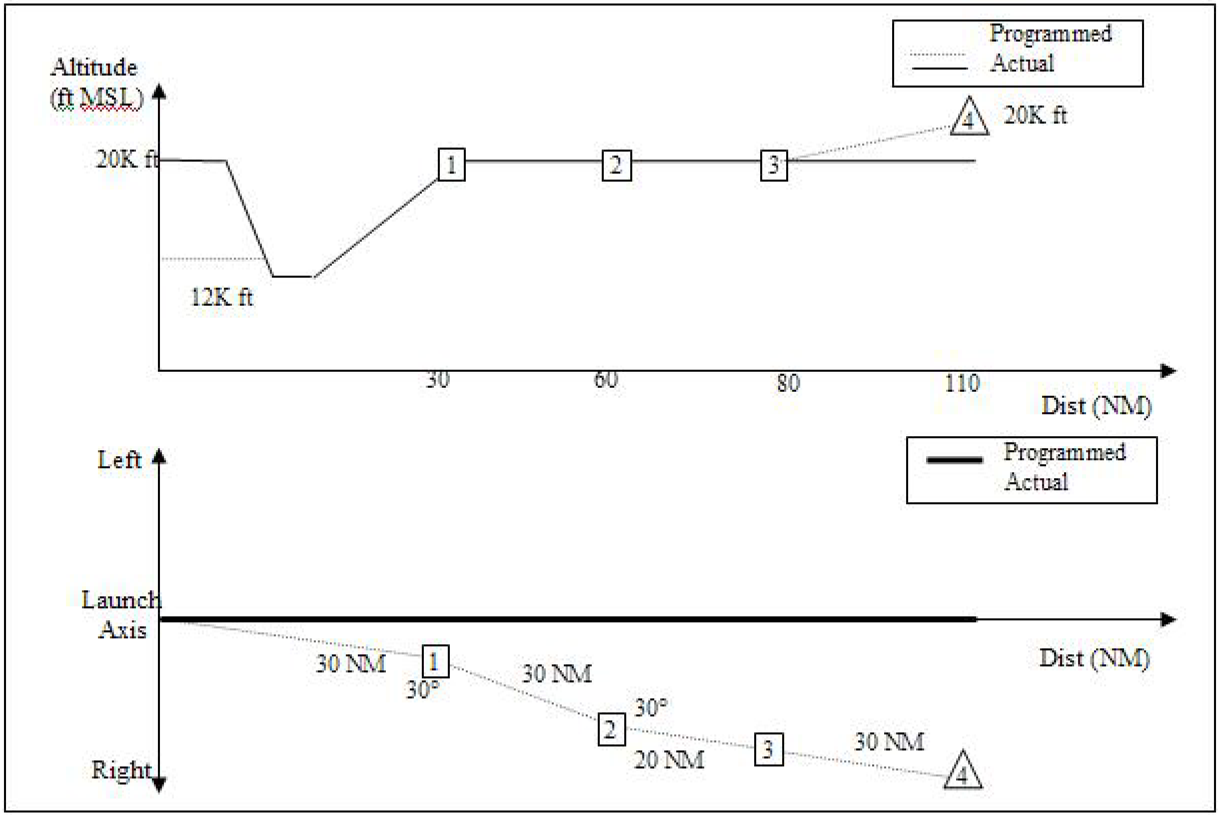


Figure 4-3: Profile 2 Route – Target of Opportunity Mode

Source: *Improved Tactical Air Launched Decoy (DT-IIIF) Flight Test Plan GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, September 2001.

Profile 3: High Altitude Strike

The objective of Profile 3, described in Table 4-3 and Figure 4-4, was to validate the ITALD-GPS ability to navigate an entire 7-waypoint route. The ITALD-GPS was to be launched at 25k ft MSL and 370 KCAS. The multiple route changes simulated evading known surface-to-air missile systems to attack the designated target [15].

Profile 4: Low Level Ingress

The objective of Profile 4, depicted in Table 4-4 and Figure 4-5, was to simulate a low-level ingress towards the target while evading enemy radar followed by a pop-up attack for weapon delivery. The land-based test range at NAWC-WD China Lake was not large enough to fly the route, so the flight was conducted over water on the Point Mugu Sea Test Range. The ITALD-GPS was to be launched at 1.3k ft AGL and 395 KCAS. The turns simulated navigating in mountainous terrain to mask the vehicle from enemy radar until the ITALD-GPS executed its simulated pop-up attack [15].

Profile 5: Direct to Last Waypoint

The objective of Profile 5, described in Table 4-5 and Figure 4-6, was to test the Direct to Last Waypoint mode of the ITALD-GPS navigation system. The programmed launch point was 10k ft MLS and 355 KCAS with a planned deviation of 30° to the right of the programmed course. The dashed lines in Figure 4-6 indicate the programmed flight path and the solid lines indicate the expected flight path [15].

Table 4-3: Profile 3 Program– High Altitude Strike

Wypt	**RANGE [NM]**	**ALTITUDE [ft – MSL]**	**TURN [degrees]**	**ENGINE SETTING**	**PAYLOAD**
Launch	0	25,000	N/A	N/A	N/A
1	25	17,000	Right 30	HIGH	OFF
2	20	25,000	Left 30	HIGH	ON
3	20	25,000	Right 20	HIGH	ON
4	20	25,000	Left 20	HIGH	ON
5	20	22,000	Left 45	Medium	ON
6	20	10,000	0	Medium	ON
7	10	10,000	N/A	Medium	ON

Source: *Improved Tactical Air Launched Decoy (DT-IIIF) Flight Test Plan GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, September 2001.

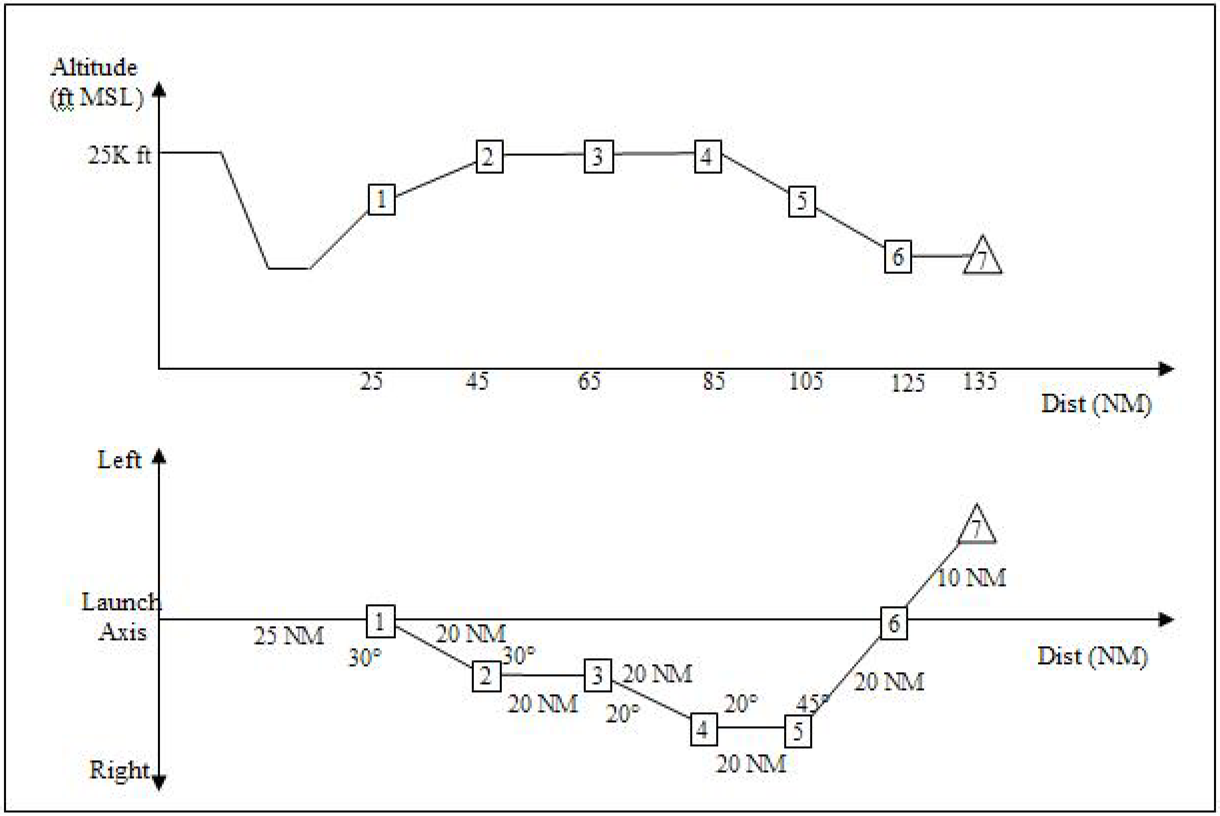


Figure 4-4: Profile 3 Route – High Altitude Strike

Source: *Improved Tactical Air Launched Decoy (DT-IIIF) Flight Test Plan GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, September 2001.

Table 4-4: Profile 4 Program – Low Level Ingress

Wypt	RANGE [NM]	ALTITUDE [ft]	TURN [degrees]	ENGINE SETTING	PAYLOAD
Launch	0	1000 AGL	N/A	N/A	N/A
1.	15	500 AGL	Left 35	HIGH	OFF
2.	20	500 AGL	Right 35	HIGH	OFF
3.	20	500 AGL	Right 45	HIGH	OFF
4.	20	6,000 MSL	0	Medium	ON
5.	15	6,000 MSL	N/A	Medium	ON

Source: *Improved Tactical Air Launched Decoy (DT-IIIF) Flight Test Plan GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, September 2001.

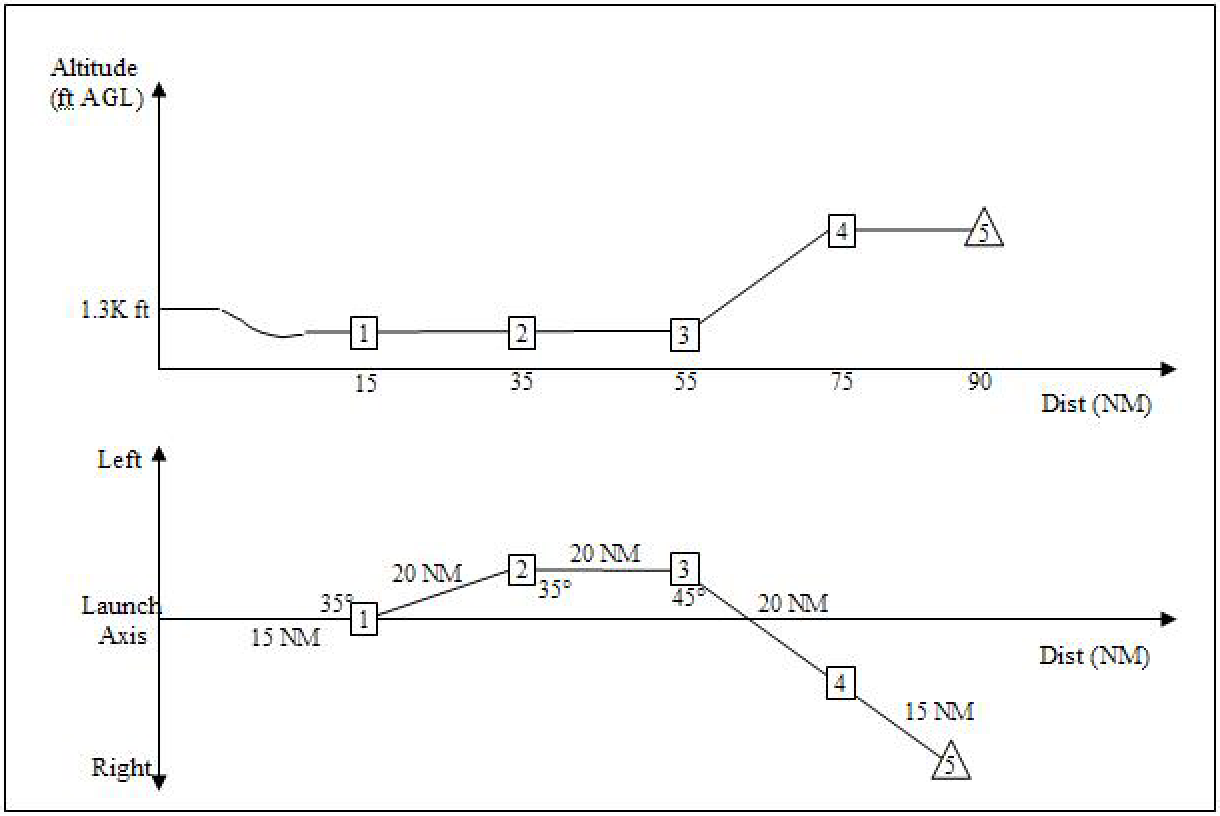


Figure 4-5: Profile 4 Route – Low Level Ingress

Source: *Improved Tactical Air Launched Decoy (DT-IIIF) Flight Test Plan GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, September 2001.

