TRAINING OF GENERAL AVIATION PILOTS

ON THE GLOBAL POSITIONING SYSTEM

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NOMENCLATURE

ADF	Automatic Direction Finder
ADS-B	Automatic Dependent Surveillance Broadcast
AGL	Above Ground Level
ATC	Air Traffic Control
C/A	Course Acquisition
CAA	Civil Aviation Authority
CDI	Course Deviation Indicator
CRM	Cockpit Resource Management
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
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
ILS	Instrument Landing System
INS	Inertial Navigation System
JPO	Joint Program Office
kHz	Kilohertz
LAAS	Local Area Augmentation System
Loran	Long-Range Navigation
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
NCA	National Command Authority
NDB	Nondirectional Beacon
nm	Nautical Mile
NOTAM	Notice to Airmen
NPA	Nonprecision Approach
ns	Nanosecond
P-code	Pseudorandom Noise (PRN) Tracking Code
PPS	Precision Positioning Service

PRN	Pseudo-Random Noise
PVT	Position, velocity, and time
RAIM	Receiver Autonomous Integrity Monitoring
RNAV	Area Navigation
SA	Selective Availability
Satnav	Satellite-Based Navigation
SPS	Standard Positioning Service
TACAN	Tactical Air Navigation
TSO	Technical Standard Order
UTC	Coordinated Universal Time
VFR	Visual Flight Rules
VHF	Very High Frequency
VOR	Very High Frequency Omnidirectional Range
VORTAC	Collocated VOR and TACAN
WAAS	Wide Area Augmentation System
WGS	World Geodetic System

CHAPTER I

INTRODUCTION

Background of the Problem

Scientists are uncertain of exactly when the art of navigation began. They do however know that ancient Mesopotamian mariners first developed navigation that relied on observed positions of prominent landmasses or celestial bodies for navigation (Heyerdahl, 1979).

The word "navigation" is of Latin origin, referring to movement, and is the science of moving a land or sea vehicle from one place to another as defined by Fishbein (1995) and it is this definition that was used for this study. Navigation has progressed from its Mesopotamian beginnings in numerous stages throughout 5000 years. It usually progressed in concurrence with a recent inventions or applications of new sciences such as astronomy.

In 1978, navigation leaped into the space age when placing NAVSTAR/Global Positioning System (GPS) satellites in orbit (Dye, 1977) developed a space-based navigation system. The Department of Defense (DOD) developed GPS as a satellite-based radio-navigation system. It is to be the Department of Defense's primary means of radio-navigation well by the decade and for years to come. It is scheduled to replace all gound-based navigation systems within the next 10 years (FAA, 1995).

GPS is a satellite based navigation system that provides extremely accurate position, velocity, and time (PVT) information by using 24 satellites. It is this positioning information on which various means of navigation may be based. GPS provides position and velocity information that is determined with respect to the World Geodetic System 1984 (WGS) map coordinates in latitude and longitude (Clarke, 1998). A properly equipped user, either military or civilian, has access to the information anywhere on earth, day or night. The DOD controlled and operated system allowed only selective availability (SA) to civilian users of GPS until May 1, 2000. The selective availability was essentially a way for the DOD to provide a deliberately degraded signal to civilian users 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). All GPS users now enjoy the precision of the full Global positioning system. However, the National Command Authority (NCA) has the ability to limit all radionavigation signals during a dire national emergency.

Since its beginnings in 1978 GPS has gained in popularity in all segments of aviation, including general aviation. The Federal Aviation Administration (FAA) has proposed that GPS be the primary radio navigation system for the National Airspace System (NAS) in the early 21st century. A phase-down will begin in 2008 for most of our currently used land based radio navigation facilities as outlined in the current Federal Radionavigation Plan (FRP). Over the last several years general aviation's reliance on GPS has grown tremendously due in part to the high navigational accuracy provided. For just a fraction of the cost, general aviation pilots can have the same navigational accuracy and sophistication as that of the equipment used by commercial airlines.

A substantial impact on everyone in the early part of the 21st century has been the explosive acceleration of technology. The use of computers and digital technology has changed technology in all phases of transportation, and the world of aviation is no exception. As with most new high technology equipment, GPS receivers are seemingly easy to operate and read. However, a pilot can be enticed into a false sense of security by believing GPS receivers are easy to operate. Michael Larson (2000) believes that keeping pace with the changes in aviation technology is becoming problematic for pilots who operate in the system. He considers that one of the most notable changes is the replacement of the current Very High Frequency Omnidirectional Range (VOR) based NAS with GPS. A pilot now thoroughly familiar with the operation of the particular GPS receiver equipment being used prior to flight might become distracted in the air while attempting to use the unfamiliar equipment. A distraction can occur while trying to perform even simple operations. These distractions, better-called pilot error, are the cause of over 80% of all general aviation accidents (Trollip & Jensen, 1991). A pilot can also be lured into believing GPS is correct, thus failing to perform the proper validity verification crosschecks of the GPS receiver and informational database inputs and updates or simple functional selections.

The reliability of the GPS signal is also often taken for granted and is of growing concern to the GPS community. In 2000, ultra-wideband (UWB) wireless technology was being hailed as a next generation communication system. However, a new report (Aviation Week, Apr. 23, 2001 pg. 80) points out potentially serious problems with its applications. The report states that the UWB signals appear to interfere with the GPS signals.

Pilots can also let GPS lead them into weather conditions they are not prepared for. They can be lured into believing they know exactly where they are. Even a pilot well trained in instrument flight rules (IFR) can become overwhelmed. Turner (1995) states "that one of the high-risk phases of flight that is inherently riskier than other phases of flight is flying in bad weather."

There are an infinite number of scenarios that can lead to potentially serious and deadly errors, mistakes, or pilot error. Pilots have to know how to recognize and avoid these scenarios. They have to identify these potential human-factor errors, and system breakdowns associated with the use of highly automated GPS systems. They must see the importance of developing and following a backup navigation plan (Lenz, 1999).

The influx of affordable GPS equipment into aviation cockpits extends the benefits of GPS technology to everyone – private and corporate, military and civilian (Larijani, 1998). Formal training on the GPS system and the many receiver units must be provided at the same pace as the influx of the technology into the cockpit. However, the training needs to be thorough and accurate. Pilots must be trained on the use of a particular or various types of GPS receiver units. They must also be trained on GPS system errors for each of the various receiver units. Training must be provided at flight schools to ensure general aviation pilots are being properly informed on all phases of GPS. Training should include theory of the GPS system and how it works. Training must also include inherent system errors, operation of various types of receivers, and common human-induced errors associated with GPS use.

Statement of the Problem

The current (1999) Federal Radionavigation Plan (FRP) projects that beginning in 2008 a phase-down will begin for most of the currently used ground-based radio navigation facilities. Larson (2000) states, "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." He further goes on to state, "There is a very real danger of this new technology outrunning the existing capabilities of the very people the system is designed to help."

A 1996 FAA technical report by Winter & Jackson also points out this very real danger. Their report expresses that pilots who have not acquired a significant amount of knowledge and training can become overwhelmed. This arises when they go beyond basic receiver functions to complex ones that are required for more difficult navigational tasks. Increasing cockpit automation by using GPS in general, aviation aircraft can have a major impact on the attentive work that is carried out in the cockpit. Consequently, operational and training requirements have changed and the potential for human error and system breakdown has shifted. Devoid of formal GPS training, human error can quickly become compounded and lead to an increase in general aviation pilot error accidents.

The FAA presently has just a few basic GPS questions in each of their Private, Commercial, Instrument, and Airline Transport pilot written exam data banks. They certainly will require all pilots in the near future to be proficient in the use of and have GPS system knowledge. However, in 1997 Kelly declared that current flight training programs do not adequately incorporate the training of GPS navigation procedures in either their ground or flight training programs. The question that arises is: are flight-training programs adequately incorporating the training of GPS navigation procedures into their ground and flight training programs?

Research Questions

The objective of this study is to provide data to the following research questions: (1) Are flight training programs providing GPS ground training as a stand-alone class or incorporated into existing courses? (2) Are GPS training aids utilized? (3) Are the flight training programs utilizing GPS? (4) Are flight instructors teaching GPS techniques receiving formal training on GPS? (5) What are the commercial GPS training materials currently on the market?

Assumptions

For the purpose of this study, the investigator accepted the following assumptions:

1. Collegiate aviation ground and flight schools provide instruction in accordance with either Federal Aviation Regulation (FAR) Part 61 and/or Part 141.
2. Collegiate aviation ground and flight schools currently provide instruction of basic aircraft navigational skills in accordance with current FAR Part 61 and/or Part 141.
3. Collegiate aviation ground and flight school instructors meet current FAR Part 61 and/or Part 141 standards.
4. Collegiate aviation flight schools training aircraft meet current FAR Part 61 and/or Part 141 equipment and currency standards.

Limitations of the Study

The following limitations might affect the extent to which any results might be generalized:

The findings of this study may not be applicable to all general aviation pilots or flight schools that are not associated with a collegiate aviation program. The findings also may not be applicable to general aviation pilots and ground or flight schools outside the United States of America.

Limitations

This study has the following limitations:

1. The number of total subjects was limited to the collegiate aviation programs list in the 1999 issue of the University Aviation Association's (UAA) Collegiate Aviation Guide.
2. The selection and assignment of the subject collegiate aviation programs were limited to those within the United States of America.
3. The subject collegiate aviation programs were only given approximately 5 weeks to complete and return the survey.

Scope of the Study

The study has the following scope:

The study dealt with collegiate aviation programs located only within the United States of America selected from the 1999 issue of the University Aviation Association's Collegiate Aviation Guide.

Definition of Terms

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.

Certified GPS Receiver - A GPS receiver that meets the Federal Aviation Administration's (FAA) Technical Standard Order (TSO) C129 requirements for instrument flight rules (IFR) usage.

Collegiate Aviation Program - A college or university in the United States that offers courses and/or majors in aviation. They offer an Associate or higher degree in an aviation field and are accredited by a regional or national accrediting association as a degree granting institution. They are also listed in the 1999 edition of the Higher Education Directory.

Dead Reckoning - Navigation by application of best-known speed over a known time interval to determine distance flown and applying it in a prescribed direction from the last known aircraft direction to determine a position.

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 – Electronic navigational equipment that allows the pilot to determine the straight line distance in nautical miles to a given transmitter on the ground.

FAR Part 61 – The requirements for issuing pilot, flight instructor, and ground instructor certificates and ratings; the conditions under which those certificates and ratings are necessary; and the privileges and limitations of those certificates and ratings.

FAR Part 141 - Prescribes the requirements for issuing pilot school certificates, provisional pilot school certificates, and associated ratings, and the general operating rules applicable to a holder of a certificate or rating.

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

Federal Aviation Regulation (FAR) – The FAA rules and regulations that govern the conduct of the operation of the civilian air transportation system in the United States.

Flight Instructor - A person who holds a flight instructor certificate issued under Part 61 of the Federal Aviation Regulations and is authorized to give training required to quality a person to fly various phases of flight.

General Aviation Pilot: A pilot that flies in the portion of civil aviation which encompasses all facets of aviation except air carriers holding a certificate of public convenience and necessity from the Civil Aeronautics Board and large commercial operators.

Global Navigation Satellite System – The GNSS is a worldwide 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 – A satellite-based radionavigation system providing positioning, velocity and time (PVT) information.

Instrument Flight Rules – The FAA rules and regulations that govern the conduct of aircraft during instrument flight.

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

Instrument Landing System – 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 fractions 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 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 earth to the magnetic north pole.

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

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 approval from the President. The term NCA is used to signify constitutional authority to direct the Armed Forces in their execution of military action.

Navigation - The science of moving a land or sea vehicle from one place to another.

Non-certified GPS Receiver – A GPS receiver that does not meet the Federal Aviation Administration's (FAA) Technical Standard Order (TSO) C129 requirements for instrument flight rules (IFR) usage.

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.

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

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.

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.

Very High Frequency (VHF) – The frequency band between 30 and 300 MHz.

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

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

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

CHAPTER II

REVIEW OF LITERATURE

Introduction

The purpose of this study is to determine if general aviation pilots in institutional settings receive training on the GPS system and GPS theory and operation. The areas that will be reviewed for this study will include; (a) GPS theory and technology; (b) Federal Aviation Regulations (FARs) on pilot training; (c) Federal Aviation Administration's (FAAs) Office of System Safety publications; (d) GPS training programs; (e) Human factors publications and studies; (f) Cockpit/crew resource management publications and studies; (g) current trade publications and manufacturer literature.

The history of navigation will be presented to understand the evolution of navigation into the science it is today. The history of GPS development and maturation into the present state of the 24 orbiting satellite constellation will then be presented, as will GPS theory and operation.

Two areas of the Federal Aviation Administration (FAA) will be explored. The first will be the Federal Aviation Regulations (FARs) and the application to general aviation training. The FARs will also be reviewed for possible general aviation GPS-training specific sections to include the FAA exam data banks to determine how many questions in each test exists. The FAA accident statistic database will be studied focusing on general aviation accident statistics. The statistics will be assessed to determine the impact on training if any or the lack of has on accidents.

A review of reports, surveys, and studies on GPS training will be completed to determine if any previous studies have been conducted directly relating to this area. Reports, surveys, and studies performed by various international aviation safety organizations will also be studied. This topic will lend a look into possible GPS and new technology training problems emerging from full-time professional pilots and if the problems can be directly correlated into training of general aviation pilots

The next logical topic to be investigated will be that of human factors in aviation. The relevance of human factors to general aviation pilots and GPS training reviewed and presented in this study. In this area, general aviation single crewmember crew/cockpit resource management (CRM) will be explored and whether this type of training is applicable to GPS training for general aviation pilots.

Finally, this study will look at general aviation training. Specifically it will look at the training materials currently being offered for GPS and if GPS training materials are manufacturer specific or training is provided on all models. The training materials will be studied to deem whether they contain GPS theory of operation and system overview.

History of Navigation

Scientists' opinions still differ when it comes to deciding whether civilization first arose in the Nile Valley of Egypt or in the river plains of Mesopotamia. They do however agree that the two areas had been in contact since the earliest rise of culture. It has been shown that the Persian Gulf island of Bahrain was a central maritime marketplace used by Mesopotamian navigators dating back to 3000 B.C. (Hyerdahl, 1979). Scientists are also uncertain of exactly when navigation began because sailors were craftsmen, learning as a youth how to pilot and navigate a ship by working beside a master sailor with no written materials for training or documented (Taylor, 1957). They do however know that these ancient Mesopotamian mariners first developed navigation. They relied on observing positions of prominent landmasses or celestial bodies for navigation (Heyerdahl, 1979).

Definitions of Navigation

The word "navigation" is of Latin origin. It refers to movement, and is the art of safely conducting a land or sea vessel or airplane form one place to another by certain known means (Harding, 1952). "The science or art of conducting ships or aircraft from one place to another" is Webster's (1981) definition of navigation. Fishbein (1995) offers a simpler yet comparable definition of navigation as "the science of moving a vehicle from one place to another." To further refine the definition, Webster (1981) states navigation is also "The method of determining position, course, and distance traveled over the surface of the earth by principles of geometry and astronomy and by reference to devices (as radar beacons or instruments) designed as aids." The Royal Navy definition divides navigation into two types, pilotage and true navigation. Pilotage occurs when in sight of land and true navigation when out of sight of land (May, 1973).

