A COMPARISON OF THE PERFORMANCE OF NAVIGATION TASKS BY FLIGHT STUDENTS USING A GEOGRAPHIC NORTH MODEL VERSUS A MAGNETIC NORTH MODEL

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Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF EDUCATION
July, 2000

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NORTH MODEL

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ACKNOWLEDGMENTS

I wish to express my sincerest appreciation to my family, friends, instructors, and colleagues who have supported and inspired me through this journey. I wish to begin by thanking the members of my Doctoral Committee. Dr. Steven Marks, as my adviser, provided the foundation with his support and encouragement, without which I literally would not have been able to finish. Dr. Kenneth Wiggins was the reason I came to OSU. His enthusiasm and personal interest in my progress kept me coming back for more. Dr. Mac McClure has been a constant force for "getting the damn thing done." I could always rely on Mac to keep me moving forward. Dr. James Key provided the impetus to get started with the dissertation. I give him full credit for my getting the first three chapters done. Thanks also to my friends and colleagues at OSU. I have truly enjoyed our association for the past seven years (Master and Doctoral degrees). I have learned and grown through and with them.

A special thanks to my family, who have always provided a strong foundation for me in good times and bad. Mom has always been there for us "kids" with her praises of our accomplishments to help us feel that what we are doing is important and we really can make a difference. Dad was truly my mentor for life. His honesty and integrity provide me with a constant image to follow. It is to Jon, Jess and their wonderful families that I dedicate this work. They are the primary motivation behind my desire to set new goals

and to never give up. Finally, I will always be indebted to Diane for her willingness to put up with me – no small task!

It has been a long, but exhilarating, journey and I feel both relief and melancholy as it ends. Now it is time to move on to the next challenge.

TABLE OF CONTENTS

Chapter Page

I. INTRODUCTION 1

Background Information 1
Problem Statement 2
Purpose Statement 5
Research Hypothesis 5
Assumptions 5
Limitations 6
Scope 7
Definition of Terms 7

II. REVIEW OF LITERATURE 14

The Development of the National Airspace System 14
The Global Positioning System (GPS) 16
Development and Operation 16
GPS Information Presentations 24
Safe Flight 21 Program 26
The Federal Radionavigational Plan 29
GPS Navigation 32
Longitude and Latitude 32
Great Circle Route (GCR) 35
The Human Factor 38
Current Training Program 38
Situational Awareness 42
Summary 46

III. METHODOLOGY 47

Introduction 47
Definition of the Population 48
Design of the Study 48
Pilotage and Dead Reckoning 50
Magnetic North Model 51
Geographic North Model 51

Chapter Page

Data Collection Instruments 52
Analysis of Data 55

IV. FINDINGS 57

Introduction 57
Prestudy Survey 57
Pretest 61
Poststudy Survey 64
Navigational Posttest 67
Cross Country Problem 67
Emergency Problem 70

V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS 74

Summary 74
Conclusions 75
Posttest Analysis 76
Prestudy Survey 79
Pretest 81
Poststudy Survey 81
Recommendations 82
General Recommendations 82
Specific Recommendations 83
Future Research Recommendations 84

BIBLIOGRAPHY 85

APPENDIXES 90

APPENDIX A – AVIATION NAVIGATION STUDY MEASUREMENT INSTRUMENTS FOR THE EXPERIMENTAL GROUP . . 91

APPENDIX B – AVIATION NAVIGATION STUDY MEASUREMENT INSTRUMENTS FOR THE CONTROL GROUP 99

APPENDIX C – AVIATION NAVIGATION STUDY GEOGRAPHIC NORTH LESSON PLAN AND INSTRUCTIONAL MATERIALS 107

APPENDIX D – AVIATION NAVIGATION STUDY MAGNETIC NORTH LESSON PLAN AND INSTRUCTIONAL MATERIALS 117

Chapter Page

APPENDIX E – INSTITUTIONAL REVIEW BOARD APPROVAL FORM AND STUDENT CONSENT FORM 125

LIST OF TABLES

Table Page

1. Prestudy Survey - Experimental Group 58

2. Prestudy Survey - Control Group 59

3. Pretest Charts 63

4. Poststudy Surveys 66

5. Posttest Charts (Cross Country) 68

6. Posttest Charts (Emergency) 71

LIST OF FIGURES

Figure Page

1. GPS Constellation 17
2. Satellite Inclinations 18
3. GPS WAAS 22
4. GPS LAAS 23
5. Multi-Function GPS Display 27
6. Federal Radionavigation Plan 30
7. GPS Phasing Out Schedule 31
8. World Coordinate System 32
9. Great Circle Route 35
10. Rhumb Line of Loxodrome 36
11. Comparison of a Rhumb Line 37
12. GPS SIAP - Basic "T" Design 44

NOMENCLATURE

ADF	Automatic Direction Finder
ADS-B	Automatic Dependent Surveillance Broadcast
AFSS	Automated Flight Service Station
AGL	Above Ground Level
APL	Airport Pseudolite
ASOS	Automated Surface Observing System
ATC	Air Traffic Control
AWOS	Automated Weather Observing System
C/A	Course Acquisition
CAA	Civil Aviation Authority
CDI	Course Deviation Indicator
DGPS	Differential Global Positioning System
DME	Distance Measuring Equipment
DOD	Department of Defense
DOP	Dilution of Precision
DOT	Department of Transportation
EMI	Electromagnetic Interference
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations

FIS	Flight Information Services
FMS	Flight Management Systems
FOC	Full Operational Capability
FRP	Federal Radionavigation Plan
GLONASS	Global Navigation Satellite System (Russia)
GNSS	Global Navigation Satellite System (ICAO)
GPS	Global Positioning System
Hz	Hertz (cycles per second)
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
IGEB	Interagency GPS Executive Board
ILS	Instrument Landing System
INS	Inertial Navigation System
IOC	Initial Operational Capability
JPO	Joint Program Office
kHz	Kilohertz
LAAS	Local Area Augmentation System
Loran	Long-Range Navigation
MAP	Missed Approach Point
MCS	Master Control Station
MHz	Megahertz
MLS	Microwave Landing System
NAS	National Airspace System

NASA	National Aeronautics and Space Administration
Navaids	Ground-Based Navigation Aids
NDB	Nondirectional Beacon
nm	Nautical Mile
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NOTAM	Notice to Airmen
NPA	Nonprecision Approach
ns	Nanosecond
P-code	Pseudorandom Noise (PRN) Tracking Code
PIREPS	Pilot Reports
PPS	Precision Positioning Service
PRN	Pseudo-Random Noise
RAIM	Receiver Autonomous Integrity Monitoring
RNAV	Area Navigation
SA	Selective Availability
Satnav	Satellite-Based Navigation
SPS	Standard Positioning Service
TACAN	Tactical Air Navigation
TCAS	Traffic Alert Collision Avoidance System
TIS	Traffic Information Services
TSO	Technical Standard Order
UTC	Coordinated Universal Time

VFR	Visual Flight Rules
VHF	Very High Frequency
VOR	Very High Frequency Onmidirectional Range
VORTAC	Collocated VOR and TACAN
WAAS	Wide Area Augmentation System
WGS	World Geodectic System

CHAPTER I

INTRODUCTION

Background Information

The dramatic acceleration of technology is having a significant impact on everyone as we begin the 21st century. The world of aviation is no exception. In fact, aviation technology is advancing so rapidly that keeping pace with the changes is becoming problematic for the pilots who operate in the system. One of the most noteworthy changes is the replacement of the current Very High Frequency Omnidirectional Range (VOR) based National Airspace System (NAS) with the Global Positioning System (GPS). GPS is a satellite based navigation system using 24 satellites to provide properly equipped users with highly accurate position, velocity, and time (PVT) information. The system, which is controlled and operated by the Department of Defense (DOD) currently provides worldwide navigation capability to both the military and the civilian segments of aviation (The Global Positioning System, 1995). Until May 1, 2000, the DOD allowed only selective availability (SA) to the civilian users. Essentially, selective availability provided a GPS signal which was deliberately degraded by the DOD for national defense purposes. The DOD now has the capability to degrade or eliminate the use of GPS in designated areas throughout the world and, therefore, has determined that it is no longer necessary for national security to degrade the GPS signal to non-military users (GPS Fluctuation, 2000). Therefore, all GPS users now enjoy the precision of the full Global Positioning System.

GPS is proposed by the Federal Aviation Administration (FAA) to be the primary radio navigation system for the NAS in the early 21st century. The current Federal Radionavigation Plan (FRP) projects that a phase-down will begin in 2008 for most of our currently used land based radio navigation facilities. The current ground based systems will either be phased out completely or remain in a lesser supportive role. In some of the more remote areas such as Alaska, the GPS is already being widely used because ground based facilities are either unavailable or unreliable. A current trial program is currently being tested and studied in the Alaska bush country to determine its validity and reliability for navigating, communicating and collision avoidance (Capstone Program, 2000).

This major transition from ground based navigation to GPS is rapidly gaining momentum while the number of pilots being trained to utilize the new system is remaining relatively stagnant. There is a very real danger of this new technology outrunning the existing capabilities of the very people the system is designed to help.

Problem Statement

Two related problems are arising in conjunction with the accelerated usage of the GPS and the proliferation of technological equipment and procedures: (a) a lack of standardization of equipment and operating procedures and (b) complex or ambiguous programming and/or operational procedures. Both of these issues tend to increase the workload for and create a distraction to the pilot. Overload and/or inattention to the primary responsibility of "flying" the aircraft can jeopardize the safety of the flight. Also, a lack of understanding either the GPS system or the procedures related to it or its related equipment can result in the inability of the pilot or crew to perform a critical maneuver with potentially disastrous results (Joseph, 1999).

In addition, the FAA certainly will, in the very near future, require pilots seeking pilot certification and currency to have system knowledge and proficiency in the use of the GPS. Current flight training programs do not adequately incorporate the training of GPS navigation procedures in either their ground or flight training programs (Kelly, 1997).

Therefore, research into GPS navigational procedures needs to be conducted now in order to develop sufficient training programs to meet the future demand. The timing is right to consider the development of a new and creative program which addresses the problem areas which are arising due to the advancing technology and its associated complexity in the aviation arena.

The capabilities of GPS render some of our former navigational concepts and procedures as unnecessarily cumbersome and antiquated. Current GPS technology affords the accuracy and simplicity of operation to provide the aviation community with a system as easy to operate as the computerized video games with which the youth of our world are already intimately familiar. The aviation community must begin to think creatively and futuristically to take advantage of the incredible capabilities of GPS. This activity is already underway as government, industry, and private enterprises are aggressively pursuing research in the fields of flight simulators, advanced displays, cockpit ergonomics, automation, human/machine interfacing, human factors, and many other vital issues associated with the new capabilities and technologies becoming available (Williams, 1999).

One area of study which is not currently being addressed relates to the enhanced usability and simplification of the present basic navigation model, which currently uses Magnetic North as its paradigm. The GPS makes the use of Magnetic North unnecessary and, indeed, undesirable. GPS automatically determines position with respect to Longitude and Latitude and motion with respect to True or Geographic North along a Great Circle route. In fact, most current aviation GPS receivers provide directional information via a moving map or a Horizontal Situation Indicator (HSI) which automatically and instantaneously displays the True Flight Track (TFT) of the aircraft with respect to Geographic North.

The cumbersome procedures of converting True Courses to Magnetic Headings by applying corrections for Wind Correction Angles, Magnetic Variation, Magnetic Deviation, and Magnetic Disturbances are no longer required for either efficacy or safety of flight. Even the Winds Aloft Forecasts which are used to perform preflight planning are given relative to True North. In addition, FAA Air Traffic Controllers (ATC) currently provide radar traffic advisory information and aircraft radar vectors relative to the flight track of the aircraft involved. ATC would be able to provide pilots with traffic advisories and radar vectors without regard to the effects of the wind and/or the current magnetic heading of the aircraft (Air Traffic Control, 2000).

Magnetic North orientation devices (for example, the magnetic compass) will continue to have value as a backup system and a method to assist the pilot(s) in determining the aircraft's heading (longitudinal axis) relative to the ground. However, Magnetic North should no longer be the primary paradigm upon which aviation bases its navigation procedures. The entire aviation system would greatly benefit from the straightforward and simplified approach which a Geographic/True North-based navigation system offers.

The question, then, is whether the use of a geographic north model will enhance pilots' ability to perform navigation tasks and, thus, ultimately improve the efficacy and safety of flight.

Purpose Statement

The purpose of this study, therefore, is to determine if the performance of navigation tasks by Oklahoma State University Theory of Flight students using a Geographic North Model exceeds that of those students using the traditional Magnetic North Model.

Research Hypothesis

Oklahoma State University Theory of Flight students performing navigation tasks based on a Geographic North Model will do so more accurately and more expeditiously than those students using the traditional Magnetic North Model.

Assumptions

This study makes the following assumptions:

1. The subjects have not previously received instruction in performing Dead Reckoning Navigation procedures.

2. The subjects have received instruction in Sectional Chart interpretation and mechanical Flight Computer (E-6B) usage.
3. The subjects proceeded at approximately the same rate of instruction such that longevity of the instruction did not bias the outcomes.
4. The instruction was homogeneously provided to both groups by using similarly structured presentations by the same professor.

Limitations

This study has the following limitations:

1. The number of total subjects was limited to the enrollment and attendance of the class members for the days of the study.
2. The number of subjects in the experimental group was not equal to the number of subjects in the control group because the selection of subjects was by class section.
3. The selection and assignment of the subjects were by class section of the Oklahoma State University's Theory of Flight classes rather than a purely random selection.
4. The subjects were asked to not discuss their class sessions with those in the other section; but this could not be completely monitored or controlled.
5. The subjects were asked not to refer to their text (which discusses the magnetic-north model) prior to or during the study; but this could not be completely monitored or controlled.

6. There was a certain amount of subject drop-out during the study due to normal student absences.

Scope

This study has the following scope:

The study was conducted during regularly scheduled class periods for each Section (I and II) of the Oklahoma State University Theory of Flight course (AVED 1113) during the spring semester, 2000.

Definition of Terms

Air Traffic Control - A service provided by the appropriate authority to promote the safe, orderly, and expeditious flow of air traffic.

Airway - A formally designated control area, the centerline of which is defined by radio navigation aids.

Area Navigation (RNAV) - Application of the navigation process providing the capability to establish and maintain a flight path on any arbitrarily chosen course that remains within the coverage area of navigation sources being used.

Controlled Airspace - Airspace within which air traffic control services will be provided. IFR flights must obtain an air traffic control clearance; VFR flights may be subject to either weather or air traffic control restrictions.

Coordinated Universal Time (UCT) - A standardized time based on the current time at the prime meridian. Formerly called Greenwich mean time.

Dead Reckoning - A method of navigation in which the pilot uses the forecast winds at the planned cruising altitude and applies trigonometry to deduce the proper heading to be flown to counteract the crosswind.

Differential GPS- A technique used to improve radionavigation system accuracy by determining positioning error at a known location and subsequently transmitting the determined error, or corrective factors, to users of the same radionavigation system, operating in the same area.

Distance Measuring Equipment (DME) - Electronic navigational equipment which allows the pilot to determine the straight line distance in nautical miles to a given transmitter on the ground.

En Route - A phase of navigation covering operations between a point of departure and termination of a mission.

Federal Aviation Administration (FAA) - The agency of the Department of Transportation charged with operating the civilian air transportation system in the United States.

Free Flight - A safe and efficient flight operating capability under instrument flight rules in which the operators have the freedom to select their path and speed in real time. Air traffic restrictions are only imposed to ensure separation, to preclude exceeding airport capacity, to prevent unauthorized flight through special use airspace, and to ensure safety of flight.

Full Operational Capability (FOC) - A system dependent state which occurs when the particular system is able to provide all of the services for which it was designed.

Geocentric - Relative to the Earth as a center, measured from the center of mass of the Earth.

Global Navigation Satellite System (GNSS) - The GNSS is a world-wide position and time determination system, that includes one or more satellite constellations, aircraft receivers, and system integrity monitoring, augmented as necessary to support the required navigation performance for the actual phase of operation.

Global Positioning System (GPS) - A satellite-based radionavigation system providing positioning, velocity and time (PVT) information.

Great Circle Route - An air route over the Earth's surface which is the shortest distance between the points of departure and destination.

Inclination - One of the orbital elements (parameters) that specifies the orientation of an orbit. Inclination is the angle between the orbital plane and a reference plane, the plane of the celestial equator for geocentric orbits and the ecliptic for heliocentric orbits.

Initial Operational Capability (IOC) - A system dependent state which occurs when the particular system is able to provide a predetermined subset of the services for which it was designed.

Instrument Flight Rules (IFR) - The FAA rules and regulations that govern the conduct of aircraft during instrument flight.

Integrity - Integrity is the ability of a system to provide timely warnings to users when the system should not be used for navigation.

Interference (electromagnetic) - Any electromagnetic disturbance that interrupts, obstructs, or otherwise degrades or limits the performance of user equipment.

Instrument Landing System (ILS) - A radionavigation facility which provides both horizontal and vertical guidance for a precision approach.

Jamming (electronic) - The deliberate radiation, reradiation, or reflection of electromagnetic energy for the purpose of preventing or reducing the effective use of a signal.

Latitude (parallels) - A measurement of position north or south of the equator in degrees, minutes and seconds (or fractions of minutes).

Longitude (meridians) - A measurement of position east or west of the prime meridian (Greenwich, England) in degrees, minutes and seconds (or fraction of minutes).

Long Range Navigation (LORAN) - A navigational system which uses low frequency signals transmitted from ground based stations around the world to provide position information.

Magnetic Course - True course corrected for magnetic variation.

Magnetic Deviation - The magnetic compass error due to the effects of electromagnetic fields created by electrical equipment in the cockpit.

Magnetic Disturbance - A geological feature of the Earth which alters the magnetic field at that point (frequently occurs in mountainous terrain).

Magnetic Heading (MH) - The alignment of the longitudinal axis (or nose) of the aircraft in relationship to magnetic north.

Magnetic North - The direction from a given location on or above the Earth to the magnetic north pole.

Magnetic Variation - The difference between true (geographic) and magnetic north in a given location due to the difference in the positions of the geographic and magnetic north poles.

Multipath - The propagation phenomenon that results in signals reaching the receiving antenna by two or more paths. Signal interference may result.

Nanosecond (ns) - One billionth of a second.

National Airspace System (NAS) - The common network of airspace, airports, navigation aids, and air traffic control equipment across the United States.

National Airspace System Plan (NASP) - A plan published by the FAA that describes future improvements to the National Airspace System.

National Command Authority (NCA) - The NCA is the President or the Secretary of Defense, with the approval of the President. The term NCA is used to signify constitutional authority to direct the Armed Forces in their execution of military action

Nautical Mile (nm) - An international unit of distance equal to 1,852 meters.