Table 4-5: Profile 5 Program– Direct to Last Waypoint

Wypt	**RANGE [NM]**	**ALTITUDE [ft – MSL]**	**TURN [degrees]**	**ENGINE SETTING**	**PAYLOAD**
Launch	0	10,000	N/A	N/A	N/A
1.	27	10,000	Left 45	HIGH	OFF
2.	25	10,000	Right 90	HIGH	OFF
3.	25	10,000	N/A	HIGH	ON

Source: *Improved Tactical Air Launched Decoy (DT-IIIF) Flight Test Plan GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, September 2001.

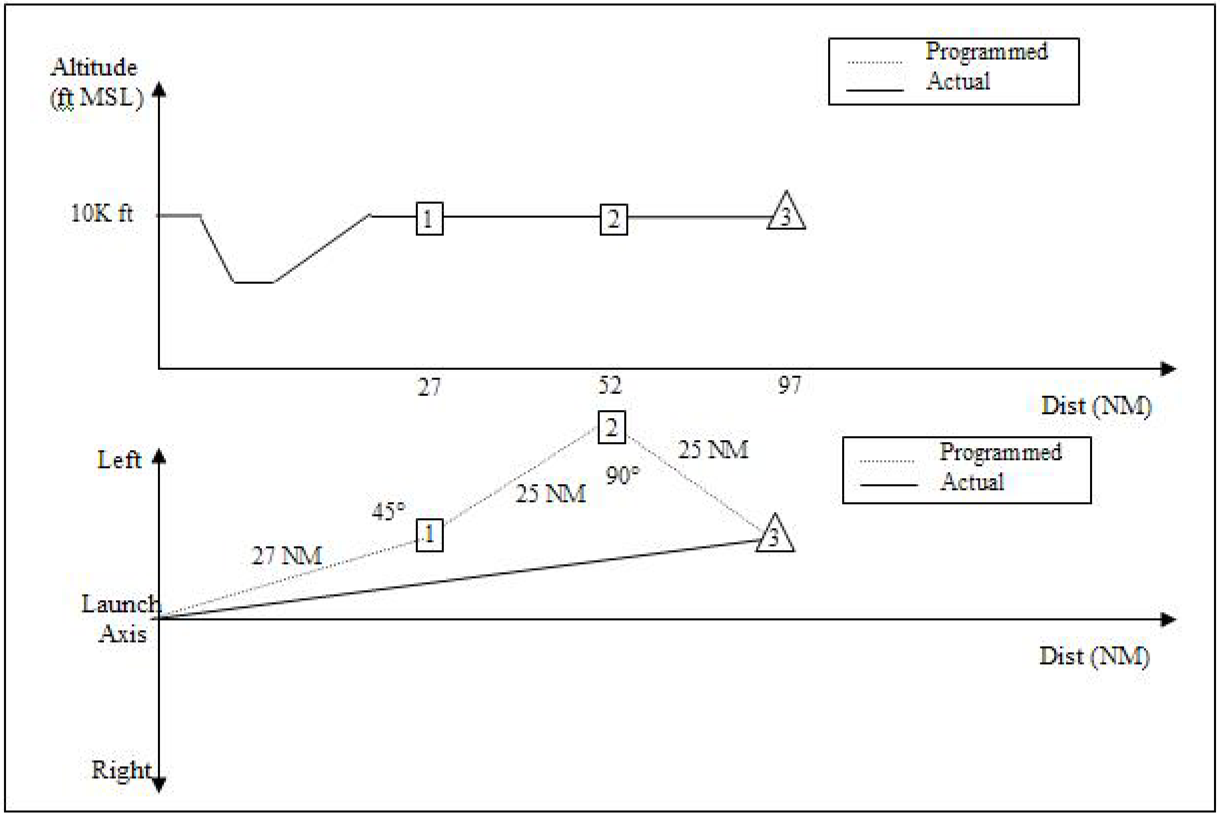


Figure 4-6: Profile 5 Route – Direct to Last Waypoint

Source: *Improved Tactical Air Launched Decoy (DT-IIIF) Flight Test Plan GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, September 2001.

CHAPTER V

ITALD-GPS TEST RESULTS

General

The five DT-IIIF test flights were conducted in October 2001 on the NAWC-WD Sea Test Range using an F/A-18C assigned to NAWC-WD China Lake and the five ITALD-GPS ET vehicles. Table 5-1 provides a summary of the actual launch conditions. The EMC SOF ground and airborne checks were successfully completed prior to Flight 1.

The Time-Space-Position Information (TSPI) overhead views and altitude plots are provided for each flight profile along with tables listing wind conditions and a comparison of the actual versus planned flight profiles.

Table 5-1: ITALD-GPS Launch Conditions

LAUNCH DATA	Profile 1 (Flight 4)	Profile 2 (Flight 2)	Profile 3 (Flight 3)	Profile 4 (Flight 5)	Profile 5 (Flight 1)
Date	12 Oct 2001	10 Oct 2001	11 Oct 2001	19 Oct 2001	05 Oct 2001
Latitude	N 33-49-00	N 33-42-00	N 33-47-00	N 33-46-44	N 33-47-00
Longitude	W 119-35-00	W 119-35-00	W 119-41-03	W 119-30-21	W 119-30-00
Heading	246.5º True	233º True	233º True	242º True	250º True
Airspeed (KCAS)	265	365	370	396	355
Airspeed (KTAS)	458	493	535	407	418
Mach	0.78	0.78	0.87	0.61	0.64
Altitude (ft MSL)	35,000	20,000	25,000	N/A	9,990
Altitude (ft AGL)	35,128	21,028	24,079	1,297	10,328

Source: *Report of Test Results, Improved Tactical Air Launched Decoy (DT-IIIF) GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, June 2002.

Flight Profile 1 -Typical Strike - Results

Separation and Engine Start

Flight Profile 1, simulating a typical strike, was conducted on Flight 4 to verify the ITALD-GPS navigational accuracy and heading change performance. Table 5-2 lists wind conditions. The decoy was launched from the outboard ITER station mounted on the F/A-18C Station 2 pylon at 35,000 ft MSL and 265 KCAS. After safe separation, the ITALD-GPS rolled left 46.5° to level flight and the wings deployed at 3.1 s. The FCA declared GPS information valid at 40.1 s during the dive for engine start. At 120.1 s (2 min 0.1 s), the engine inlet cover ejected and the engine began its windmill start process at 122.6 s (2 min 2.6 s). At 15,700 ft MSL and 124.2 s (2 min 4.2 s) the igniter fired and the engine started successfully. The ITALD-GPS bottomed out at 13,100 ft MSL post start and the decoy began a climb to 30,000 ft MSL [22].

Navigation Performance

Table 5-3 summarizes planned versus actual flight performance. Figure 5-1 and 5-2 are time-space-position plots showing overhead and side views of the flight. The ITALD-GPS intercepted Wypt 1 at 651.5 s (10 min 51.5 s), Wypt 2 at 813.4 s (13 min 33.4 s), and initiated turn toward Wypt 3. The navigation system commanded a 72° heading change vice the planned 90° due to system drift and gyroscopic limitations resulting in an 8.3 nm lateral miss distance from the third and final waypoint at 1046.0 s (17 min 26 s). GPS performance was adequate during flight. The descent command was also overridden due to the course correction towards the last waypoint.

Table 5-2: Profile 1 Wind Conditions

Altitude (ft MSL)	Wind Direction (ºTrue)	Wind Speed (knots)	Crosswind (knots)	Tailwind (knots)
15,000	317	21	20 left to right	7
20,000	322	27	26 left to right	6
25,000	325	29	29 left to right	5
30,000	328	33	33 left to right	4
35,000	329	26	26 left to right	3

Source: *Report of Test Results, Improved Tactical Air Launched Decoy (DT-IIIF) GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, June 2002.

Table 5-3: Profile 1 Planned Versus Actual

Flight Event	PLANNED			ACTUAL			Winds (Knots / ºTrue)
	Altitude (ft MSL)	Course (º True)	Mach	Altitude (ft MSL)	Course[1] (º True)	Mach	
Launch Point	35,000	246.5	0.78	35,000	246.5	0.78	26 / 329
Approaching Waypoint 1	30,000	246.5	0.81	30,100	244	0.80	33 / 328
After Turn at Waypoint 1	30,000	292	0.81	30,200	292	0.80	33 / 328
Approaching Waypoint 2	30,000	292	0.81	31,000	290	0.83	33 / 328
After Turn at Waypoint 2	30,000	202	0.82	31,000	218	0.83	33 / 328
Approaching Waypoint 3	15,000	202	0.80	30,000	220	0.80	33 / 328

Note 1: The ITALD-GPS experienced continuous course changes on each flight profile. The value shown represents the average of the course variations, which were less than ± 2.5°.

Source: *Report of Test Results, Improved Tactical Air Launched Decoy (DT-IIIF) GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, June 2002.

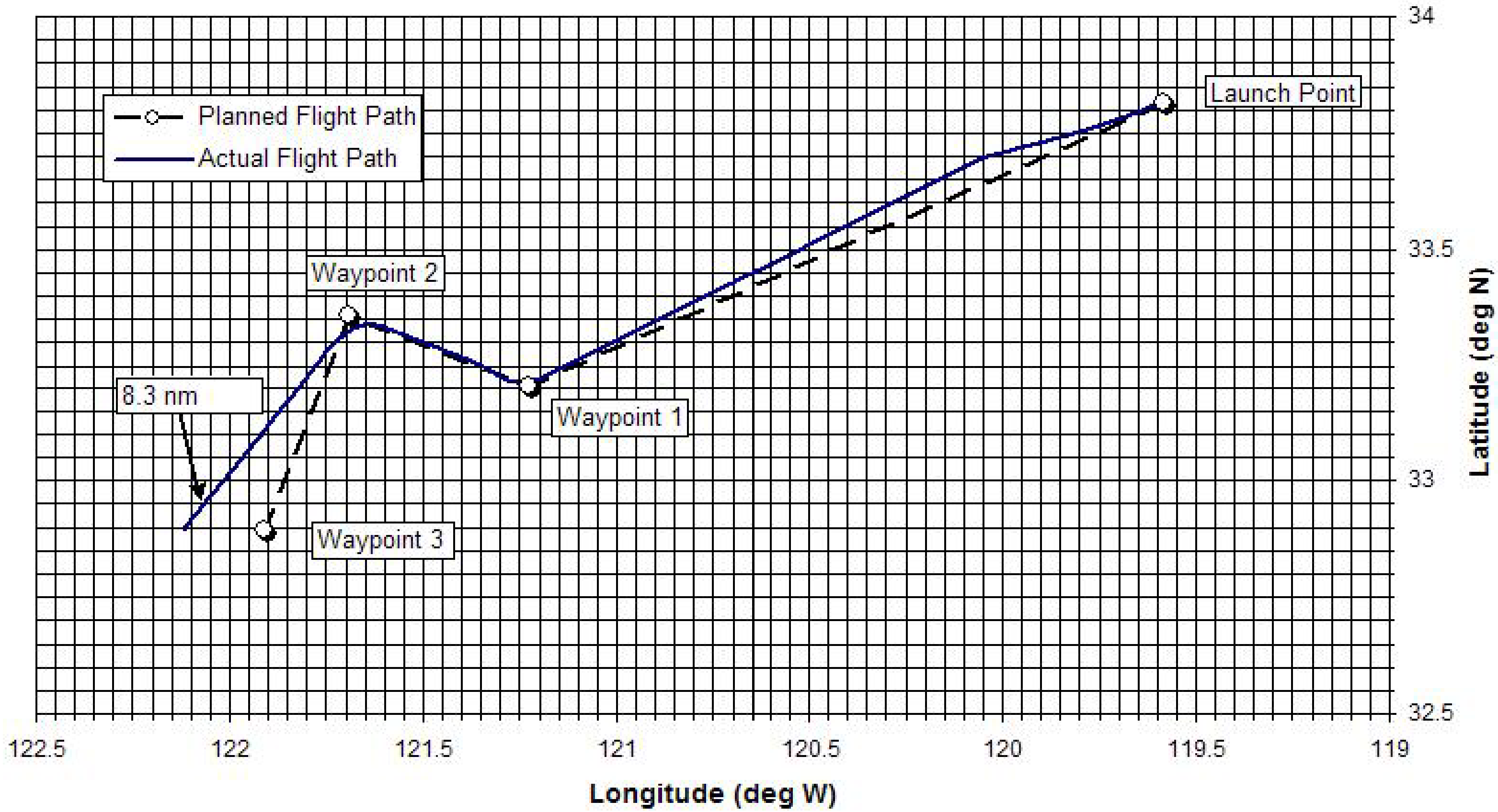


Figure 5-1: ITALD-GPS Profile 1 Ground Track

Source: *Report of Test Results, Improved Tactical Air Launched Decoy (DT-IIIF) GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, June 2002.