Early navigators, when out of sight of land, used the position of the midday sun and the shadow it cast to divide the sky into east and west (Taylor, 1957). The true development of navigation by means of celestial observations did not progress past methods involving sun observations until astronomers could accurately chart and/or predict the movement of heavenly bodies, which took several centuries to achieve (Harding, 1952).

The advent of the magnetic compass developed near the end of the twelfth century by the Chinese provided the most useful instrument to the navigator up to that time. The compass was first used as a means of checking wind direction and not direct steering. This was possible because the needle of the compass actually pointed to the North Magnetic Pole and not the geographic North Pole. Compass variation between locations was plotted by comparing the indicated direction with the direction of the North Star (Polaris). Louis Harding (1952) states that Christopher Columbus was the first person documented at sea to accomplish this in 1492. The compass could then be used for steering.

Dead reckoning came into use shortly after the adoption of the compass for navigation in the late part of the thirteenth century and is still used by navigators. The Department of the Air Force (1977) defines dead reckoning as "navigation by application of best known speed over a known time interval to determine distance flown and applying it in a prescribed direction from the last known aircraft direction to determine a dead reckoning position."

Development of Cartography

Maps were the next big development for the art of navigation. Once again it cannot be stated when the first maps were drawn. Until their development it had been up to the navigator to memorize land features. Earliest of navigators would sketch rough drawings of landmasses as ships passed close to various inlets or islands. So early maps were free hand drawings and were far from accurate as is today's maps and charts. Toward the end of the thirteenth century the so-called portolan charts (Figure 1) began to appear in the Mediterranean. They initially were intended merely to illustrate sailing directions (May, 1973).

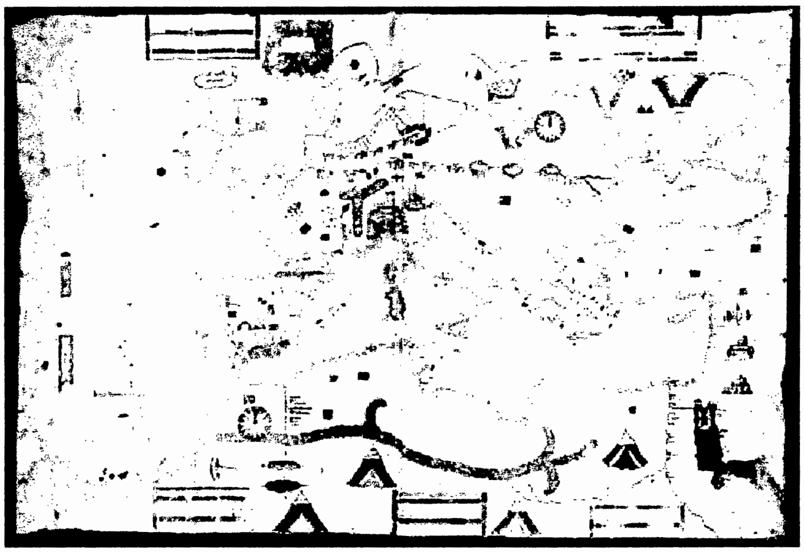


Figure 1. Portolan Chart.

Degrees of latitude and longitude as a means of describing positions on the earth's surface date back to 150 B.C. but were not used by navigators until the fifteenth century. At that time the Portuguese started exploring down the coast of Africa. The Portuguese navigators were finally leaving the narrow confines of the Mediterranean where latitude didn't really matter. Sixteenth century charts were made on the assumption that the earth was flat. In 1569 the first Mercator chart (Figure 2) of the world was produced. This style of map projection accounted for the spherical earth and addressed the problem of the meridians becoming closer together at the poles on other styles of charts. This was accomplished by the meridians parallel while stretching the latitude scales as one receded from the equator. The mathematical principles behind this type of projection was demonstrated by Edward Wright in 1599 and evolved into what is used today (May, 1973).

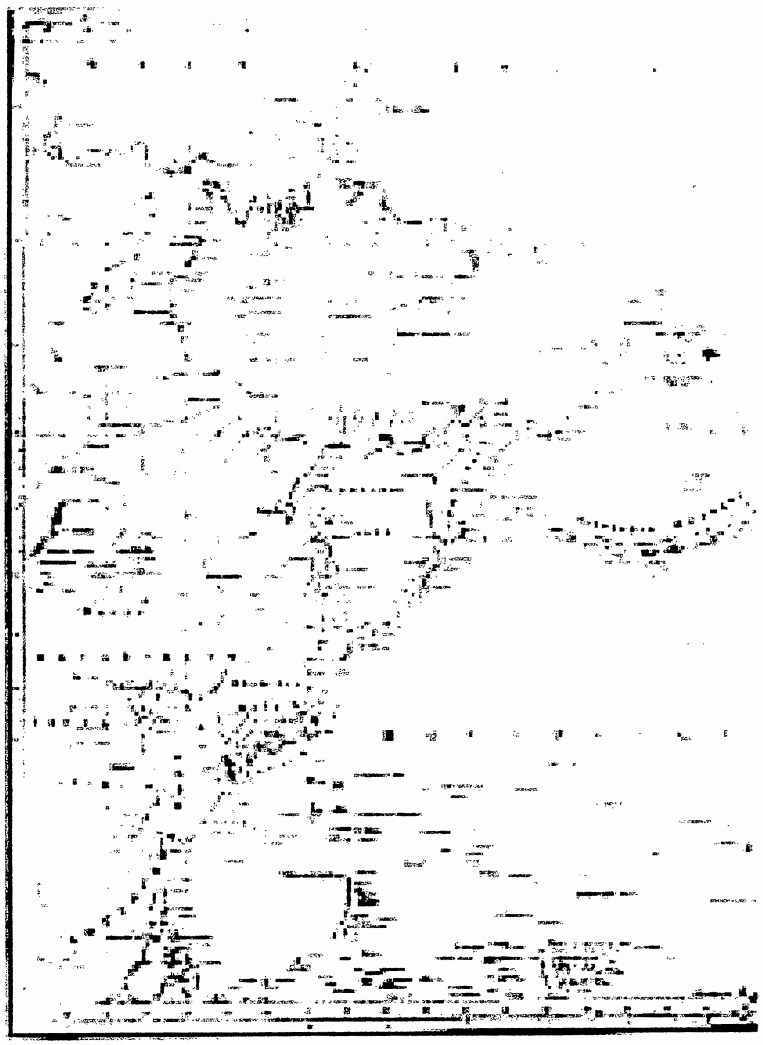


Figure 2. Mercator Chart.

Chronometer

As the earth rotates the degrees of longitude passes directly beneath the sun. With the earth taking 24 hours to rotate 360 degrees it can be calculated that the earth rotates one degree of longitude in 4 minutes, 15 degrees each hour and 360 degrees in 24 hours. Thus with clocks a navigator can measure the difference between local and prime time to determine longitude. In theory navigators knew for centuries how to determine their longitude but in actuality lacked the accurate timepieces required (Quill, 1966).

The idea of using a chronometer to calculate longitude dates from the thirteenth century but the actual invention of the chronometer was not made until the eighteenth century by English clock-maker, John Harrison (Quill,1966). The first of his series of five sea-clocks (chronometers) H.I was completed in 1735. The key advance in H.I was that instead of a pendulum a balance spring was used so that if it was tilted or turned, as by the movement of the sea, the "regularity of the balances" was not disturbed. A sea-trial of H.I in 1736 was performed when it was used on a sailing trip Lisbon (Quill,1966).

In June 1737 Harrison proposed to a Board of Longitude meeting that a second and improved longitude time-keeper should be constructed, the H.2 which he completed in 1739. The main innovation in the mechanism of H.2, one which Harrison used in all his subsequent longitude time-keepers was a remontoire. Remontoire mechanism ensures that the force on the escapement is constant and improves the accuracy of the clock (Quill, 1966).

By 1741 John Harrison had commenced constructing H.3 but the time-keeper had the serious drawback of being impossible to adjust without dismantling and re-assembling both of which were long procedures. Upon completion of H.3 Harrison immediately began work on H.4 which had a diameter of only 5.25 inches. To enable the reduction in size of H.4 Harrison used oil as a lubricant for his instrument. The trial for H.4 commenced in October 1761 when it left Britain on HMS Deptford for Jamaica. The trip lasted two months. The H.4 was determined to be only five seconds slow at the end of the trip. This corresponded to an error in longitude of only 1.25 minutes. Harrison's final longitude time-keeper H.5 was completed in 1772 and was mechanically very similar to H.4. Following the invention of H.4 the small-scale manufacture of chronometers spread quickly as did their use for determing longitude (Quill, 1966).

Gyrocompass

The next big event in the history of navigation came in the form of the gyrocompass. In 1852, Jean Foucault, a French physicist, built a gyroscope, the Foucault pendulum, to demonstrate that the earth rotates. Foucault named the instrument from two Greek words--*gyros*, meaning *circle* or *ring*, and *skopein*, and meaning to view--because the gyroscope had enabled him to view the rotation of the earth.

It was the first satisfactory demonstration of the earth's rotation using laboratory apparatus rather than astronomical observations (Wertz, 2000). By 1890 G.M. Hopkins invented the first electrically driven gyroscope. A gyroscope is a disk mounted on a base in such a way that the disk can spin freely on its X- and Y-axes; that is; the momentum of the disk will cause the disk to retain its attitude no matter what direction the base is moved. The advantage of a gyrocompass over a magnetic compass is that the gyrocompass required no correction for deviation (Harding, 1952).

Special air charts were first produced in 1919 but due to the slow speed of aircraft, pilots were content to continue using automobile road maps. Little progress was made on air maps until the early 1930s. In 1933 special air navigation maps were introduced but once again they failed to quickly advance. Air navigation maps were significantly advanced during the World War II air war (Anderson, 1951).

Art to Science

As faster modes of transportation evolved, so did navigation. Navigation evolved from an art to science. Once navigation became a science the application of mathematics to determine a vehicles' position was applied. Once the navigator was able to determine a position he became able to direct the vessel to a predetermined destination. Pilots not schooled in the science of navigation still simply followed railroad tracks, bonfires, or rotating beacons.

Throughout time, technology advanced and radio positioning and celestial techniques were developed to satisfy the need for highly accurate navigational requirements. In the early 1950's the Very High Frequency (VHF) Omnidirectional Range System (VOR) was adopted as the worldwide standard short-range navigation aid to be used for the newly developed airways system (Fishbein, 1995).

The development of the Instrument Landing System (ILS) led to another form of VHF technology being used for navigation. It too became a world standard and with new developments in autopilot technology, the ILS system helped improve all-weather automatic landing capability (Fishbein, et al., 1995).

Advancements in electronic systems during the 1940s and the 50s led to development of navigation/communication (NAV/COM) systems. These systems combined reception of navigation and communication signals into a single piece of electronic equipment. Other systems developed during this time were the military

Tactical Air Navigation (TACAN) and distance-measuring equipment (DME). Radar, both ground-based and in-flight, provided much greater accuracy and safety than had been thought possible just a few years earlier.

Throughout the years, several other forms of airborne navigation systems have been developed. They include automatic electronic celestial tracking, Doppler, inertial navigation system (INS), and Ring-Laser Gyro (RLG) systems. However, due to various reasons, including cost, general aviation pilots did not adopt these systems.

Two systems that were adopted by general aviation pilots included the previously mentioned VOR and DME systems. They became the navigational cornerstones for the national airways system. Two other widely accepted ground-based navigation systems used by general aviation pilots include the long-range navigation (LORAN) and the non-directional beacon (NDB). The TACAN system has however never been accessible to general aviation pilots. It was developed to be used exclusively by the military. It simply combined the features of a VOR and a DME into a single unit operating on special military only authorized frequencies.

The next generation technology advances in the science of navigation came in the form of space-based navigation systems. In 1978 placing satellites in orbit started the NAVSTAR/Global Positioning System (GPS). This system provides not only highly accurate navigation positioning but has been adopted by other groups such as geologists and agricultural experts. It has even been adopted into the automobile industry, providing navigation and directions to drivers.

GPS History

Over the last 40 years, air navigation has consisted basically of various forms of radio direction finding such as VOR, DME and NDBs. The LORAN-C system came into prominence in the 1980s primarily being developed for marine use. It was quickly adapted for aviation use and was widely embraced by general aviation pilots. Each of these systems however has various drawbacks. Beside their assorted shortcomings they also suffer from an overall lack of consistently good navigational accuracy. In the 1970s a system of global satellite navigation was developed by the United States armed services. The system known originally as the NAVSTAR Global Positioning System (GPS) would be able to position an aircraft or weapon warhead accurately within a few meters within three dimensions: latitude, longitude, and altitude (Clarke, 1998).

The U.S. Department of Defense (DOD) developed the satellite-based radionavigation system in the 1970s to be the DOD's primary means of radionavigation well into the 21st century. It was developed in three phases with the first phase beginning in 1973. The first phase included concept studies, projected system performance, and overall feasibility of the system (Clarke et al., 1998).

Rockwell International was awarded a contract in 1974 to develop three prototype satellites. At the same time General Dynamics was awarded a contract to develop the user and control segments of the system. Phase I ended in 1979 after having launched five satellites, allowing three-dimensional navigation for the first time.

The second phase of GPS development began in 1980 and ran through 1985. It involved the full-scale development and testing of the system. Following in the successful footsteps of Phase II, Phase III started in 1985. During this phase the master control station was moved from Vandenberg AFB, California, to Falcon AFB, Colorado which has since been renamed Schriever AFB. The system was used by the military shortly thereafter. In April 1995 the entire system became operational for worldwide civilian use (Federal Aviation Administration Academy, 1998).

GPS Theory and Operation

The Global Positioning System provides a limitless amount of GSP receiver equipped users continuous global navigational coverage. The system consists of three segments: space, user, and control. The space segment is made up of 24 satellites (three of which are in-orbit spares), which send signals with ephemeris data. The ephemeris data each satellite transmits consists of a burst of data containing its position and time data. The satellites are arranged in six varying orbital planes (Figure 3), orbiting earth once every 12 hours (Joint Program Office, 1997). This configuration allows GPS receivers to resolve the mathematical equations for latitude, longitude, and time with three satellites in view. If a fourth satellite is present height or altitude can also be calculated. Using the ephemeris data GPS position can be determined. This is accomplished by using a concept called time of arrival ranging. This principle of time of arrival ranging, employs basic mathematics. It merely calculates the time it takes a signal to travel form one point to another. The measured time is then converted into distance. (Clarke et al., 1998).

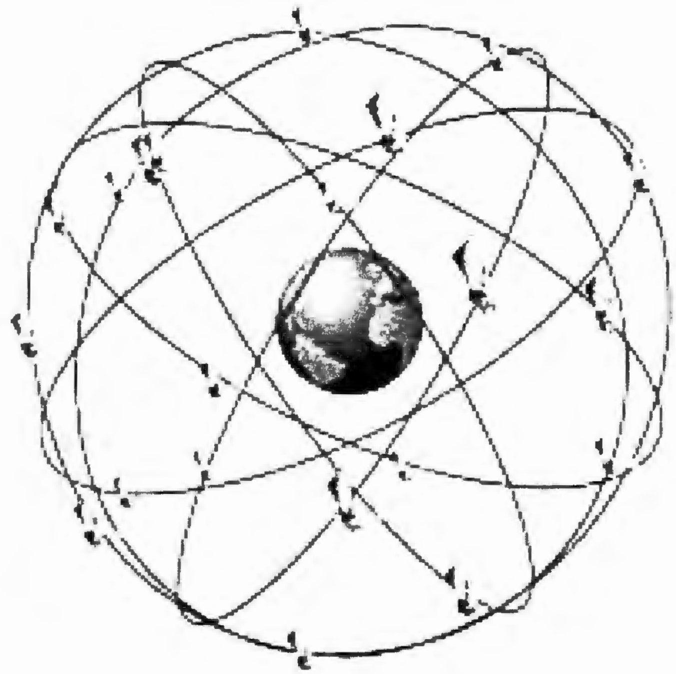


Figure 3. GPS Constellation.