Navigation - The process of planning, recording, and controlling the movement of a craft or vehicle from one place to another.

Nondirectional Radio Beacon (NDB) - A radio navigation beacon that transmits a uniform signal omnidirectionally using either the Low Frequency or the Medium Frequency radio frequency band. It provides bearing information to the NDB for pilot navigation.

Nonprecision Approach - A standard instrument approach procedure in which no electronic glide path is provided.

Pilotage - A means of VFR navigation using navigational charts for position determination.

Precision Approach - A standard instrument approach procedure in which electronic glide path is provided.

Radionavigation - The determination of position, or the obtaining of information relating to position, for the purposes of navigation by means of the propagation properties of radio waves.

Radar Vector - A magnetic heading issued by an Air Traffic Controller to the pilot of an aircraft.

Receiver Autonomous Integrity Monitoring (RAIM) - A technique whereby a GPS receiver/processor determines the integrity of the GPS navigation signals without reference to external systems other than to the GPS satellite signals themselves or to an independent input of altitude information.

Reliability - The probability of performing a specified function without failure under given conditions for a specified period of time.

Sectional Chart - The most commonly used navigation chart used for VFR flight. It has a scale of 1:500,00.

Sole-Means Air Navigation System - A sole-means navigation system approved for a given operation or phase of flight must allow the aircraft to meet all four navigation system performance requirements: accuracy, integrity, availability, and continuity of service.

Statute Mile - A unit of distance on land in English-speaking countries equal to 5,280 feet.

Supplemental Air Navigation System - A navigation system that may only be used in conjunction with a primary- or sole-means navigation system.

Tactical Air Navigation (TACAN) - A radionavigation system similar to the VOR/DME which is used primarily by the military.

True North - The direction from a given location on or above the Earth to the geographic north pole.

True Flight Track (TFT) - The actual flight path of an aircraft over the earth's surface relative to geographic north.

Very High Frequency (VHF) - The frequency band between 30 and 300 mHz.

Visual Flight Rules - Rules that govern the procedures for conducting flight under visual meteorological conditions (VMC).

VHF Omnidirectional Range (VOR) - A ground based navigation aid that transmits a VHF navigation signal 360 degrees in azimuth. It is the primary navigation aid upon which the airways of the NAS are based.

World Aeronautical Chart (WAC) - A navigation chart similar to the sectional chart, but it has a scale of 1:1,000,000.

World Geodetic System (WGS) - A consistent set of constants and parameters describing the Earth's geometric and physical size and shape, gravity potential and field, and theoretical normal gravity.

CHAPTER II

REVIEW OF LITERATURE

The Development of the National Airspace System

The use of navigational radio systems to aid pilots in locating their positions and in flying from one point to another began in the 1920s with the installation of four-course radio ranges and the development of nondirectional beacons (NDBs). These ground based systems, coupled with a receiver on board the aircraft, provided the pilot with a crude but usable means to navigate without reference to geographical features of the terrain below. Navigation along federal airways became feasible day or night in visual meteorological conditions (VMC) or instrument meteorological conditions (IMC) by reference to the emitted radio signals. Unfortunately, these systems were often confusing, inaccurate, and unreliable (Millbrooke, 1999).

In the early 50s, a major advancement took place when the Civil Aeronautics Authority (CAA – now the FAA) began creating Victor Airways using the Very High Frequency Omni Range (VOR). This system was also ground based, but, when coupled with an onboard receiver in the aircraft, it provided a much easier to use, more accurate and reliable course guidance than the radio range or NDB. The VOR was the technological breakthrough of its time and its validity is seen by the fact that it became and has remained the basis of the worldwide navigation system (Nolan, 1994).

The VOR system has been enhanced with Distance Measuring Equipment (DME), TACAN (Tactical Air Navigation), and computer based Area Navigation (RNAV), but the airway structure utilizing the omnidirectional signals from the VOR transmitting stations has remained basically the same to the present day.

Along with en route navigation, aircraft operators needed guidance systems for terminal operations at the departure and destination airports. Instrument departure and approach procedures were developed to selected airports using VOR and nondirectional beacons (NDBs) for nonprecision approaches. Precision ground based radio navigational facilities such as the Instrument Landing System (ILS) and the Microwave Landing System (MLS) were also developed to provide landing in lower ceiling and visibility conditions – in some cases, as low as zero ceiling and zero visibility. These systems have served the aviation community extremely well over the years and are still valid today (Bilstein, 1994).

In addition, a network of radar facilities was established to provide increased guidance and safety to the aircraft using the airspace. These radar facilities were strategically placed near high density traffic areas and Air Traffic Controllers (ATC) were trained to monitor the radar screens and control air traffic near larger airports and along federal airways for flights conducted under IFR. ATC continues to provide traffic control and also provides several other services including flight monitoring, radar vectors, traffic advisories and separation, terrain avoidance information, emergency assistance, and, time permitting, weather information and general assistance. The range of the ground based radar antenna is limited depending on the type of radar facility, the surrounding terrain, the altitude of the aircraft and the equipment on board the aircraft. Unfortunately, the radar sites do not cover the more remote areas and ATC services are usually available only along Victor or Jet Airways or near larger airports (Nolan, 1994).

Various changes and improvements have been made to the NAS over the past 50 years including Area Navigation (RNAV), Microwave Landing Systems (MLS), Inertial Navigation Systems (INS), LORAN-C (Long Range Navigation), and Mode C transponders to name a few. However, the basic system of ground based radio navigation and radar surveillance systems remains. This will change in the 21st century as the GPS is phased in as the foundation of the National Airspace System. As this happens, currently used ground based navigational aids will be phased out or relegated to a backup capacity (The Global Positioning System, 1995).

The Global Positioning System (GPS)

Development and Operation

In 1973 the NAVSTAR (Navigation System by Time and Ranging) GPS Joint Program Office (JPO) was established and directed to start the concept development phase of a space satellite based, all weather navigation system (Clarke, 1998). JPO was staffed by personnel from the U.S. Air Force, U.S. Navy, U.S. Army, U.S. Marine Corps, U.S. Coast Guard, U.S. Defense Mapping Agency, NATO nations, and Australia. The equipment development and production phases followed, and the first GPS satellite was launched in 1978. Initial Operational Capability (IOC) was accomplished in 1993. Full Operational Capability (FOC) was reached in 1995 when 24 GPS Satellite Vehicles (SVs) had been deployed in their operational constellation and successfully completed testing.

The GPS constellation consists of 21 operational and 3 relocatable spare SVs orbiting in six orbital planes around the earth at an altitude of approximately 10,900 nautical miles above the Earth's surface (Figure 1) or about 14,350 nm from the Earth's center.

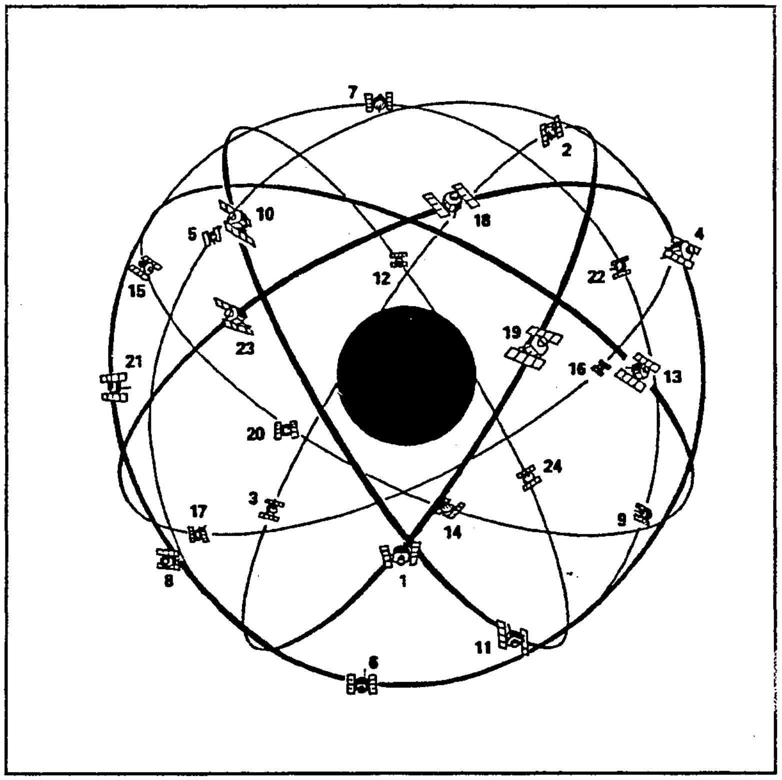

Figure 1. GPS Constellation.

Each of the six planes contains four equally spaced SVs which orbit the Earth every 12 hours at an inclination of 55 degrees to the equatorial plane (Figure 2). This spacing provides for five to eight SVs to remain visible from anywhere on or above Earth at all times (Hofmann-Wellenhor, 1994). It is necessary for a GPS receiver to receive Signals in Space (SIS) from at least four different SVs in order to determine three dimensional position. A fifth signal (or a barometric altimeter input) is required to determine if any of the signals are corrupted using the Receiver Autonomous Integrity Monitoring (RAIM) function required for flight under Instrument Flight Rules (Aeronautical Information Manual, 2000).

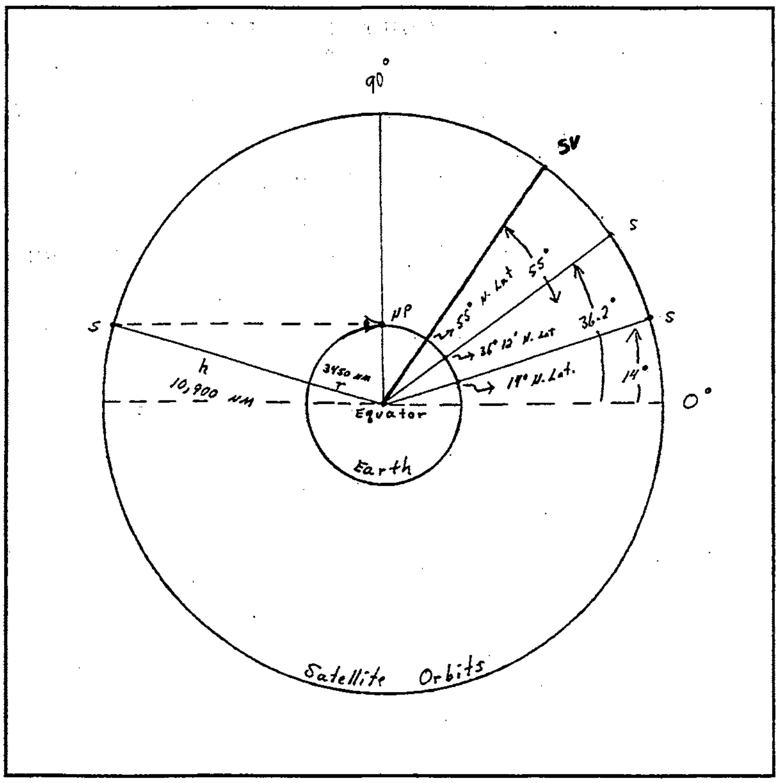

Figure 2. Satellite Inclinations.

The GPS is a passive system in that each SV transmits signals which can be received by an infinite number of users in any location around the world. Therefore the capacity of the system has no limits either in the number of users or the location of its use. Previous navigation systems were limited by "line-of-sight" transmissions (for example, VOR), finite capacity two-way interaction between transmitters and receivers (for example, DME), or meteorological phenomenon interference (for example, NDB). The GPS has none of these limitations. The GPS, unlike many of the ground based navigational aids, is usable anywhere in the world from the surface up and in all meteorological conditions. This is because the signals originate from satellites and there are few obstructions to interfere with the signal reaching the GPS receiver in the aircraft, and the SIS frequencies of 1575.42 MHz for L1 and 1227.60 MHz for L2 are not susceptible to meteorological interference. Pilots in Alaska and other remote and/or mountainous areas have been using GPS to assist their VFR and IFR navigation since IOC in 1993 and have found the system to be extremely accurate and reliable. With this capability, uninterrupted and seamless navigation from any point on Earth to another is possible and any airport in the world has the potential for instrument approaches without ground based facilities (Tucker, 1998).

The GPS signals provide Position, Velocity and Time (PVT) information to the user. Position is computed by the GPS receiver, which measures the Time of Arrival (TOA) of the SIS from 3 or more SVs, calculates the distance from each of the SVs (distance = speed of light x time), and uses triangulation to determine its position in three dimensional space. This 3-D point in space is then converted to the familiar form of Longitude, Latitude and Altitude and correlated to the World Geodetic Survey of 1984 (WGS-84) mapping system. In February, 2000, NASA used a Shuttle Radar Topography Shuttle Mission to perform a high-resolution 3D mapping of approximately 80% of the world. These 3D topographical maps will be incorporated into the GPS displays of the future with high-resolution photography replacing cartography as the basis of GPS displays (Covault, 2000).

Velocity is determined by the GPS receiver measuring the *Doppler* shift of the frequency of each SIS and thus determining the relative motion between itself and each of the SVs being monitored. The GPS receiver/computer uses triangulation to determine the velocity vector (includes both speed and direction) of the receiver (Mission Mathematics, 1997).

Time is transmitted along with a NAV-msg from each SV to the GPS receiver. Each SV has four atomic clocks which have an accuracy of 100-nanoseconds (.0000001 second) UTC (Universal Coordinated Time) time-transfer accuracy. The GPS receivers do not have atomic clocks, but maintain their accuracy by constantly being updated through the NAV-msg. The NAV-msg to the GPS receiver also contains an Almanac of information about the SV along with its ephemeris (precise position in orbit).

Initial use of GPS was limited to military use, but civilian use was soon to follow, and by late 1993, a few civilian GPS approach procedures were established in conjunction with preexisting ground based non-precision approaches such as VOR and NDB. In 1994, the first GPS route was established and stand-alone non-precision approaches were being allowed (Clarke, 1998).

The Department of Defense (DOD), however, limited the accuracy of the GPS to non-military users for national security reasons. The military was able to achieve Precise Positioning Service (PPS) of 16 meters while non-military users were provided with

Standard Positioning Service (SPS) of 100 meters. This was done by degrading the SIS available to non-military users through a process called Selective Availability (SA).

Beginning May 2, 2000, however, the DOD ceased degrading the SIS to all users and everyone is able to achieve near PPS accuracy. The GPS horizontal and vertical errors diminished significantly around 0405 UTC (shortly after midnight EDT) to a circular error of only 2.8 meters and a spherical error of 4.6 meters during the first few hours of SA-free operation. As an illustration, consider a football stadium. With SA activated, you really know only if you are on the field or in the stands at that football stadium. With SA switched off, you know which yard marker you are standing on (GPS Fluctuations, 2000).

Selective Availability was ceased because the DOD now possesses the ability to either degrade or eliminate the GPS signal in selected regions of the world should it be necessary in the event of a military conflict or threat to national security. The military still acquires a slightly higher precision because it is able to utilize both the L1 and L2 signals while non-military users are presently limited to L1 only. The ability to acquire both signals reduces the error introduced by the SIS traveling through the ionosphere (Clarke, 1998). This limitation will be mostly negated, however, with the addition of two more SIS frequencies to new SVs to be placed in orbit (Federal Radionavigation Plan, 1999).

Efforts coordinated by the International Civil Aviation Organization (ICAO) to combine the capability of the U.S. GPS system with Russia's Global Navigation Satellite System (GLONASS), Europe's Geostationary Navigation Overlay Stystem (EGNOS) and Japan's Multi-Satellite Augmentation System (MSAS) are certain to bring world wide advancements to satellite navigation (Satnav). These systems are all being coordinated to make up the integrated Global Navigation Satellite System (GNSS) (Johns, 1997).

Even with the new accuracy provided by the GPS, more accuracy and reliability is needed for precision instrument approaches to airports. Therefore, the GPS system is being augmented with separate Differential GPS (DGPS) such as the Wide Area Augmentation System (WAAS) and the Local Area Augmentation System (LAAS). These systems will allow more precise instrument approaches than are currently available with basic GPS. DGPS operates on the principle that if the error in the SIS can be determined and a correction applied to the GPS receiver/computer to accommodate for the error, the result is a highly precise PVT (Kaplan, 1996).

The WAAS is a wide area coverage system and is based on SIS received from several SVs by ground reference stations which have a precise geodetically surveyed positions (Figure 3). The positions determined by the reference stations' GPS

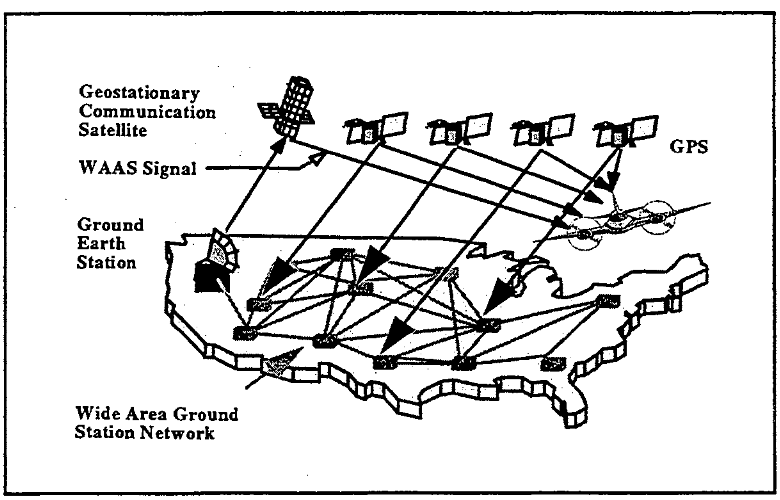

Figure 3. GPS WAAS.

receivers/computers from the SIS are then compared to its known precise geographic positions and error algorithms are calculated and sent to the users' GPS receiver via a datalink satellite. The users' GPS receiver/computer consequently uses this error correction information to perform its own calculations using the same SIS and improve its own navigation solution (Operational Requirements Document, 1994).

The LAAS is similar to the WAAS except that it is designed for a smaller coverage area near an airport to improve the accuracy for instrument approaches (Figure 4). Since the reference station is close to both the airport and the user aircraft, the error algorithm it calculates is a closer match to the error experienced by the users' GPS receiver. The error message is sent via radio transmission directly to the user aircraft's GPS receiver rather than by a satellite datalink (Operational Requirements Document, 1995).