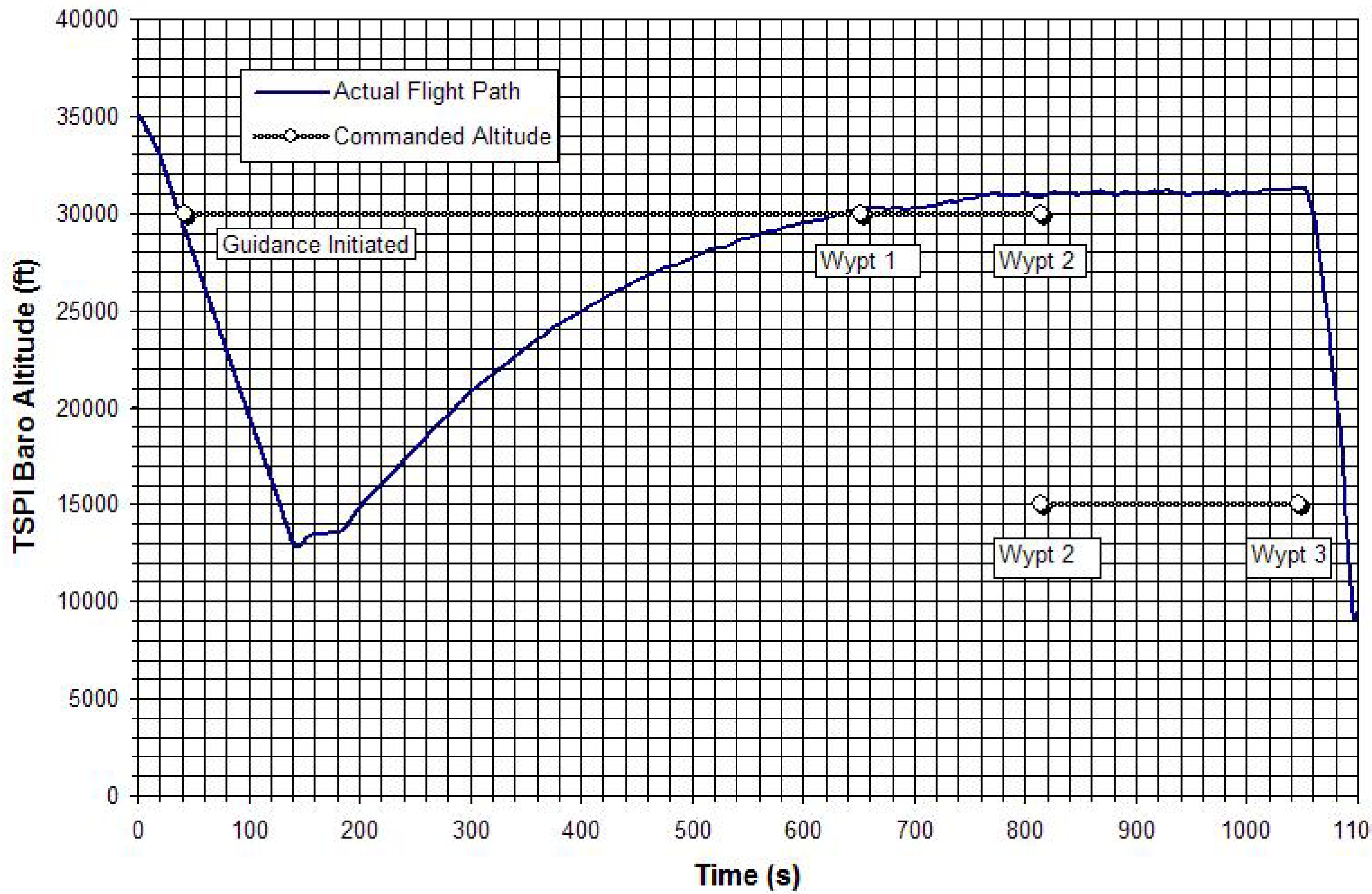


Figure 5-2: ITALD-GPS Profile 1 Side View

Source: *Report of Test Results, Improved Tactical Air Launched Decoy (DT-IIIF) GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, June 2002.

The ITALD-GPS received the destruct command at 1,100 s (18 min 20 s) and TM loss occurred at 1,112 s (18 min 32 s) [22].

Flight Profile 2 - Target of Opportunity - Results

Separation and Engine Start

Flight Profile 2, which tested the Target of Opportunity (TOO) mode, was conducted on Flight 2. Table 5-4 lists the wind conditions. The ITALD-GPS was launched at 20,000 ft MSL and 365 KCAS from the inboard ITER station mounted on the F/A-18C Station 2 pylon along a course of 234° true. After safe separation, the ITALD-GPS rolled right 46.5° to level flight and the wings deployed at 3.1 s. At 28.8 s, the engine inlet cover ejected and the engine windmill start process began at 32.9 s. At 15,400 ft MSL and 34.4 s the igniter fired and the engine started successfully. The ITALD-GPS bottomed out at 12,700 ft MSL post start and began a climb back up to 20,000 ft MSL [22].

Navigation Performance

Table 5-5 provides a comparison of actual versus planned performance. Figure 5-3 and 5-4 are time-space-position plots showing overhead and side views of the flight. The FCA declared the GPS data valid at 51.9 s and the ITALD-GPS tracked an average course of 235° true with a maximum deviation rate of 0.07 degrees/minute. The GPS stabilized heading kept the ITALD-GPS tracking to within a degree of the launch bearing. The ITALD-GPS also climbed and maintained the correct altitude of 20,000 ft MSL vice descending to the programmed 12,000 ft MSL

Table 5-4: Profile 2 Wind Conditions

Altitude (feet MSL)	Wind Direction (ºTrue)	Wind Speed (knots)	Crosswind (knots)	Tailwind (knots)
15000	296	15	13 left to right	7
20000	304	17	16 left to right	6

Source: *Report of Test Results, Improved Tactical Air Launched Decoy (DT-IIIF) GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, June 2002.

Table 5-5: Profile 2 Planned Versus Actual

Flight Event	PLANNED			ACTUAL			Winds (Knots / º True)
	Altitude (ft MSL)	Course (º True)	Mach	Altitude (ft MSL)	Course[1] (° True)	Mach	
Launch Point	20,000	233	0.78	20,000	233	0.78	17 / 304
Final Point	20,000	233	0.82	20,250	235	0.82	17 / 304

Note 1: The ITALD-GPS experienced continuous course changes on each flight profile. The value shown represents the average of the course variations, which were less than ± 2.5 °.

Source: *Report of Test Results, Improved Tactical Air Launched Decoy (DT-IIIF) GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, June 2002.

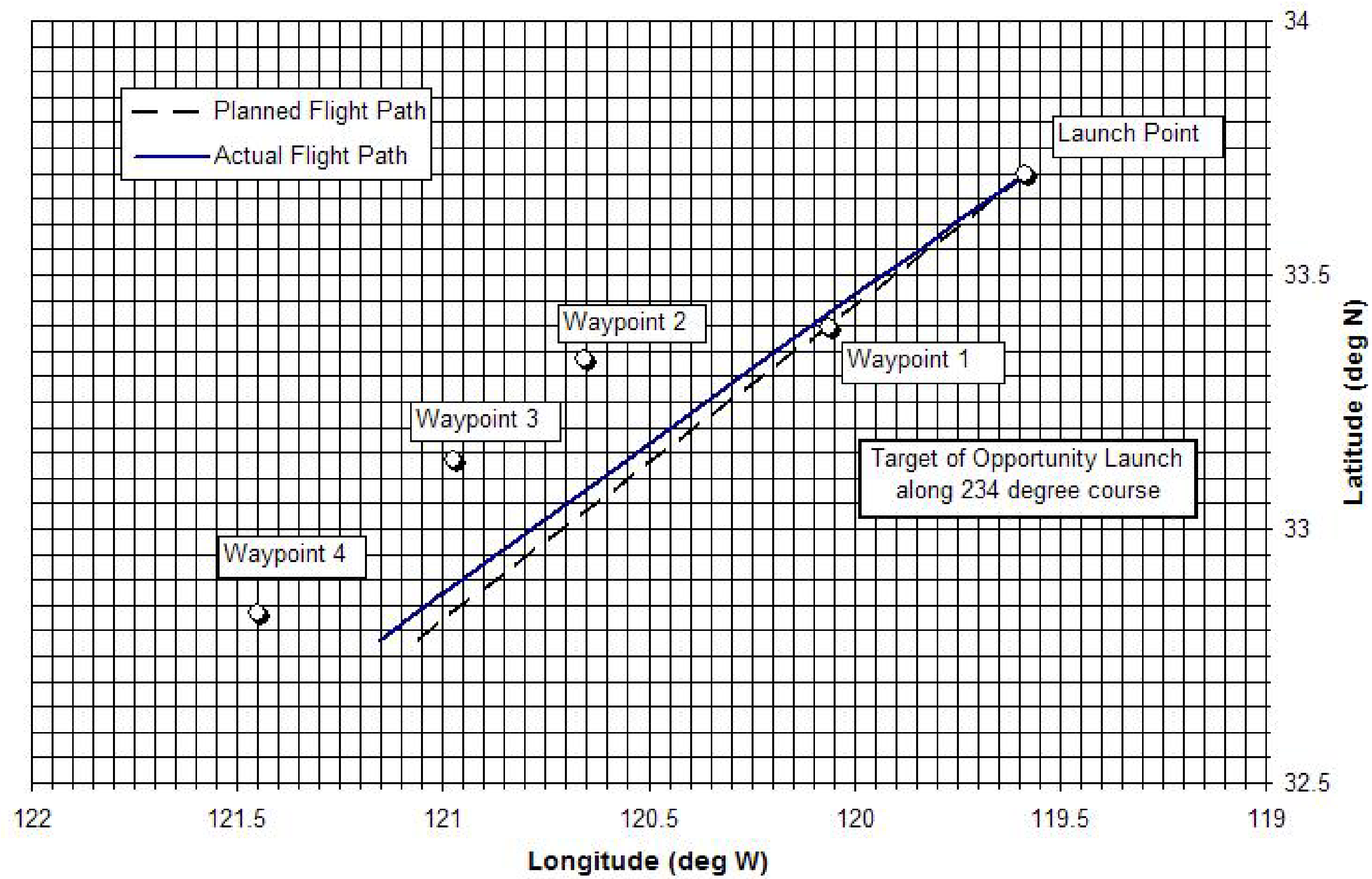


Figure 5-3: ITALD-GPS Profile 2 Ground Track

Source: *Report of Test Results, Improved Tactical Air Launched Decoy (DT-IIIF) GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, June 2002.