Everyone as a child performed a simple slow-speed example of time arrival ranging. An estimate could be made of the distance from your location to a thunderstorm by watching for the lightning flash. After observing the lightning flash one could then count the seconds until the thunder was heard. If the delay was five seconds then the storm was approximately one mile away. This is the same principle used by a GPS receiver, the second segment of the GPS system. The receiver merely measures the time from each of the satellites it is tracking. Then by using mathematical calculations the receiver can determine the distance from each GPS satellite. Each satellite transmits data letting the receiver know the satellite's precise orbital position. By using triangulation the receiver can determine the latitudinal and longitudinal position while tracking a minimum of three satellites. If it is tracking a fourth satellite, altitude can be calculated.

The third segment of the GPS system is the control segment. Its purpose is to track GPS satellites and provide them with periodic updates, correcting their ephemeris constants and their internal clocks. These parameters are used in defining the orbit of a celestial body or man-made satellite (Logsdon, 1995). Errors in the ephemeris data directly relates to position errors in the final calculations presented by the GPS receiver.

GPS Interference

The reliability of the GPS signal may be mistakenly taken for granted by many users. However reliability and fidelity is of growing concern to the GPS community. In 2000, ultra wide band (UWB) wireless technology was being hailed as the greatest new invention. In spite of this a new report is pointing out potentially serious problems with UWB. It provides broadband services by "piggybacking" on spectrums occupied by wireless services. The technology has the potential of providing short-range wireless data transmissions that would be as fast as a wired connection. "The problem is that the UWB signals appear to interfere with signals used by cell phones, television news crews working with satellite uplinks, C-band satellite dishes used to distribute television programming…and Global Positioning Systems" (Aviation Daily, March 20, 2001).

Joe Canny, deputy assistant secretary for navigation system policy at the Transportation Department, said the report "demonstrated there are some serious problems between some types of UWB and GPS receivers. The test showed UWB can cause interference at power levels below that which had been proposed by the FCC." The problem is apparent on the GPS 1.2 and 1.5 GHz bands, which are used to control both flight and landing of aircraft (Aviation Daily, March 20, 2001).

Federal Aviation Administration

The FAA developed a 15-year GPS utilization plan in 1994 followed by the creation of order 8260.38A in April 1995. The order's subject was "Civil Utilization of Global Positioning System (GPS)" with the purpose to provide criteria to be used in conjunction with Order 8260.38, U.S. Standard for Terminal Instrument Procedures (TERPS), for establishing GPS non-precision approaches (FAA, 1995). The FAA's plan is to phase out all other forms of radionavigation and rely solely on GPS during the first decade of the millennium. The FAA's original aggressive plan of converting solely to GPS is not under consideration until ramifications of such a move can be further studied.

Accident Statistics

Presently the FAA's database of civilian aircraft accidents reflects accident statistics from 1994 and prior. This will be of no use for this study since GPS came into use in civilian aviation in the early 1990s.

Almost every year since World War II, both the accident and fatal accident rates have fallen. The accident rate for general aviation is about eight accidents per 100,000 hours flown, and less than two fatal accidents per 100,000 hours flown (Trollip & Jensen, 1991). The most common, specific causes of accidents, in order of frequency, are:

1. Loss of directional control
2. Poor judgment
3. Airspeed not maintained
4. Poor preflight planning and decision-making
5. Clearance not maintained

6. Inadvertent stalls

7. Poor crosswind handling

8. Poor in-flight planning and decision-making

As can be seen from this list, almost all causes of accidents are a result of poor pilot judgment. Another name for poor pilot judgment is human factors. Human factors deal with errors that pilots make, why they make them, and how they can prevent them (Trollip & Jensen, 1991). When faulty pilot technical cause is traced back, it is usually found to have been an error in the pilot's decision-making process (Turner, 1995).

Human Factors

"Only man, not technology, can cope with the unpredictable" (Logsdon et al., 1995). Human factors in aviation include the study of the human's capabilities, limitations, and behaviors. It also involves the integration of knowledge into systems design with the goals of enhancing safety, performance, and the general well being of the operators of the systems. (Koonce, 1979).

Human factors are traditionally called "pilot error" and are the cause of nearly 80 percent of all general aviation accidents. The airline and corporate flight communities have shown that teaching the control of adverse human factors is possible. This type of training is directly linked to an improvement in overall accident statistics (Turner, 1995).

In the 1990s many of the aviation technologies, have changed. With the advent of microcomputers and flat panel display technologies, the aircraft cockpits of the modern airplane are vastly different from the cockpits of past airplanes. Navigational systems are extremely precise. They also are integrated with autopilot systems allowing the capability of fully automated flight from just after takeoff to touchdown. The pilot is becoming a passive observer of the airplane's systems. The major challenge for designers of today's cockpits is what to do with the pilot during automated flight (Garland, Wise, & Hopkin, 1999).

Accidents have occurred in which the pilot was not aware of his location with respect to dangerous terrain. Accidents have also occurred because the pilot was unaware of the current status of the airplane's systems (Garland, Wise, & Hopkin et al., 1999). Human factors were attributable to from 69-79 percent of all general aviation accidents. The percentage depended on what class of airplane they were flying. Obviously eliminating even just a few of the typical human-factor mistakes made in general aviation would greatly reduce the number of accidents.

Cockpit Resource Management

One such way to help reduce the human-factor mistakes would be to use Cockpit Resource Management (CRM) techniques. Commercial air carriers as well as the military use these CRM techniques. Significant positive results in lowering accidents that can be contributed to pilot errors have been realized. If general aviation pilots in each human-factor accident had employed the decision-making principles of CRM such as the air carriers and military pilots, the accident rate for general aviation pilots would also significantly decrease (Turner, 1995).

Cockpit resource management is nothing more than a name given to a concept. The concept is simply to maximize mission effectiveness and safety through effective utilization of all available resources (Kern, in press). What makes CRM unique, as a training program is the environment and target audience for which the training is designed. CRM is designed to train aviators how to achieve maximum flight effectiveness. It is also designed to train pilots to achieve this effectiveness in a time-constrained environment, under stress.

Unfortunately most of the language of CRM reflects the notion that there is more than one person to help with the work and to make decisions. The skills and techniques taught to increase safety in airplanes requiring more than one pilot have not been translated into information readily usable to the single-pilot operator (Turner, 1995).

CRM deals directly with the definitions of a few key terms already mentioned. One such term is maximizing flight effectiveness, which can be broken down into three areas. The first area is achieving the objective, getting from point A to point B. Next comes preserving resources, which encompasses not crashing airplanes or killing/injuring people, saving fuel, and preventing pilot induced aircraft damage (i.e., over-Gs). The final area is to enrich training efficiency along with better student instructor rapport and interaction. In order to accomplish this more effective communication during inflight instruction is a requisite (Kern et al., in press).

The term available resources, means just that. All available resources include such things as hardware, software, printed materials, people power (your own and others), the environment (sun, terrain, etc.), time, fuel, etc. Research has demonstrated that many pilots cannot identify all of the resources at their command. If pilots are incapable of identifying all of their available resources, they will be unable to access them in a time-stressed emergency situation.

CRM training is designed to produce pilots who consistently use sound judgment. It also teaches pilots to make quality decisions. Pilots are also educated on accessing all required resources, under stressful conditions in a time-constrained dynamic environment.

Aviators have been making poor judgments since the day Icarus decided to checkout the maximum service ceiling of his new wings. In an Inspector General (IG) report, Poor Teamwork as a Cause of Air Craft Accidents, (1951), data was gathered from 7,518 major accidents taken between 1948 and 1951. The report determined that poor organization, personnel errors, and poor teamwork resulted in the majority of aircraft accidents. Further that the human element… and effective teamwork is essential to reducing the accident rate. The IG report even went as far as recommending a teamwork program. Conversely the IG unfortunately neglected to add a suspense date for the training programs implementation.

The aviation community refocused on the need for some type of human factors training following the much-publicized crash of a United Airlines DC-8 in Portland, Oregon, in December 1978. Attempting to ascertain the nature of a possible landing gear problem, the aircrew allowed the aircraft to run out of fuel. This was done while circling near the landing field on a clear night in good weather. The result of this refocused attention was the amendment of Part 121 of the Federal Aviation Regulations (FARs) allowing airlines to training what is now called CRM (Kern et al., in press).

Following CRM implementation, air carriers began to notice dramatic decreases in their accident rates. United Airlines has been an industry leader in CRM training, implementing a CRM program in 1981. In the 20 years of the program, the airline has not had a single fatality contributed to a human-factor error. Over those 20 years United

Airlines has flown approximately 2400 flights daily. This equates to over 1.7 million human factors safe operations over those 20 years.

Military application of these principles lagged behind civilian counterparts. Finally in the mid-1980s, the Naval Safety Center and the old Military Airlift Command (MAC) began to implement airline-style programs. The programs generated good results. The popularity of these programs grew throughout the 1980s and early 1990s in both the commercial aviation industry and military aviation. The programs have grown to the point where nearly everyone has a CRM program.

Military CRM training includes the following eight core curriculum elements (AFI, 1994):

1. Situational awareness
2. Group dynamics
3. Effective communication
4. Risk management and decision-making
5. Workload management
6. Stress awareness and management
7. Mission planning, review, and critique strategies
8. Human performance

CRM is not just about how to stock pencils or shuffle paper. It's about real-time decision-making. It also teaches pilots on the subject of the other tools that are available to them.

There are many external factors that affect people on a daily basis. These factors affect them whether they are trying to achieve manned flight or not. Some of them are positive in nature and some are negative. What CRM does is show aviators how to recognize and deal with both the positive and negative factors. Pilots are faced with these factors every time they begin the process of getting an aircraft in the air. These factors come into play during mission planning and continue through to the end of the flight. How they deal with these factors has a direct impact on how successful they are with their flight (Turner, 1995).

Reports, Surveys, and Studies

Numerous studies have been performed over the last decade concerning cockpit automation in aviation and human factors. The reports and studies in this area are mostly concerned with automation and human factors in large commercial or military aircraft. These types of aircraft are multi-crewmembers and are operated differently than are general aviation aircraft. However, several studies have been conducted in Australia and New Zealand pertaining to general aviation pilots and human factors associated with cockpit automation and GPS.

One of the first studies (Nendick & St. George, 1996) was concerned with general aviation pilot behaviors being changed by using GPS. General aviation pilots in general felt more confident when using GPS than when not using it. The study concluded that on the issue of training, a more formal approach was needed for general aviation pilots. The respondents to the study's survey also believed a more formal training approach was needed. The study reported that "pilots need to fully understand how GPS functions and how to use it effectively in conjunction with other navigation techniques."

In another study performed in Australia (Nendick & St. George, 1996) the survey identified many human factors and flight safety implications for inadequate training. The survey showed that these issues are not typically addressed by the current training methods, and are less likely to be corrected through individual experience as the operator becomes more proficient with GPS units. The study goes on to say "training must emphasize the need for close monitoring of GPS like any other automated equipment and for comparison of GPS data with other navigational sources."

It is possible that the average visual flight rules (VFR) pilot will not have the instrument monitoring experience required to realize the importance and difficulty involved in this task of comparison of navigational sources. The major danger is that of blindly trusting GPS and the information it is giving the pilot. Training must emphasize the appropriate use of maps and charts in conjunction with GPS, to develop and follow a backup plan of navigation with their charts and maps. Also, flight training should teach correct methods of flight planning and checking or monitoring flight progress with regard to airspace and terrain. As well, reversionary procedures must be considered as a requisite during flight training (Nendick, 1995).

As stated earlier, pilots tend to feel that GPS is simple to operate. A 1998 study (Joseph, Jahns, Nendick, & St. George) warns of general aviation pilots being captivated by the inherent simplicity and minimal training required to execute frequently used basic GPS receiver functions. However, as Winter and Jackson (1995) demonstrated, pilots that have not acquired a significant amount of knowledge and training can become overwhelmed when they go beyond basic GPS receiver functions to complex ones.

CHAPTER III

METHODOLOGY

Design of the Study

The purpose of this study is to provide data to the following research questions: (1) Are flight training programs providing GPS ground training as a stand-alone class or incorporated into existing courses? (2) Are GPS training aids utilized? (3) Are the flight training programs utilizing GPS? (4) Are flight instructors teaching GPS techniques receiving formal training on GPS? (5) What are the commercial GPS training materials currently on the market?

The results will be shared with numerous flight safety organizations, aviation agencies, and aviation journals. Such agencies will include but are not limited to the Federal Aviation Administration (FAA), Aircraft Owners and Pilot's Organization (AOPA), University Aviation Association (UAA), and Experimental Aircraft Association (EAA).

This study will also determine if further research needs to be accomplished on GPS formal training concerns for general aviation pilots. The concerns in this area will be revealed once the final results of this study are published. If this study does reveal further research is required steps should be taken to ensure such research is conducted.

The results should then be published and shared with the appropriate agencies and organizations previously mentioned.

Population

The study population consisted of 106 collegiate aviation programs located throughout the United States of America listed in the GPS Training Survey Mailing List (Appendix E). There are 114 collegiate aviation programs located in the United States of which eight provided only aviation maintenance or radio repair training. The list of 106 collegiate aviation programs was obtained from the University Aviation Association's (UAA) Collegiate Aviation Guide (1999). All 106 collegiate aviation programs that meet the criteria of being in the United States and offering either ground or flight training or both were sent surveys for this study.

Instrument Description

The researcher prepared a GPS Training Survey (Appendix C) containing 7 demographic questions followed by 32 GPS training specific questions designed to meet the objective of this study, to provide data to the following research questions: (1) Are flight training programs providing GPS ground training as a stand-alone class or incorporated into existing courses? (2) Are GPS training aids utilized? (3) Are the flight training programs utilizing GPS? (4) Are flight instructors teaching GPS techniques receiving formal training on GPS? (5) What are the commercial GPS training materials currently on the market? The survey was separated into the following seven sections: (1) Demographics, (2) Ground Training, (3) Training Aids, (4) Flight Training, (5) Instructors, (6) Planned Purchases, and (7) Comments.

Also included in the mailing were the GPS Training Survey Cover Letter (Appendix A), containing the Institutional Review Board (IRB) Form approval number (Appendix F), and a stamped self-addressed return envelope.

The GPS Training Survey package was mailed to the 106 collegiate aviation programs, January 4, 2002. A GPS Training Survey Follow-up Letter (Appendix B) was mailed one month later without the instrument included.

The GPS Training Survey was verified to fulfill the research objectives by the following individuals: Dr. Craig Kanske, Dr. Kenneth Sperry, Dr. Michael Larson, and Dr. David Conway, Dr. Steve Marks, Dr. Nelson Ehrlich, Dr. Cecil Dugger, and Dr. Kay Bull. Individuals for the verification process were selected for their expertise and experience with GPS as well as general aviation training.

Data Analysis

Data for the study was first collected and tabulated from the 7 demographic and 32 GPS training specific questions of the returned GPS Training Surveys. A descriptive statistics approach was used to report and interpret findings from the GPS Training Survey questions with the results being displayed in histogram form using a nominal scale to provide the lowest level of quantification of the objectives to be measured. The nominal scale allowed for simple sorting of the objectives and classes into mutually exclusive categories.