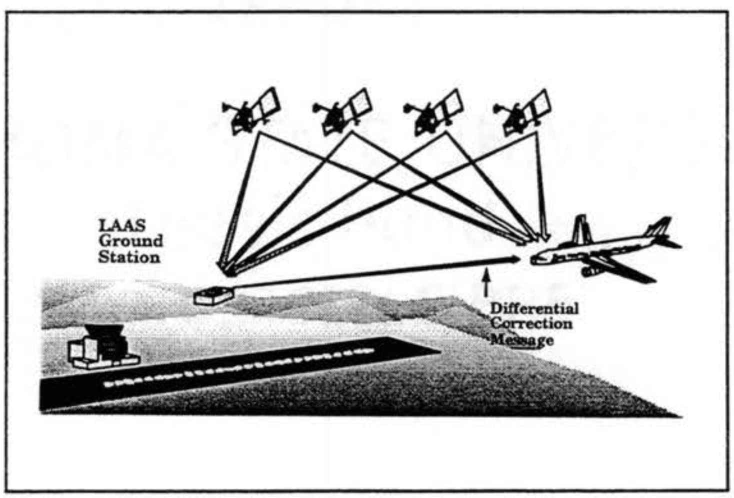

Figure 4. GPS LAAS.

GPS Information Presentations

The simplicity of the GPS for navigation is based on constantly assessing the aircraft position relative to its current location on or above a point on the surface of the earth at that precise moment. Since this computerized assessment is done several times a second, the information received by the GPS receiver and displayed to the pilot is almost instantaneous. For this reason, very accurate and timely navigational data is relayed to the pilot. Course deviations, changes in ground speed, and changes in altitude are reported almost instantaneously.

The GPS is capable of displaying real time information in many different and useful formats. The most basic GPS navigation units provide the pilot with current position information using longitude and latitude, ground track, and ground speed. More advanced GPS receiver units include computer capability which can store and supply thousands of pre-determined points such as airports, VORs, NDBs, and airway intersections. In addition, numerous self-determined *user* points can be entered into the computer memory by simply entering the appropriate coordinates of a desired location. Most units have the capability of instantly storing the coordinates of an aircraft's current location with, usually, just the touch of one button. These points can be readily retrieved, simply by selecting them from the memory. The computer can then plot a course from one point to another or from the aircraft's present position to any of these points and, concurrently, provide information of aircraft position relative to the desired course and distance and time to the destination. Pertinent airport information such as elevation, runway orientation and length, radio frequencies and available facilities is normally available from the memory databank as well (Williams, 2000).

The display of information to the pilot is another advantage of the GPS. Information can be displayed textually or graphically. The GPS can be set to display information similar to that of a VOR or Horizontal Situation Indicator (HSI). Many display a moving map showing topographical details similar to those found on an aeronautical chart, along with a course line indicating the flight path desired and the flight track actually flown. The display can often be oriented with the top of the display being either north, the track of the aircraft, or the direction of the course to be flown. This capability has many possibilities, one of which is the location of the nearest airport in the event of a need to divert. Many GPS units have the capability of displaying several of the closest airports along with information about each airport with the touch of just one button (Williams, 1998).

Investigation is just beginning into the concept of using GPS for aircraft pitch, bank and yaw information currently provided by the gyroscopic Attitude Indicator and Turn Coordinator instruments. By placing GPS antennas on the wing tips, the nose and the tail of the aircraft, relative position and velocity of the separate antennas can be computed and translated into motion around the three aircraft axes.

In fact, the GPS could quite literally replace all six of the basic flight instruments: airspeed indicator, attitude indicator, altimeter, vertical speed indicator, heading indicator, and turn coordinator.

Safe Flight 21 Program

On February 18, 2000 the U.S. Department of Public Affairs issued the following press release entitled "New Radionavigation Plan Eyes Transition to Satellite-Based Services in the 21st Century" to introduce the FAA's Safe Flight 21 Program:

> U.S. Secretary of Transportation Rodney E. Slater and U.S. Secretary of Defense William S. Cohen today announced the release of a plan which highlights government-operated navigation system, as well as the transition to satellite navigation – guidance system of the 21st century.
>
> The U.S. Department of Transportation (DOT) and U.S. Department of Defense (DOD) today jointly released the 1999 Federal Radionavigation Plan (FRP), which includes plans for two additional Global Positioning System (GPS) signals for civil use and a revised schedule for making the transition to GPS. This plan emphasizes again the administration's strong commitment to civil GPS modernization by placing two new signals on the GPS satellites as promised by Vice President Al Gore in March 1998. (p. 1)

This program is a three-year joint government/industry initiative designed to demonstrate and validate, in a real-world environment, the capabilities of advanced surveillance systems and air traffic procedures associated with free flight, using Automatic Dependent Surveillance - Broadcast (ADS-B) and Traffic Information Services (TIS-B) as enabling technologies.

Under the FAA's Safe Flight 21 Program, the Alaska Region's Capstone Program has been initiated to evaluate and validate the GPS based ADS-B system for operational enhancements in efficacy and safety. This program is being conducted in the remote Alaska bush near Bethel in the Yukon-Kuskokwim river delta area where ground based communications, navigation and radar capabilities are severely limited. Approximately 200 commuter aircraft are involved in the program with each of these aircraft equipped by the FAA with: (a) an IFR-certified GPS navigation receiver, (b) an ADS-B transceiver,

(c) a moving map display with Traffic Information Service - Broadcast (TIS-B), (d) Flight Information Service (FIS), and (e) a multi-function color display (Capstone Program, 2000).

The ability of the GPS receiver to very accurately determine its position, velocity and time (PVT) provides valuable navigational capability and terrain avoidance information to the users. The moving map (Figure 5) displays this information to the pilot/crew in the cockpit through real time navigational data, color coded terrain data, and cartographic data in a format which is readily interpretable by the user. In addition, warnings are generated on the display whenever Controlled Flight Into Terrain (CFIT) becomes a threat.

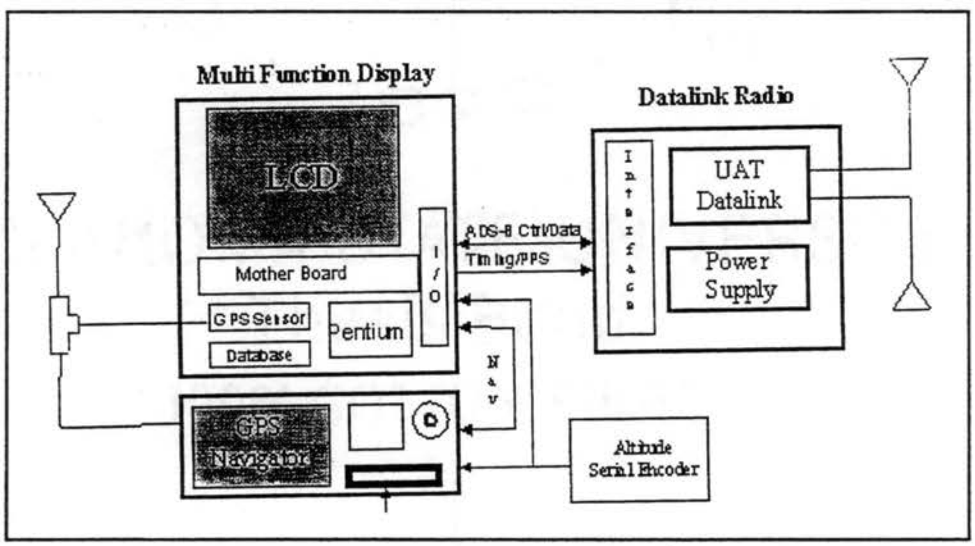

Figure 5. Multi-Function GPS Display.

Through the Automatic Dependent Surveillance-Broadcast (ADS-B) transmitter/receiver installed in each participating aircraft, the PVT information for each aircraft is shared by providing this information on each participant's moving map display in the cockpit. Thus, each aircraft will have position and movement information of all other participating aircraft in their vicinity. The information is transmitted between the ADS-B units via a datalink provided by a Universal Access Transceiver (UAT) in each aircraft in conjunction with 12 ground stations. It is anticipated that the datalinking will ultimately be accomplished via satellite.

The Flight Information Service (FIS) equipment provides the capability of receiving information via UAT datalink communications. Weather maps, special use airspace status, wind shear alerts, NOTAMS, and PIREPS will be available and can be displayed on the user's cockpit multi-function color display.

In addition, the Capstone Program will commence in late June or early July 2000 testing the Micro En route Automated Radar Tracking System (M-EARTS). With this system, the PVT information can also be relayed via datalink to the Anchorage Air Traffic Control Center (ATCC). Thus, very precise information pertaining to the location and movement of any participating aircraft in the Bethel area, either airborne or on the ground, can be monitored by ATC. This information gathered by ATC can then be transmitted back to aircraft with a Traffic Information Service-Broadcast (TIS-B) system installed to provide the pilot/crew with equivalent traffic information. In addition, any aircraft, obstruction or other target which the ATCC displays on its radar screen can be incorporated into the TIS-B information and displayed on the user's multi-function display. The benefit to the operator regarding traffic, terrain and obstruction collision avoidance capability is obvious. Unlike the limited ground based radar system, the GPS based surveillance system can be virtually unlimited when the necessary datalink satellites are in position (Capstone Program, 2000).

As new generation GPS receivers certified for both visual (VMC) and instrument flight conditions (IMC) become more available and affordable, their usage in the aircraft using the National Airspace System is going to escalate dramatically. Currently there are many approved GPS Oceanic Routes and hundreds of GPS Overlay and Stand-Alone instrument approaches in the United States. In addition, the FAA now allows the use of an IFR certified GPS receiver in lieu of an NDB or a DME (Aeronautical Information Manual, 2000).

The Federal Radionavigational Plan

> The Federal Radionavigation Plan (FRP) is prepared as required by 10 U.S.C.2281 (c) and delineates policies and plans for Federally provided radionavigation systems. The plan sets forth the Federal interagency approach to the implementation and operation of Federally provided, common use (civil and military) radionavigation systems. The FRP is a review of existing and planned radionavigation systems used in air, land, marine, and space navigation. (Federal Radio Navigation Plan, 1999, p. xv)

The FRP provides projected dates for the phasing in and out of the radionavigation systems which make up the National Aviation System (Figure 6). The GPS itself has been fully operational since 1995. WAAS is projected to achieve Initial Operational Capability (IOC) in September of 2000, followed by FOC in 2006 if the required system performance is achieved. Recent testing of the WAAS showed that the accuracy exceeded the standards required, but the monitoring systems to reliably detect a corruption in the system did not meet the necessary standards (Collins, 2000). WAAS will allow the

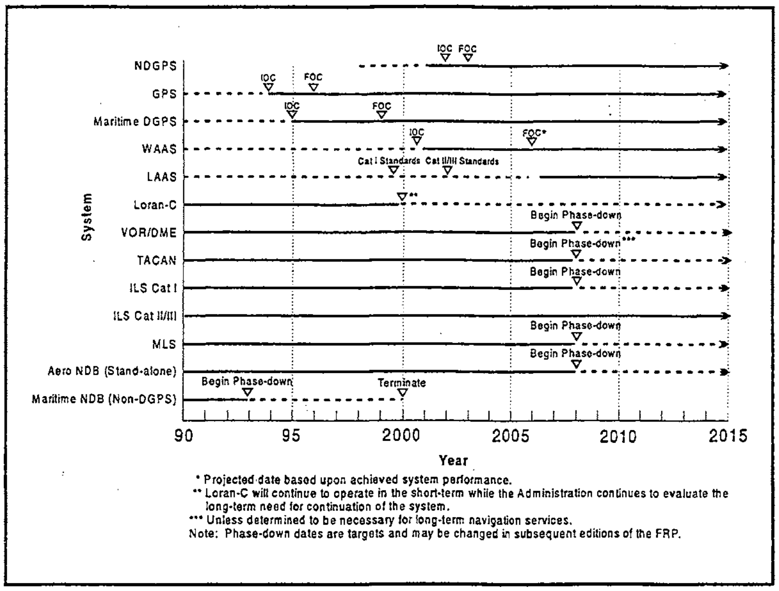

Figure 6. Federal Radionavigation Plan.

performance of en route navigation, nonprecision approaches and selected Category I ILS approaches when it reaches IOC. When WAAS achieves FOC, more Category I ILS approaches will be available.

LAAS is currently being tested at a few select airports for Category I ILS approaches and will ultimately provide the needed accuracy for Category II and III ILS approaches. LAAS is projected to be phased in by 2006.

While the GPS based capabilities are being phased in, certain ground based facilities will be phased out. The Omega system was already phase out in 1998. Projected future phasing out schedules are shown in Figures 6 and 7. As currently projected, phase

down is slated to begin in 2008. The current network of approximately 1050 VOR/DMEs, 1050 ILSs, and 750 NDBs will be phased down to a "Basic Backup Network" of several hundred VOR/DMEs, some Category I ILSs, approximately 100 (all) Category II/III ILSs, and no NDBs after 2013. It can be seen that in the projected future, VOR/DME and ILS facilities will remain as a backup to insure safety and reliability of the basic National Airspace System. It should also be noted that these dates are merely projections, and the actual schedule "will be updated as Satnav program milestones are achieved; as the actual performance of Satnav (satellite navigation) systems is documented; and as users equip with Satnav avionics" (Federal Radionavigation Plan, 1999, p. 3-26).

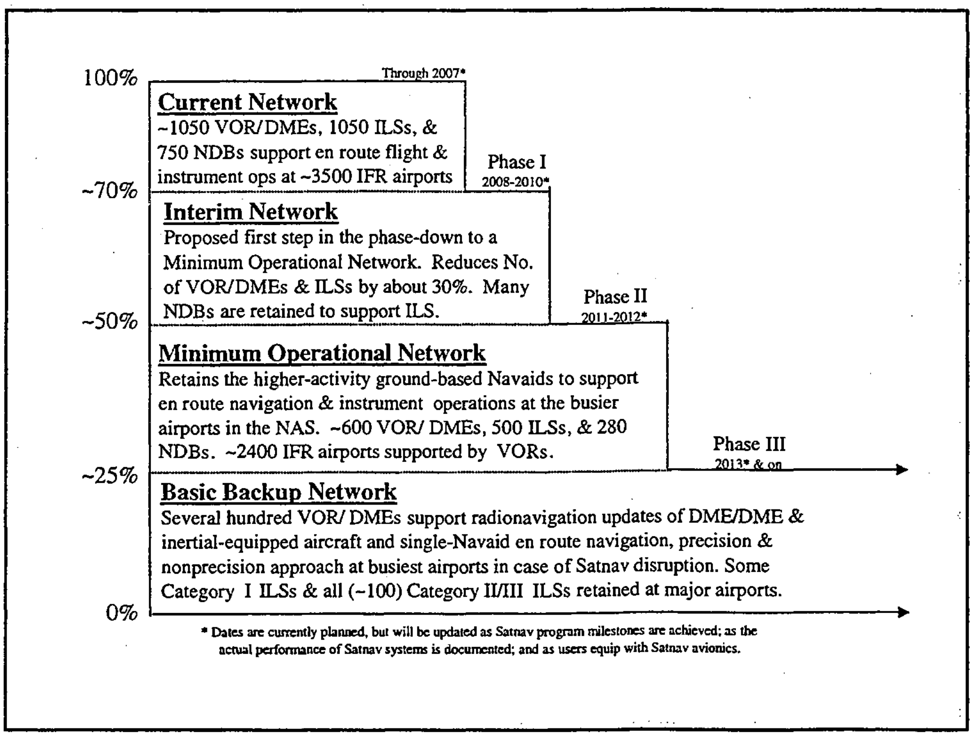

Figure 7. GPS Phasing Out Schedule.

GPS Navigation

Longitude and Latitude

The geographical-coordinate system of latitude and longitude is the language of the GPS receiver. It is possible to locate any point in the world if the longitude and latitude are known. Since the GPS measures the position of the aircraft relative to a point on the Earth's surface, it is only logical that the GPS use longitude and latitude as its format for indicating position and calculating navigational algorithms. Whereas land based navigation systems do not rely heavily on the user's familiarity with the Earth's coordinate system, competent use of the GPS system mandates a functionally sound working knowledge of longitude and latitude (Clarke, 1998).

The Earth's coordinate system is made up of imaginary reference lines known as degrees of latitude and longitude (Figure 8). The imaginary lines that circle the surface of

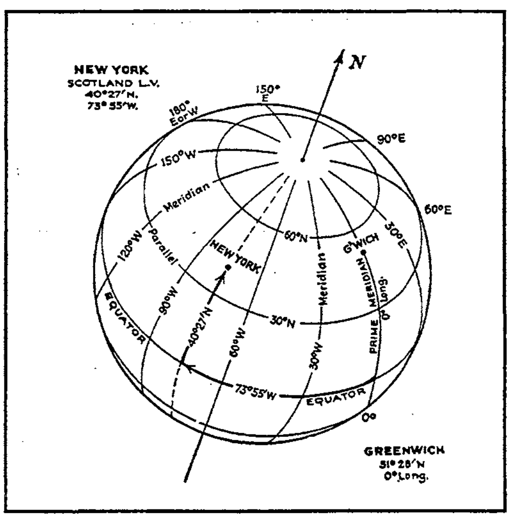

Figure 8. World Coordinate System.

the Earth east to west are called *parallels of latitude.* These parallels of latitude begin with zero degrees latitude at the equator and increase to 90 degrees north at the North Geographic Pole and 90 degrees south at the South Geographic Pole. At all degrees between the North and South Poles, the parallels of latitude are always parallel to the equator and to each other, and the imaginary circles they construct around the surface of the earth become smaller and smaller as they get closer to the poles. Parallels of latitude run east and west, but measure angular degrees north and south. Thus, latitude measurements north of the equator are designated in degrees of north latitude, whereas the measurements south of the equator are designated in degrees of south latitude (Bowditch, 1981).

Meridians of longitude are also imaginary lines that circle the earth's surface. However, meridians are not parallel to each other. Rather, meridians always pass through the North and South Poles and are always perpendicular to the parallels of latitude. Meridians of longitude run north and south, but measure angular degrees east and west. Greenwich, England, is the location of the zero degree or prime meridian. The measure of degrees of longitude increase in both east and west directions from this beginning point until they meet at the 180-degree point halfway around the earth at the International Date Line (passes north/south through the western portion of the Aleutian Chain of Alaska). Thus, longitude measurements eastward from Greenwich, England, are designated in degrees of east longitude whereas the measurements westward are designated in degrees of west longitude (Griffith, 1998).

Any position on earth can be expressed in degrees of east or west longitude and north or south latitude. Inversely, if the coordinates of a location are known, the location can be found on a globe or chart by noting where the line defined by its degrees of east or west longitude intersects with the line defined by its degrees of north or south latitude. For more precision, each degree is divided into 60 equal parts called *minutes* and every minute is divided into 60 equal parts called *seconds* (Bowditch, 1981). For example, the airport at Stillwater, Oklahoma has the coordinates of 36 degrees, 10 minutes, 47 seconds north latitude and 97 degrees, 5 minutes, 22 seconds west longitude. Frequently, a GPS display will provide the coordinates of "seconds" as tenths or hundredths of a "minute" (for example, 47 seconds as .78 minutes).