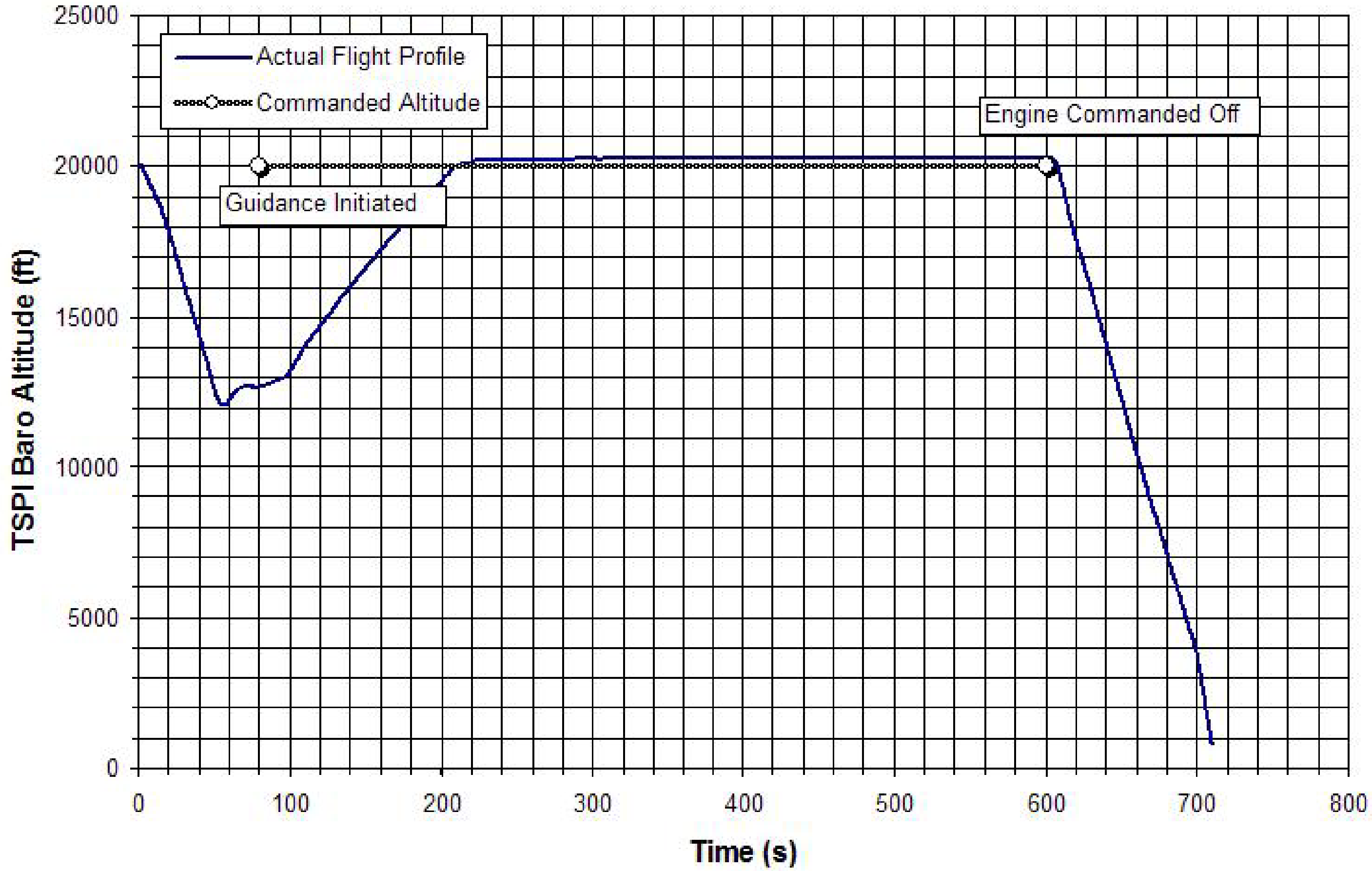


Figure 5-4: ITALD-GPS Profile 2 Side View

Source: *Report of Test Results, Improved Tactical Air Launched Decoy (DT-IIIF) GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, June 2002.

The engine shutdown command was on time at 600.0 s (10 min) and TM loss occurred at 614 s (10 min 14 s) [22].

Flight Profile 3 - High Altitude Strike - Results

Separation and Engine Start

Flight Profile 3, simulating a high altitude strike with 7 waypoints, was conducted on Flight 3. Table 5-6 lists the wind conditions. The ITALD-GPS was launched at 25,000 ft MSL and 370 KCAS. The vehicle was mounted on the outboard ITER station attached to the F/A-18C Station 8 pylon. After safe separation, the ITALD-GPS rolled right 46.5° to level flight and the wings deployed at 3.0 s. At 58.2 s, the engine inlet cover ejected and the windmill start began at 62.2 s (1 min 2.2 s). At 15,400 ft MSL and 64.4 s (1 min 4.4 s), the igniter fired and the engine started successfully. The lowest altitude during the start process was 12,500 ft MSL [22].

Navigation Performance

Table 5-7 provides a comparison of actual versus planned performance. Figure 5-5 and 5-6 are time-space-position plots showing overhead and side views of the flight. The GPS system did not obtain a valid fix until 144.1 s (2 min 24.1 s) due to an insufficient number of GPS satellites acquired during the engine start dive. The FCA initiated guidance commands at 145.1 s (2 min 25.1 s), to correct the ITALD-GPS towards the programmed flight route. The decoy intercepted Waypoint 1 at 146.6 s (2 min 26.6), Waypoint 2 at 329.6 s (5 min 29.6 s), Waypoint 3 at 491.6 s (8 min 11.6 s), Waypoint 4 at 641.7 s (10 min 41.7 s), Waypoint 5 at 777.6 s (12 min 57.6 s), Waypoint 6 at 933.7 s (15 min 33.7 s), and waypoint 7 at 1003.0 s (16 min 43 s).

Table 5-6: Profile 3 Wind Conditions

Altitude (feet MSL)	Wind Direction (°True)	Wind Speed (knots)	Crosswind (knots)	Tailwind (knots)
15,000	310	21	20 left to right	7
20,000	318	29	28 left to right	6
25,000	313	28	28 left to right	5

Source: *Report of Test Results, Improved Tactical Air Launched Decoy (DT-IIIF) GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, June 2002.

Table 5-7: Profile 3 Planned Versus Actual

Flight Event	PLANNED			ACTUAL			Winds (Knots / °True)
	Altitude (ft MSL)	Course (° True)	Mach	Altitude (ft MSL)	Course[1] (° True)	Mach	
Launch Point	25,000	233	0.87	25,000	233	0.87	28 / 313
Approaching Waypoint 1	17,000	233	0.75	13,500	226	0.78	20 / 310
After Turn at Waypoint 1	17,000	263	0.75	13,500	255 - 283	0.78	20 / 310
Approaching Waypoint 2	25,000	263	0.75	20,500	255 - 262	0.76	29 / 318
After Turn at Waypoint 2	25,000	233	0.75	20,500	231	0.76	29 / 318
Approaching Waypoint 3	25,000	233	0.82	25,500	233	0.81	28 / 313
After Turn Waypoint 3	25,000	253	0.82	25,500	254	0.81	28 / 313
Approaching Waypoint 4	25,000	253	0.82	25,500	253	0.82	28 / 313
After Turn at Waypoint 4	25,000	233	0.82	25,500	232	0.82	28 / 313
Approaching Waypoint 5	22,000	233	0.78	22,400	233	0.78	28 / 313
After Turn at Waypoint 5	22,000	188	0.78	22,400	188	0.78	28 / 313
Approaching Waypoint 6	10,000	188	0.80	16,400	189	0.84	21 / 310
After Waypoint 6	10,000	188	0.80	16,400	189	0.84	21 / 310
Approaching Waypoint 7	10,000	188	0.80	11,000	187	0.77	19 / 309

Note 1: The ITALD-GPS experienced continuous course changes on each flight profile. An average value for course is given when actual course variations were less than ± 2.5°. A range of values is given when actual course variations were greater than ±2.5°.

Source: *Report of Test Results, Improved Tactical Air Launched Decoy (DT-IIIF) GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, June 2002.

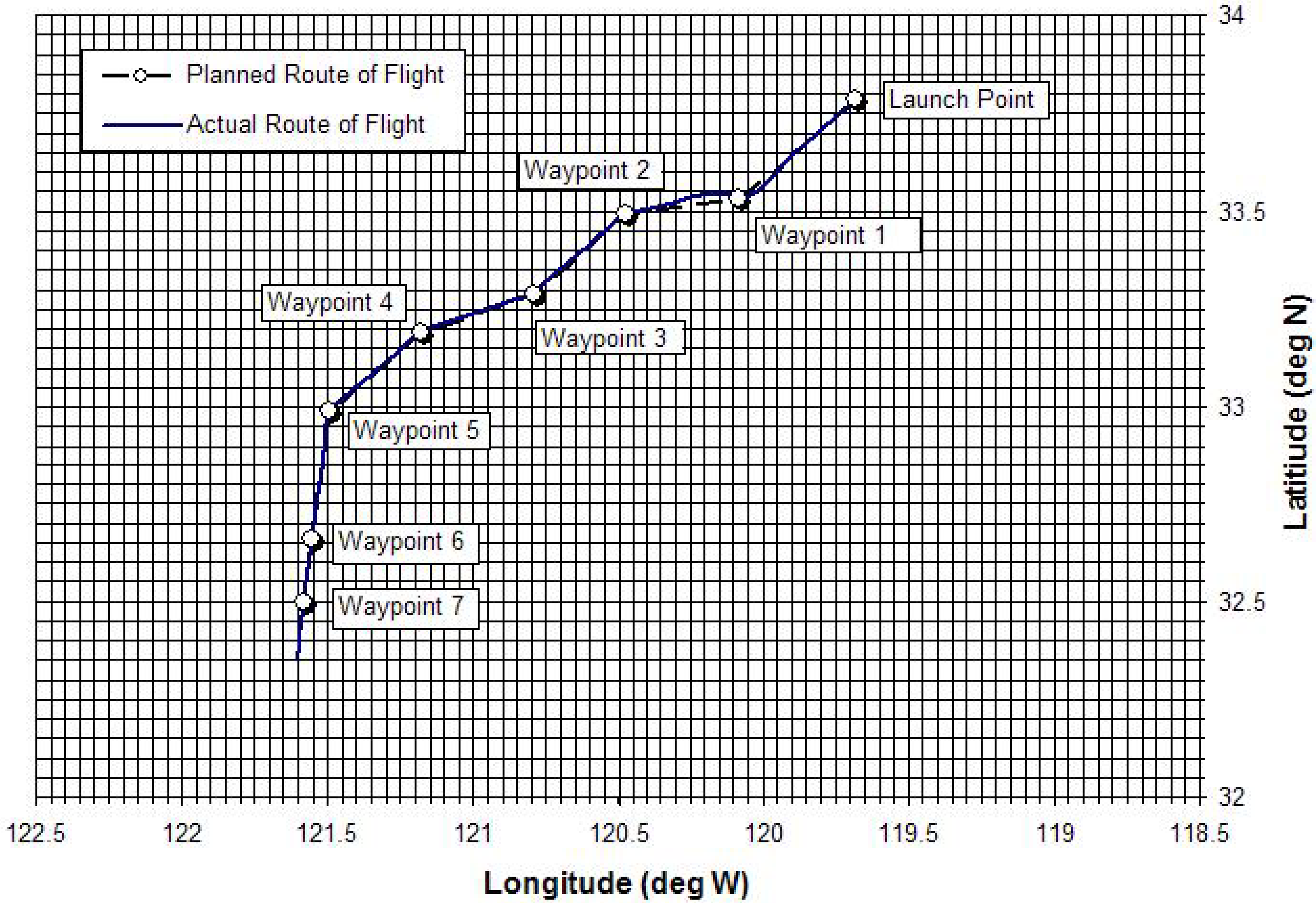


Figure 5-5: ITALD-GPS Profile 3 Ground Track

Source: *Report of Test Results, Improved Tactical Air Launched Decoy (DT-IIIF) GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, June 2002.