CHAPTER IV

FINDINGS

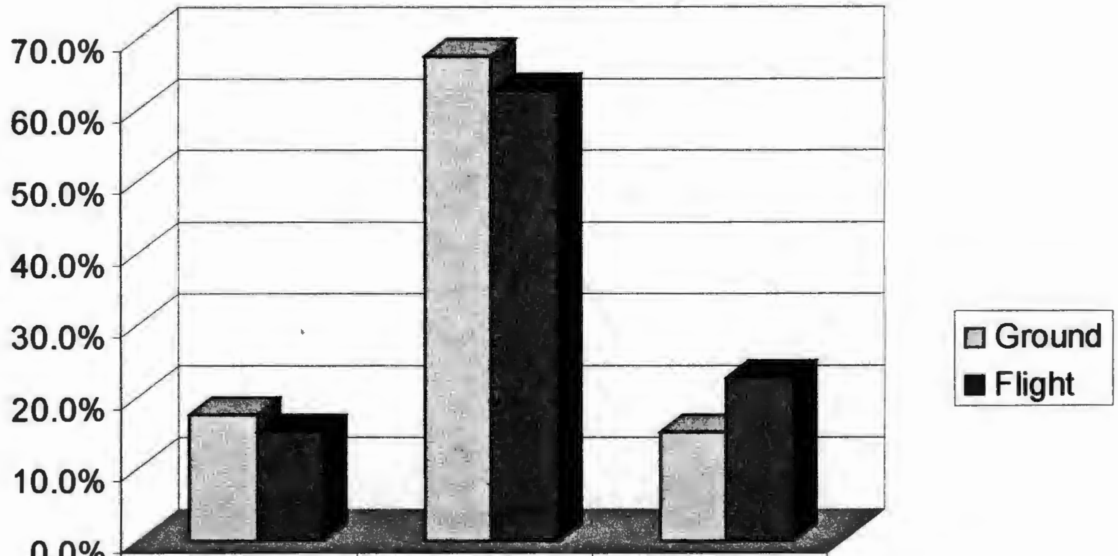
Introduction

The purpose of this chapter is to describe and analyze the data collected in the study. Looking at the seven categories of the GPS Training Survey separately will approach this procedure. Next, a comparison of current flight instructors and flight instructor student training to other levels; private, commercial, and instrument student training will be completed.

Demographics

Forty of the 106 (38%) of the collegiate aviation programs completed and returned the GPS Training Survey. One of the surveys was returned without completion of any of the 39 total questions and was not used for this study. Ground instruction under FAR Part 61 is 17.5 %; 67.5 % provide FAR part 141 instruction, and 15% give instruction under both FAR Part 61 and 141. Flight instruction is supplied by 15% of the programs using FAR Part 61; Part 141 training is offered by 62.5%, and 22.5% supplying flight instruction with both FAR Parts (Graph 1).

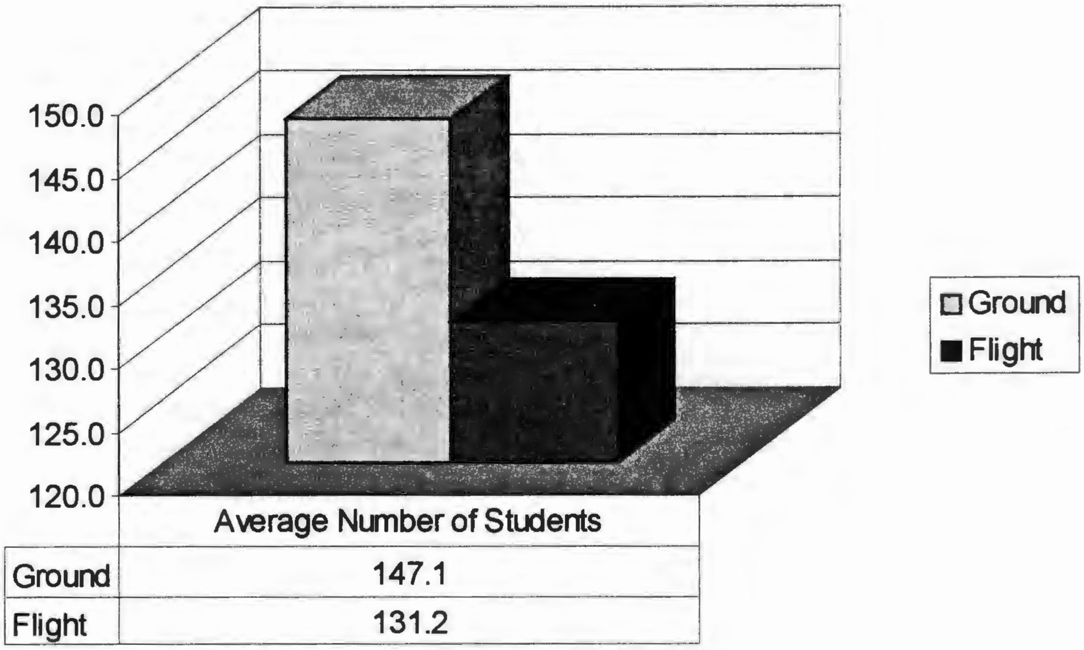
Graph 1. Percentage of Instruction by FAR Part Number



	Part 61	Part 141	Both
Ground	17.5%	67.5%	15.0%
Flight	15.0%	62.5%	22.5%

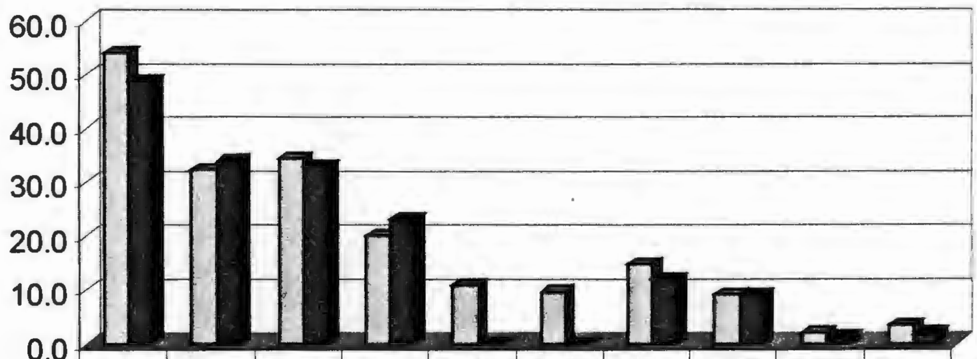
Ground training programs, average 147 students per school with an average of 54 enrolled in private pilot ground school, 32 commercial, 34 instrument, 20 multi-engine, 11 basic ground instructor, 10 advanced ground instructor, 15 certified flight instructor-airplane, 9 certified flight instructor-instrument, 2 airline transport pilot, and 4 in other ground training classes (Graph 2).

Graph 2. Average Number of Students Per School



Flight training programs, average 131 students per school with an average of 49 enrolled in private pilot flight school, 34 commercial, 33 instrument, 23 multi-engine, 12 certified flight instructor-airplane, 9 certified flight instructor-instrument, 1 airline transport pilot, and none in other flight training classes (Graph 3).

Graph 3. Average Number of Students Per Type of Training



	Priv	Com	Inst	ME	BGI	AGI	CFIA	CFII	ATP	Other
Ground	53.9	32.2	34.4	20.0	10.9	9.7	14.8	9.1	2.2	3.5
Flight	48.6	33.8	32.9	23.2	0.0	0.0	12.0	9.2	1.3	2.0

Controlled airfields are used by 47.5% of the flight schools for flight training, 17.5% use uncontrolled airfields and 10% use both types of airfields (Graph 4).

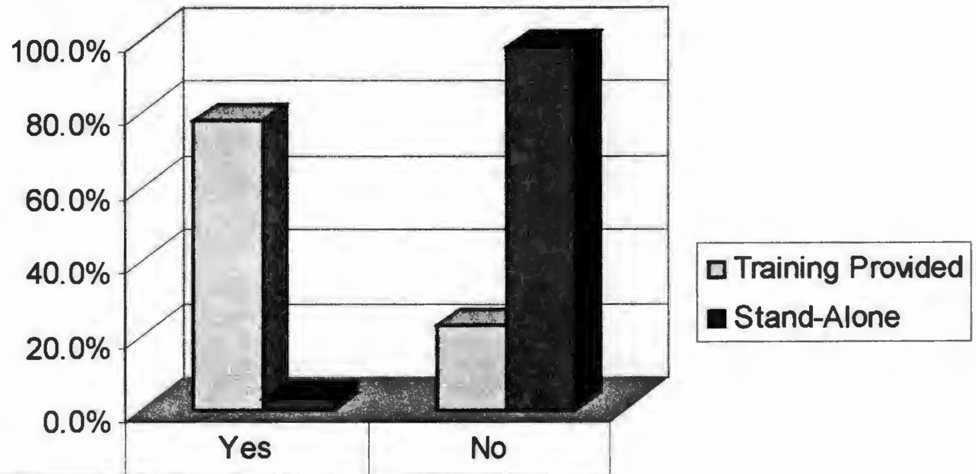
Graph 4. Percentage of Types of Airfields Used

	Controlled	Uncontrolled	Both
Airfield	47.5%	42.5%	10.0%

Ground Training

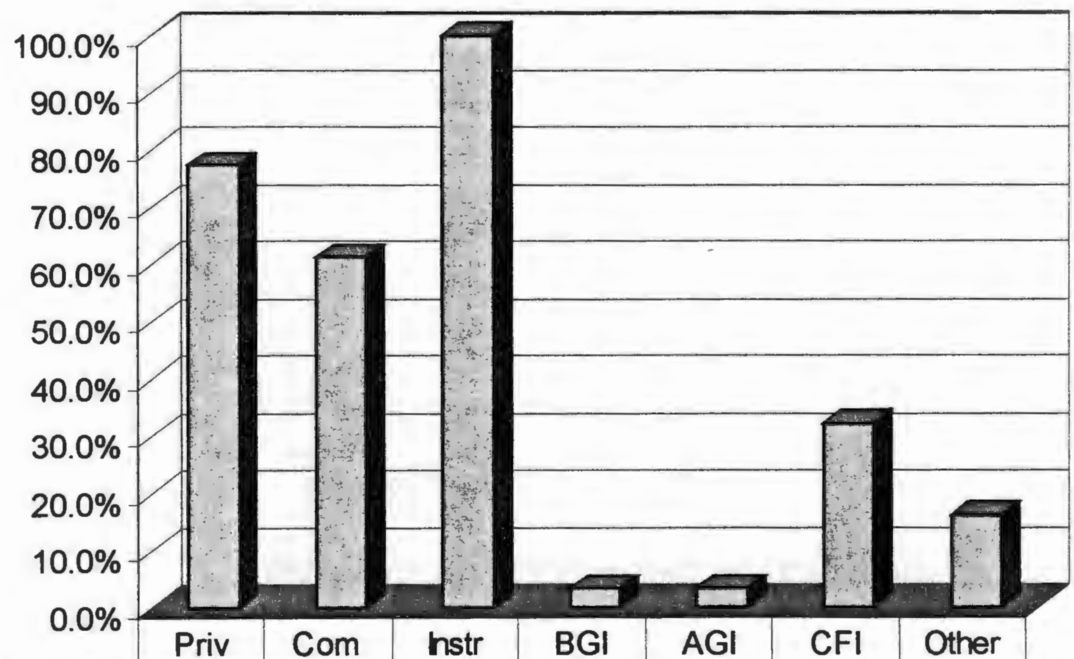
GPS ground training is provided at 31 of the 40 (77.5%) of the flight schools that responded to the survey (Graph 5). Of the 31 flight schools providing GPS ground training 24 (77%) incorporate it into their private pilot course with 40% of those 24 schools providing less than 30 minutes training; 52% providing between 30 and 60 minutes and two 8% between 60 and 90 minutes (Graphs 6 & 7). Nineteen (61%) of the 31 flight schools incorporate GPS ground training into their commercial pilot course with 20% providing less than 30 minutes training with 35% providing between 30 and 60 minutes, 35% between 60 and 90 minutes, and 10% 90 to 120 minutes. All thirty one (100%) incorporate GPS ground training into their instrument pilot course with 10% providing less than 30 minutes, 31% providing between 30 and 60 minutes, 24% between 60 and 90 minutes, 34% 90 to 120 minutes, and one program (3%) offering more than 120 minutes of training. One program (3%) of the 31 providing GPS ground training offers less than 30 minutes of training for both basic and advanced ground instructor training. Ten (32%) of the 31 flight schools incorporate GPS ground training into their flight instructor course with 39% providing less than 30 minutes, 38% providing between 30 and 60 minutes, 15% between 60 and 90 minutes, and 8% 90 to 120 minutes. Five (16%) of the 31 flight schools incorporate GPS ground training into other types of courses with 33% providing less than 30 minutes, 33% between 60 and 90 minutes, 17% 90 to 120 minutes, and one program offering more than 120 minutes of training. Only one program (3%) of the 36 that answered question four of the survey offered stand-alone GPS ground training, a three credit hour course.

Graph 5. Percentage of Schools Providing GPS Ground Training



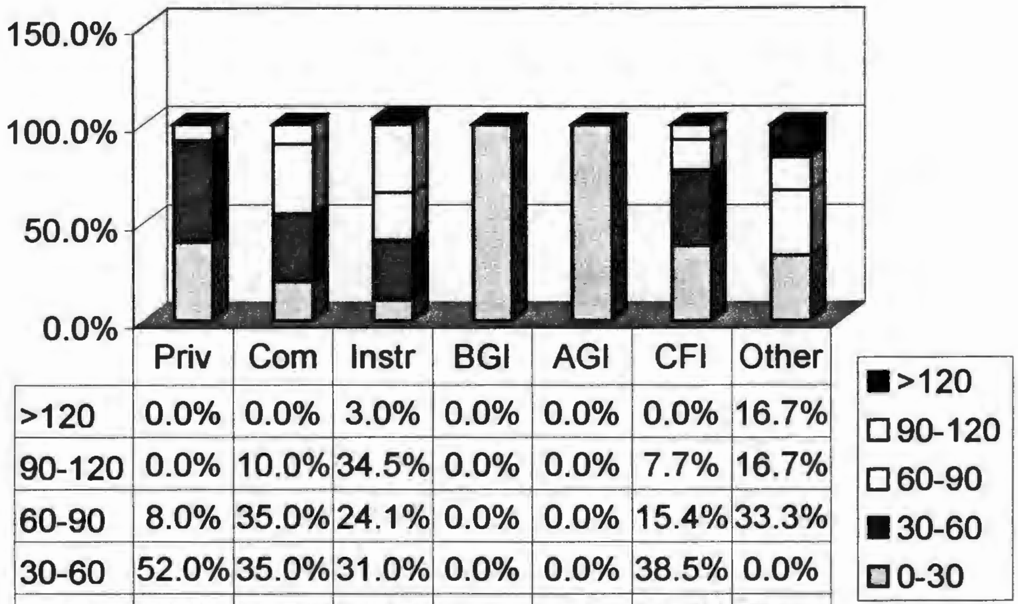
	Yes	No
Training Provided	77.5%	22.5%
Stand-Alone	2.8%	97.2%

Graph 6. Percentage of Schools Providing GPS Training Per Course



	Priv	Com	Instr	BGI	AGI	CFI	Other
Courses	77.4%	61.3%	100.0%	3.2%	3.2%	32.3%	16.1%