Additionally, it is 90 degrees or 5,400 minutes or 324,000 seconds from the equator north to the North Pole or south to the South Pole. Likewise, it is 180 degrees or 10,800 minutes or 648,000 seconds from the prime meridian (Greenwich, England) east or west to the International Date Line. In either case (either north/south or east/west) it is 360 degrees or 21,600 minutes or 1,296,000 seconds around the earth. Since the imaginary circles formed by the meridians of longitude are always the same size (unlike the parallels of latitude, which get smaller as they get farther from the equator), the measure of degrees measured north and south (degrees of latitude) along these meridian lines corresponds directly with the measure of distance along these same lines at the earth's surface. As a matter of fact, one minute of distance traveled north or south along a meridian is equal to one nautical mile (nm) or 6080 feet (Tucker, 1998). Therefore, 36 degrees north latitude (the approximate north latitude of Stillwater, Oklahoma) measures 36 degrees x 60 minutes/degree = 2400 minutes = 2400 nm north of the equator. Using this same formula, the earth's circumference can be calculated as 360 degrees x 60 minutes/degree = 21,600 nm, which is a close estimate of the distance around the world. All of these calculations assume that the Earth is a perfect sphere, which it isn't, so they are only approximations.

Great Circle Route (GCR)

When traveling on or above the Earth's sphere, the shortest distance between two points is called the Great Circle Route (Figure 9). The GCR can be best illustrated by connecting any two points on a globe with a string. The GCR can also be pictured as a segment of the circumference of a circular disc bisecting the Earth. A flight along a meridian of longitude or along the equator would represent special cases of a GCR (Gardener, 1997). GPS based navigation again demonstrates a great advantage over the traditional VOR system because it automatically provides all courses and tracks using a great circle format. A track is defined as the actual path the aircraft makes over the Earth. The VOR, on the other hand, uses a *Rhumb line* format which is expressed by headings rather than tracks.

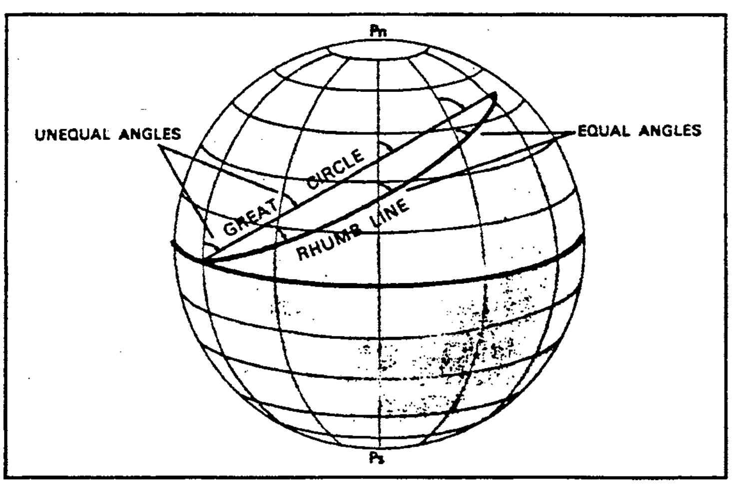

Figure 9. Great Circle Route.

True Headings can be thought of as the angle between the longitudinal axis of the aircraft and the meridians of longitude which are always oriented to *True (Geographic) North.* This angle is then converted to a circular *compass rose* divided into 360 degrees beginning with north = 0 degrees and rotating clockwise to east = 90 degrees, south = 180 degrees, west = 270 degrees, and returning to north = 360 or 0 degrees. Thus, a True Heading of 240 degrees would be a heading 240 degrees clockwise from north = southwest.

Magnetic Headings are calculated by applying the *Magnetic Variation* for any location on Earth to the True Heading. Magnetic Variation is the difference between *True North* and *Magnetic North* due to the geographic and magnetic north poles being at different locations (Thom, 1994).

Following a fixed heading or Rhumb line in a zero wind condition will actually result in traversing a curved path or loxodrome (Figure 10) with the exception of flights exactly parallel or perpendicular to meridians of longitude.

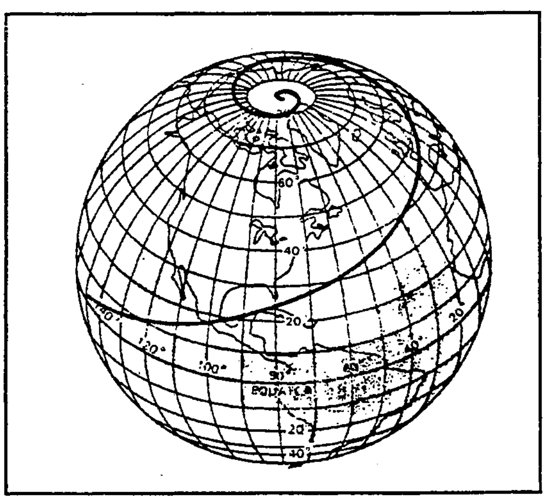

Figure 10. Rhumb Line of Loxodrome.

It is to be noted that flying the GCR requires a constant change in the heading of the aircraft. This can be seen by observing the route of a flight from a point (N 34 degrees 00 minutes, W 119 degrees 00 minutes) on the west coast of the United States to a second point (N 34 degrees 00 minutes, W 78 degrees 00 minutes) on the east coast (Figure 11). For a flight using the longer Rhumb line (2039 nm), the flight would simply maintain a true heading of 90 degrees since both points are on the same parallel of latitude. Of course, this true heading would have to be corrected for the changing

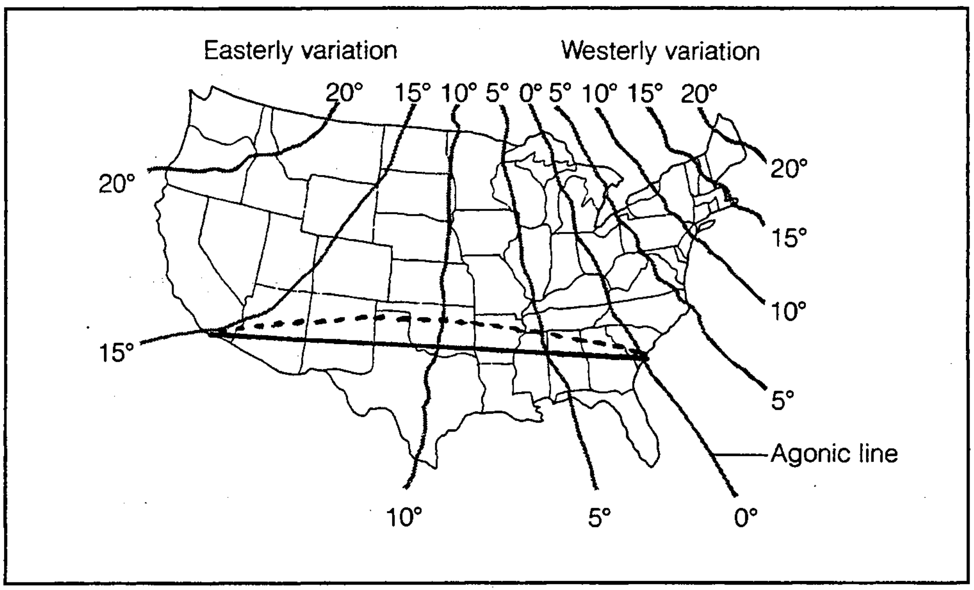

Figure 11. Comparison of a Rhumb Line (solid line) and Great Circle Route (dashed line) on a Mercator projection map.

magnetic variation along the flight route from the west to east coast (- 14 degrees to 0 degrees) in order to use magnetic headings.

The shorter GCR (2025 nm) would start with a track of 78 degrees, equal the Rhumb line magnetic heading (90 degrees) in the middle of the flight and finish with a track of 102 degrees. It is important to remember, however, that GPS automatically provides course information, and the pilot merely needs to follow the course shown on the GPS receiver's True Flight Track Indicator (TFTI) (Appendix C).

Most of our aeronautical charts use a Lambert Conformal Conic chart, which closely depicts the real 3-dimensional spherical world on a 2-dimensional chart. Courses drawn on these charts are nearly great circle routes. A course flown using the GPS will closely follow the course drawn on the chart. However, for flights using headings or VORs for navigation, the course for the flight is measured near the center of the route which, unfortunately, then effectively converts the great circle route to a Rhumb line route (The Private Pilot Manual, 1997).

The Human Factor

Current Training Programs

The FAA and the major aviation instructional product companies do not currently have many programs or syllabi available which relate to pilot flight training in the use of GPS navigation. Only one major aviation textbook and instructional materials company is currently incorporating GPS information, and that information is presented in a theoretical rather than a practical nature (Kelly, 1997). In the FAA's Flight Training Handbook (174), VOR/DME and NDB radio aids are the only two forms of radio navigation discussed for use in cross country navigation.

The current method of testing the aeronautical knowledge of pilot applicants is via a computer generated Aeronautical Knowledge Test. This multiple choice test contains a varied selection of questions selected from a pool of published questions. The applicant has access to the pool of questions beforehand, but is assigned specific questions via computer upon examination. The questions relating to radio navigation test the applicant's understanding of the operation and utilization of only ground based navigational facilities. The FAA currently has no GPS related questions in their pool of test questions for their Aeronautical Knowledge Tests (Gleim, 1998).

Areas of knowledge tested relate to the preflight planning for and the use of the radio navaids to determine present position, track to or from the facility, intercept specific radials or bearings, conduct instrument approach and holding procedures (Aviation Instructor's Handbook, 1977).

The current FAA method of testing the knowledge and skill of the pilot applicant for a pilot's license or rating is to administer a *Practical Test* to the applicant after he or she has acquired the necessary ground and flight training and has (in most cases) successfully passed the Aeronautical Knowledge Test. The FAA has developed Practical Test Standards (PTS) books to establish the standards which must be met for each license or rating sought. The Practical Test usually consists of an oral and a flight examination given by an FAA inspector or an FAA Designated Examiner. The FAA currently has no reference to GPS navigation in any of its Practical Test Standards (PTS) books.

The following exerpt from the Private Pilot PTS (FAA, Private Pilot PTS, 1997, p. 1-19, 20) provides an example of the Navigational Area of Operation guidelines for an applicant for a Private Pilot license:

Task: Pilotage and Dead Reckoning

The objective of this task is to determine that the applicant:

1. exhibits knowledge of the elements related to pilotage and dead reckoning.
2. follows the preplanned course solely by reference to landmarks.
3. identifies landmarks by relating surface features to chart symbols.
4. navigates by means of pre-computed headings, ground speeds, and elapsed time.
5. corrects for and records the differences between preflight fuel, ground speed, and heading calculations and those determined en route.
6. verifies the airplane's position within 3 nautical miles of the flight-planned route at all times.
7. arrives at the en route checkpoints and destination within 5 minutes of the ETA.
8. maintains the appropriate altitude, + or - 200 feet and established heading, + or - 15 degrees.
9. completes all appropriate checklists.

Task: Navigation Systems and Radar Services

The objective of this task is to determine that the applicant:

1. exhibits knowledge of the elements related to navigation systems and radar systems.
2. selects and identifies the appropriate navigational system/facility.

3. locates the airplane's position using radials, bearings, or coordinates, as appropriate.

4. intercepts and tracks a given radial or beating, if appropriate.

5. recognizes and describes the indication of station passage, if appropriate.

6. recognizes signal loss and takes appropriate action.

7. uses proper communication procedures when utilizing ATC radar procedures.

8. maintains the appropriate altitude, + or - 200 feet.

<u>Task: Diversion</u>

The objective of this task is to determine that the applicant:

1. exhibits knowledge of the elements related to diversion.

2. selects an appropriate alternate airport and route.

3. diverts promptly toward the alternate airport.

4. makes an accurate estimate of heading, ground speed, arrival time, and fuel consumption to the alternate airport.

5. maintains the appropriate altitude, + or - 200 feet and established heading + or - 15 degrees.

<u>Task: Lost Procedures</u>

The objective of this task is to determine that the applicant:

1. exhibits knowledge of the elements related to lost procedures.

2. selects the best course of action when given a lost situation.

3. maintains the original or an appropriate heading and climbs, if necessary.

4. identifies the nearest concentration of prominent landmarks.
5. uses navigation system/facilities and/or contacts an ATC facility for assistance, as appropriate.
6. plans a precautionary landing if deteriorating weather and/or fuel exhaustion is imminent.

It is apparent from the FAA's Safe Flight 21 Program and the Federal Radionavigation Plan (FRP) that GPS is the future foundation for the National Aerospace System. This fact makes it imperative that new and progressive training and evaluation programs be developed. It is during this time of transition that new and creative concepts, procedures and technologies need to be addressed.

Situational Awareness

It is accepted that approximately 80% of all aviation accidents are due to pilot error. One of the major contributing factors leading pilot error induced aircraft accidents and incidents is the loss of Situational Awareness of the current flight conditions or status by the pilot or flight crew. This condition can lead to the pilot/crew improperly performing a critical task in a timely fashion and can have disastrous results. There are several factors which can lead to a loss of situational awareness. Two that are present in current GPS technology are (a) excessive workload and (b) distractions (Patterson, 1997).

Each individual has his/her workload threshold beyond which a form of tunnel vision/thinking to a particular task or set of tasks occurs with the exclusion of others. At this point critical tasks may be omitted from the thought process and remain unmonitored or unperformed for a period of time or until some dramatic event demands refocusing. Unfortunately, this may occur too late to divert a catastrophe.

The rapid development of technology often has a tendency to outrun the ability of the human to cope. Many systems which were initially developed to help pilots and crews operate their aircraft in a more efficient and safe manner have actually created hazards due to cumbersome and ambiguous operating procedures. Non-standardization of equipment creates a high learning curve for the users when switching from one type to another, and multiple manual inputs of information required by the pilot to program the higher technology equipment increases the probability of human error being committed (Hawkins, 1993).

One example of excessive workload becoming a significant factor occurs when using the GPS for instrument approaches. The GPS Standard Instrument Approach Procedure (SIAP) itself (Figure 12) is straightforward and logical and the FAA design criteria for the GPS receiver appears to be simple. The FAA mandates that IFR certified GPS receivers meet the following requirements (Aeronautical Information Manual, 2000):

1. The receiver must comply with Technical Standard Order C-129 (TSO C-129).
2. The receiver must have RAIM capability;
3. The receiver must be coupled with an independant navigation instrument displaying course displacement using a Course Deviation Indicator (CDI).
4. Waypoints, fixes, intersections, and facility locations to be used must be retrieved from the GPS airborne database. No substitutions are allowed.

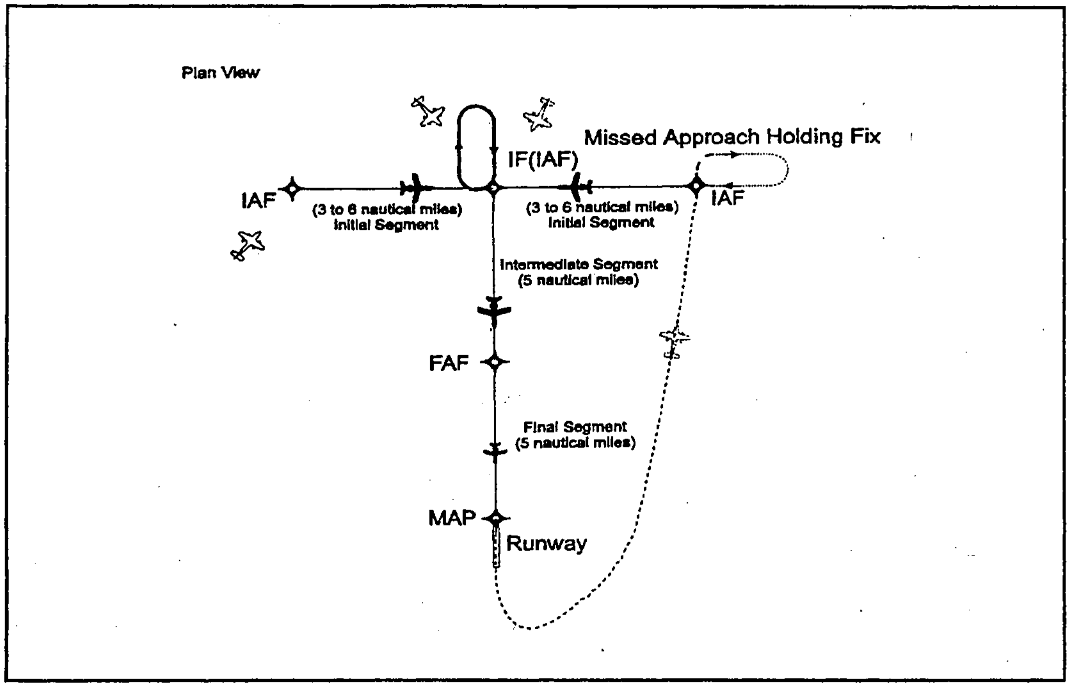

Figure 12. GPS SIAP - Basic "T" Design.

Unfortunately, the fourth requirement for pre-programmed approaches presents a tenuous situation for the unwary pilot or crew who, for whatever reason, do not follow the approach exactly as programmed. The result is a mad scramble to reprogram the GPS while maintaining control of the airplane during critical phases of an instrument approach. This is especially problematic when the flight is being conducted as a one-pilot operation with no auto pilot (typical of most single engine general aviation flights). To exacerbate the problem, the format of programming the GPS varies from one manufacturer to another and, often times, even between different models from the same manufacturer. In a recent Safety Advisor pamphlet distributed by the Air Safety Foundation of the Airplane Owners and Pilots Association this "trap" along with many others is discussed (Safety Advisor, 2000, p. 13).

One partial solution to this problem is to become intimately familiar with the specific GPS being used. A better solution, however, would be to standardize the equipment so that the operating procedures learned for one system would apply to all systems. Another solution is to evaluate the procedures and requirements mandated by the FAA. For example, the concept of a prestored approach is acceptable only if the consequences of deviating from the stored sequence does not result in a greatly increased workload for the pilot/crew.

Distractions are nonroutine events which shift a person's attention away from the task at hand and toward the distraction. The result can be an omission of other tasks resulting in a loss of situational awareness. GPS related distractions fall into two main groups: (a) GPS task related distractions and (b) GPS reliance distractions.

Along with much of the newer high technology existing in the modern airplane, the GPS can take considerable time to program and use. It has been noted that in crew situations, the pilots spend so much time relating to the computer systems that they tend not to communicate with each other and are otherwise distracted from performing other necessary tasks. A good example of this is the reprogramming of a Flight Management System when a new clearance or routing needs to be inputted. Near misses with other aircraft have been reported when the pilot/crew have diverted their attention to the FMS (or GPS) instead of looking for traffic (Wiener, Kanki & Helmreich, 1993).