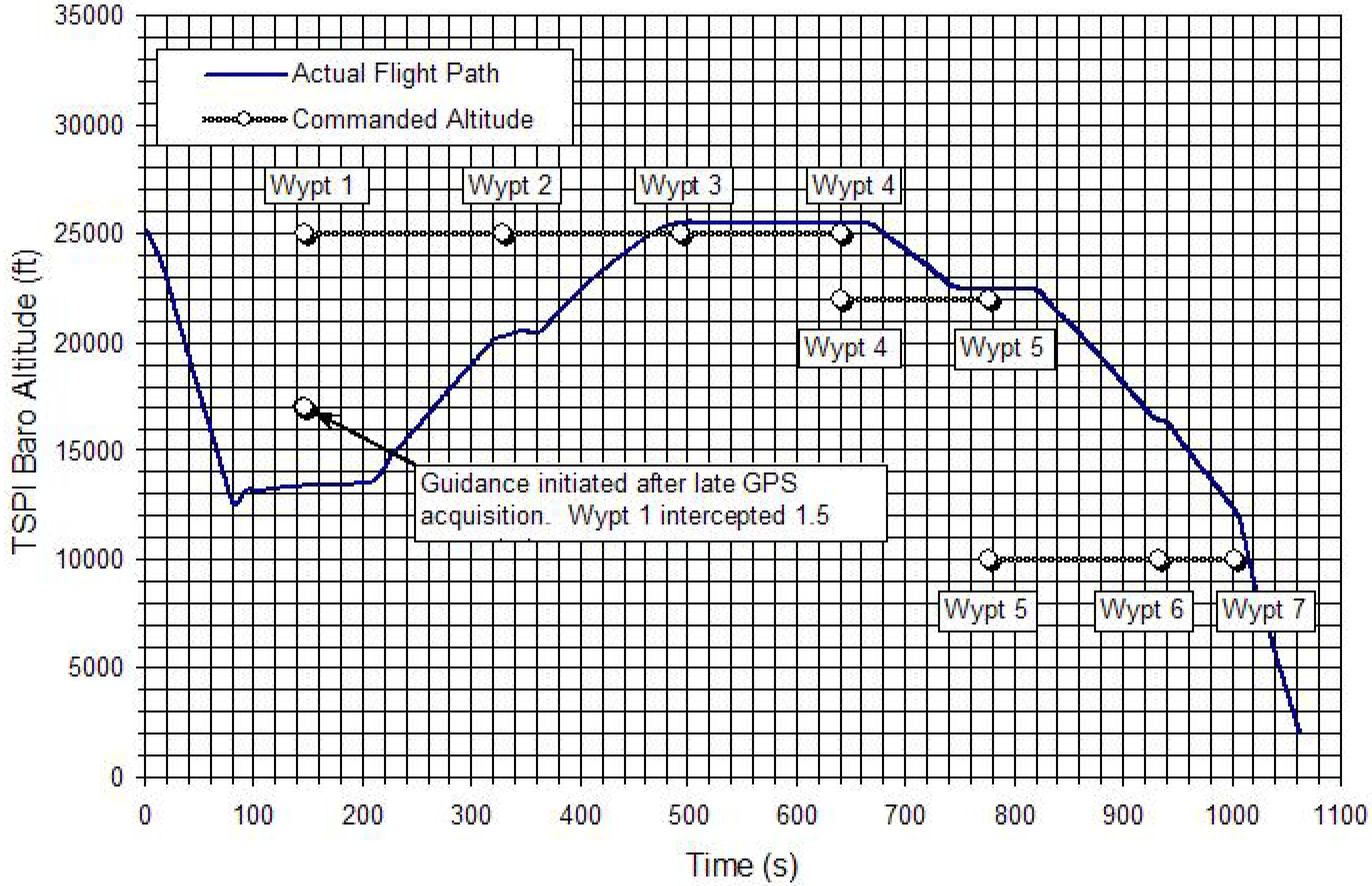


Figure 5-6: ITALD-GPS Profile 3 Side View

Source: *Report of Test Results, Improved Tactical Air Launched Decoy (DT-IIIF) GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, June 2002.

The lateral miss distance at the 7th and final waypoint was 0.03 nm. The ITALD-GPS commanded engine shutdown at 1,000 s (16 min 40 s) and TM was lost at 1035.5 s (17 min 15.5 s) [22].

Flight Profile 4 - Low Level Ingress - Results

Separation and Engine Start

Flight Profile 4, simulating low altitude ingress to the target was conducted on Flight 5 to test the radar altimeter functionality and navigational accuracy. Table 5-8 lists the wind conditions. The ITALD-GPS was launched at 1,297 ft AGL and 395 KCAS from the inboard ITER station mounted on the F/A-18C Station 8 pylon. After safe separation the decoy rolled left 46.5° to level flight and the wings deployed at 3.1 s. The engine inlet cover ejected at 4.1 s and the windmill start process began at 7.9 s. At 990 ft AGL and 8.9 s, the igniter fired and the engine started successfully. The ITALD-GPS descended to a minimum altitude of 341 feet AGL [22].

Navigation Performance

Table 5-9 provides a comparison of actual versus planned performance. Figure 5-7 and 5-8 are time-space-position plots showing overhead and side views of the flight. The FCA declared the GPS inputs valid at 44.2 s and the ITALD-GPS reached Waypoint 1 at 109.5 s (1 min 49.5 s), Waypoint 2 at 254.6 s (4 min 14.6 s), Waypoint 3 at 395.6 s (6 min 35.6 s) and Waypoint 4 at 562.5 s (9 min 22.5 s). After Waypoint 4, the flight program called for a climb from 500 ft AGL to 6000 ft MSL, but the navigation system inhibited the climb command due to the cross range error exceeding the 3,000 ft threshold parameter.

Table 5-8: Profile 4 Wind Conditions

Altitude (feet MSL)	Wind Direction (ºTrue)	Wind Speed (knots)	Crosswind (knots)	Headwind (knots)
500	104	15	9 right to left	12
1,000	106	11	11 right to left	11
1,300	88	12	7 right to left	10

Source: *Report of Test Results, Improved Tactical Air Launched Decoy (DT-IIIF) GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, June 2002.

Table 5-9: Profile 4 Planned Versus Actual

Flight Event	PLANNED			ACTUAL			Winds (Knots / ºTrue)
	Altitude (ft AGL)	Course (º True)	Mach	Altitude (ft AGL)	Course[1] (º True)	Mach	
Launch Point	1,300	242	0.61	1,297	242	0.61	12 / 88
Approaching Waypoint 1	500	242	0.67	600	241	0.75	15 / 104
After Turn Waypoint 1	500	207	0.67	600	207	0.75	15 / 104
Approaching Waypoint 2	500	207	0.75	600	207	0.75	15 / 104
After Turn Waypoint 2	500	242	0.75	600	239	0.75	15 /104
Approaching Waypoint 3	500	242	0.78	600	240 - 246	0.76	15 / 104
After Turn Waypoint 3	500	287	0.78	600	279 - 294	0.76	15 / 104
Approaching Waypoint 4	6000	287	0.68	550	278 - 299	0.75	15 / 104
After Waypoint 4	6000	287	0.68	550	309 - 266	0.75	15 / 104
Approaching Waypoint 5	6000	287	0.66	850	252 - 315	0.74	10 / 106

Note 1: The ITALD-GPS experienced continuous course changes on each flight profile. An average value for course is given when actual course variations were less than ± 2.5°. A range of values is given when actual course variations were greater than ±2.5°.

Source: *Report of Test Results, Improved Tactical Air Launched Decoy (DT-IIIF) GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, June 2002.

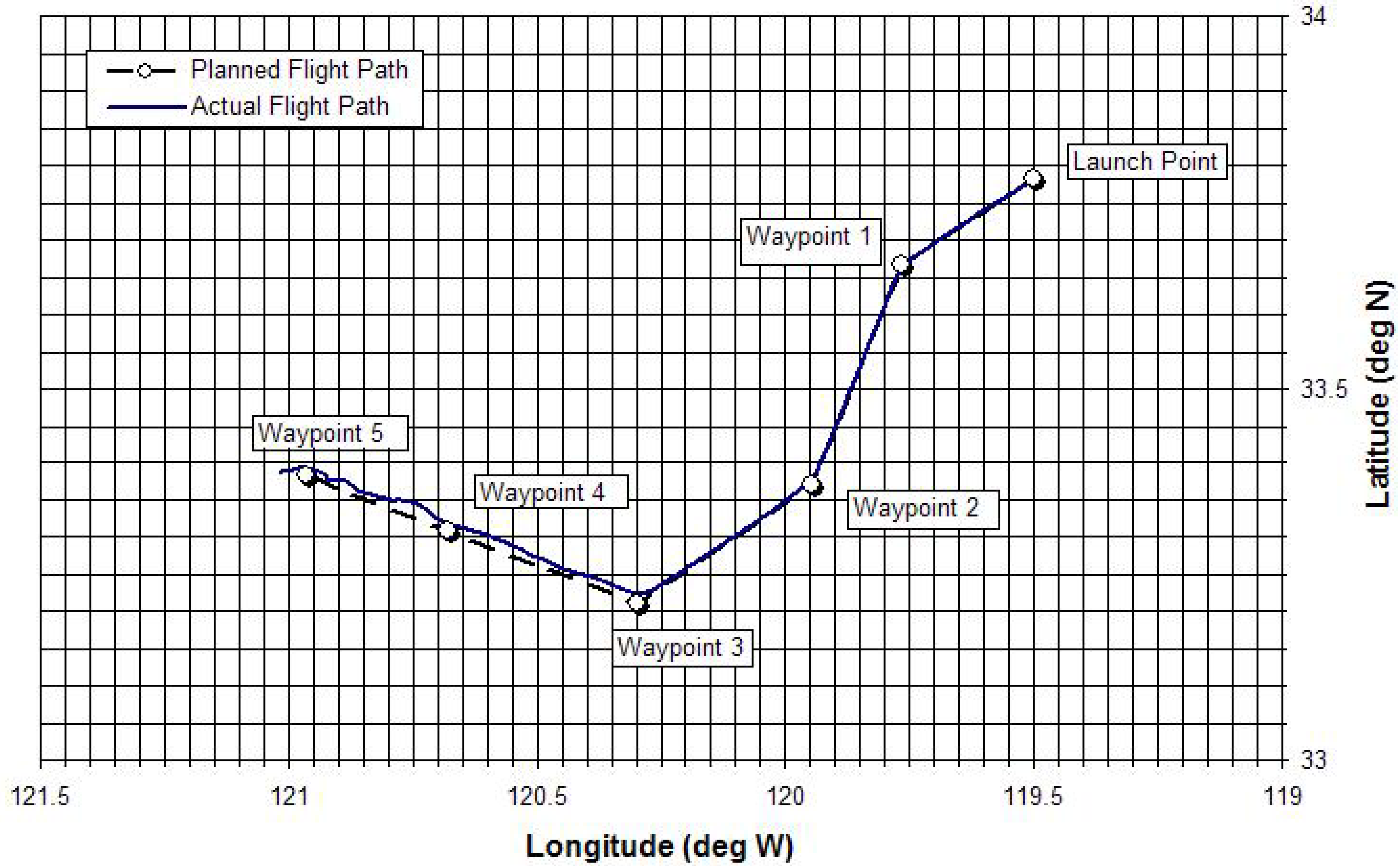


Figure 5-7: ITALD-GPS Profile 4 Ground Track

Source: *Report of Test Results, Improved Tactical Air Launched Decoy (DT-IIIF) GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, June 2002.

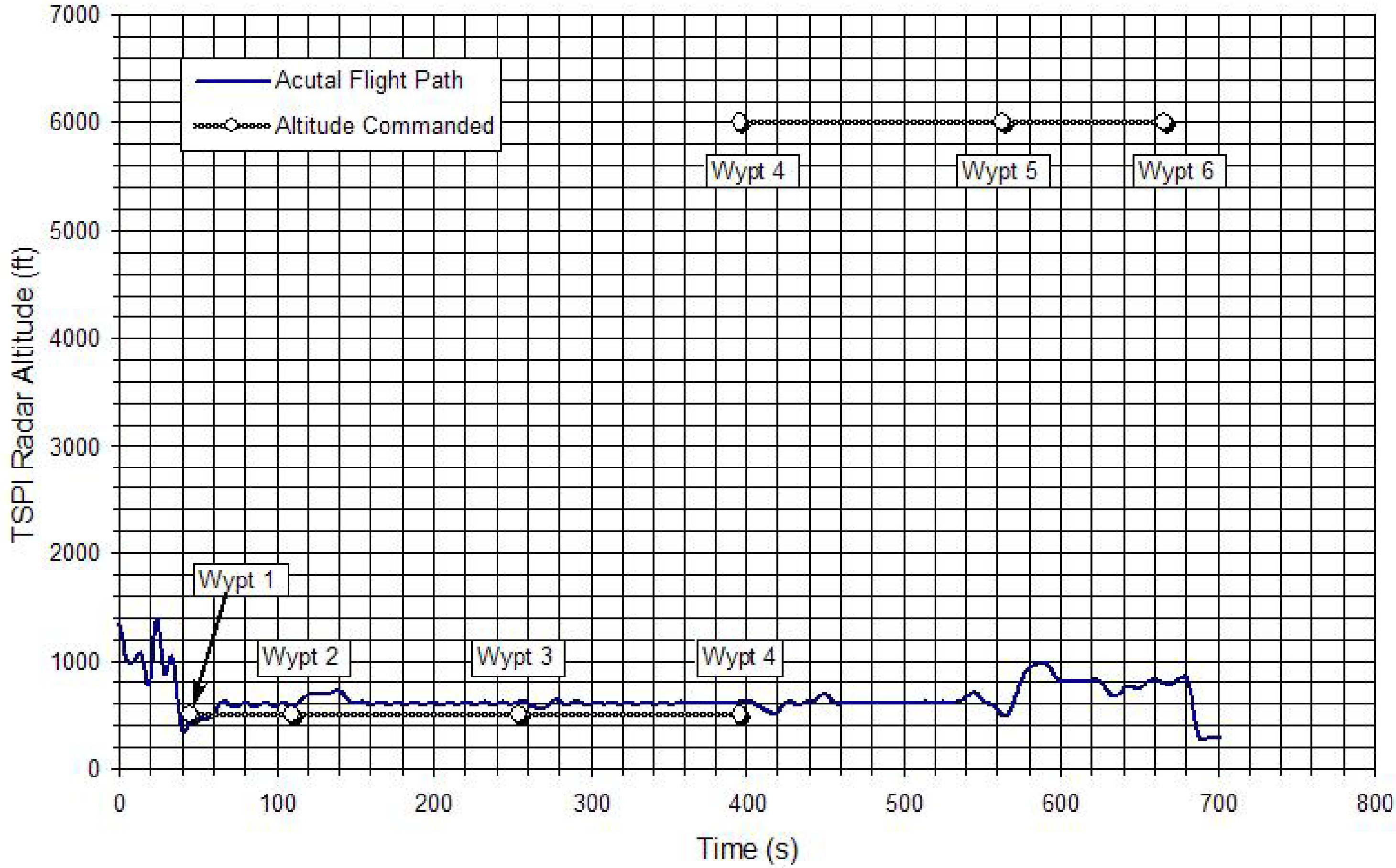


Figure 5-8: ITALD-GPS Profile 4 Side View

Source: *Report of Test Results, Improved Tactical Air Launched Decoy (DT-IIIF) GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, June 2002.