Graph 7. Percentage of Time for GPS Training Per Course



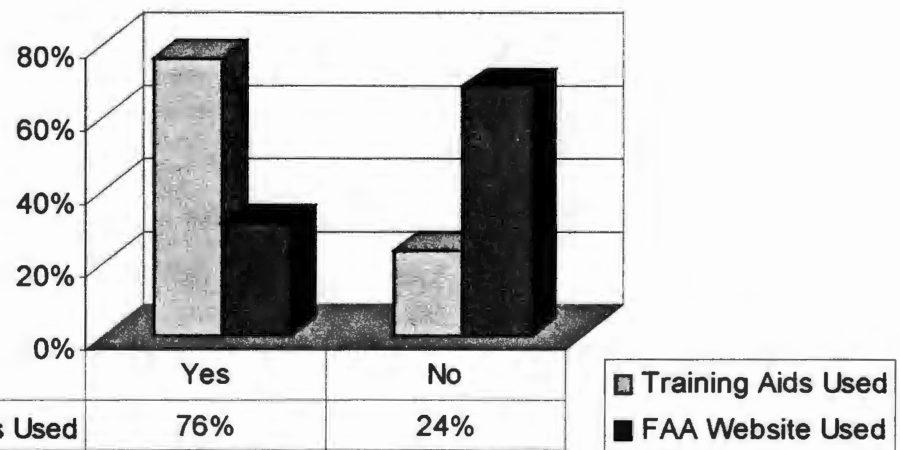
	Priv	Com	Instr	BGI	AGI	CFI	Other
>120	0.0%	0.0%	3.0%	0.0%	0.0%	0.0%	16.7%
90-120	0.0%	10.0%	34.5%	0.0%	0.0%	7.7%	16.7%
60-90	8.0%	35.0%	24.1%	0.0%	0.0%	15.4%	33.3%
30-60	52.0%	35.0%	31.0%	0.0%	0.0%	38.5%	0.0%
0-30	40.0%	20.0%	10.3%	100.0	100.0	38.5%	33.3%

Training Aids

Seventy six percent of the training programs use GPS training aids in their training classes with 31% utilizing the Federal Aviation Administration's GPS web site for training purposes (Graph 8). Eighteen of the schools used a chalk/white board as a GPS training aid, 10 the internet, 12 a flight simulator with GPS, 5 a stand-alone GPS simulator, 14 a computer GPS simulator, 7 a computer-based training (CBT) program, 11 an actual GPS receiver, 5 used videos, and 1 overhead slides (Graph 9).

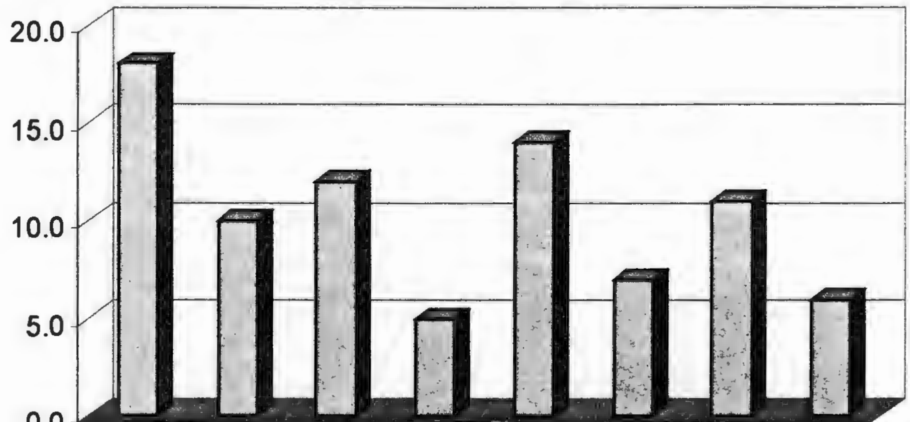
Twenty-nine schools devote less than one chapter, averaging 2 pages to GPS in private pilot course work, 2 devote one chapter, and 3 devote none. Twenty-one schools devote less than one chapter, averaging 2 pages to GPS in commercial pilot course work, 5 devote one chapter, and 3 devote none. Twenty-five schools devote less than one chapter, averaging 4 pages to GPS in instrument pilot course work, 10 devote one chapter, 1 devotes none, and 2 devote more than one chapter. One school devotes less than one chapter, 2.5 pages to GPS in basic ground instructor course work, and 5 devote none. One school devotes less than one chapter, 2.5 pages to GPS in advanced ground instructor course work, and 3 devote none. Ten schools devote less than one chapter, averaging 2 pages to GPS in flight instructor course work, 1 devotes one chapter, and 6 devote none. Three schools devote less than one chapter, averaging less than 2 pages to GPS in other course work, 2 devote one chapter, 3 devote none, and 1 devote more than one chapter (Graph 10).

Graph 8. Percentage of Schools Utilizing GPS Training Aids & FAA Website



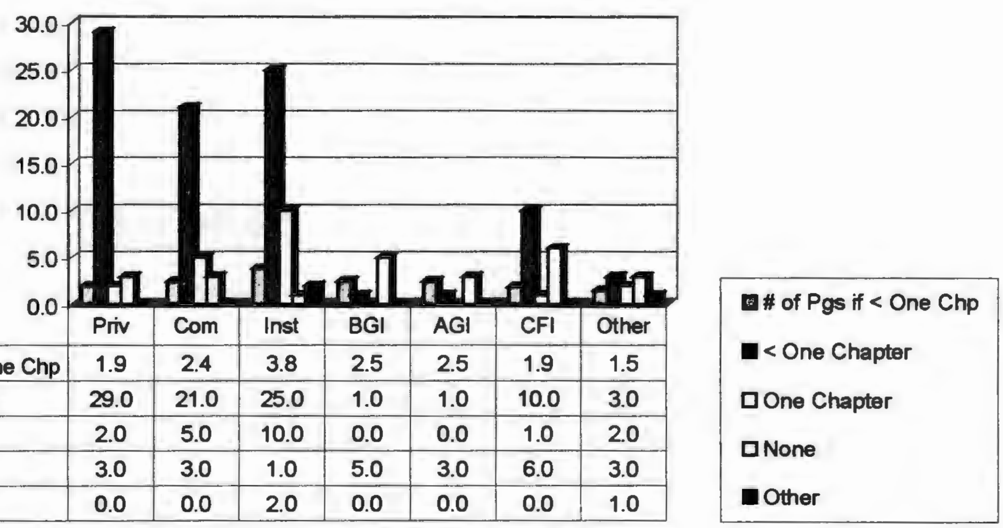
	Yes	No
Training Aids Used	76%	24%
FAA Website Used	31%	69%

Graph 9. Number of Schools Utilizing Each Type of Training Aid



	Chalk Board	Web	Flight Sim	GPS Sim	Comp Sim	CBT	Actual GPS	Other
Types Of Aids	18.0	10.0	12.0	5.0	14.0	7.0	11.0	6.0

Graph 10. Textbook Usage



	Priv	Com	Inst	BGI	AGI	CFI	Other
# of Pgs if < One Chp	1.9	2.4	3.8	2.5	2.5	1.9	1.5
< One Chapter	29.0	21.0	25.0	1.0	1.0	10.0	3.0
One Chapter	2.0	5.0	10.0	0.0	0.0	1.0	2.0
None	3.0	3.0	1.0	5.0	3.0	6.0	3.0
Other	0.0	0.0	2.0	0.0	0.0	0.0	1.0

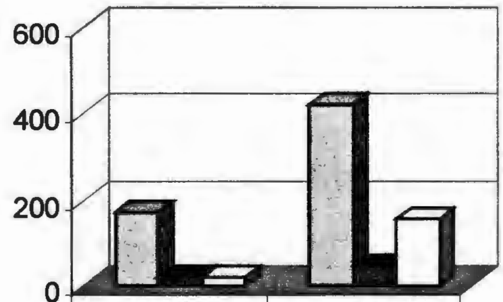
Flight Training

A total of 173 VFR equipped aircraft are used for flight training with 23 being equipped with a non-certified GPS receiver and 24 equipped with a certified GPS receiver. A total of 420 IFR equipped aircraft are used for flight training with 49 being equipped with a non-certified GPS receiver and 159 equipped with a certified GPS receiver (Graph 11).

Sixteen (43%) of the 37 schools that responded to question 15 of the survey allow students to use a handheld GPS receiver during flight training, seven (27%) of the 26 schools responding to question 16 of the survey encourage students to use handheld GPS receivers during flight training but none of the schools require students to purchase a handheld GPS receiver. Twenty two (58%) of the 38 schools responding to question 20 of the survey allow flight instructors to use a handheld GPS receiver during flight training (Graph 12).

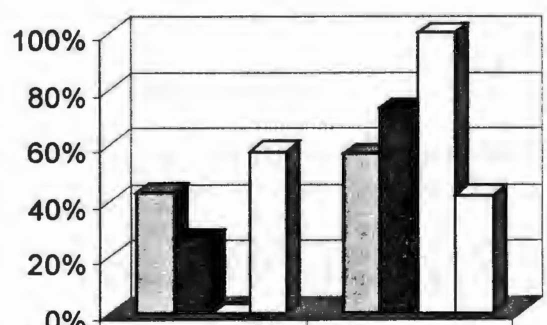
Eight (32%) of the 25 schools responding to question 17 of the survey responded that none of their students use a handheld GPS receiver during flight training, with six (25%) reporting that none of their students have purchased a handheld GPS receiver. Fourteen (56%) of the 25 schools responded that less than 25% of their students use a handheld GPS receiver during flight training, with 18 (75%) reporting that less than 25% of their students have purchased a handheld GPS receiver and 23 (85%) reported that less than 25% of their flight instructors use a handheld GPS receiver during flight training. Two (8%) of the 25 schools responded that between 25% and 50% of their students use a handheld GPS receiver during flight training and 3 (11%) reported that between 25% and 50% of their flight instructors use a handheld GPS receiver during flight training. Only one school reported that more than 50% of their students use a handheld GPS receiver during flight training and one reported that more than 75% of their flight instructors use a handheld GPS receiver during flight training (Graph 13).

Graph 11. Training Aircraft Equipped with GPS



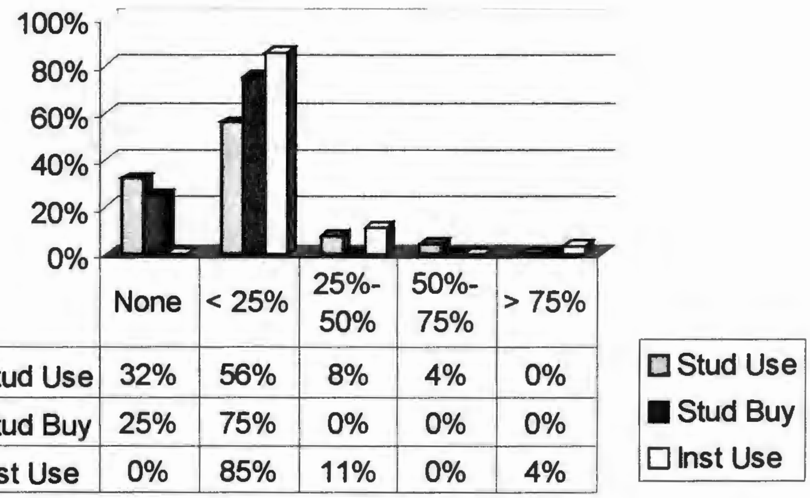
	Non-IFR	IFR
Total Aircraft	173	420
Non-certified GPS	23	49
Certified GPS	24	159

Graph 12. Allowed Handheld GPS Usage



	Yes	No
Allowed	43%	57%
Encouraged	27%	73%
Purchase	0%	100%
Inst Allowed	58%	42%

Graph 13. Handheld GPS Usage



	None	< 25%	25%-50%	50%-75%	> 75%
Stud Use	32%	56%	8%	4%	0%
Stud Buy	25%	75%	0%	0%	0%
Inst Use	0%	85%	11%	0%	4%

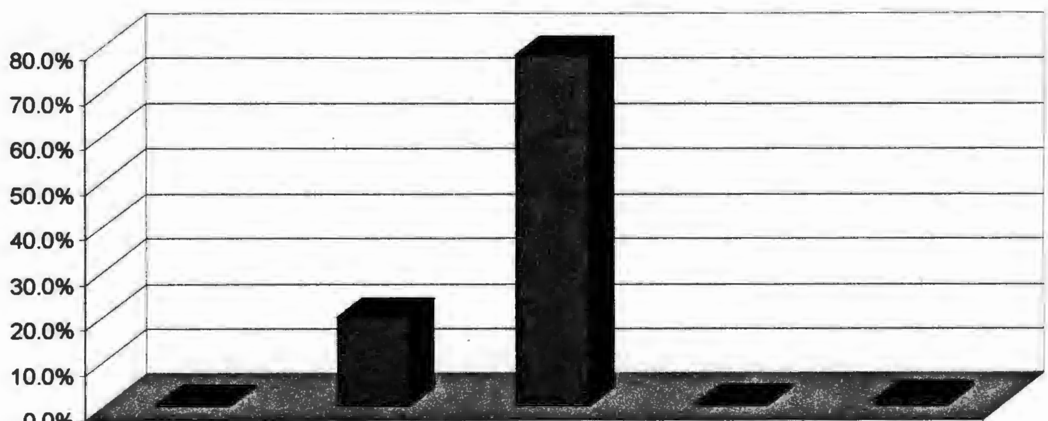
Instructors

Forty one percent of the responding schools indicated that all instructors and 37 % that some of the instructors have received formal GPS training (Graph 14). Seventy eight percent of the instructors received their GPS training from a Part 141 school, 20% from a Part 61 school, less than 1% from GPS manufacturers and the military, and 1% from other sources (Graph 15).

Graph 14. Percentage of Instructors GPS Trained

	Yes	No
All	41.0%	59.0%
Some	37.1%	62.9%

Graph 15. Where Instructors Received GPS Training



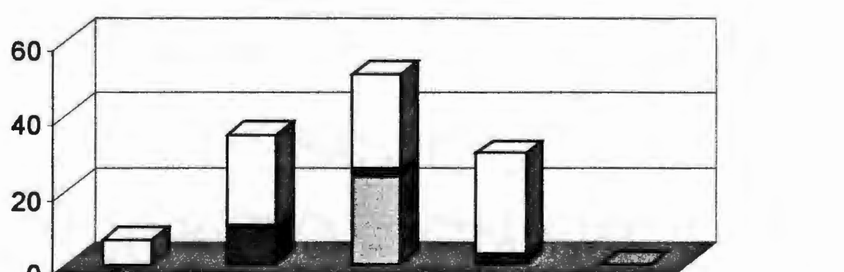
	Manufact	Part 61	Part 141	Military	Other
% of Instructors	0.5%	19.9%	78.1%	0.3%	1.3%

Planned Purchases

Seven institutions responding to the survey plan on purchasing a total of 24 handheld GPS receivers in the 2-5 year time frame. Three schools plan on purchasing a total of 11 non-certified GPS receivers in 1- 2 years, two schools plan on purchasing a one non-certified GPS receiver each in 2-5 years, and three schools also plan on purchasing one non-certified GPS receiver in 5-10 years. Five schools plan on purchasing a total of 7 certified GPS receivers in less than 1 year, four schools a total of 24 in 1-2 years, five schools a total of 25 in 2-5 years, and three schools a total of 27 in 5-10 years (Graph 16).