The GPS provides a wealth of highly useful information to aid the pilot/crew in conducting the flight. Unfortunately, too much reliance, sometimes referred to as "automatic complacency" (Hawkins, 1993, p. 265), can be placed on the capabilities of the GPS while some of the basics of flight are being ignored. For example, ATC reports an increase in aircraft entering Special Use Airspace (SUA) such as Restricted or Prohibited Areas. It can be suspected that the pilot/crew in this scenario merely selected a waypoint from the GPS databank and followed the course direction displayed by the GPS. This, of course, omits many basic principles of properly preparing for and planning a flight by referencing aeronautical charts, NOTAMS, PIREPS, weather reports and forecasts, and many other important resources. In essence, GPS makes it too easy and the results of the pilot's laxity can be a violation of FARs or worse (Lenz, 2000).

Summary

The development of the National Airspace System has progressed to the point where new and progressive systems and procedures need to be researched and developed to take advantage of the tremendous potential presented by the GPS. Irregardless of the future plans by the FAA, DOD, DOT, ICAO and others are to make GPS the basic foundation of the 21st century NAS, human factors issues are not keeping pace with the technological advancements. Training, testing, standardization, system simplification, and human/machine interface considerations must be addressed and updated to meet the rapidly changing needs of the pilots and crews who will be operating in this new system.

CHAPTER III

METHODOLOGY

Introduction

The purpose of this study is to determine if the performance of navigation tasks by Oklahoma State University Theory of Flight students using a Geographic North Model exceeds that of those students using the traditional Magnetic North Model. The procedures followed in conducting this study were formulated to compare the effect of the two treatment levels of the independent variable (Geographic North versus Magnetic North-based models) on the dependent variable (measurement of performance of navigation tasks) for the two subject groups observed in this study. The procedures used include: (a) selecting the population sample, (b) administering a prestudy survey and a pretest to help verify homogeneity within and between the two study groups, (c) conducting a poststudy survey to help verify homogeneity between the two instructional presentations (geographic north versus magnetic north), (d) creating a lesson plan for each presentation (geographic north versus magnetic north), and (e) analyzing the data collected using t-tests for interval ratio scale data and Chi-square tests for the nominal scale data.

Definition of the Population

The subjects for this study were selected from the population of Aviation Education students at Oklahoma State University enrolled in Section I and Section II of the Theory of Flight (AVED 1113) course during the regular spring 2000 schedule of classes. The 11 subjects in Section I received navigation instruction based on the Geographic North paradigm and the 10 subjects in Section II received navigation instruction based on the Magnetic North paradigm.

The selection and assignment of the subjects was random only to the extent that the students were initially able to randomly enroll for either Section I or Section II of the Theory of Flight course. The subjects were not randomly selected or assigned to groups by the researcher.

The rights and privacy of the students were a high priority during this study. The procedures to assure the protection of the students were implemented in accordance with the guidelines established by the Oklahoma State University Institutional Review Board from whom an "Exempt" status was received (IRB # ED-00-224) on April 4, 2000. The students received a thorough description of the study prior to its initiation, they were informed that their participation was voluntary, and both the student and the researcher signed a student consent form prior to the student's participation in the study (Appendix E).

Design of the Study

The study was based on the presentation of two instructional lessons to the two groups. The experimental group received instruction to perform navigation tasks based on the use of a geographic north model. The control group received instruction to perform navigation tasks based on the use of a magnetic north model. The instruction was administered to both subject groups in the same classroom and during the regularly scheduled class periods for each section. The two study groups met at different times on different days. Surveys (Appendixes A and B) were administered to both groups before and after the study to assess the homogeneity of the two groups and the consistency of the instructional environment.

At the conclusion of the study, the experimental group (Section I) received a one hour video tape covering the magnetic north related navigational material which they had missed in their geographic north-based instruction. The purpose of this video was to provide them with the additional information needed to successfully complete the FAA Private Pilot Aeronautical Knowledge test administered at the conclusion of the semester.

The lesson plans (Appendixes C and D) were developed by the researcher based on his background and experience as a FAA Certified Flight Instructor (Gold Seal, Airplane Single and Multiengine Instrument Airplane) and as a FAA Designated Pilot Examiner and the following resources:

1. FAA Designated Pilot Examiner's Handbook
2. FAA Aviation Instructor's Handbook
3. FAA Flight Training Handbook
4. FAA Practical Test Standards
5. The Flight Instructor's Handbook by William K. Kershner
6. The Flight/Ground Instructor by Irvin N. Gleim
7. Fundamentals of Flight Instruction by Irvin N. Gleim

8. Private Pilot Manual by Jeppessen Sanderson, Inc.

9. The Complete Private Pilot by Bob Gardner

10. The Pilot's Manual: Private and Commercial by Trevor Thom

The lesson plans were constructed to consider two elements of planning a cross country flight: (a) pilotage and (b) dead reckoning.

Pilotage and Dead Reckoning

Pilotage is the technique by which a desired course is plotted on an aeronautical chart prior to the flight. During the flight, the pilot determines present position or navigates from one point to another by referencing the cartographic information on the aeronautical chart and comparing this to what is actually visually observed in relationship to the plotted course. By this method, the pilot can constantly monitor the position and progress of her or his aircraft (Private Pilot Manual, 1997) .

Dead reckoning is the technique of pre-determining the position and flight path of the aircraft prior to and, also, at any time during a flight from one point to another. This information is acquired by using a *flight plotter* (Appendixes C and D) to measure the course direction and distance of the desired flight leg from an aeronautical chart. This flight course data is combined with the known true airspeed (TAS) of the aircraft and the velocity/direction of the winds at the altitude to be flown (winds aloft) to calculate the wind correction angle (WCA), the ground speed (GS) at which the aircraft will travel, and the position and progress of the aircraft at any given time during the flight. This calculation is accomplished by using trigonometry (usually done with an E6-B flight computer). Estimated time en route (ETE) and, therefore, fuel consumption can also be calculated. The private pilot is advised to use both pilotage and dead reckoning techniques when preparing for and navigating on a cross country flight (Private Pilot Manual, 1997).

Magnetic North Model

The magnetic north model lesson plan (Appendix D) was developed by the researcher to follow the traditional format of navigation by using *magnetic heading* (MH), the *magnetic compass* and the gyroscopic *heading indicator* as the primary guidance system. Magnetic heading is calculated from the *true course* (TC) plotted on the aeronautical chart for the cross country flight by adjusting for the *wind correction angle* (WCA) and *magnetic variation. Magnetic deviation* was included in the instruction to compute *compass heading*, but it was not included in the evaluation of the subjects' performance. Wind correction angle, ground speed and fuel consumption are calculated in the traditional fashion using the *E6-B flight computer* (Private Pilot Manual, 1997).

Geographic North Model

The geographic north model lesson plan (Appendix C) was developed by the researcher to be similar to the traditional magnetic north based instruction with the exception that the determination of a magnetic heading (MH) is not required because the GPS navigation display automatically depicts the *true flight track* (TFT) of the aircraft as the primary guidance system without regard to wind correction angle, magnetic variation or magnetic deviation. The TFT information is displayed by the GPS receiver via alpha numeric data, moving map display, a simulated horizontal situation indicator (HSI), or a combination of the three. TFT is equivalent to the Great Circle Route (GCR) of the flight and is nearly identical to the *true course* plotted on the aeronautical chart (Lambert Conformal Conical format) (Private Pilot Manual, 1997).

The E6-B is still used to calculate wind correction angle and ground speed for en route time and fuel use calculations. The wind correction angle, while not needed for course guidance with this model, will still be included in this exercise to determine the relationship between the heading of the aircraft and the TFT. Pilots need this information to maintain a general orientation of their aircraft's longitudinal axis to the earth's surface and to other traffic.

Data Collection Instruments

Three instruments were used in this study to measure the performance of the subjects in each study group. The first instruments were the pre and post study surveys (Appendixes A and B). The prestudy survey posed questions through which the subjects could rank their experience and knowledge levels. This was designed to be an indicator of the homogeneity within each group and between the two separate study groups.

The poststudy survey posed questions through which the subjects could rank the understandability and difficulty levels of the navigational information presented and the navigational devices (sectional chart, plotter, and E6-B) used to perform the tasks presented to them. This was designed to be an indicator of the consistency between the two different treatments.

The prestudy and poststudy surveys were developed by the researcher based on his experience as a FAA Certified Flight Instructor, FAA Designated Examiner, Chief Pilot and Instructor for Part 135 Air Taxi operations, Assistant Chief Flight Instructor for Part 141 Flight Schools, Owner Operator of a Part 61 Flight School, Aviation Professor at Oklahoma State University, and Certified K-12 teacher in the State of Nebraska.

The second instrument was the pretest (Appendixes A and B), which consisted of a navigational task which was identical for both groups. The pretest was designed to measure the subject's knowledge and skill level in performing the navigational computer (E6-B) portion of navigation task for cross country flight. Two parameters were measured: (a) the accuracy of the computations performed by the subject and (b) the amount of time needed to accomplish the task. A short 15 minute review session on the use of the E6-B computer was administered to each group prior to the pretest.

The problem consisted of each subject calculating the *wind correction angle* (WCA), the *ground speed* (GS), and the *estimated time en route* (ETE), given the *winds aloft*, the aircraft *true airspeed* (TAS), and the *en route distance*. The accuracy of the subjects' answers was measured by comparing their answers to the correct responses, and the difference recorded as a numerical error value. The students were given an error margin of one degree for WCA, one knot for GS and 1 minute for ETE before an error was assigned. The rationale for this error margin is based on the inherent interpretation error of the E6-B due to the necessity to interpolate/extrapolate the values obtained during the operation of the computer. For example, an error of three degrees for WCA was recorded as a two degree error, an error of five knots for GS was recorded as a four knot error, and an error of 8 minutes was recorded as a 7 minute error. The duration of time for each subject to accomplish the task was noted and recorded to the nearest minute.

The third instrument was the posttest (Appendixes A and B), which consisted of a cross country navigational problem and an emergency deviation to the nearest airport problem. The navigation problems were the same with the exception that the experimental group based their measurements and calculations on geographic north parameters whereas the control group used the traditional magnetic north parameters.

Similarly to the pretest, both posttests required the subjects to calculate the *wind correction angle* (WCA), the *ground speed* (GS), and the *estimated time en route* (ETE), from the *winds aloft*, the aircraft *true airspeed* (TAS), and the *en route distance*. Different from the pretest, however, the posttest additionally measured the calculation of *magnetic heading* (MH) for the control group and the calculation of true flight track (TFT) for the experimental group. It is important to note that the TFT and the MH are the primary course guidance parameters which would be used for navigation for their respective navigation models (geographic north versus magnetic north). Therefore this measurement is the measure of accuracy that primarily reflects the impact of two different models on the performance of each group. The calculations done by the experimental group to compute TFT are similar to the calculations done by the control group to compute MH with the exception that there are fewer steps to find TFT versus finding MH.

The accuracy of the subjects' answers was measured by comparing their answers to the correct responses, and the difference recorded as a numerical error value. For each answer on the posttest, the students were given the same error margin as was allowed in the pretest for WCA, GS, ETE before an error value was assigned. As was done in the pretest, the duration of time for each subject to accomplish the problem was noted and recorded to the nearest minute.

The pretest and posttest were developed by the researcher based on the criteria established by the FAA Private Pilot Aeronautical Knowledge Test and the FAA Private Pilot Practical Test Standards.

Analysis of Data

The objective of this study was to compare the performance of the two different groups. This study compares the performance by considering the accuracy and the expediency of performing the navigational tasks presented. However, because the sample size was small and the selection and assignment of the subjects were not random, a great deal of emphasis was placed on determining the homogeneity of the two subject groups and the consistency of the two different instructional lesson plans.

Thus, the first step was to analyze the prestudy survey and the pretest to establish a relationship within and between the two study groups and between the two instructional presentations. A combination of two-tailed t-tests and Chi-square tests with alphas of .05 was used for this analysis.

The second step concentrated on the main objective of comparing the performance of the two groups by evaluating: (a) the accuracy of the computations performed by the subjects and (b) the amount of time they needed to accomplish the task.

The accuracy of the subjects' computations on the pre and posttests was expected to vary in either a positive or negative direction from the correct answer. The original intent was to analyze this data using a two-tail t-test with an alpha of .05. But, for the pre and posttest problems, the data collected to measure the accuracy of calculating GS (Ground Speed) and WCA (Wind Correction Angle) did not adequately measure the degree or amount of error, but only if an error was made. Therefore, the amount of error measured did not proportionally reflect the level of knowledge or skill of the subject, but only the nominal scale value of whether the subject did or did not make an error. Subsequently, a Chi-square test was used for this data.

The time to accomplish the task provided ratio scale data. The researcher logically expected the time required to perform the task to be shorter for the experimental group than for the control group. It was, therefore, a temptation to use a one-tail t-test for these values, but it was decided to remain conservative and analyze the data using a two-tail t-test with an alpha of .05.

CHAPTER IV

FINDINGS

Introduction

The purpose of this chapter is to describe and analyze the data collected in the study. This procedure will be approached from three levels: (a) evaluate the homogeneity of the two study groups (experimental and control) by assessing the prestudy survey and the pretest administered to the subjects, (b) evaluate the homogeneity of the two instructional presentations by assessing the poststudy survey, and (c) evaluate the posttest data to determine if the geographic north based model used by the experimental group had a significant effect on their performance of navigational tasks when compared to the control group's performance of similar navigational tasks.

Prestudy Survey

A prestudy survey (Appendixes A and B) was conducted at the beginning of the study for both the experimental and the control groups in order to help evaluate the homogeneity of the two groups. Because the two groups were not randomly selected or assigned, considerable effort was taken to bolster the internal validity of the study.

Survey data (Tables 1 and 2) are provided on the next two pages by the two charts for the experimental and control samples. This data is presented in a matrix detailing

TABLE 1

PRESTUDY SURVEY– EXPERIMENTAL GROUP

Subject	Age	Grade	Major	Art	Eng Lit	Soc Stdy	Math	Sci	Know Exp	Private Pilot	Profess Pilot	Aviation Career	Just Interest	Read Ch. 9
1	18	1	Engin.	3	1	2	5	4	1	X		X		No
2	19	1	Electric	2	5	3	1	4	6	X				No
3	22	—	Marketg	3	1	4	2	5	2	X			X	No
4	25	4	Psych.	2	1	4	3	5	4				X	No
5	—	1	Busin.	3	2	1	4	5	7	X	X			No
6	18	1	Av/Pil.	2	4	1	5	3	7		X			No
7	21	3	Educat.	3	2	1	5	4	2	X				No
8	19	1	Biochm	2	1	4	3	5	6	X				No
9	21	3	—	1	3	2	5	4	10	X				No
10	25	4	Av/Mgt	2	4	5	3	1	1	X		X		No
11	22	4	Me/Eng	2	1	3	5	4	2	X				No
<u>Statistic</u>														
N	10	10	NA	11	11	11	11	11	11	%	%	%	%	% No
$\bar{X}$	21	2.3	NA	2.27	2.27	2.73	3.73	4.00	4.36	64	13	10	13	100
ΣX	210	23	NA	25	25	30	41	44	48					
ΣX^2	4470	71	NA	61	79	102	173	190	300					
s	3.00	1.42	NA	.65	1.49	1.42	1.42	1.18	3.01					
s^2	9.00	2.01	NA	.42	2.22	2.02	2.02	1.40	9.05					

TABLE 2

PRESTUDY SURVEY– CONTROL GROUP

Subject	Age	Grade	Major	Art	Eng Lit	Soc Stdy	Math	Sci	Know Exp	Private Pilot	Profess Pilot	Aviation Career	Just Interest	Read Ch. 9
1	24	3	Psych	3	4	2	1	5	3	X				No
2	20	1	Av/Pilot	2	2	2	1	4	2	X	X			No
3	30	1	Biology	4	2	1	3	5	4	X				No
4	18	1	Av/Engn	4	1	2	5	3	4	X		X		No
5	21	3	Psych	4	4	5	1	4	4	X		X	X	No
6	20	3	—	3	1	2	4	5	5				X	No
7	19	1	Av/Engn	3	2	1	5	4	0	X		X		yES
8	18	1	Fire/Saf	1	4	3	5	2	2	X				No
9	21	2	Av/Mgmt	4	2	1	3	5	6	X	X			No
10	24	4	Biology	4	2	3	1	5	3	X				No
Statistic														
N	10	10	NA	10	10	10	10	10	10	%	%	%	%	% No
$\bar{X}$	21.5	2.0	NA	3.20	2.40	2.20	3.00	4.30	3.30	63	10	13	13	90
ΣX	215	20	NA	32.0	24.0	21.9	30.2	42.8	33					
ΣX^2	4743	52	NA	110.2	68.2	57.9	116.2	195.1	135					
s	3.66	1.15	NA	.93	1.08	1.05	1.67	1.15	1.70					
s^2	13.39	1.33	NA	.86	1.18	1.11	2.78	1.33	2.90					

information regarding each subject's age, college level, study major, academic areas of interest, aviation navigation knowledge and experience level, future aviation career plans or interest, and whether the subject had read chapter 9 in her or his aviation textbook.

The mean age of the subjects in the experimental group was 21.0 years versus 21.5 years for the control group.

The mean grade level of the subjects in the experimental group was 2.3 versus 2.0 for the control group. These values are ordinal scale values based on the assignment of the following numbers: 1 to freshmen, 2 to sophomores, 3 to juniors and 4 to seniors.

The students' stated majors were used only as an anecdotal indicator to see if either group was skewed more heavily toward the aviation program at OSU. The data indicates a wide spectrum of majors with two aviation education majors in each study group.

The academic preference of the students, likewise, was an attempt to determine if either group was skewed more heavily toward either end of the academic spectrum. Both groups tended to emphasize the mathematics and science end of the scale.

The knowledge and experience level of each subject was considered to be of statistical value because it related directly to the students' prior exposure to the subject area to be studied and could be a direct influencing factor for the outcome of the study. The subjects were asked to rate their knowledge and experience levels with several areas of aviation (Appendixes A and B). The two sets of data for aviation knowledge and experience level were analyzed to determine if the two groups could be considered to be drawn from the same population. This was done by using a two-tail t-test where:

H_o: $u_1 - u_2 = 0$ (the samples are from the same population)

H_a: $u_1 - u_2 \neq 0$ (the samples are not from the same population)

The resulting calculations for the Survey data indicating the subjects' experience level with Pilotage and Dead Reckoning Navigation are:

$$t_{X_1 - X_2 \text{ observed}} = |-.98| < t_{\text{critical } (.05/2,19)} = 2.093$$

Thus the null hypothesis should not be rejected and the samples could be considered as being from the same population.

The future aviation plans of the students, likewise, was an attempt to determine if either group was skewed more heavily toward either end of the interest spectrum. A large disparity in the two groups could influence their performance simply due to incentive and enthusiasm. The data, however, shows that both groups show a very similar interest level in their futures in aviation.