The ITALD-GPS remained below 1000 ft AGL and intercepted the fifth and final waypoint at 666.3 s (11 min 6.3 s) with a lateral miss distance of 0.63 nm. The engine shutdown command was initiated at 678 s (11 min 18 s) and TM loss occurred at 687.0 s (11 min 27 s) [22].

Flight Profile 5 - Direct to Last Waypoint - Results

Separation and Engine Start

Flight Profile 5, designed to test the Direct to Last Waypoint mode, was conducted on Flight 1. Table 5-10 lists the wind conditions. The ITALD-GPS was launched from the outboard ITER station mounted on the F/A-18 Station 2 pylon at 9,900 ft MSL and 355 KCAS. After safe separation, the decoy rolled left 46.5° and wing deployment occurred at 3.1 s. At 5.6 s, the engine inlet cover ejected, engine windmill started at 9.8 s, and ignition and engine start occurred at 11.4 s. The ITALD-GPS descended to a lowest altitude of 5,200 ft MSL during the start process [22].

Navigation Performance

Table 5-11 provides a comparison of actual versus planned performance. Figure 5-9 and 5-10 are time-space-position plots showing overhead and side views of the flight. The ITALD-GPS navigation system declared the GPS input valid at 55.8 s and guidance started at 58.1 s. The ITALD-GPS commanded a turn directly toward the last waypoint, shown in Figure 5-9, and intercepted it at 459.9 s (7 min 39.9 s) with a 0.12 nm lateral miss distance. Engine shutdown was commanded at 470 s (7 min 50 s) and TM was lost at 526.8 s (8 min 46.8 s) [22].

Table 5-10: Profile 5 Wind Conditions

Altitude (feet MSL)	Wind Direction (ºTrue)	Wind Speed (knots)	Crosswind (knots)	Tailwind (knots)
6100	151	16	15 right to left	5
10000	136	17	16 right to left	7

Source: *Report of Test Results, Improved Tactical Air Launched Decoy (DT-IIIF) GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, June 2002.

Table 5-11: Profile 5 Planned Versus Actual

Flight Event	**PLANNED**			**ACTUAL**			**Winds**
	Altitude (ft MSL)	**Course (º True)**	**Mach**	**Altitude (ft MSL)**	**Course[1] (º True)**	**Mach**	**(Knots / ºTrue)**
Launch Point	10,000	250	0.64	9,990	250	0.64	17 / 136
Approaching Last Waypoint	10,000	221	0.80	10,300	217	0.80	17 / 136

Note 1: The ITALD-GPS experienced continuous course changes on each flight profile. The value shown represents the average of the course variations, which were less than ± 2.5°.

Source: *Report of Test Results, Improved Tactical Air Launched Decoy (DT-IIIF) GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, June 2002.

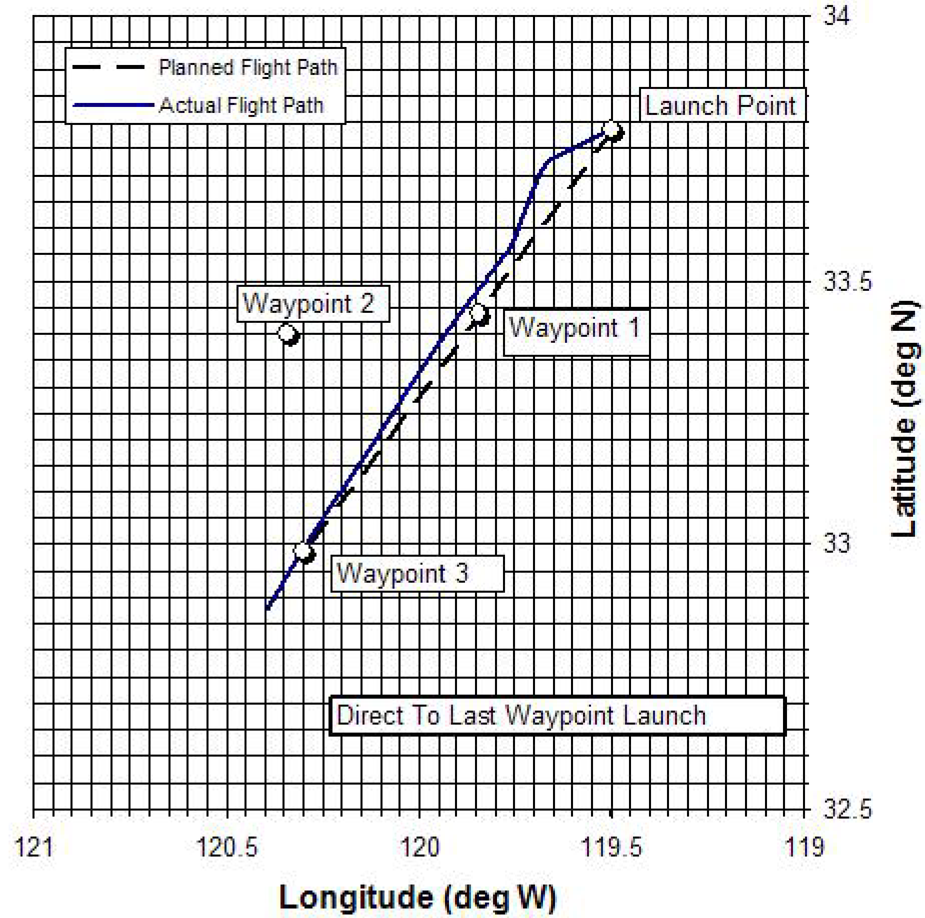


Figure 5-9: ITALD-GPS Profile 5 Ground Track

Source: *Report of Test Results, Improved Tactical Air Launched Decoy (DT-IIIF) GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, June 2002.

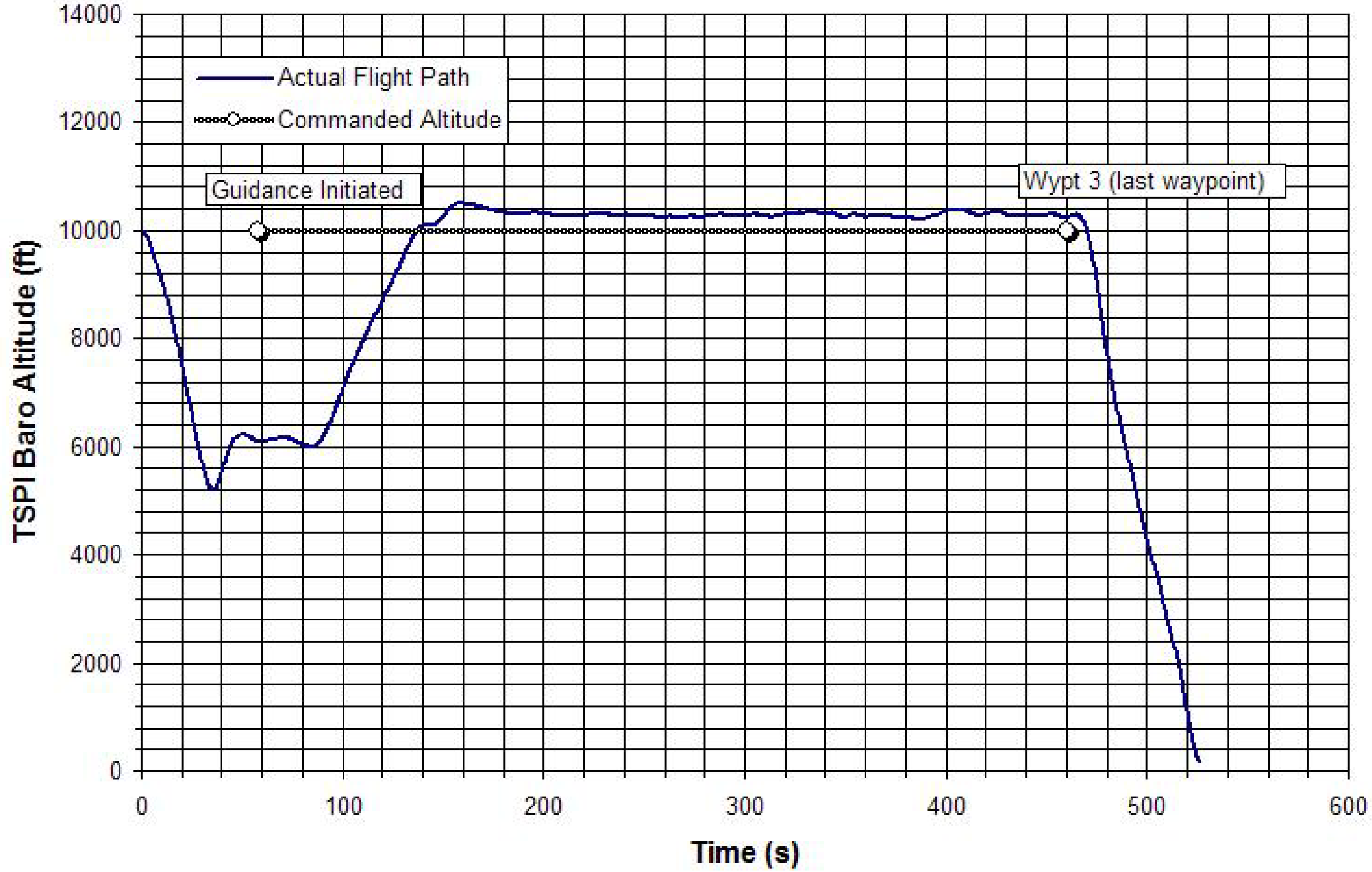


Figure 5-10: ITALD-GPS Profile 5 Side View

Source: *Report of Test Results, Improved Tactical Air Launched Decoy (DT-IIIF) GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, June 2002.

CHAPTER VI

DISCUSSION OF RESULTS

General

The ITALD-GPS design was evaluated on five flights during the DT-IIIF Developmental Flight Test Program conducted by the NAWC-WD Point Mugu test team in October 2001. The GPS system was incorporated into the navigation design to correct gross navigational errors that rendered the ITALD ineffective in the defense suppression mission. The developmental test results from the previous design reported two serious (Part I) and one moderate (Part II) deficiencies with the navigation system. In order to properly simulate attacking strike aircraft, the ITALD-GPS had to navigate to within the field of regard of the intended enemy surface-to-air missile site to be engaged.

This section discusses the flight test results in detail with regards to the new navigation design. A table at then end of this chapter provides a summary of results.

GPS Acquisition

The GPS acquisition time, Test Objective 1.1a, was evaluated on all the flight profiles. The Trimble GPS system was chosen because of its ability to rapidly acquire a position post start. Table 6-1 lists the acquisition times for each flight profile. On every profile, except Profile 3, the time required for a valid GPS fix was less than one minute.

Table 6-1: GPS Acquisition Times

Profile Number	1	2	3	4	5
GPS Acquisition Time (s)	40.1	51.9	144.1	44.2	55.8

Source: *Report of Test Results, Improved Tactical Air Launched Decoy (DT-IIIF) GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, June 2002.