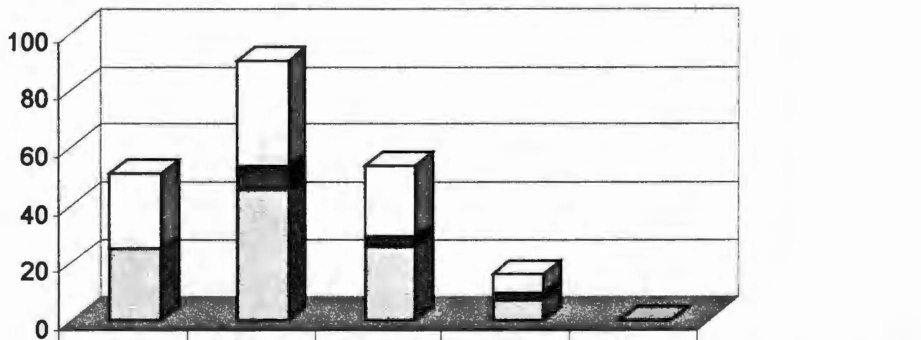
Five schools that responded to the GPS survey plan on purchasing a total of 25 aircraft without GPS receivers in less than 1 year, eight schools a total of 45 in 1-2 years, five schools a total of 26 in 2–5 years, and two schools a total of 7 in 5-10 years. Two institutions responding to the GPS survey plan on purchasing a total of 9 aircraft with non-certified GPS receivers in 1-2 years, two schools a total of 3 in 2–5 years, and two schools a total of 3 in 5-10 years. Six of the responding institutions plan on purchasing a total of 26 aircraft with certified GPS receivers in less than 1 year, six schools a total of 36 in 1-2 years, four schools a total of 25 in 2–5 years, and two schools a total of 6 in 5-10 years (Graph 17).

Graph 16. Planned GPS Receiver Purchases



	< 1 Yr	1-2 Yrs	2-5 Yrs	5-10 Yrs	Other
Certified	7	24	25	27	0
Non-Cert	0	11	2	3	0
Handheld	0	0	24	0	0

Graph 17. Planned GPS Aircraft Purchases



	< 1 Yr	1-2 Yrs	2-5 Yrs	5-10 Yrs	Other
Certified	26	36	25	6	0
Non-Cert	0	9	3	3	0
Any Aircraft	25	45	26	7	0

Comments

One school reported that they have just completed a fleet replacement and they have no intention of purchasing aircraft for 12 years and that 18 of the 26 aircraft purchased were equipped with IFR GPS receivers. One program commented that they were a small aviation program and were in the process of phasing out. A third comment stated, "Without expanding the time devoted to the instrument rating course, it will be difficult to add GPS until we take something out such as ADF." The comment goes on to say, "We have added a ground course that covers advanced flight systems including FMS, GPS, EFIS, TCAS, GPWS, CVR, etc. GPS is not installed in the training fleet."

Yet another comment said, "Jeppesen flight/ground training program for private/instrument/commercial do not devote any time to GPS training. We have developed classroom training on our own and use computer-based interactive software on the flight training end."

One comment was that the school only had one of four aircraft with GPS installed. The GPS receiver is a certified unit but the school has elected to not keep it IFR certified due to the cost of database updates. Primarily students who are "time-building" after their private pilot certificate use the aircraft with the panel-mounted GPS receiver. The last comment was a school stating they were exploring FMS training and systems integration.

The data from questions 12 and 14 in the Flight Instruction section of the survey were not used in this study due to several comments about confusion of required data.

Commercial GPS Training Materials

Numerous aviation journals, periodicals, and aviation specialty store catalogs were reviewed for advertisements over a 12 month period starting March 2001 to determine if there is a lack of commercial GPS training materials on the market. The ASA Company offers a GPS Trainer to assist pilots in learning three of the major selling GPS systems using a computer-based training program. Sporty's Pilot Shop offers a thirty-one minute training video on entitled "GPS En Route" and has other GPS training materials as part of an advanced IFR flight-training course. Sporty's also includes a set of "Simplified Directions" with each GPS unit sold.

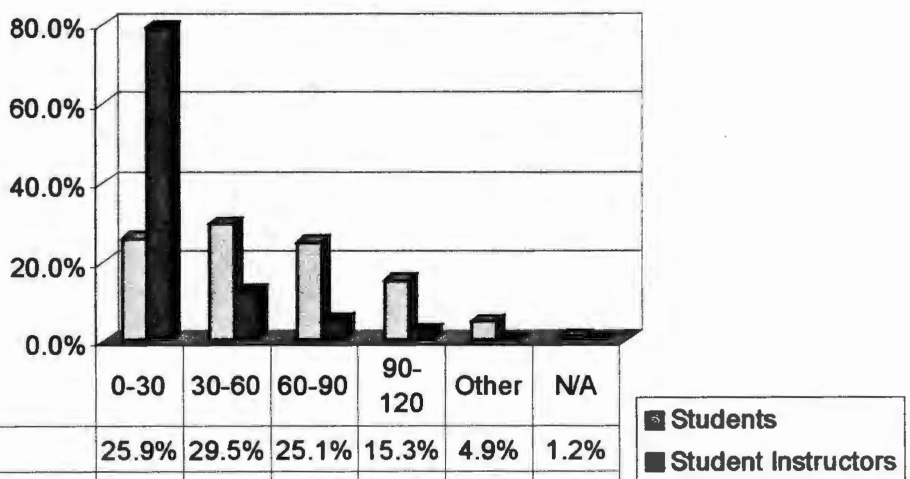
Student- Student Instructor Comparison

Seventy nine percent of student instructors receive 0-30 minutes of GPS ground training compared to 26% of all other flight students, 13% receive 30-60 minutes of GPS ground training compared to 30% of other flight students, 5% receive 60-90 minutes of

GPS ground training compared to 25% of other flight students, 3% receive 90 or more minutes of GPS ground training compared to 21% of other flight students (Graph 18).

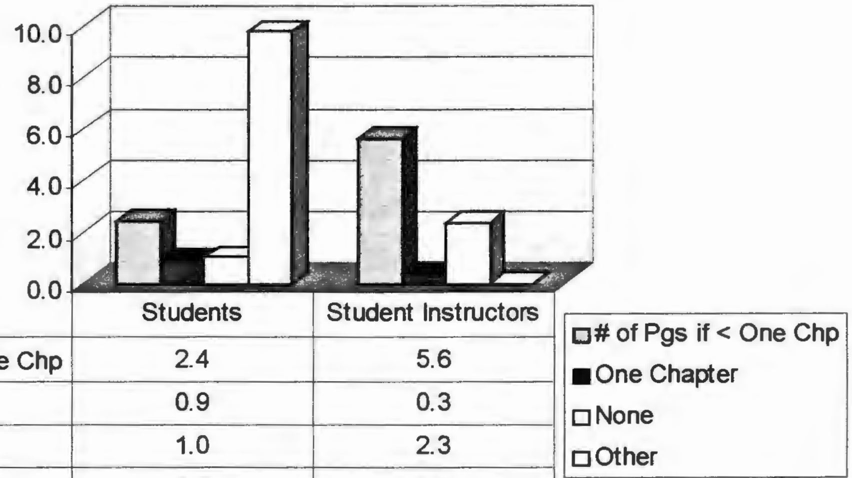
Student instructors have an average of 6 pages compared to 2 pages for students if less than one chapter of GPS training in textbooks is offered. Less than 1% of student instructors compared to 1% for students have one chapter of GPS training in textbooks offered. Two percent of student instructors compared to 1% for students have no GPS training in textbooks offered and no student instructors compared to 10% for students have other GPS training in textbooks offered (Graph 19).

Graph 18. Student-Student Instructor Training Time Comparison



	0-30	30-60	60-90	90-120	Other	N/A
Students	25.9%	29.5%	25.1%	15.3%	4.9%	1.2%
Student Instructors	79.5%	12.8%	5.1%	2.6%	0.0%	0.0%

Graph 19. Student-Student Instructor Training Material Comparison



	Students	Student Instructors
# of Pgs if < One Chp	2.4	5.6
One Chapter	0.9	0.3
None	1.0	2.3
Other	9.8	0.0

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to determine the level to which general aviation pilots are receiving training on the Global Positioning System (GPS). The current (1999) Federal Radionavigation Plan (FRP) projects that beginning in 2008 a phase-down will begin for most of the currently used ground-based radio navigation facilities. Larson stated in his 2000 study, "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." He further went on stating, "There is a very real danger of this new technology outrunning the existing capabilities of the very people the system is designed to help."

The FAA presently has just a few basic GPS questions in their pilot written exam data banks. The FAA will require all pilots in the near future to be proficient in the use of and have GPS system knowledge. In 1997 Kelly declared that current flight training programs do not adequately incorporate the training of GPS navigation procedures in either their ground or flight training programs. The question that arises is: are flight-training programs adequately incorporating the training of GPS navigation procedures into their ground and flight training programs in 2002?

In the review of literature the researcher did not locate any research being conducted to study the level to which general aviation pilots are receiving training on the Global Positioning System (GPS). There was no previously developed instrument for studying the level to which general aviation pilots are receiving training on GPS.

The study was accomplished by preparing a GPS Training Survey (Appendix C) containing 7 demographic questions followed by 32 GPS training specific questions designed to meet the objective of this study and to provide data to the following research questions: (1) Are flight training programs providing GPS ground training as a stand-alone class or incorporated into existing courses? (2) Are GPS training aids utilized? (3) Are the flight training programs utilizing GPS? (4) Are flight instructors teaching GPS techniques receiving formal training on GPS? (5) What are the commercial GPS training materials currently on the market? The survey was separated into the following seven sections: (1) Demographics, (2) Ground Training, (3) Training Aids, (4) Flight Training, (5) Instructors, (6) Planned Purchases, and (7) Comments.

The study population consisted of 106 collegiate aviation programs located throughout the United States of America listed in the GPS Training Survey Mailing List (Appendix E). The list of 106 collegiate aviation programs was obtained from the University Aviation Association's (UAA) Collegiate Aviation Guide (1999). Forty of the 106 (38%) of the collegiate aviation programs completed and returned the GPS Training Survey.

Conclusions

The following conclusions to the following research questions evolved from the data analyses, (1) Are flight training programs providing GPS ground training as a stand-alone class or incorporated into existing courses? (2) Are GPS training aids utilized? (3) Are the flight training programs utilizing GPS? (4) Are flight instructors teaching GPS techniques receiving formal training on GPS? (5) What are the commercial GPS training materials currently on the market:

The conclusion of research questions one is that flight training programs are not providing GPS ground training as a stand-alone class (3%) rather they are incorporating the training into existing courses (97%). Of the students receiving GPS training only 6% are receiving more than 2 hours of GPS specific training in the classroom with more than 50% receiving less than 1 hour of training.

The conclusion to research question two is that GPS training aids are being utilized and are being utilized in several different forms. Seventy six percent of the schools reporting GPS training-aids utilization with only 31% utilizing the Federal Aviation Administration's (FAA) GPS website. The diversity of simulator type GPS training aids used is as follows; 35% use a GPS flight simulator, 15% a stand-alone GPS simulator, and 41% a computer GPS simulator. Thirty two percent of the responding institutions train in the classroom using an actual GPS receiver as a training aid.

The researcher concluded from the data that less than 50% of flight training programs are utilizing GPS in flight training. Only 27% of non-IFR equipped and 49% of IFR equipped flight training aircraft are equipped with a GPS receiver, either a certified or non-certified unit. Of the institutions responding to the survey only 43% allow their students to use a handheld GPS receiver and only 58% allow instructors to use handheld receivers. Of those schools that allow handheld usage 88% reported that less than 25% of their students used handheld GPS receivers and 85% reported that less than 25% of their instructors use handheld receivers.

The study revealed that the conclusion to the research question of whether flight instructors teaching GPS techniques are receiving formal training on GPS is that less than less than 50% are. The study revealed that only 41% of the schools responded that all their instructors had been GPS trained. Thirty seven percent of the schools responded that only some of their instructors have been trained on GPS. Instructors are expected to know the systems they instruct on and the research shows that this is not the case for GPS.

The final research question was to determine what commercial GPS training materials are currently on the market. The research found only a few limited GPS commercial training aids. Of the commercial GPS training materials currently on the market one company offers a GPS computer-based training (CBT) program to assist pilots in learning three of the major selling GPS systems. Only one of the major aviation supply companies offers a thirty-one minute training video entitled "GPS En Route" and has one other GPS training segment as part of an advanced IFR flight-training course. The same company also includes a set of "Simplified Directions" with each GPS unit they sell. With the fast growth of GPS into general aviation cockpits it is uncertain as to where general aviation pilots will receive their training without the presence of numerous commercial quality training products. General aviation pilots will be going from a radial and bearing defined National Airspace System (NAS) to a latitude/longitude based system. A major change for pilots who have not received training on the differences in the two types.

Another conclusion the researcher developed from the study was that the FAA GPS website (http://gps.faa.gov) is an excellent source of information and material on GPS. The site includes GPS history, system operations operation, and future plans and how those plans relate to the National Airspace System (NAS). The site includes numerous links to other GPS websites including but not limited to other government agencies and leading GPS industry commercial sites. The site should be used more extensively by flight training institutions than the 31% that reported using the site for a training aid on the GPS survey. The site would be excellent as a prerequisite assignment to a GPS ground training class.

The study also revealed that the Federal Aviation administration needs to take a more active role in defining GPS training requirements followed by a timely implementation plan. Currently there are only a few exam questions in the commercial, instrument and airline transport pilot exam databases. Flight schools develop their training curriculum based on exam questions and FAA guidance. Without FAA guidance flight schools will wait until directed by the FAA to implement GPS training courses.

The FAA GPS training requirements should also be developed to include training on maintaining a backup navigation plan. The training should not only stress the consequences if a backup plan is not maintained but also the importance of following and practicing a backup navigation plan on each and every flight.

Recommendations

The following recommendations are offered as things that need to be accomplished as a result of the findings of this study. The results of this study provide encouragement to pursue further research into general aviation pilot GPS training. One such future study needs to be carried out on the first four research questions by replicating this study using flight training schools other than collegiate aviation programs and comparing the studies. This study should also be replicated to study the first four research questions and comparing small flight schools and their GPS training with that of large aviation training programs.

A study of commercial GPS training materials available should be conducted annually. This is needed to determine whether there is an increase in available commercial GPS training products and the rate of annual growth in these types of products. The study should also determine the effectiveness of the materials and their ease of use and understanding.

Further study should be conducted to determine whether the amount of current GPS training levels would be sufficient to afford pilots of all levels the knowledge required to operate safely the future National Airspace System (NAS) when GPS is the sole means of navigation within the NAS. The study should also include determining the amount of time an average general aviation pilot will require to after receiving the training to operate proficiently within the sole GPS NAS. These results should be passed to the FAA so they will have a basis for their training requirements and the implementation periods for such training.

The training standards study should also include research to determine the importance of maintaining a backup plan of navigation within a GPS only NAS. The research should investigate frequency of use of such a backup navigation plan and the reasons why such a plan was implemented such as NAS equipment failures or aircraft system failures.

A study should be conducted to determine the average time it would take a student to access, study and comprehend all information on the FAA GPS website. This information should then be made available to the FAA along with a recommendation to the FAA to advertise their website as a training aid for flight schools, biennial flight reviews and other types of recurring flight training.

One further recommendation from the findings of this study is the need for further study into annual purchases of aircraft and GPS receivers for all flight schools. The study should look into the purchases annually and present the rate of annual growth along with the reason for purchases or non purchases of aircraft and or GPS receivers.