The last item on the survey relates to reading Chapter 9 in the textbook used for the course. Chapter 9 in the Jeppesen Private Pilot Manual discusses navigation principles which could enhance a student's performance during the study. One student in the control group indicated having read the chapter.

Pretest

The pretests (Appendixes A and B) were administered to the students to assess their level of performance using the E6-B flight computer. This device was previously covered in their course and its operation was assumed to be known. The students' knowledge of the use of the E6-B was essential to their ability to performing the navigation problems presented to them in the study. A short review was given to the students before they took the pretest.

As was mentioned in Chapter III, the comparison of the performance between the two groups was measured using the (a) accuracy of problem solutions and the (b) duration of time required to accomplish the task.

For the pretest problems, the data collected (Table 3) to measure the accuracy of calculating GS (Ground Speed) and WCA (Wind Correction Angle) did not adequately measure the degree or amount of error, but only if an error was made. Therefore, the amount of error measured did not proportionally reflect the level of knowledge or skill of the subject, but only the nominal scale value of whether the subject did or did not make an error. Since the GS error and the WCA error were measured identically for both study groups, they were combined for this analysis without sacrificing any comparative evaluation.

Since these nominal scale values are non-parametric, the Chi-square test was used to analyze this data where:

H_o: the errors are independent of the study population

H_1: the errors are related to the study population

The resulting calculation for the Pretest data indicating the subjects' errors committed for GS and WCA computations was:

$$x^2_{\text{observed}} = |1.36| < x^2_{\text{critical}\,(.05,1)} = 3.8415$$

TABLE 3

PRETEST CHARTS

Subject	GS* Error	WCA* Error	Time in Minutes
Experimental Group			
1	No	No	3
2	No	No	5
3	No	Yes	12
4	No	No	3
5	Yes	Yes	5
6	No	No	8
7	No	No	8
8	No	No	6
9	Yes	Yes	7
10	No	No	3
11	No	No	5
Statistic	2 Errors = 18%	3 Errors = 27%	
N	11	11	11
$\bar{x}$	NA	NA	5.91
ΣX	NA	NA	65
ΣX^2	NA	NA	459
s	NA	NA	2.74
s^2	NA	NA	7.49
Control Group			
1	Yes	No	17
2	No	No	6
3	No	No	3
4	No	No	3
5	No	Yes	5
6	No	No	3
7	No	Yes	9
8	No	No	3
9	No	No	3
10	No	No	2
Statistic	1 Error = 10%	2 Errors = 20%	
N	10	10	10
$\bar{x}$	NA	NA	5.40
ΣX	NA	NA	54
ΣX^2	NA	NA	480
s	NA	NA	4.57
s^2	NA	NA	20.9

Note: *GS = Ground Speed; *WCA = Wind Correction Angle.

Thus the null hypothesis should not be rejected and the errors made were independent of the study groups. The samples could be considered as being from the same population.

The duration-of-time data from the pretest were parametric and were analyzed to determine if the two sample groups were considered to be drawn from the same population. This was done by using a two-tail t-test where:

$$Ho: u_1 - u_2 = 0 \quad \text{(the samples are from the same population)}$$

$$Ha: u_1 - u_2 \neq 0 \quad \text{(the samples are not from the same population)}$$

The resulting calculation for the Pretest data indicating the subjects' skill level in using the E6-B flight computer was:

$$t_{x_1 - x_2 \text{ observed}} = |-.314| < t_{\text{critical } (.05/2,19)} = 2.093$$

Thus the null hypothesis should not be rejected and the samples were considered as being from the same population.

Poststudy Survey

A second survey (Appendixes A and B) was conducted at the termination of the study for both the Experimental and the Control Groups in order to help evaluate the homogeneity of the two different instruction presentations. This survey required the subjects to rate their difficulty level of performance of the navigation tasks and their self perceived level of understanding of the navigation concepts presented to them. This evaluation assisted in determining the internal validity of the study by comparing the consistency of the two different instructional presentations.

Each set of data (Table 4) from the poststudy survey are analyzed to determine if the two sample groups were considered to be drawn from the same population. This was done by using a two-tail t-test where:

$$Ho: u_1 - u_2 = 0 \quad \text{(the samples are from the same population)}$$

$$Ha: u_1 - u_2 \neq 0 \quad \text{(the samples are not from the same population)}$$

The resulting calculations for the 5 sets of poststudy survey data indicating the subjects' difficulty/understanding level in performing the navigation problems were:

1. Navigation Difficulty:

$$t_{x_1 - x_2 \text{ observed}} = |.340| < t_{\text{critical } (.05/2,19)} = 2.093$$

2. Chart Difficulty:

$$t_{x_1 - x_2 \text{ observed}} = |-.086| < t_{\text{critical } (.05/2,19)} = 2.093$$

3. Plotter Difficulty:

$$t_{x_1 - x_2 \text{ observed}} = |-.538| < t_{\text{critical } (.05/2,19)} = 2.093$$

4. E6-B Difficulty:

$$t_{x_1 - x_2 \text{ observed}} = |-.694| < t_{\text{critical } (.05/2,19)} = 2.093$$

5. Navigation Understanding:

$$t_{x_1 - x_2 \text{ observed}} = |-.158| < t_{\text{critical } (.05/2,19)} = 2.093$$

The null hypothesis should not be rejected for any of these five sets of data, and the two sample groups were considered as being from the same population.

TABLE 4

POSTSTUDY SURVEYS

Subject	Navigation Difficulty	Chart Difficulty	Plotter Difficulty	E6-B Difficulty	Navigation Understand
Experimental Group					
1	1	1	1	1	2
2	3	2	1	5	2
3	3	2	2	3	2
4	1	2	1	1	2
5	3	1	2	2	2
6	3	2	2	2	3
7	4	2	4	4	4
8	2	1	2	2	2
9	3	1	1	4	2
10	2	2	2	3	2
11	4	3	3	3	3
Statistic					
N	11	11	11	11	11
$\bar{X}$	2.64	1.73	1.91	2.73	2.36
ΣX	29	19	21	30	26
ΣX^2	87	37	49	98	66
s	1.03	.65	.94	1.27	.67
s^2	1.05	.42	.89	1.62	.45
Control Group					
1	4	1	3	2	2
2	1	1	1	1	1
3	4	3	2	3	4
4	3	2	2	1	2
5	4	3	2	5	4
6	3	1	3	2	2
7	3	1	1	5	3
8	2	1	1	1	2
9	1	1	1	1	1
10	3	3	1	2	2
Statistic					
N	10	10	10	10	10
$\bar{X}$	2.80	1.70	1.70	2.30	2.30
ΣX^2	28	17	17	23	23
ΣX	90	37	35	75	63
s	1.14	.95	.82	1.57	1.06
s^2	1.29	.90	.68	2.46	1.12

Note: *1 = easiest; *5 = hardest.

Navigational Posttest

The navigational posttest (Appendixes A and B) consisted of two parts: (a) performing navigation tasks for two legs of a cross country flight and (b) performing a navigation task for an emergency deviation to the nearest airport while en route. The posttest was conducted at the completion of the instruction for both the Experimental and the Control Groups.

Cross Country Problem

The data (Table 5) from the cross country portion of the posttest was analyzed to determine if the there was a significant difference between the two sample groups which was considered to be a result of the navigation model used rather than by chance. As was mentioned in Chapter III, the comparison of the performance outcomes between the two groups was measured using the (a) accuracy of problem solutions and the (b) duration of time required to accomplish the task.

Accuracy Data. The data collected for the errors of calculating GS (Ground Speed), WCA (Wind Correction Angle), Magnetic Heading, and TFT (True Flight Track) did not adequately measure the degree or amount of error, but only if an error was made. Therefore, the amount of error measured did not proportionally reflect the level of knowledge or skill of the subject. Since the GS error and the WCA error were measured identically for both study groups, they can be combined for this analysis without sacrificing any comparative information. The TFT and MH were different variables for the

TABLE 5

POSTTEST CHARTS (CROSS COUNTRY)

Subject	GS* Error	WCA* Error	TFT* Error	Time in Min.
Experimental Group				
1	No	No	No	4
2	No	No	No	4
3	Yes	Yes	No	5
4	No	No	No	4
5	No	No	No	3
6	Yes	Yes	No	6
7	No	No	No	5
8	No	No	No	3
9	No	Yes	No	5
10	No	No	No	8
11	No	No	No	4
Statistic	2 Errors = 18%	3 Errors = 27%	0 Errors = 0 %	
N	11	11	11	11
$\bar{x}$	NA	NA	NA	4.64
ΣX	NA	NA	NA	51
ΣX^2	NA	NA	NA	257
s	NA	NA	NA	1.43
s^2	NA	NA	NA	2.5
Control Group				
1	No	No	Yes	9
2	No	No	No	4
3	No	No	No	6
4	No	No	No	6
5	No	No	Yes	8
6	No	No	No	6
7	No	No	Yes	5
8	No	No	No	5
9	No	No	No	4
10	No	No	No	5
Statistic	0 Errors = 0%	0 Errors = 0%	3 Errors = 30%	
N	10	10	10	10
$\bar{x}$	NA	NA	NA	5.80
ΣX	NA	NA	NA	58
ΣX^2	NA	NA	NA	360
s	NA	NA	NA	1.62
s^2	NA	NA	NA	2.62

Note : *GS = Ground Speed; *WCA = Wind Correction Angle; *TFT = True Flight Track; *MH = Magnetic Heading.

experimental and control groups respectively, and they were analyzed separately from GS and WCA.

The nominal scale values of the GS and WCA error data were non-parametric and the statistic of Chi-square was used to analyze this data where:

Ho: the errors are independent of the study population

H1: the errors are related to the study population

The resulting calculation for the posttest data indicating the subjects' errors committed for GS and WCA computations was:

$$x^2_{\text{observed}} = |5.15| > x^2_{\text{critical}\,(.05,1)} = 3.8415$$

The null hypothesis was rejected and the errors made are related to the study groups. Therefore, the two groups were considered as being from different populations, with the experimental group committing more errors for the computation of GS and WCA than did the control group.

The nominal scale values of the TFT and MH error data were non-parametric and the statistic of Chi-square was used to analyze this data where:

Ho: the errors are independent of the study population

H1: the errors are related to the study population

The resulting calculation for the posttest data indicating the subjects' errors committed for TFT and MH computations was:

$$x^2_{\text{observed}} = |3.55| < x^2_{\text{critical}\,(.05,1)} = 3.8415$$

The null hypothesis was not be rejected and the errors made were independent of the study groups. Therefore, the two groups were considered as being from the same population.

Duration of Time Data. The data collected for the duration of time required to complete the task were ratio scale parametric values and the statistic of a two-tail t-test was used to analyze this data where:

Ho: $u_1 - u_2 = 0$ (the difference between the sample groups is not significant)

Ha: $u_1 - u_2 > 0$ (the difference between the sample groups is significant)

The resulting calculation was:

$$t_{x_1 - x_2 \text{ observed}} = 1.74 < t_{\text{critical } (.05,19)} = 2.093$$

Thus the null hypothesis was not rejected, the difference between the sample groups was not significant.

Emergency Problem

The data (Table 6) from the emergency portion of the posttest were analyzed in a similar fashion as was done for the cross country portion. The same parameters and methods of analysis applied. There was less data for this section of the posttest because three subjects misinterpreted the instructions for the emergency problem and, therefore, inappropriately performed the computations.

Accuracy Data. The nominal scale values of the GS and WCA error data were non-parametric and the statistic of Chi-square was used to analyze this data where:

TABLE 6

POSTTEST CHARTS (EMERGENCY)

Subject	GS* Error	WCA* Error	TFT* Error	Time in Min.
Experimental Group				
1	No	No	No	4
2	No	No	No	3
3	No	Yes	No	8
4	No	No	No	4
5	—	—	—	—
6	Yes	Yes	Yes	5
7	Yes	Yes	Yes	3
8	No	No	No	4
9	No	No	No	4
10	No	No	No	2
11	—	—	—	—
Statistic	2 Errors = 22%	3 Errors = 33%	2 Errors = 22%	
N	9	9	9	9
$\bar{X}$	NA	NA	NA	4.11
ΣX	NA	NA	NA	37
ΣX^2	NA	NA	NA	175
s	NA	NA	NA	1.69
s^2	NA	NA	NA	2.86
Control Group				
1	No	No	Yes	6
2	No	No	No	5
3	No	No	No	6
4	No	No	Yes	5
5	No	No	Yes	5
6	No	No	No	6
7	No	Yes	Yes	6
8	No	No	No	7
9	No	No	No	7
10	—	—	—	—
Statistic	0 Errors = 0%	1 Error = 11%	4 Errors = 44%	
N	9	9	9	9
$\bar{X}$	NA	NA	NA	5.89
ΣX	NA	NA	NA	53
ΣX^2	NA	NA	NA	317
s	NA	NA	NA	.78
s^2	NA	NA	NA	.61

Note: *GS = Ground Speed; *WCA = Wind Correction Angle; *MH = Magnetic Heading; *TFT = True Flight Track.

Ho: the errors are independent of the study population

H_1: the errors are related to the study population

The resulting calculation for the posttest data indicating the subjects' errors committed for GS and WCA computations was:

$$x^2_{\text{observed}} = |3.20| < x^2_{\text{critical}\,(.05,1)} = 3.8415$$

The null hypothesis was not rejected and the errors made were independent of the study groups. Therefore, the two groups were considered as being from the same population.

The nominal scale values of the TFT and MH error data were non-parametric and the statistic of Chi-square was used to analyze this data where:

Ho: the errors are independent of the study population

H_1: the errors are related to the study population

The resulting calculation for the posttest data indicating the subjects' errors committed for TFT and MH computations was:

$$x^2_{\text{observed}} = |1.00| < x^2_{\text{critical}\,(.05,1)} = 3.8415$$

The null hypothesis was not rejected and the errors made were independent of the study groups. Therefore, the two groups were considered as being from the same population.

Duration of Time Data. Similar to the cross country scenario, the emergency duration-of-time to complete the task data were ratio scale parametric values and the statistic of a two-tail t-test was used to analyze this data where:

Ho: $u_1 - u_2 = 0$ (the difference between the sample groups is not significant)

Ha: $u_1 - u_2 > 0$ (the difference between the sample groups is significant)

The resulting calculation was:

$$t_{X_1\text{-}X_2 \text{ observed}} = 4.61 \quad > \quad t_{\text{critical } (.05,16)} = 2.093$$

Thus the null hypothesis was not rejected, the difference between the sample groups was significant.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to determine if the performance of navigation tasks by flight students using a Geographic North Model was done more accurately and more expeditiously than flight students using the traditional Magnetic North Model. This was done with two groups of Oklahoma State University students enrolled in the Aviation Education Department's Theory of Flight course during the Spring semester of 2000. The study group began with 28 students, but due to subject drop-out during the study, usable data was gathered from 11 students in the experimental group and 10 students in the control group.

It is notable that this researcher did not find any other research being conducted to study the impact of using a geographic north model as the basic navigation paradigm for the NAS in place of the currently used magnetic north model. There were no previously developed instructional or evaluation instruments for the proposed geographic north model. The researcher developed these instruments based on his prior aviation and education knowledge and experience along with guidelines from government and industry sources related to the traditional magnetic model.

The methodology proved to be successful in accomplishing the intent of the study. However, the data gathered for the determination of error for the calculations of wind correction angle, ground speed, true flight track and magnetic heading were not measurable as ratio scale values as anticipated. The original intent was to measure the amount of error committed by each subject, but the data could only be interpreted as to whether there was or was not an error committed. This information changed from ratio scale data to ordinal scale data and, thus, changed the analysis instrument changed from a t-test to a Chi-square test.

In general, the study proceeded as planned, but the findings were not as robust as was hoped. Many revelations about this study were seen while it was being conducted, and perhaps the best outcome of the study is that the researcher is encouraged from the results to do further and improved research into the benefits of changing the current magnetic north based navigation model to geographic north paradigm.

Conclusions

The hypothesis for this study was that Oklahoma State University Theory of Flight students performing navigation tasks based on a Geographic North Model would do so more accurately and more expeditiously than those students using the traditional Magnetic North Model. This hypothesis was tested by conducting the following two separate evaluations: (a) accuracy of the task performance and (b) the duration-of-time to perform the task. The posttest posed two separate scenarios (a cross country navigation task and an emergency navigation task) to perform these evaluations.

A second issue to be addressed in this conclusion is the matter of bolstering the internal validity of the study. This was done by: (a) carefully evaluating the homogeneity within and between the experimental and the control groups through a prestudy survey and a pretest given to all of the subjects, and (b) analyzing the consistency of the two different instructional presentations via a poststudy survey.

Posttest Analysis

Cross Country Problem. The accuracy of performing the navigation task for the cross country problem was measured for the calculation of the wind correction angle (WCA) and ground speed (GS) for both the experimental and control groups. The procedures and computations required to reach these solutions (WCA and GS) were exactly the same for both the experimental group and the control group and, therefore, were not dependent on the independent variable of the navigation model type (that is, geographic north or magnetic north-based). Therefore, this data was not used to evaluate the hypothesis.

The accuracy of performing the navigation task for the cross country problem was also measured for the calculation of the true flight track (TFT) for the experimental group and magnetic heading (MH) for the control group. TFT was the basic guidance parameter used by the geographic north model and MH was the basic guidance parameter used by the magnetic north model. The procedures and computations required to reach these solutions (TFT and MH) were different and dependent upon the model they represented. Therefore the accuracy of the TFT and MH calculations for the experimental group and control group, respectively, were analyzed to test the hypothesis.

The error data collected (Table 5) showed 0 errors for the 11 subjects in the experimental group and 3 errors for the 10 subjects in the control group. A Chi-square (alpha = .05) performed on this data did not show an adequate significant difference between the two groups to support the hypothesis that the experimental group performed more accurately than the control group.

The duration-of-time data required to perform the cross country navigation task was measured for both the experimental group and the control group. The data collected (Table 5) shows that the duration-of-time to accomplish the task was an average of 4.64 minutes for the experimental group and 5.80 minutes for the control group – a difference of 1.16 minutes. A two-tail t-test (alpha = .05) performed on this data did not show an adequate significant difference between the two groups to support the hypothesis that the experimental group performed the task more expeditiously than the control group.

Emergency Problem. Based on the same rationale as set forth in the previous discussion for the cross country problem, the data for WCA and GS was not used in the emergency problem to evaluate the hypothesis.

Likewise, based on the same rationale as set forth in the previous discussion for the cross country problem, the experimental problem data regarding the accuracy of the TFT and MH calculations for the experimental group and control group, respectively, were analyzed to test the hypothesis.