For Profile 3, the simulated 7-waypoint high altitude strike, the FCA declared the GPS data valid at 144.1 s, causing the ITALD-GPS to skip the first waypoint and proceed to waypoint 2. The fix was delayed because the GPS had not acquired the minimum of four GPS satellites required for valid position information. The NAWC-WD Point Mugu test team reported the excessive time for GPS satellite acquisition will cause the ITALD-GPS to fly an unguided flight path until satellites are acquired, reducing the capability to satisfactorily preplan a mission profile, a Part III deficiency that should be avoided in future designs. Despite the excessive time to acquire a valid GPS fix on flight profile 3, the GPS acquisition met the specification requirements in that GPS satellites were acquired on every mission [22].

GPS Positional Accuracy

The ITALD-GPS navigation system positional accuracy, defined by the ability of the decoy to accurately identify its location during flight, was evaluated on each of the five profiles. For each of the three navigation modes, Pre-Planned Route, Direct to Last

Waypoint, and Target of Opportunity, the ITALD-GPS accurately identified ownship position throughout the flight and achieved a final miss distance of less than one nm, not counting Profile 1 where GPS commands were overridden by gyro limitations. The positional accuracy of the GPS system optimized navigation thus enhancing the effectiveness of the ITALD-GPS as an airborne decoy. The GPS accuracy was satisfactory [22].

ITALD-GPS Navigation Modes

Pre-Planned Route Flight Mode

The Pre-Planned Route Mode, Test Objective 1.2a, was evaluated on Profiles 1, 3, and 4; the typical strike, high altitude strike and low level ingress respectively. On all three flights, the ITALD-GPS flew the entire route accurately with the exception of the final waypoint on Profile 1. The decoy missed the third and final waypoint by 8.3 nm because it failed to perform a 90° heading change due to a combination of potential gyroscopic alignment, gyroscopic drift, and wind shear. These factors caused the vehicle to operate at the designed gyroscopic limit, which ensured stable and controlled flight, thus restricting the vehicle's ability to further correct its heading. The GPS system maintained accurate position information the entire flight, but the course corrections were overridden by the FCA to prevent the ITALD-GPS from departing controlled flight. On Profiles 3 and 4, the ITALD-GPS intercepted all of the planned waypoints and achieved a final miss distance of 0.03 nm and 0.63 nm respectively. The planned route of flight mode met the requirements of the specification in that ITALD-GPS was commanded to fly to each programmed waypoint [22].

Target of Opportunity Mode

The Target of Opportunity Mode, Test Objective 1.2b, was evaluated on Profile 2. The pilot launched the ITALD-GPS out of the programmed launch basket along a course of 234° true. The decoy flew a straight-line path within 1° of the launch bearing until engine shutdown was commanded at 600 s. The Target of Opportunity Mode was satisfactory and met the requirements of the specification [22].

Direct to Last Waypoint Mode

The Direct to Last Waypoint Mode, Test Objective 1.2c, was evaluated during Profile 5, which consisted of three programmed waypoints. The pilot purposely launched the ITALD-GPS 30° to the right of the programmed course to invoke the Direct to Last Waypoint Mode. The ITALD-GPS successfully navigated directly to the last waypoint with a miss distance of 0.12 nm. The Flight towards Last Waypoint Mode was satisfactory and met the requirements of the specification [22].

Lateral Maneuvers - Heading Change

The new ITALD-GPS design to navigate a series of waypoints expanded the flight profiles available to the mission planner from that of the previous design which offered a single heading change or lateral offset maneuver. The ability of the ITALD-GPS to perform heading changes and lateral maneuvers, Test Objectives 1.3 and 1.3a, was evaluated on every profile; however Profiles 1, 3, and 4 required specific heading changes. The ITALD-GPS successfully performed accurate heading changes on every profile except Profile 1.

Profile 1, Typical Strike, tested the ability of the ITALD-GPS to perform accurate heading changes at limit of the gyro's capability. The profile commanded a 45º right turn at waypoint 1 followed by a 90º left turn at waypoint to the third and final waypoint. The winds at flight altitude, 31,000 ft MSL, were 328° true at 30 kts, nearly all crosswind. Due to system drift and gyroscopic limitations, the ITALD-GPS turned only 72º vice 90º resulting in a miss of the final waypoint by 8.3 nm, the worst performance of the entire evaluation by an order of magnitude. A combination of potential gyroscopic alignment, gyroscopic drift, and wind shear caused the decoy to reach a physical gyroscopic limit that ensured stable flight by preventing the vehicle from tumbling when too large of a heading change was made. During the final leg, the GPS system functioned as designed, but the ITALD-GPS was unable to execute the guidance commands. The NAWC-WD Point Mugu test team determined that the insufficient heading change for a commanded 90º turn was a Part II deficiency which should be corrected as soon as practical [22].

The continued use of the substandard 2-axis gyro resulted in an ITALD-GPS performance deficiency when commanded to execute a 90º heading change. However, the decoy still performed significantly better than the previous design when system drift remained unchecked for the entire flight.

Heading Error Rate

The ITALD-GPS heading error rate (drift), Test Objective 1.4a, was evaluated on each of the five flight profiles. For the two straight line profiles (2 and 5), the heading error rate was determined by comparing the initial flight heading after GPS guidance was available to the final heading as measured by the range instrumentation. The initial flight heading was calculated over the first 100 s of flight after a 20 s settling time. The NAWC-WD Point Mugu test team used the 100 s averaging process to minimize TSPI measurement errors. The initial flight heading was compared to the final 100 s of level flight prior to termination. The difference between the initial and final heading divided by the average time between the 100 s segments equaled the heading error for the flight. Even though the heading error rate for Profile 5 was significantly higher than the other four, the ITALD-GPS only missed the final waypoint by 0.12 nm. For profiles with programmed turns (1, 3 and 4), the initial heading after the decoy leveled out of the turn was compared to the final heading prior to the next turn. Table 6-2 lists the heading error rates for all five missions. The ITALD-GPS met the specification requirement in that the heading error rates were less than 2 degrees/minute [22].

Table 6-2: Heading Error Rates

Profile Number	1	2	3	4	5
Heading Error Rate (deg/min)	0.12	0.07	0.1	0.15	1.2

Source: *Report of Test Results, Improved Tactical Air Launched Decoy (DT-IIIF) GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, June 2002.

Navigation Accuracy

The accuracy of the new ITALD-GPS navigation system, Test Objective 1.4b, was evaluated during every flight and the results are listed in Table 6-3. On profile 1 the decoy missed the final waypoint by 8.3 nm, due to inadequately performing the required 90° turn toward the final waypoint. On Profiles 2 through 5, the miss distances were well within the 1 nm requirement. Despite the fact that the navigational accuracy failed to meet the requirements of the specification in that accuracy to the final waypoint exceeded the maximum of 1 nm by 830% on Profile 1, the new ITALD-GPS navigation performance significantly improved from that of the previous design. If the mission planner compensated for the 2-axis gyro limitations during profile selection, the ITALD-GPS decoy would be suitable for the defense suppression mission.

Altitude Control

The ability of the ITALD-GPS to control its altitude, Test Objective 1.5, was evaluated on each of the five missions. The ITALD-GPS used barometric pressure sensors, the radar altimeter and GPS altitude information to maintain altitude.

Table 6-3: ITALD-GPS Miss Distances at Final Waypoint

Profile Number	1	2	3	4	5
Miss Distance (nm)	8.3	N/A	0.03	0.63	0.12

Source: *Report of Test Results, Improved Tactical Air Launched Decoy (DT-IIIF) GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, June 2002.

Low Altitude Cruise

The ITALD-GPS flight at low altitude between 500 ft AGL and 10,000 ft MSL, Test Objective 1.5a, was evaluated using Profiles 4 and 5. During the low altitude ingress on Profile 4, the ITALD-GPS overrode the climb command from 500 ft AGL to 6000 ft MSL due to executing a course correction. On Profile 5, the ITALD maintained 10,000 MSL as planned. Altitude control during low altitude cruise between 500 ft AGL and 10,000 ft MSL was satisfactory and met the specification requirements [22].

High Altitude Cruise

Steady flight at high altitude between 20,000 ft and 30,000 ft MSL, Test Objective 1.5b, was evaluated during Profiles 1, 2, and 3. On Profile 1, the ITALD-GPS was launched at 35,000 ft MSL and climbed to the waypoint 1 programmed altitude of 13,400 ft MSL after engine start. The decoy climbed to 30,200 by waypoint 2 and maintained that altitude until flight termination. On Profile 2, Target of Opportunity Mode, the ITALD-GPS was launched at 20,000 ft MSL, performed its windmill start and climb to back to the launch reference altitude and maintained 20,100 ft for the remainder of the flight. Profile 3, the high altitude, 7-waypoint strike, the ITALD-GPS was launched at 25,000 ft MSL, executed a series of programmed climbs to 25,500 ft MSL by waypoint 3 and a series of descents to 11,000 ft by waypoint 7. Controlled flight at high altitude, between 20,000 and 30,000 ft MSL was satisfactory and met the requirements of the specification [22].

Altitude Sensors Control Flight Altitude

Test Objective 1.5c of the flight test objective matrix dictated that the ITALD-GPS maintain altitude within 300 ft or 15% of the programmed altitude, Test Objective 1.5c. Altitude tolerances were evaluated satisfactory on all five flights and met the specification requirement [22].

Ability to Climb or Dive at Selected Point

The ITALD-GPS ability to climb or dive at selected points, Test Objective 1.5d, was evaluated on Profiles 1, 3, and 4. On Profile 1, the ITALD-GPS was programmed to descend from 30,000 ft MSL to 15,000 ft MSL, but the command was overridden because it was attempting to perform a 90° turn toward the last waypoint at the limits of the gyro. However, this was not reported as a deficiency since the ITALD-GPS would still be engaged by the enemy surface-to-air missile systems. The climb performance on Profile 3 was satisfactory. On Profile 4, the low altitude ingress, the ITALD-GPS was programmed to climb from 500 ft AGL to 6000 ft MSL following a right 45º turn at waypoint 3. Out of the turn, the ITALD-GPS was right of course by 4000 ft because the decoy used 45º angle of bank for the turn vice the programmed 35º. System gyroscopic drift caused the navigation system to erroneously sense wings level when the decoy was in a continual 10 ºright turn. The ITALD-GPS attempted to null the crossrange error by using a series of left turns to no avail. The navigation system inhibited the climb command because the crossrange error exceeded the 3000 ft threshold for the remainder of the flight. The NAWC-WD Point Mugu test team reported that a failure to change altitude as programmed would prevent the ITALD-GPS from climbing high enough after engine start to stimulate the threat defense system, rendering the decoy ineffective, a Part I deficiency which should be corrected as soon as possible. The climb capability of the ITALD-GPS failed to meet the specification requirements because the ITALD-GPS did not climb to the programmed altitude in Profile 4 [22].

Flight Stability during Flight and Programmed Maneuvers

Because previous ITALD designs had a tendency to become unstable and depart controlled flight during separation and programmed maneuvers, flight stability, Test Objective 1.5e, was evaluated on each profile. On some flights the ITALD-GPS would oscillate in roll plus or minus 2°, a characteristic experienced in previous ITALD testing. However, this roll oscillation had no negative impact on flight stability. The ITALD-GPS flight stability characteristics during flight and programmed maneuvers were satisfactory and met the requirements of the specification in that ITALD-GPS maintained 1g, stable flight [22].

Table 6-4 provides a summary of the flight test objective results.

Table 6-4: DT-IIIF Flight Test Objective Results

Objective Description		Measures of Effectiveness	Profile #1	Profile #2	Profile #3	Profile #4	Profile #5
1.0	EVALUATE ITALD-GPS FLIGHT CONTROLS						
1.1	GPS Acquisition						
a	Verify GPS Acquisition	GPS Acquired	Pass	Pass	Pass[1]	Pass	Pass
1.2	ITALD-GPS Navigation Modes		–	–	–	–	–
a	Verify Pre-Planned Route Flight Mode	Flies waypoints	Pass	–	Pass	Pass	–
b	Verify Target of Opportunity Mode	Flies straight ahead	–	Pass	–	–	–
c	Verify Direct to Last Waypoint Mode	Flies towards last waypoint	–	–	–	–	Pass
1.3	Lateral Maneuvers						
a	Verify left or right heading change	Heading change correct	FAIL	Pass	Pass	Pass	Pass
1.4	Navigational Error						
a	Verify heading error rate	Error < 2.0 °/min	Pass	Pass	Pass	Pass	Pass
b	Verify Navigational accuracy	< 1 nm accuracy to final waypoint	FAIL	Pass	Pass	Pass	Pass
1.5	Altitude Control						
a	Verify cruise at low alt.	500 feet AGL – 10,000 feet MSL	–	–	–	Pass	Pass
b	Verify cruise at high alt.	20,000 – 30,000 feet MSL	Pass	Pass	Pass	–	–
c	Verify alt sensors control flight with specified tolerances	Attain/hold w/in 300 feet or 15% of alt	Pass	Pass	Pass	Pass	Pass
d	Verify ability to climb / dive at selected point	Climbs / dives at selected waypoints	Pass	–	Pass	FAIL	–
e	Verify flt stability during flt and programmed maneuvers	1g stable, sustained flight	Pass	Pass	Pass	Pass	Pass

Note (1) – The GPS took 144 s to obtain its first fix causing the ITALD-GPS to skip the first waypoint

Source: *Report of Test Results, Improved Tactical Air Launched Decoy (DT-IIIF) GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, June 2002.