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APPENDIXES

APPENDIX A

GPS TRAINING SURVEY COVER LETTER

Richard J. Quinnette
9516 S. Shields Blvd #179
Moore, Ok. 73160

Dear Participants:

My name is Richard Quinnette and I am a graduate student under the direction of Dr. Nelson Ehrlich, a professor at Oklahoma State University. I am conducting a research study entitled " Training Of General Aviation Pilots On The Global Positioning System." The focus of this study is to explore the level flight training programs are incorporating the training of GPS navigation procedures into their ground and flight training programs.

You were selected to participate in this survey from the list of programs provided in the 1999 University Aviation Association's Collegiate Aviation Program Guide. Your participation is voluntary and will involve completing the enclosed survey. This will take approximately thirty minutes of your time. Confidentiality of responses will be maintained. There are no benefits or risks if you decide to participate in the study. Please return the completed survey as soon as possible.

The survey is designed to obtain a portrait of current and projected GPS training. If the events of September 11, 2001 have changed your institution's current and/or future GPS training please annotate those changes on the survey where appropriate.

The survey has been approved by my graduate committee and the Institutional Review Board (IRB), application number ED0262. IRB questions should be directed to Ms. Sharon Bacher at 405-744-5700.

Your input is very important in obtaining an accurate picture of GPS training. Please mail your responses in the enclosed postage-paid envelope. If you have any questions concerning the study please call me at (405) 319-6578 or e-mail me at rquinnette@drc.com. Thank you for your time and contributions to this research.

Sincerely,

Richard J. Quinnette
Graduate Student

APPENDIX B

GPS TRAINING SURVEY FOLLOW-UP LETTER

Richard J. Quinnette
9516 S. Shields Blvd #179
Moore, Ok. 73160

Dear Participants:

My name is Richard Quinnette and I am a graduate student under the direction of Dr. Nelson Ehrlich, a professor at Oklahoma State University. I am conducting a research study entitled "Training Of General Aviation Pilots On The Global Positioning System." The focus of this study is to explore the level flight training programs are incorporating the training of GPS navigation procedures into their ground and flight training programs.

A few weeks ago you should have received a survey for this study. If you have already completed and returned the survey I would like to take this opportunity to thank you for your time and contributions to my research. If you as of yet have not completed it, I would like to encourage you to take approximately thirty minutes of your time to complete it at this time. Please return the completed survey by February 15, 2002 in the postage-paid return envelope. Confidentiality of responses will be maintained.

The survey has been approved by my graduate committee and the Institutional Review Board (IRB), application number ED0262. IRB questions should be directed to Ms. Sharon Bacher at 405-744-5700.

Your input is very important in obtaining an accurate picture of GPS training. If you have any questions concerning the study please call me at (405) 319-6578 or e-mail me at rquinnette@drc.com. Thank you for your time and contributions to this research.

Sincerely,

Richard J. Quinnette
Graduate Student

APPENDIX C

GPS TRAINING SURVEY

GPS TRAINING SURVEY

Instructions
Please circle the appropriate answer(s), or fill in the blanks as required.

If you wish to write extra comments on GPS training you are encouraged to write on the survey, the comments section provided at the end of this survey or enclose extra pages.

DEMOGRAPHICS

1. Ground instruction is offered under which FAR part?

   Part 61 Part 141

2. Flight instruction is offered under which FAR part?

   Part 61 Part 141

3. How many students are enrolled in your ground training program?

   Total _______

4. How many students are enrolled in your flight training program?

   Total ______

5. What levels of ground training do you offer and how many students are enrolled in each? *(Put number of students in each appropriate blank)*
   a) Private ______
   b) Commercial ______
   c) Instrument ______
   d) Multi-engine ______
   e) Basic Ground Instructor ______
   f) Advanced Ground Instructor ______
   g) CFIA ______
   h) CFII ______
   i) ATP ______
   j) Other *(Specify)* ______

6. What levels of flight training do you offer and how many students are enrolled in each? *(Put number of students in each appropriate blank)*
   a) Private ______
   b) Commercial ______
   c) Instrument ______
   d) Multi-engine ______
   e) CFIA ______
   f) CFII ______
   g) ATP ______
   h) Other *(Specify)* ______

7. What type of airfield is used for flight training?

   Controlled   Uncontrolled

GROUND TRAINING

1. Is GPS ground training provided?

   Yes No

   (If "Yes" proceed to question #2. If "No" proceed to question #10)

2. GPS ground training is incorporated into which course(s)? *(Circle all that apply)*
   a) Private
   b) Commercial
   c) Instrument
   d) Basic Ground Instructor
   e) Advanced Ground Instructor
   f) Flight Instructor
   g) Other *(Specify)*______

3. How many minutes are devoted in each course for GPS ground training? *(Circle all appropriate answers)*
   a) Private

      0-30 30-60 60-90 90-120 Other *(Specify)*_____ N/A

   b) Commercial

      0-30 30-60 60-90 90-120 Other *(Specify)*_____ N/A

   c) Instrument

      0-30 30-60 60-90 90-120 Other *(Specify)*_____ N/A

   d) Basic Ground Instructor

      0-30 30-60 60-90 90-120 Other *(Specify)*_____ N/A

   e) Advanced Ground Instructor

      0-30 30-60 60-90 90-120 Other *(Specify)*_____ N/A

   f) Flight Instructor

      0-30 30-60 60-90 90-120 Other *(Specify)*_____ N/A

   g) Other (ATP, etc.)

      0-30 30-60 60-90 90-120 Other *(Specify)*_____ N/A

4. Is a stand-alone GPS ground training course offered?

   Yes No

   (If "Yes" proceed to question #5. If "No" proceed to question #6)

5. How much credit is the stand-alone GPS ground training course worth? *(Credit Hours)*

   1 2 3 4 Other *(Specify)*____

TRAINING AIDS

6. Are training aids utilized in GPS ground training classes?

   Yes   No

   (If "Yes" proceed to question #7. If "No" proceed to question #8)

7. Which types of training aids are being utilized? *(Circle all appropriate answers)*

   a) Chalk/White Board
   b) Internet (GPS web sites)
   c) Flight simulator with GPS
   d) Stand-alone GPS simulator
   e) Computer GPS simulator
   f) Computer based training (CBT) program
   g) Actual GPS receiver
   h) Other *(Specify)* ________________________

8. Are instructors utilizing the FAA's GPS web site (http://gps.faa.gov)?

   Yes   No

9. How much is devoted in each textbook to GPS? *(Circle all appropriate answers)*

   a) Private
      1) Less than one chapter *(Specify # of Pages)* _______
      2) One chapter
      3) None
      4) Other *(Specify)* ______
   b) Commercial
      1) Less than one chapter *(Specify # of Pages)* _______
      2) One chapter
      3) None
      4) Other *(Specify)* ______
   c) Instrument
      1) Less than one chapter *(Specify # of Pages)* _______
      2) One chapter
      3) None
      4) Other *(Specify)* ______
   d) Basic Ground Instructor
      1) Less than one chapter *(Specify # of Pages)* _______
      2) One chapter
      3) None
      4) Other *(Specify)* ______
   e) Advanced Ground Instructor
      1) Less than one chapter *(Specify # of Pages)* _______
      2) One chapter
      3) None
      4) Other *(Specify)* ______

f) Flight Instructor
   1) Less than one chapter *(Specify # of Pages)*_______
   2) One chapter
   3) None
   4) Other *(Specify)*______

g) Other (ATP, etc.)
   1) Less than one chapter *(Specify # of Pages)*_______
   2) One chapter
   3) None
   4) Other *(Specify)*______

FLIGHT TRAINING

10. How many aircraft do you have for flight training? *(Write number in blank)*
    a) Non-IFR equipped _____
    b) IFR equipped _____

11. How many aircraft are equipped with a "non-certified" GPS *(handheld or in panel)*? *(If none please proceed to question #13)*
    a) Non-IFR equipped _____
    b) IFR equipped _____

12. To what level are these GPS equipped aircraft being utilized? *(Put percentage of overall usage in each appropriate blank)*
    a) Private _____
    b) Commercial _____
    c) Instrument _____
    d) Flight Instructor _____
    e) Flight Instructor - Instrument _____
    f) Other *(Specify)*_____

13. How many aircraft are equipped with "certified" in panel GPS? *(If none please proceed to question #15)*
    a) Non-IFR equipped _____
    b) IFR equipped _____

14. To what level are these GPS equipped aircraft being utilized? *(Put percentage of overall usage in each appropriate blank)*
    a) Private _____
    b) Commercial _____
    c) Instrument _____
    d) Flight Instructor _____
    e) Flight Instructor - Instrument _____
    f) Other *(Specify)*_____

15. Are students allowed to use a handheld GPS during flight training?

Yes No

(If "No" proceed to question #20)

16. Are students encouraged to use a handheld GPS during flight training?

Yes No

(If "Yes" proceed to question #17. If "No" proceed to question #20)

17. How many students use handheld GPS during flight training?

a) None
b) Less than 25%
c) 25%-50%
d) 50%-75%
e) More than 75%

18. How many students are buying their own handheld GPS?

a) None
b) Less than 25%
c) 25%-50%
d) 50%-75%
e) More than 75%

19. Are students required to purchase a handheld GPS?

Yes No

20. Are instructors allowed to use handheld GPS during flight training?

Yes No

(If "Yes" proceed to question #21. If "No" proceed to question #22)

21. How many instructors use handheld GPS during flight training?

a) Less than 25%
b) 25%-50%
c) 50%-75%
d) Greater than 75%

INSTRUCTORS

22. Have all instructors received formal GPS training?

Yes No

(If "Yes" proceed to question #23. If "No" proceed to question #24)

23. From whom did they receive their training? *(Put number of instructors in each appropriate blank)*

a) Manufacturer _____
b) Flight school (Part 61) _____
c) Flight school (Part 141) _____
d) Military _____
e) Other *(Specify)*__________

24. Have some but not all instructors received formal GPS training?

Yes No

(If "Yes" proceed to question #25. If "No" you have completed the survey, Thank You)

25. How many of these instructors have received formal GPS training?

a) Less than 25%
b) 25%-50%
c) 50%-75%
d) Greater than 75%

26. From whom did these instructors receive their training? *(Put number of instructors in each appropriate blank)*

a) Manufacturer _____
b) Flight school (Part 61) _____
c) Flight school (Part 141) _____
d) Military _____
e) Other *(Specify)*__________

PLANNED PURCHASES

27. How many handheld GPS units are you planning to purchase in the following time frames? *(Put number in appropriate blank) (If none please proceed to question #28)*

a) Within 1 year _____
b) 1-2 years _____
c) 2-5 years _____
d) 5-10 years _____
e) Other *(Specify)* _____

28. How many "non-certified" GPS units are you planning to purchase for installation in current aircraft in the following time frames? *(Put number in appropriate blank) (If none please proceed to question #29)*

a) Within 1 year _____
b) 1-2 years _____
c) 2-5 years _____
d) 5-10 years _____
e) Other *(Specify)* _____

29. How many "certified" GPS units are you planning to purchase for installation in current aircraft in the following time frames? *(Put number in appropriate blank)(If none please proceed to question #30)*

a) Within 1 year _____
b) 1-2 years _____
c) 2-5 years _____
d) 5-10 years _____
e) Other *(Specify)* _____

30. How many aircraft are you planning to purchase in the following time frames? *(Put number in appropriate blank)(If none you have completed the survey, Thank You)*

a) Within 1 year _____
b) 1-2 years _____
c) 2-5 years _____
d) 5-10 years _____
e) Other *(Specify)* _____

31. How many aircraft with "non-certified" GPS units are you planning to purchase in the following time frames? *(Put number in appropriate blank)(If none please proceed to question #32)*

a) Within 1 year _____
b) 1-2 years _____
c) 2-5 years _____
d) 5-10 years _____
e) Other *(Specify)* _____

32. How many aircraft with "certified" GPS units are you planning to purchase in the following time frames? *(Put number in appropriate blank)*

a) Within 1 year _____
b) 1-2 years _____
c) 2-5 years _____
d) 5-10 years _____
e) Other *(Specify)* _____

If you wish to write extra comments on GPS training you are encouraged to write on the survey or to enclose extra pages.

Comments:

Thank you for completing and returning this Survey.

APPENDIX D

GPS TRAINING SURVEY RAW RESULTS

Legend: *The bolded/underlined number at the end of each question is the total number of respondents to that question. Percentages and averages for each answer are also placed next to or below the answer in a bold/underlined font.*

GPS TRAINING SURVEY RESULTS

Instructions

Please circle the appropriate answer(s), or fill in the blanks as required.

If you wish to write extra comments on GPS training you are encouraged to write on the survey, the comments section provided at the end of this survey or enclose extra pages.

DEMOGRAPHICS

1. Ground instruction is offered under which FAR part? **40**

   Part 61 **7 = 17.5%** Part 141 **27 = 67.5%** Both **6 = 15%**

2. Flight instruction is offered under which FAR part? **40**

   Part 61 **6 = 15%** Part 141 **25 = 62.5%** Both **9 = 22.5%**

3. How many students are enrolled in your ground training program?

   Total **5885 Average per respondent (40) = 147.125**

4. How many students are enrolled in your flight training program?

   Total **5246 Average per respondent (40) = 131.15**

5. What levels of ground training do you offer and how many students are enrolled in each? *(Put number of students in each appropriate blank)* APR (Average Per Respondent)

   a) Private **2102 APR(39) = 53.897**
   b) Commercial **1256 APR(39) = 32.205**
   c) Instrument **1375 APR(40) = 34.375**
   d) Multi-engine **520 APR(26) = 20**
   e) Basic Ground Instructor **76 APR(7) = 10.857**
   f) Advanced Ground Instructor **58 APR(6) = 9.667**
   g) CFIA **503 APR(34) = 14.794**
   h) CFII **209 APR(23) = 9.087**
   i) ATP **11 APR(5) = 2.2**
   j) Other *(Specify)* **14 APR(4) = 3.5**

6. What levels of flight training do you offer and how many students are enrolled in each? *(Put number of students in each appropriate blank)*
   a) Private **1848 APR(38) = 48.632**
   b) Commercial **1251 APR(37) = 33.811**
   c) Instrument **1251 APR(38) = 32.921**
   d) Multi-engine **718 APR(31) = 23.161**
   e) CFIA **408 APR(34) = 12.000**
   f) CFII **239 APR(26) = 9.192**
   g) ATP **4 APR(3) = 1.333**
   h) Other *(Specify)* ______

7. What type of airfield is used for flight training? **40**
   Controlled **19 = 47.5%** Uncontrolled **17 = 42.5%** Both **4 = 10%**

GROUND TRAINING

1. Is GPS ground training provided? **40**
   Yes 31 = 77.5% No 9 = 22.5%
   (If "Yes" proceed to question #2. If "No" proceed to question #10)

2. GPS ground training is incorporated into which course(s)? *(Circle all that apply)*
   h) Private **24 = 77%**
   i) Commercial **19 = 61%**
   j) Instrument **31 = 100%**
   k) Basic Ground Instructor **1 = 3%**
   l) Advanced Ground Instructor **1 = 3%**
   m) Flight Instructor **10 = 32%**
   n) Other *(Specify)* **5 = 16%**