The error data collected (Table 6) showed 2 errors for 9 subjects completing the problem in the experimental group and 4 errors for 9 subjects completing the problem in the control group. A Chi-square (alpha = .05) performed on this data did not show an adequate significant difference between the two groups to support the hypothesis that the experimental group performed more accurately than the control group.

This study cannot substantiate a conclusion that the experimental group performed more accurately than the control group. However, this researcher wishes to note that the data in Tables 5 and 6 showed that the experimental group committed more errors than the control group (statistically significant in the cross country WCA/GS data) in the calculation of the non-dependent variables of WCA and GS. On the contrary, the data in Tables 5 and 6 showed that the experimental group committed fewer errors in calculating TFT than the control group did in calculating MH. When it is considered that the accuracy of calculating TFT and MH were the primary dependent variables of the two levels (geographic north versus magnetic north) of the independent variable of the geographic model used for the navigation task, it encourages this researcher to continue to investigate the hypothesis.

The duration-of-time data required to perform the cross country navigation task was measured for both the experimental group and the control group. The data collected (Table 6) showed that the duration-of-time to accomplish the task was an average of 4.11 minutes for the experimental group and 5.89 minutes for the control group – a difference of 1.78 minutes. A two-tail t-test (alpha = .05) performed on this data did show a significant difference between the two groups and did support the hypothesis that the experimental group performed the task more expeditiously than the control group.

This study can substantiate a conclusion that the experimental group performed the navigation task more expeditiously than the control group in the Emergency problem. However, this researcher is cautious in this conclusion because only one of the two navigation tasks showed a significant difference between the duration-of-time to perform the navigation task. Here again, the researcher is encouraged from the results to continue research into the benefits of a geographic north model navigational paradigm.

Prestudy Survey

The purpose of the prestudy survey was to evaluate the homogeneity within and between the two study groups. The data in Tables 1 and 2 showed the following:

1. The mean age difference between the experimental and control groups was 21.5 - 20.5 = .5 years. It was this researcher's opinion that this age difference did not have an impact on the outcome of the study.
2. The average grade level was 2.3 for the experimental group versus 2.0 for the control group. According to the scale assigned to the grade levels (1-4 for freshmen to seniors) both groups would represent a mean student being a sophomore. It was this researcher's opinion that this grade level difference did not have an impact on the outcome of the study.
3. The subjects' stated majors in both groups indicated a wide spectrum of majors with two aviation education majors in each group. It was this researcher's opinion that the subjects were sufficiently diverse within each group and sufficiently similar between them to not have an impact on the outcome of the study.
4. The academic preference indicated by the subjects in both groups tended toward the mathematics and science end of the academic spectrum and

there was no obvious disparity between the two groups to imply this factor created an impact on the outcome of the study.

5. The aviation related knowledge and experience level of the subjects provided ratio scale values for both the experimental and control groups and this data was analyzed using a Chi-square test. The results showed that there was no significant difference between the two groups with regard to their aviation knowledge and experience levels.

6. It was conjectured that a definite interest in an aviation career could impact the motivation level of the subjects and thus their performance. Therefore, future plans of the subjects were evaluated. The data shows that both groups shared similar interest levels regarding their futures in aviation, and it was this researcher's opinion that the subjects' aviation future plans did not have an impact on the outcome of the study.

7. Only one subject had read Chapter 9 in the course textbook. This subject was in the control group, and the information gained from reading Chapter 9 could have enhanced his performance during the study. Since the study hypothesis was based on an improved performance from the experimental group, the impact of this factor may have worked in opposition to the hypothesis.

Pretest

The purpose of the pretest was to evaluate the homogeneity within and between the two study groups regarding their ability to perform a cross country navigation task. The data in Table 3 showed the following:

1. The error data collected showed 5 errors (WCA and GS) for the 11 subjects in the experimental group and 3 errors (WCA and GS) for the 10 subjects in the control group. A Chi-square (alpha = .05) performed on this data showed that the two groups were not significantly different.
2. The duration-of-time data required to perform the cross country navigation task was measured for both the experimental group and the control group. The data collected (Table 3) showed that the duration-of-time to accomplish the task was an average of 5.91 minutes for the experimental group and 5.40 minutes for the control group – a difference of .51 minutes. A two-tail t-test (alpha = .05) performed on this data showed that the two groups were not significantly different.

Poststudy Survey

The purpose of the poststudy survey was to evaluate the consistency of the two different instructional presentations given to the two different groups. The survey measured the subjects' perception of the difficulty of the tasks performed and the understandability of the navigation concepts presented. The data in Table 4 showed the following:

A two-tail t-test (alpha = .05) was performed on each of the subjects' ratings of navigation difficulty, chart difficulty, plotter difficulty, E6-B difficulty, and navigation understanding. The results of all 5 tests showed that there was no significant difference between the subjects' perceptions of the difficulty/understandability level of the two different instructional presentations. This supports the similarity of the two different instructional presentations.

This study can conclude that the experimental group and the control group displayed the properties of being homogeneous groups, and the two different instructional presentations of the geographic model and the magnetic north model appeared to be consistent in their difficulty and understandability level to all the subjects. While these measures bolster the internal validity of this study, it is recommended that future research incorporate several improved methodologies to enhance the study's internal and external validity.

Recommendations

General Recommendations

This research has laid the foundation for further study into the impact of changing the basic paradigm of aviation navigation to a geographic north-based model rather than the currently used magnetic north based model. The results of this study provide encouragement to pursue further research along with new insight of ways to improve the methods and procedures.

The lesson plans created for this study proved adequate for the purpose, but enhancements became apparent throughout the study and can be incorporated into future studies. In addition, more time needs to be allotted for the purpose of conducting these lessons and administering the testing instruments.

A considerable amount of time and energy was exerted to bolster the internal validity of the study because of the small number of subjects and the lack of their random selection and assignment to study groups. It does appear that the homogeneity of the groups and of the instruction was shown to be adequate to somewhat offset the lack of numbers and randomness. However, both the internal and external validity of future studies will be greatly enhanced by a more random selection of a larger population sample with random assignment to the experimental and control groups.

Specific Recommendations

The 20/20 hindsight provided by this study has revealed several factors which could have made the results of this research more significant. Some specific improvements to this and future studies are:

1. Increase the number of subjects.
2. Randomly select the subjects.
3. Randomly assign the subjects to the sample groups.
4. Provide an instructional and testing procedure where the interaction between the two study groups can be minimized.
5. Develop a methodology which is not inclined to subject drop-out.
6. Develop better measurements of the data.

7. Utilize Personal Computer Aviation Training Devices (PCATDs) more in future research to more accurately measure the performance of the subjects.

Future Research Recommendations

The rapid expansion of technology in aviation demands a similar advancement in the human/technology/machine interface which in turn demands new and creative approaches to aviation operations. Continued research needs to be accelerated in the following areas:

1. Advantages of the geographic north navigation model.
2. Ergonomics of the aircraft cockpit.
3. Improvement of the display and easy interpretation of information to pilots/users.
4. Simplification of the National Airspace System by utilizing the full capabilities of GPS based navigation.
5. Standardization of information accessibility.
6. Standardization of equipment operation.
7. Training for human and technology management considerations for the highly technical future of aviation.

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APPENDIXES

APPENDIX A

AVIATION NAVIGATION STUDY MEASUREMENT INSTRUMENTS FOR THE EXPERIMENTAL GROUP

Subject # _____

AVIATION NAVIGATION STUDY

Subject Survey

1. Age: _____

2. Grade Level: ___________

3. Major: _________________

4. Number the following subject areas from 1 (your Least Favorite) to 5 (your Most Favorite):

   a. Art _____
   b. English/Literature _____
   c. Mathematics _____
   d. Science _____
   e. Social Studies _____

5. Rate the following from 0 (no knowledge/experience) to 5 (a lot of knowledge/experience):

   a. Pilotage Navigation _____
   b. Dead Reckoning Navigation _____
   c. Radio Navigation _____
   d. Global Positioning System _____
   e. Use of an E6-B Flight Computer _____
   f. Use of a Navigation Plotter _____
   g. Flights on an Airliner _____
   h. Flights on a small airplane (2-4 seats) _____

6. Future Aviation Plans (select those that apply):

   a. Private Pilot – flying for personal reasons _____
   b. Professional Pilot – flying as a career _____
   c. Aviation oriented career ; but not as a pilot _____
   d. Non, just wanted to learn more about Aviation _____

7. I (have, have not) read Chapter 9, Section A prior to today.

AVIATION NAVIGATION STUDY

PRETEST

You are a student pilot planning a cross-country flight from Guthrie, OK (KGOK, N 35° 50.99, W 97° 24.94) to Henryetta, OK (KF10, N 35° 24.42, W 96° 00.95) to Madille, OK (K1F4, N 34° 08.42, W 96° 48.72). You are flying a C-172 during the daytime and the weather is good VFR.

Using the information shown on the accompanying Flight Log, use your E6-B Computer to determine Ground Speed (GS), Wind Correction Angle (WCA), Estimated Time Enroute (ETE) and the amount of Fuel Used. Enter your answers on the Flight Log.

Note: Disregard takeoff/departure and arrival/landing variables for determining ETE and Fuel Burn.

Subject # _____

FLIGHT LOG

Leg One

KGOK to KF10

Test Start Time: _________

Flight Altitude	Winds Aloft	Distance	True AirSpeed	True Course	Wind Correction Angle	Ground Speed	Estimated Time Enroute	Fuel Used (8.0 GPH)
7,500 MSL	270° @ 20 Kts	73 NM	105 Kts	111°				

Test End Time: ________

Leg Two

KF10 to K1F4

Test Start Time: _________

Flight Altitude	Winds Aloft	Distance	True AirSpeed	True Course	Wind Correction Angle	Ground Speed	Estimated Time Enroute	Fuel Used (8.0 GPH)
4,500 MSL	190° @ 15 Kts	85 NM	105 Kts	213°				

Test End Time: _______

AVIATION NAVIGATION STUDY

POSTTEST

You are a student pilot planning a cross-country flight from **Tyler, TX** (KTYR, N 32° 21' W 95° 24') to **Terrell, TX** (KTRL, N 32° 42' W 96° 16') to **Clarksville, TX** (7F6, N 33° 36' W 95° 04'). You are flying a C-172 during the daytime and the weather is good VFR.

With the information shown on the accompanying Flight Log, use your Dallas-Ft. Worth Sectional Chart, your Navigation Plotter and your E6-B Computer to determine the rest of the Dead Reckoning information for your flight. Enter your answers on the Flight Log.

Note: Disregard takeoff/departure and arrival/landing variables for determining ETE and Fuel used.

Subject # ______

AVIATION NAVIGATION STUDY

FLIGHT LOG

Leg One

KTYR to KTRL

Test Start Time: ________

Flight Alt.	Winds Aloft	TAS	DIST.	TFT	GS	WCA	ETE	GPH / Fuel
4500 MSL	300° 28 Kt	105 Kt						8.0

Test End Time: ________

Leg Two

KTRL to 7F6

Test Start Time: ________

Flight Alt.	Winds Aloft	TAS	DIST.	TFT	GS	WCA	ETE	GPH / Fuel
5500 MSL	320° 34 Kt	105 Kt						8.0

Test End Time: ________

Subject # ______

AVIATION NAVIGATION STUDY

EMERGENCY

Between Terrell (KTRL)) and Clarksville (7F6) you suddenly discover as you are flying past the small town of Sulpher Bluff that, due to a fuel leak, you have only 1 gallon of fuel left. You decide to fly directly to the nearest airport to land. Fill in the missing information on the Flight Log below:

Emergency Leg

Test Start Time: _______

Flight Alt.	Winds Aloft	TAS	DIST.	TFT	GS	WCA	ETE	GPH Fuel
5500 MSL	320° 34 Kt	105 Kt						8.0

Test End Time: ________

Assuming that you started immediately toward the nearest airport, will you make it before running out of fuel? Yes No

PLEASE COMPLETE THE POSTTEST SURVEY ON THE BACK OF THIS SHEET

AVIATION NAVIGATION STUDY

POSTTEST SURVEY

1. Please rate your difficulty level of performing the Posttest navigation problems by checking one of the following choices:

____ Easy
____ Below average difficulty
____ Average difficulty
____ Above average difficulty
____ Hard

2. Please rate the following navigation devices as to your difficulty level of understanding and using them:

A. Sectional Chart (check one of the following choices)

____ Easy
____ Below average difficulty
____ Average difficulty
____ Above average difficulty
____ Hard

B. Navigation Plotter (check one of the following choices)

____ Easy
____ Below average difficulty
____ Average difficulty
____ Above average difficulty
____ Hard

C. E6-B Computer (check one of the following choices)

____ Easy
____ Below average difficulty
____ Average difficulty
____ Above average difficulty
____ Hard

3. Please rate your understanding of the Dead Reckoning Navigation information presented during this study by checking one of the following:

____ I understand all of it and could navigate to anywhere with confidence.

____ I understand most of it and would only occasionally get lost.

____ I understand about half of it and would probably be lost half the time.

____ I understand some of it and would probably get lost a lot.

____ I don't understand any of it and am lost!

APPENDIX B

AVIATION NAVIGATION STUDY MEASUREMENT

INSTRUMENTS FOR THE CONTROL GROUP

Subject # _____

AVIATION NAVIGATION STUDY

Subject Survey

1. Age: _____

2. Grade Level: __________

3. Major: ________________

4. Number the following subject areas from 1 (your Least Favorite) to 5 (your Most Favorite):

   a. Art _____
   b. English/Literature _____
   c. Mathematics _____
   d. Science _____
   e. Social Studies _____

5. Rate the following from 0 (no knowledge/experience) to 5 (a lot of knowledge/experience):

   a. Pilotage Navigation _____
   b. Dead Reckoning Navigation _____
   c. Radio Navigation _____
   d. Global Positioning System _____
   e. Use of an E6-B Flight Computer _____
   f. Use of a Navigation Plotter _____
   g. Flights on an Airliner _____
   h. Flights on a small airplane (2-4 seats) _____

6. Future Aviation Plans (select those that apply):

   a. Private Pilot – flying for personal reasons _____
   b. Professional Pilot – flying as a career _____
   c. Aviation oriented career ; but not as a pilot _____
   d. Non, just wanted to learn more about Aviation _____

7. I (have, have not) read Chapter 9, Section A prior to today.

AVIATION NAVIGATION STUDY

PRETEST

You are a student pilot planning a cross-country flight from Guthrie, OK (KGOK, N 35° 50.99, W 97° 24.94) to Henryetta, OK (KF10, N 35° 24.42, W 96° 00.95) to Madille, OK (K1F4, N 34° 08.42, W 96° 48.72). You are flying a C-172 during the daytime and the weather is good VFR.

Using the information shown on the accompanying Flight Log, use your E6-B Computer to determine Ground Speed (GS), Wind Correction Angle (WCA), Estimated Time Enroute (ETE) and the amount of Fuel Used. Enter your answers on the Flight Log.

Note: Disregard takeoff/departure and arrival/landing variables for determining ETE and Fuel Burn.

Subject # _____

FLIGHT LOG

Leg One

KGOK to KF10

Test Start Time: _________

Flight Altitude	Winds Aloft	Distance	True AirSpeed	True Course	Wind Correction Angle	Ground Speed	Estimated Time Enroute	Fuel Used (8.0 GPH)
7,500 MSL	270° @ 20 Kts	73 NM	105 Kts	111°				

Test End Time: ________

Leg Two

KF10 to K1F4

Test Start Time: _________

Flight Altitude	Winds Aloft	Distance	True AirSpeed	True Course	Wind Correction Angle	Ground Speed	Estimated Time Enroute	Fuel Used (8.0 GPH)
4,500 MSL	190° @ 15 Kts	85 NM	105 Kts	213°				

Test End Time: _______

AVIATION NAVIGATION STUDY

POSTTEST

You are a student pilot planning a cross-country flight from **Mineral Wells, TX** (KMWL, N 32° 47' W 98° 03') to **Throckmorton, TX** (72F, N 33° 11' W 99° 08') to **Bowie, TX** (0F2, N 33° 36' W 97° 45'). You are flying a C-172 during the daytime and the weather is good VFR.

Using the information below and on the accompanying Flight Log, use your Dallas-Ft. Worth Sectional Chart, your Navigation Plotter and your E6-B Computer to determine the rest of the Dead Reckoning information for your flight. Enter your answers on the Flight Log.

Note: Disregard takeoff/departure and arrival/landing variables for determining ETE and Fuel used.

COMPASS CORRECTION CARD

For	N	30	60	E	120	150	S	210	240	W	300	330
Steer	001	032	064	093	121	147	176	207	239	272	303	332

FLIGHT LOG

Subject # _____

Leg One

KMWL to 72F

Test Start Time: ________

Flight Alt.	Winds Aloft	TAS	DIST.	TC	GS	WCA	TH	VAR. / MH	DEV / CH	ETE	GPH / Fuel
4500 MSL	300° 28 Kt	105 Kt									8.0

Test End Time: ________

Leg Two

72F to 0F2

Test Start Time: ________

Flight Alt.	Winds Aloft	TAS	DIST.	TC	GS	WCA	TH	VAR. / MH	DEV / CH	ETE	GPH / Fuel
5500 MSL	320° 34 Kt	105 Kt									8.0

Test End Time: ________

Subject # ______

AVIATION NAVIGATION STUDY

EMERGENCY

Between Throckmorton (72F) and Bowie (0F2) you suddenly discover as you are flying over the powerlines just south of the small town of Shannon that, due to a fuel leak, you have only 1 gallon of fuel left. You decide to fly directly to the nearest airport to land. Fill in the missing information on the Flight Log below:

Emergency Leg

Test Start Time: ________

Flight Alt.	Winds Aloft	TAS	DIST.	TC	GS	WCA	TH	VAR. / MH	[redacted]	ETE	GPH / Fuel
5500 MSL	320° 34 Kt	105 Kt									8.0

Test End Time: ________

Assuming that you started immediately toward the nearest airport, will you make it before running out of fuel? Yes No

PLEASE COMPLETE THE POSTTEST SURVEY ON THE BACK OF THIS SHEET

AVIATION NAVIGATION STUDY

POSTTEST SURVEY

1. Please rate your difficulty level of performing the Posttest navigation problems by checking one of the following choices:

____ Easy
____ Below average difficulty
____ Average difficulty
____ Above average difficulty
____ Hard

2. Please rate the following navigation devices as to your difficulty level of understanding and using them:

A. Sectional Chart (check one of the following choices)

____ Easy
____ Below average difficulty
____ Average difficulty
____ Above average difficulty
____ Hard

B. Navigation Plotter (check one of the following choices)

____ Easy
____ Below average difficulty
____ Average difficulty
____ Above average difficulty
____ Hard

C. E6-B Computer (check one of the following choices)

____ Easy
____ Below average difficulty
____ Average difficulty
____ Above average difficulty
____ Hard

3. Please rate your understanding of the Dead Reckoning Navigation information presented during this study by checking one of the following:

____ I understand all of it and could navigate to anywhere with confidence.

____ I understand most of it and would only occasionally get lost.

____ I understand about half of it and would probably be lost half the time.

____ I understand some of it and would probably get lost a lot.

____ I don't understand any of it and am lost!

APPENDIX C

AVIATION NAVIGATION STUDY GEOGRAPHIC NORTH LESSON PLAN AND INSTRUCTIONAL MATERIALS

True North GPS Based Navigation

April 10-14, 2000

Experimental Group

I. Pilotage -- Navigation -- getting from one place to another using visual cues (10 minutes)

A. Show GPS Simulation

B. Show Sectional Chart on Elmo

C. Walking to class -- what visual cues do you use?

(Sidewalks, buildings, signs, streets, trees ...)