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The ITALD-GPS navigation performance was a dramatic improvement over the previous design. By incorporating the GPS inputs into the flight control logic to null the drift rate, the designers found a relatively simple and inexpensive solution to the navigational deficiencies reported by the DT-IIIE flight tests. The GPS positional accuracy enhanced the ITALD-GPS effectiveness as a decoy. The ITALD-GPS failed to execute a climb on Profile 4, a Part I deficiency, and failed to complete a 90° turn on Profile 1, a Part II deficiency. The excessive time for GPS acquisition on Profile 3 was a Part III deficiency.

GPS Acquisition (1.1a)

The excessive time for GPS satellite acquisition will cause the ITALD-GPS to fly an unguided flight path until satellites are acquired, reducing the capability to satisfactorily preplan a mission profile, a Part III deficiency that should be avoided in future designs. Despite the excessive time to acquire a valid GPS fix on flight profile 3, the GPS acquisition met the specification requirements in that GPS satellites were acquired on every mission [22].

GPS Positional Accuracy

The positional accuracy of the GPS system optimized navigation thus enhancing the effectiveness of the ITALD-GPS as an airborne decoy. The GPS accuracy was satisfactory [22].

ITALD-GPS Navigation Modes (1.2)

Pre-Planned Route Flight Mode (1.2a)

The ITALD-GPS missed the final waypoint on Profile 1 because it failed to perform a 90° heading change due to a combination of potential gyroscopic alignment, gyroscopic drift, and wind shear. However, the planned route of flight mode met the requirements of the specification in that ITALD-GPS was commanded to fly to each programmed waypoint [22].

Target of Opportunity Mode (1.2b)

The Target of Opportunity Mode was satisfactory and met the requirements of the specification [22].

Direct to Last Waypoint Mode (1.2c)

The Flight towards Last Waypoint Mode was satisfactory and met the requirements of the specification [22].

Lateral Maneuvers - Heading Change (1.3/1.3a)

The ITALD-GPS successfully performed accurate heading changes on every profile except Profile 1, where the decoy failed to perform a full 90º heading change.

The insufficient heading change for a commanded 90º turn was a Part II deficiency which should be corrected as soon as practical [22].

Heading Error Rate (1.4a)

The heading error rate (gyro drift) was satisfactory and met the requirements of the specification [22].

Navigation Accuracy (1.4b)

The navigational accuracy failed to meet the specification requirement of 1 nm by 830% (8.3 nm) because the ITALD-GPS failed to perform a 90º turn on Profile 1 due to gyro limitations. Because the GPS heading commands were accurate the entire flight, the ITALD-GPS would be suitable for the defense suppression mission if the planner was able to compensate for potential gyro limitations while planning the route [22].

Altitude Control (1.5)

Low Altitude Cruise (1.5a)

Altitude control during low altitude cruise between 500 ft AGL and 10,000 ft MSL was satisfactory and met the specification requirements [22].

High Altitude Cruise (1.5b)

Controlled flight at high altitude, between 20,000 and 30,000 ft MSL was satisfactory and met the requirements of the specification [22].

Altitude Sensors Control Flight Altitude (1.5c)

Altitude tolerances were evaluated satisfactory on all five flights and met the specification requirement [22].

Ability to Climb or Dive at Selected Point (1.5d)

A failure to change altitude as programmed would prevent the ITALD-GPS from climbing high enough after engine start to stimulate the threat defense system, rendering the decoy ineffective, a Part I deficiency which should be corrected as soon as possible. The climb capability of the ITALD-GPS failed to meet the specification requirements because the ITALD-GPS did not climb to the programmed altitude in Profile 4 [22].

Flight Stability during Flight and Programmed Maneuvers (1.5e)

The ITALD-GPS flight stability characteristics during flight and programmed maneuvers were satisfactory and met the requirements of the specification in that ITALD-GPS maintained 1g, stable flight [22].

Recommendations

The NAWC-WD Point Mugu test team provided the following recommendations regarding the future of the ITALD-GPS program [22].

1. The single Part I deficiency, climb performance, should be corrected prior to operational testing possibly by increasing the crossrange error threshold (3000 ft) that inhibits altitude change commands.
2. The one Part II deficiency, heading change, should be corrected as soon as practical. A proposed interim solution called for establishing a mission

planning process to define the probability of encountering gyroscopic limitations for specific flight profiles thereby ensuring adequate compensation for in-flight conditions.

3. The test team recommended that the contractor investigate the cause of the late satellite acquisition time during Profile 3 and incorporate satellite acquisition time predictions into a mission planning document.

LIST OF REFERENCES

LIST OF REFERENCES

1. Prindle, Tara. *NativeTech History and Background of Duck Decoys.* Native American Technology and Art, 2000.
   URL: www.nativetech.org/decoy/DUCKDECOYS.htm

2. URL: *www.israeli-weapons.com/weapons/missile_systems/air_missiles/itald/TALD.*

3. Norman, Cassidy LCDR. *Low Cost Modification of the TALD Brief.* Point Mugu, CA: Naval Air Warfare Center, Weapons Division, March 2002.

4. *ADM-141A Tactical Air-Launched Decoy (TALD), ADM-141C Improved TALD (ITALD)*. Washington DC: Federation of American Scientists Military Analysis Network, 1999.
   URL: *www.fas.org/man/dod-101/sys/ac/equip/tald.htm*

5. Parsch, Andreas. *IMI (Brunswick) ADM-141 TALD*. Munich, Germancy: Directory of US Rockets and Missiles. Designation-Systems.net, 2002
   URL: *www.designation-systems.net/dusrm/m-141.html*

6. *Detail Specification for the ITALD System AS-6153*. Washington DC: Naval Air Systems Command, 19 June 1996.

7. Hutson, Brad. *Information on ITALD Test History Memo*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, 11 April 2000.

8. *Report of Test Results, Developmental Test (DT-IIIE) Evaluation of the Improved Tactical Air Launched Decoy*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, March 1999.

9. *Operational Requirements Document for the ITALD, No. 364-88-9*. Washington DC: Naval Air Systems Command, 21 June 1994.

10. Reed, David R. *Compendium of Terminology – Kentucky Windage*. www.snipercountry.com, 1996.
    URL: www.snipercountry.com/Compendium/Comp_K.htm.

11. *ITALD Mission Planning Document BC Document No 43-212*. Costa Mesa CA: Brunswick Defense Corporation, January 1996.

12. Choi, Yosup. *ITALD Drift Rate Analysis Project*. Point Mugu, CA. Naval Air Warfare Center, Weapons Division, 2000.

13. *Report Writing Guide for Flight Test and Engineering Group Reports*. Patuxent River MD: Naval Air Warfare Center Aircraft Division, 1 March 1994

14. Bathrick, Mark CDR. *ITALD Video Teleconference Brief to N880* (Washington DC). Point Mugu, CA. Naval Air Warfare Center, Weapons Division, 24 June 99

15. *Improved Tactical Air Launched Decoy (DT-IIIF) Flight Test Plan GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, September 2001.

16. *Proposal for ITALD-GPS Rev A*, NAVAIR Contract Modification No. N00019-97-C-0097 P002. Patuxent River, MD: Israeli Military Industries LTD., June 2000.

17. *ITALD-GPS Final Design Review*. Israel: Israeli Military Industries, LTD, June 2001.

18. Terando, Steve. *ITALD Mission Programming Brief.* Point Mugu, CA: Naval Air Warfare Center, Weapons Division, 2002.

19. *Lassen SK II GPS System Designer Reference Manual*. Sunnyvale, CA: Trimble Navigation Limited, November 1999.

20. *F/A-18C NATOPS Manual, A1-F-18A/C-NFM-000*. San Diego, CA, Naval Air Systems Command, February 2000.

21. *F/A-18 Hornet*. Washington DC: Federation of American Scientists Military Analysis Network, 25 April 2000.
URL: www.fas.org/man/dod-101/sys/ac/equip/tald.htm

22. *Report of Test Results, Improved Tactical Air Launched Decoy (DT-IIIF) GPS Upgrade Evaluation*. Point Mugu, CA: Naval Air Warfare Center, Weapons Division, June 2002.

23. *United States Naval Test Pilot School Report Writing Handbook – Change 3*. Patuxent River, MD. United States Naval Test Pilot School. January 2000.

APPENDIX

APPENDIX A
NAVAL AIR WARFARE CENTER DEFICIENCY CLASSIFICATION

The US Navy developmental test and evaluation program classifies deficiencies as Part I, II or III based on the severity of their impact on the mission suitability of the aircraft or system. The following deficiency ratings are defined in the United States Naval Test Pilot School Handbook [23].

Part I: Indicates a deficiency, the correction of which is necessary because it adversely affects;

- The airworthiness of the aircraft or system
- The capability of the aircraft of system to accomplish its primary or secondary mission.
- The safety of the crew or the integrity of an essential subsystem. In this regard, a real likelihood of an injury or damage must exist. Remote possibilities or unlikely sequences of events shall not be used as a basis for safety items.

Part II: Indicates a deficiency of lesser severity than a Part I which does not substantially reduce the ability of the aircraft or system to accomplish its primary or secondary mission, but the correction of which will result in significant improvement in the operational cost, effectiveness, reliability, maintainability, or safety of the aircraft or system, or requires significant operator compensation to achieve the desired level of performance; however, the aircraft or system being tested is still capable of accomplishing its mission with an adequate degree of safety and effectiveness.

Part III: Indicates a deficiency, which is minor or that appears too impractical or costly to correct in this model but which should be avoided in future designs. Included are violations of specifications for use by the contract negotiator in final settlement of the contract.

Vita

Scott Kenneth Toppel was born in Ann Arbor, Michigan on April 9, 1968. He was raised in Sunnyvale, CA, graduated from Homestead High School in 1986, and attended college at the University of California, Davis where he received a B.S. in Electrical Engineering in 1991. After college, he joined the United States Navy and received his officer commission from Aviation Officer's Candidate School in November 1991.

He attended flight training at VT-2 in Milton, FL. in December 1991, was selected to fly jet aircraft in June 1992. He reported to NAS Meridian, MS for intermediate jet training at VT-19 in July 1992 and advanced jet training in VT-7 in April 1993. After carrier qualification, he received his Wings of Gold in January 1994. In March 1994, he reported to VFA-125 in NAS Lemoore, CA for training in the F/A-18 Hornet strike fighter aircraft. He joined VFA-27, his first fleet squadron, on deployment the western Pacific in December 1994 and moved with them to Atsugi, Japan in June 1996. He deployed aboard the USS Independence (CV 62) in February 1997 in support of western Pacific security. He graduated from the Empire Test Pilot School in Boscombe Down, England in December 1998 and reported to Naval Weapons Test Squadron, Point Mugu as the Advanced Medium Range Air-to-Air Missile (AMRAAM) and Improved Tactical Air Launched Decoy (ITALD) project officer. In January, 2001 he joined the staff of Carrier Air Wing 8 in Oceana, VA and deployed onboard the USS Enterprise (CVN 65) in April 2001 in support of Operations SOUTHERN WATCH and ENDURING FREEDOM. He moved back across the country to NAS Lemoore, CA in

July 2002 for training in the F/A-18F Super Hornet. He reported to VFA-41 as a department head in October 2002 and deployed onboard the USS Nimitz (CVN 68) in March 2003 in support of Operation IRAQI FREEDOM.

He has accumulated over 2200 flight hours in 47 different aircraft and 457 arrested landings. He flew 37 combat missions over Afghanistan and Iraq in support of Operations ENDURING FREEDOM and IRAQI FREEDOM.

He is currently a department head in VFA-41 at NAS Lemoore, CA.