3. How many minutes are devoted in each course for GPS ground training? *(Circle all appropriate answers)*

   a) Private **25**

0-30	30-60	60-90	90-120	Other *(Specify)* _____	N/A
10=40%	**13=52%**	**2 = 8%**			

   b) Commercial **20**

0-30	30-60	60-90	90-120	Other *(Specify)* _____	N/A
4=20%	**7=35%**	**7=35%**	**2=10%**		

   c) Instrument **29**

0-30	30-60	60-90	90-120	Other *(Specify)* _____	N/A
3=10.3%	**9=31%**	**7=24.1%**	**10=34.5%**	**1 >120 Minutes=3%**	

   d) Basic Ground Instructor **1**

0-30	30-60	60-90	90-120	Other *(Specify)* _____	N/A
1=100%					

   e) Advanced Ground Instructor **1**

0-30	30-60	60-90	90-120	Other *(Specify)* _____	N/A
1=100%					

f) Flight Instructor **13**

0-30	30-60	60-90	90-120	Other *(Specify)*_____	N/A
5-38.5%	**5-38.5%**	**2=15.4%**	**1=7.7%**		

g) Other (ATP, etc.) **6**

0-30	30-60	60-90	90-120	Other *(Specify)*_____	N/A
2=33.3%		**2=33.3%**	**1=16.7%**	**1=16.7%**	

4. Is a stand-alone GPS ground training course offered? **36**

   Yes **1 = 2.8%** No **35 = 97.2%**

   (If "Yes" proceed to question #5. If "No" proceed to question #6)

5. How much credit is the stand-alone GPS ground training course worth? *(Credit Hours)* **1 for 3 HRS**

   1 2 3 4 Other *(Specify)*_____

TRAINING AIDS

6. Are training aids utilized in GPS ground training classes? **34**

   Yes **26 = 76.47%** No **8 = 23.53%**

   (If "Yes" proceed to question #7. If "No" proceed to question #8)

7. Which types of training aids are being utilized? *(Circle all appropriate answers)* **34**

   a) Chalk/White Board **18**
   b) Internet (GPS web sites) **10**
   c) Flight simulator with GPS **12**
   d) Stand-alone GPS simulator **5**
   e) Computer GPS simulator **14**
   f) Computer based training (CBT) program **7**
   g) Actual GPS receiver **11**
   h) Other *(Specify)* **5 videos/1 overhead slides**

8. Are instructors utilizing the FAA's GPS web site (http://gps.faa.gov)? **32**

   Yes **10 = 31.25%** No **22 = 68.75%**

9. How much is devoted in each textbook to GPS? *(Circle all appropriate answers)*

   a) Private
      1) Less than one chapter *(Specify # of Pages)*_______
      2) One chapter
      3) None
      4) Other *(Specify)*______

   b) Commercial
      1) Less than one chapter *(Specify # of Pages)*_______
      2) One chapter
      3) None
      4) Other *(Specify)*______

c) Instrument
   1) Less than one chapter *(Specify # of Pages)*_______
   2) One chapter
   3) None
   4) Other *(Specify)*______

d) Basic Ground Instructor
   1) Less than one chapter *(Specify # of Pages)*_______
   2) One chapter
   3) None
   4) Other *(Specify)*______

e) Advanced Ground Instructor
   1) Less than one chapter *(Specify # of Pages)*_______
   2) One chapter
   3) None
   4) Other *(Specify)*______

f) Flight Instructor
   1) Less than one chapter *(Specify # of Pages)*_______
   2) One chapter
   3) None
   4) Other *(Specify)*______

g) Other (ATP, etc.)
   1) Less than one chapter *(Specify # of Pages)*_______
   2) One chapter
   3) None
   4) Other *(Specify)*______

FLIGHT TRAINING

10. How many aircraft do you have for flight training? *(Write number in blank)*
   a) Non-IFR equipped _____
   b) IFR equipped _____

11. How many aircraft are equipped with a "non-certified" GPS *(handheld or in panel)*? *(If none please proceed to question #13)*
   a) Non-IFR equipped _____
   b) IFR equipped _____

12. To what level are these GPS equipped aircraft being utilized? *(Put percentage of overall usage in each appropriate blank)*
   a) Private _____
   b) Commercial _____
   c) Instrument _____
   d) Flight Instructor _____
   e) Flight Instructor - Instrument _____
   f) Other *(Specify)*_____

13. How many aircraft are equipped with "certified" in panel GPS?
(If none please proceed to question #15)
a) Non-IFR equipped _____
b) IFR equipped _____

14. To what level are these GPS equipped aircraft being utilized?
(Put percentage of overall usage in each appropriate blank)
a) Private _____
b) Commercial _____
c) Instrument _____
d) Flight Instructor _____
e) Flight Instructor - Instrument _____
f) Other *(Specify)*_____

15. Are students allowed to use a handheld GPS during flight training? **37**
Yes **16 = 43.24%** No **21 = 56.76%**
(If "No" proceed to question #20)

16. Are students encouraged to use a handheld GPS during flight training? **26**
Yes **7 = 26.9%** No **19 = 73.1%**
(If "Yes" proceed to question #17. If "No" proceed to question #20)

17. How many students use handheld GPS during flight training? **25**
a) None **8 = 32%**
b) Less than 25% **14 = 56%**
c) 25%-50% **2 = 8%**
d) 50%-75% **1 = 4%**
e) More than 75% ______

18. How many students are buying their own handheld GPS? **24**
a) None **6 = 25%**
b) Less than 25% **18 = 75%**
c) 25%-50% ______
d) 50%-75% ______
e) More than 75% ______

19. Are students required to purchase a handheld GPS? **26**
Yes _______ No **26 = 100%**

20. Are instructors allowed to use handheld GPS during flight training? **38**
Yes **22 = 57.9%** No **16 = 42.1%**
(If "Yes" proceed to question #21. If "No" proceed to question #22)

21. How many instructors use handheld GPS during flight training? 27

a) Less than **25% 23 = 85.2%**
b) 25%-50% **3 = 11.1%**
c) 50%-75%
d) Greater than 75% **1 = 3.7%**

INSTRUCTORS

22. Have all instructors received formal GPS training? 39

Yes **16 = 41%** No **23 = 59%**

(If "Yes" proceed to question #23. If "No" proceed to question #24)

23. From whom did they receive their training? *(Put number of instructors in each appropriate blank)*

a) Manufacturer _____
b) Flight school (Part 61) **70 / 3 = 23.33**
c) Flight school (Part 141) **261 / 15 = 17.4**
d) Military _____
e) Other *(Specify)* **1 - Individual Instruction**

24. Have some but not all instructors received formal GPS training? 35

Yes **13 = 37.1%** No **22 = 62.9%**

(If "Yes" proceed to question #25. If "No" you have completed the survey, Thank You)

25. How many of these instructors have received formal GPS training? **15**

a) Less than **25% 8 = 53.3%**
b) 25%-50% **4 = 26.7%**
c) 50%-75% **2 = 13.3%**
d) Greater than 75% **1 = 6.7%**

26. From whom did these instructors receive their training? *(Put number of instructors in each appropriate blank)* **60**

a) Manufacturer **2 = 3.3%**
b) Flight school (Part 61) **8 = 13.3%**
c) Flight school (Part 141) **45 = 75%**
d) Military **1 = 1.7%**
e) Other *(Specify)* **4 = 6.7%**

PLANNED PURCHASES

27. How many handheld GPS units are you planning to purchase in the following time frames? *(Put number in appropriate blank) (If none please proceed to question #28)* **24**
    a) Within 1 year _____
    b) 1-2 years _____
    c) 2-5 years **24 = 6 per**
    d) 5-10 years _____
    e) Other *(Specify)* _____

28. How many "non-certified" GPS units are you planning to purchase for installation in current aircraft in the following time frames? *(Put number in appropriate blank) (If none please proceed to question #29)* **16**
    a) Within 1 year _____
    b) 1-2 years **11 = 5.5 per**
    c) 2-5 years **2 = 2 per**
    d) 5-10 years **3 = 1.5 per**
    e) Other *(Specify)* _____

29. How many "certified" GPS units are you planning to purchase for installation in current aircraft in the following time frames? *(Put number in appropriate blank) (If none please proceed to question #30)* **83**
    a) Within 1 year **7 = 1.4 per**
    b) 1-2 years **24 = 6 per**
    c) 2-5 years **25 = 5 per**
    d) 5-10 years **27 = 6.75 per**
    e) Other *(Specify)* _____

30. How many aircraft are you planning to purchase in the following time frames? *(Put number in appropriate blank) (If none you have completed the survey, Thank You)* **103**
    a) Within 1 year **25 = 5 per**
    b) 1-2 years **45 = 5.625 per**
    c) 2-5 years **26 = 5.2 per**
    d) 5-10 years **7 = 3.5 per**
    e) Other *(Specify)* _____

31. How many aircraft with "non-certified" GPS units are you planning to purchase in the following time frames? *(Put number in appropriate blank) (If none please proceed to question #32)* **15**
    a) Within 1 year _____
    b) 1-2 years **9 = 4.5 per**
    c) 2-5 years **3 = 1.5 per**
    d) 5-10 years **3 = 1.5 per**
    e) Other *(Specify)* _____

32. How many aircraft with "certified" GPS units are you planning to purchase in the following time frames? *(Put number in appropriate blank)* **93**

a) Within 1 year **26 = 4.33 per**
b) 1-2 years **36 = 6 per**
c) 2-5 years **25 = 6.25 per**
d) 5-10 years **6 = 3 per**
e) Other *(Specify)* _____

If you wish to write extra comments on GPS training you are encouraged to write on the survey or to enclose extra pages.

Comments:

Thank you for completing and returning this Survey.

APPENDIX E

GPS TRAINING SURVEY MAILING LIST

SURVEY MAILING LIST

1. Auburn University
2. Academy Education Center
3. Aims Community College
4. Andrews University
5. Antelope Valley College
6. Arizona State University
7. Averett College
8. Aviation Institute, Broward Community College
9. Baylor University
10. Bob Jones University
11. Bowling Green State University
12. Bridgewater State College
13. Catonsville Community College
14. Central Missouri State University
15. Central Texas College
16. Central Washington University-Flight Technology Program
17. Clayton College & State University
18. Cochise College
19. College of Aeronautics
20. Colorado Northwestern Community College
21. Community College of Beaver County
22. Cumberland County College
23. Daniel Webster College
24. Delta State University
25. Dixie College
26. Dowling College
27. Eastern Kentucky University
28. Eastern Michigan University
29. Embry-Riddle Aeronautical University
30. Embry-Riddle Aeronautical University - Prescott
31. Fairmont State University
32. Florida Institute of Technology
33. Florida Memorial College
34. Fox Valley Technical College
35. Gateway Technical College
36. Georgia State University
37. Guilford Technical Community College
38. Hampton University
39. Henderson State University
40. Honolulu Community College
41. Indian Hills Community College
42. Indiana State University

43. Inver Hills Community College
44. Iowa Lakes Community College
45. Jacksonville University
46. Kansas State University-Salina
47. Kent State University
48. Lehigh Carbon Community College
49. Lenoir Community College
50. LeToureau University
51. Lewis University
52. Long Beach College
53. Louisiana Tech University
54. Mercer County Community College
55. Metropolitan State College of Denver
56. Miami-Dade Community College
57. Middle Tennessee State University
58. Minnesota State University-Mankato
59. Mountain View College
60. Mt. San Antonio College
61. Navarro College
62. North Shore Community College
63. Northeast Louisiana University
64. Northern Michigan University
65. Northland Community & Technical College
66. Northwestern Michigan College
67. Northwestern State University of Louisiana
68. Ohio University
69. Oklahoma State University
70. Palo Alto College
71. Purdue University
72. Rocky Mountain College
73. Salt Lake Community College
74. San Jacinto College
75. Schenectady County Community College
76. Southeastern Oklahoma State University
77. Southern Illinois University-Carbondale
78. Southwest Texas Junior College
79. St. Cloud State University
80. St. Francis College
81. St. Louis University
82. State University of New York College of Technology at Farmingdale
83. Tennessee State University
84. Texas Southern University
85. Texas State Technical College
86. The Ohio State University

87. Tulsa Community College
88. University of Alaska Anchorage
89. University of Cincinnati-Clermont College
90. University of Dubuque
91. University of Illinois-Institute of Aviation
92. University of Maryland Eastern Shore
93. University of Nebraska at Kearney
94. University of Nebraska at Omaha
95. University of New Haven
96. University of North Dakota
97. University of Oklahoma
98. University of Southern California
99. Utah State University
100. Utah Valley State College-Aviation Science
101. Wallace State Community College
102. Western Michigan University
103. Western Oklahoma State College
104. Wichita State University
105. Wilmington College
106. Winona State University

APPENDIX F

INSTITUTIONAL REVIEW BOARD APPROVAL FORM

Oklahoma State University
Institutional Review Board

Protocol Expires: 12/12/02

Date: Thursday, December 13, 2001

IRB Application No ED0262

Proposal Title: TRAINING OF GENERAL AVIATION PILOTS ON THE GLOBAL POSITIONING SYSTEM

Principal
Investigator(s):

Richard J. Quinnette
9516 S. Shields Blvd, #179
Moore, OK 73160

Nelson Ehrlich
317 Willard
Stillwater, OK 74078

Reviewed and
Processed as: Exempt

Approval Status Recommended by Reviewer(s): Approved *

Dear PI :

Your IRB application referenced above has been approved for one calendar year. Please make note of the expiration date indicated above. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved projects are subject to monitoring by the IRB. If you have questions about the IRB procedures or need any assistance from the Board, please contact Sharon Bacher, the Executive Secretary to the IRB, in 203 Whitehurst (phone: 405-744-5700, sbacher@okstate.edu).

Sincerely,

Carol Olson

Carol Olson, Chair
Institutional Review Board

*NOTE: Please include Dr. Ehrlich's first name on the solicitation letter.

VITA 2

Richard J. Quinnette

Candidate for the Degree of

Doctor of Education

Thesis: TRAINING OF GENERAL AVIATION PILOTS ON THE GLOBAL POSITIONING SYSTEM

Major Field: Applied Educational Studies

Biographical Data:

Personal Data: Born in Beech Grove, Indiana on October 22, 1953, the son of Joseph and Bernadine Quinnette.

Education: Graduated from Beech Grove High School, Beech Grove, Indiana in May 1972; received Bachelor of Science degree in Aerospace Technology from Indiana State University, Terre Haute, Indiana in December 1977. Completed the requirements for Master of Science degree with a major in Operational Management at the University of Arkansas, Blytheville Air Force Base, Arkansas in May 1984. Completed the requirements for the degree of Doctor of Education with a major in Applied Educational Studies at Oklahoma State University, Stillwater, Oklahoma in December 2001.

Experience: Retired from the U.S. Air Force in July 1995 after serving over 17 years as a master navigator aboard B-52 and B-1 bombers. Duties while in the Air Force included B-52 instructor and evaluator, B-1 flight test officer, B-1 flight test conductor/director, and operations manager for aircrew training device evaluations. Currently a Training Situation Senior Engineer, managing development of U.S. Customs National Aviation Center's (CNAC) training roadmap, national test data bank, and cockpit resource management (CRM) course. Previously served as a senior systems engineer managing testing for all avionics and software upgrades during the B-52 Avionics Midlife Improvement (AMI) program, as a staff systems analyst for all phases of B-1 Preprocessor Flight Software (PFS) lab and flight tests, and as a training manager, instructor and subject matter expert (SME) for a U.S. Air Force Cockpit Resource Management (CRM) course. Served as an adjunct Instructor for Embry-Riddle Aeronautical University since 1994 and for Oklahoma State University since 2002.

Professional Memberships: Aircraft Owners and Pilots Association, Experimental Aircraft Association, University Aviation Association.