D. Driving to the store -- what visual cues do you use?

(Streets, buildings, street signs...)

E. Driving on a long trip -- what visual cues do you use?

1. Road Map

2. Probably Plan the trip in advance

3. Road Signs, Towns, State Lines, Rivers, Bridges, etc.

F. Flying X-C -- what visual cues do you use?

1. Can't read signs -- water towers maybe?!

2. Aeronautical Charts -- Sectionals (1:500,000), WAC (1:1,000,000), Terminal Area (1:250,000)

a. Symbols depict references on the ground -- chart legend

b. Orient in reference to a course of some sort

1. Follow a road

2. Airport to Airport

3. Follow a shoreline

4. Follow a straight line drawn on the chart -- Direct -- of flight

3. GPS moving map -- directly relates position of airplane to terrain features -- 2-D

4. New format -- NASA 3-D mapping will present a picture of real terrain -- not seasonal, though!

5. Good idea to select several check points along a course to assure frequent assessment of progress (compare to missing your highway turnoff)

G. Problems with Pilotage

1. Must be able to see the ground (GPS can remedy this, however)

a. Night

b. Clouds

c. Visibility

d. Remote areas/Ocean -- Charles Lindbergh, Amelia Earhart

2. Without planning, it's not very accurate

a. Fuel planning -- compare to car

b. Flight plans and safety

c. Time schedules

d. Inefficient

II. What is the solution -- Dead Reckoning (usually used in conjunction w/pilotage) (15 minutes)

A. Using available information to calculate and plan the flight navigation

1. Direction to fly -- measure from the chart

2. Duration of the flight -- see reasons stated above

   a. Distance -- measure from chart

   b. Speed -- POH

   c. Time = Distance/Speed -- (E6-B)

3. Unfortunately, this rarely works out, why? Wind!! Show Video

B. Wouldn't it be nice if we could just reference the Course/Track we are flying regardless of the WCA -- we can!! GPS has made this possible. Let's take a look at course guidance instruments in the airplane

1. Mag. Heading Indicator (MHI) -- mechanical/gyroscopic instrument -- also called the Directional Gyro (DG)

   a. Must be set initially and updated periodically due to precession

   b. Must be set to Mag. Compass -- has many errors & corrections

      1. Variation

      2. Deviation

      3. Turning error

      4. Acceleration error

      5. Magnetic disturbances -- especially mountains

      6. Current accuracy -- swinging the compass

   c. Hard to set in flight in turbulence or while turning

NOTE: From this point on the material will deviate from that currently used for navigation and will need to be subsequently taught to the student via video presentation.

2. True Track Indicator (TTI) -- devised for this presentation

a. GPS allows a display that constantly and precisely provides True Track -- relative to True North (geographic north pole)

b. GPS provides Great Circle Route (GCR) navigation (shortest distance from point to point over a sphere -- Earth Demo. -- New York to Rome). The Track/Course changes during GCR navigation (especially noticeable over a long distance -- Laptop Illus. -- PAMR to KSWO) and the GPS automatically follow this course.

c. A constant heading would follow a "rhumb line"and is not the shortest distance. VOR uses rhumb line navigation.

Note: rhumb line remains at the same angle to meridians of Longitude -- constant Course or Heading.

C. The rest of this presentation is based on navigation of the future -- GPS is a True North based navigation system in which the magnetic compass will only be a backup. This actually takes us back to early days of Stellar navigation -- now GPS satellites have, in a sense, taken place of the stars.

1. GPS based on a Constellation of 24 Satellite Vehicles (SVs) orbiting the Earth at 10,900 miles above the surface. Orbits of about 12 hours.

2. GPS provides a very precise PVT

a. P = Position: 3-D position in space represented to us by Longitude, Latitude and Altitude (MSL) -- accuracy up to a few feet

b. V = Velocity -- accuracy to better than a fraction of a Kt

c. T = Time -- atomic clocks with accuracy of a billionth of a sec.

3. For the rest of this presentation, we will assume all navigation will be based on True North.

Remember -- The actual course/track of our flight will be represented by the True Track Indicator (TTI) which will directly display our True Flight Track (TFT) to us.

III. Dead Reckoning Problems -- Flight Planning (25 minutes)

A. Pass out Flight Logs

B. Fill out the Flight Logs in order (OK73-KCHK-KHBR-OK73)

OK73 = Seiling, OK @ N 36° 09.50' W 98° 46.50'

KCHK = Chikasha, OK @ N 35° 05.20' W 97° 58.40'

KHBR = Hobart, OK @ N 34° 59.20' W 99° 03.10'

1. Given Information

a. Altitude -- use safety, efficiency, VFR E/W rule based on True North

1. 0/360° - 179° = odd thousand + 500

2. 180° - 359° = even thousand + 500

b. Winds Aloft -- FSS Briefing

1. Direction -- already True North-based

2. Velocity -- Knots

3. Temperature -- used for TAS (we will ignore in our planning)

c. TAS -- POH

2. Chart Information

a. Distance -- Plotter (discuss)

1. Proper Chart (Sectional or WAC)

2. Proper Scale (Nautical Mile or Statute Mile)

b. True Flight Track (TFT) -- Plotter (discuss)

1. Meridians of Longitude -- North/South running through Poles

a. True North and South oriented

b. Prime Meridian = 0° (Greenwich, England)

International Dateline = 180° (Bering Strait -- not straight)

1. West Longitude includes United States

2. East Longitude includes Russia

3. 15° = 1 hour

c. Degrees, Minutes (60 min. = 1°), Seconds (60 sec. = 1 min.)

Note: Aviation typically uses minute/decimal -- N 35° 28.74'

2. Parallels of Latitude -- East/West running -- parallel the Equator

a. True East and West oriented

b. Equator = 0°

c. North Latitude = 0° - 90° = Equator to North Pole

d. South Latitude = 0° - 90° = Equator to South Pole

e. Degrees, Minutes & Seconds (or decimals) -- W 96° 42.35'

3. E6-B -- Wind Side

a. Ground Speed

b. WCA -- Why?

1. General orientation -- you will not fly where the nose of the airplane (heading) is pointed -- no different than now
2. Radar Traffic Advisories using clock positions, e.g. 3 O'clock
3. Future advisories will probably be GPS TCAS (Traffic Collision Avoidance System) based on TFT.

4. E6-B -- Computer Side
   a. ETE -- ETA
   b. GPH -- Fuel Used

C. Do other practice routes:

IV. Notes for Posttest:

A. Hand out information page and locate points on the charts -- do not start
   1. Students may help each other at this point -- but not later
   2. Have students put "subject #" on the Sectional Chart

B. Hand out Posttest -- Note Start/Stop times for each Leg

C. Raise hand when done with Leg # 2
   1. Additional short exercise
   2. Final Survey

D. Bring materials to me and I will trade for a video

FLIGHT LOG

________ to ________

Flight Altitude	Winds Aloft	Distance	True AirSpeed	True Course	Wind Correction Angle	Ground Speed	Estimated Time Enroute	Fuel Used (5.5 GPH)
MSL	° @ Kts	NM	Kts	°	°	Kts	Hr. Min.	Gal.

FLIGHT LOG

Leg One

(Given Info.)			(Chart Info.)		(E6-B Wind)		(E6-B Comp.)	
Flight Alt.	Winds Aloft	TAS	DIST.	TFT	GS	WCA	ETE	GPH Fuel

Leg Two

(Given Info.)			(Chart Info.)		(E6-B Wind)		(E6-B Comp.)	
Flight Alt.	Winds Aloft	TAS	DIST.	TFT	GS	WCA	ETE	GPH Fuel

Leg Three

(Given Info.)			(Chart Info.)		(E6-B Wind)		(E6-B Comp.)	
Flight Alt.	Winds Aloft	TAS	DIST.	TFT	GS	WCA	ETE	GPH Fuel

Leg Four

(Given Info.)			(Chart Info.)		(E6-B Wind)		(E6-B Comp.)	
Flight Alt.	Winds Aloft	TAS	DIST.	TFT	GS	WCA	ETE	GPH Fuel

APPENDIX D

AVIATION NAVIGATION STUDY MAGNETIC NORTH

LESSON PLAN AND INSTRUCTIONAL MATERIALS

Magnetic North Based Navigation

4-12-00

Control Group

I. Pilotage -- Navigation -- getting from one place to another using visual cues

A. Show GPS Simulation

B. Show Sectional Chart on Elmo

C. Walking to class -- what visual cues do you use?

(Sidewalks, buildings, signs, streets, trees ...)

D. Driving to the store -- what visual cues do you use?

(Streets, buildings, street signs...)

E. Driving on a long trip -- what visual cues do you use?

1. Road Map

2. Probably Plan the trip in advance

3. Road Signs, Towns, State Lines, Rivers, Bridges, etc.

F. Flying X-C -- what visual cues do you use?

1. Can't read signs -- water towers maybe?!

2. Aeronautical Charts -- Sectionals (1:500,000), WAC (1:1,000,000), Terminal Area (1:250,000)

a. Symbols depict references on the ground -- chart legend

b. Orient in reference to a course of some sort

1. Follow a road

2. Airport to Airport

3. Follow a shoreline
4. Follow a straight line drawn on the chart -- Direct -- advantages of flight

3. GPS moving map -- directly relates position of airplane to terrain features -- 2-D

4. New format -- NASA 3-D mapping will present a picture of real terrain -- not seasonal, though!

5. Good idea to select several check points along a course assure frequent assessment of progress (compare to missing your highway turnoff)

G. Problems with Pilotage

1. Must be able to see the ground (GPS can remedy this, however)
   a. Night
   b. Clouds
   c. Visibility
   d. Remote areas/Ocean -- Charles Lindbergh, Amelia Earhart

2. Without planning, its not very accurate
   a. Fuel planning -- compare to car
   b. Flight plans and safety
   c. Time schedules
   d. Inefficient

II. What is the solution -- Dead Reckoning (usually used in conjunction w/pilotage)

A. Using available information to calculate and plan the flight navigation

1. Direction to fly -- measure from the chart

2. Duration of the flight -- see reasons stated above

   a. Distance -- measure from chart

   b. Speed -- POH

   c. Time = Distance/Speed

3. Unfortunately, this rarely works out, why? <u>Wind</u>!!

B. Show Video

1. Mag. Heading Indicator (MHI) -- mechanical/gyroscopic instrument -- also called the Directional Gyro (DG)

   a. Must be set initially and updated periodically due to precession

   b. Must be set to Mag. Compass -- has many errors & corrections

      1. Variation

      2. Deviation

      3. Turning error

      4. Acceleration error

      5. Magnetic disturbances -- especially mountains

      6. Current accuracy -- swinging the compass

   c. Hard to set in flight in turbulence or while turning

III. Dead Reckoning Problems -- Flight Planning

A. Pass out Flight Logs

B. Fill out the Flight Logs in order (KCUH-KOKM-KADH-KCUH)

1. Given Information

   a. Altitude -- use safety, efficiency, E/W rule based on Magnetic North

b. Winds Aloft -- FSS Briefing

1. Direction -- True North based

2. Velocity -- Knots

3. Temperature -- used for TAS (we will ignore in our planning)

c. TAS -- POH

2. Chart Information

a. Distance -- Plotter (discuss)

b. True Course (TC) -- Plotter (discuss)

1. Longitude and Latitude

2. Protractor

3. E6-B -- Wind Side

a. Ground Speed (GS)

b. WCA -- True Heading (TH)

1. General orientation -- you will not fly where the nose of the airplane (heading) is pointed

2. Radar Traffic Advisories using clock positions, e.g. 3 O'Clock

4. Magnetic Variation -- Magnetic Heading

a. Magnetic and Geographic North Poles are different

b. Isogonic Lines -- lines on charts to show degrees of Variation

1. Degrees West -- add the degrees to TH to get MH

2. Degrees East -- subtract the degrees from TH to get MH

3. Memory saying -- East is least, West is best

5. Magnetic Deviation -- usually caused by electrical disturbances in airplane
    a. Compass Deviation Card corrects MH for CH
    b. Compass must be "swung" (calibrated) every so often
6. E6-B -- Computer Side
    a. ETE -- ETA
    b. GPH -- Fuel Used

C. Do other practice routes

IV. Notes for Posttest:

A. Hand out information page and locate points on the charts -- do not start
1. Students may help each other at this point -- but not later
2. Have students put "subject #" on the Sectional Chart

B. Hand out Posttest -- Note Start/Stop times for each Leg

C. Raise hand when done with Leg # 2
1. Additional short exercise
2. Final Survey

D. Bring materials to me and I will trade for a video -- due back Thursday of Dead Week.

FLIGHT LOG

________ to ________

Flight Altitude	Winds Aloft	Distance	True AirSpeed	True Course	Wind Correction Angle	Ground Speed	Estimated Time Enroute	Fuel Used (5.5 GPH)
MSL	° @ Kts	NM	Kts	°	°	Kts	Hr. Min.	Gal.

FLIGHT LOG

Leg One

______ to ______

Flight Alt.	Winds Aloft	TAS	DIST.	TC	GS	WCA	TH	VAR. / MH	DEV / CH	ETE	GPH / Fuel

Leg Two

______ to ______

Flight Alt.	Winds Aloft	TAS	DIST.	TC	GS	WCA	TH	VAR. / MH	DEV / CH	ETE	GPH / Fuel

Leg Three

______ to ______

Flight Alt.	Winds Aloft	TAS	DIST.	TC	GS	WCA	TH	VAR. / MH	DEV / CH	ETE	GPH / Fuel

APPENDIX E

INSTITUTIONAL REVIEW BOARD APPROVAL

FORM AND STUDENT CONSENT FORM

OKLAHOMA STATE UNIVERSITY
INSTITUTIONAL REVIEW BOARD

Date:	April 4, 2000 IRB #: ED-00-224
Proposal Title:	"A COMPARISON OF THE PERFORMANCE OUTCOMES OF STUDENT PILOTS RECEIVING DEAD-RECKONING NAVIGATION GROUND INSTRUCTION BASED SOLELY ON A GEOGRAPHIC-NORTH MODEL VERSUS THE TRADITIONAL MAGNETIC-NORTH MODEL"
Principal Investigator(s):	Stephen Marks Michael Larson
Reviewed and Processed as:	Exempt

Approval Status Recommended by Reviewer(s): Approved

Signature:

Carol Olson, Director of University Research Compliance

April 4, 2000
Date

Approvals are valid for one calendar year, after which time a request for continuation must be submitted. Any modification to the research project approved by the IRB must be submitted for approval with the advisor's signature. The IRB office MUST be notified in writing when a project is complete. Approved projects are subject to monitoring by the IRB. Expedited and exempt projects may be reviewed by the full Institutional Review Board.

CONSENT FORM
for
AVIATION NAVIGATION STUDY

A. Authorization

I, ______________________________, hereby authorize Michael K. Larson, or associates or assistants of his choosing, to perform the following procedure:

B. Description

1. The purpose of this study is to determine the value of a new instructional procedure which will hopefully benefit you and future students regarding the enhanced usage capabilities provided by GPS navigation.

2. Procedure -- The study to be performed will involve in-class instruction of cross country 'dead reckoning' navigation and flight planning. A thirty minute pretest will be administered, after which you will receive a one hour presentation regarding the navigational planning of a typical cross country flight.

The study will end with a thirty minute posttest relevant to the presentation received. The outcome of these tests will remain confidential and will not be reflected on your course grade. However, your attendance in class will be provided to your instructor as per your Course Syllabus.

3. The study will be conducted during regular class periods during the week of April 10-14, 2000. In addition, as a requirement for this study, you may be asked to view an additional one hour video in the subsequent class after completion of the study.

4. The study will be conducted in a typical classroom lecture style and will require your involvement in a manner typical of a normal in-class presentation.

C. Participation

I understand that participation is voluntary, that there is no penalty for refusal to participate, and that I am free to withdraw my consent and participation in this project at any time without penalty after notifying the project director.

I may contact Michael K. Larson at 319 Willard Hall, Telephone (405)744-9892.

I may also contact University Research Services, 001 Life Science East, Oklahoma State University, Stillwater, OK 74078; Telephone: (405) 744-5700.

I have read and fully understand the consent form. I sign it freely and voluntarily. A copy has been given to me.

Date: ________________ Time ___________

Signed ____
(Signature of Student)

I certify that I have personally explained all elements of this form to the subject before requesting the subject to sign it.

Signed Michael K. Larson
(Michael K. Larson)

2

VITA

Michael Kent Larson

Candidate for the Degree of

Doctor of Education

Thesis: A COMPARISON OF THE PERFORMANCE OF NAVIGATION TASKS BY FLIGHT STUDENTS USING A GEOGRAPHIC NORTH MODEL VERSUS A MAGNETIC NORTH MODEL

Major Field: Applied Educational Studies

Biographical:

Education: Graduated from Stromsburg High School, Stromsburg, Nebraska in May 1963; received Bachelor of Science degree in Education, Mathematics and Physics from Nebraska Wesleyan University, Lincoln, Nebraska in May 1967; received the Master of Science degree with a major in Aviation Education from Oklahoma State University in May 1993. Completed the requirements for the Doctor of Education degree with a major in Aviation and Space Education at Oklahoma State University in July 2000.

Experience: Taught mathematics, physical science and physics at Raytown High School in Raytown, Missouri and at Waverly High School in Waverly, Nebraska, 1967 to 1972; served as the aerospace education representative, state newsletter editor and state pilot for the Nebraska Department of Aeronautics, 1972 to 1987; served as chief pilot for Star City Air Ambulance Carrier, 1987 to 1989; based in Berlin, Germany as flight engineer and first officer for Pan American World Airways, 1989 to 1991; served as pilot for Oklahoma State University, 1992 to 1993; served as pilot and chief pilot for Lake Clark Air, Inc. in Alaska, 1993 to 1999; owned and operated Lake Clark Flight School in Alaska, 1995 to 1999; taught aviation courses at Oklahoma State University, 1992 to 1993 and 1997 to present.

Professional Memberships: Airplane Owners and Pilots Association, FAA Safety Counselor, Seaplane Pilots Association.