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Proposed IFR Air Ambulance Coverage for Middle and East Tennessee

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To the Graduate Council:

I am submitting herewith a thesis written by James Christopher Mills entitled "Proposed IFR Air Ambulance Coverage for Middle and East Tennessee." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Aviation Systems.

Ralph Kimberlin, Major Professor

We have read this thesis and recommend its acceptance:

G. Garrison, R. Ranaudo

Accepted for the Council:
Dixie L. Thompson

Vice Provost and Dean of the Graduate School

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

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Acceptance for the Council
Anne Mayhew___________
Vice Provost and Dean of
Graduate Studies

(Original signatures on file with official student records.)

PROPOSED IFR AIR AMBULANCE COVERAGE FOR MIDDLE AND EAST TENNESSEE

A Thesis

Presented for the Master of Science

Degree

The University of Tennessee, Knoxville

James Christopher Mills

August 2003

DEDICATION

I would like to dedicate this work to my wife Jennifer, my two daughters, Jordan and Emery and the rest of my family who have supported me in this endeavor and throughout my career. Without their patience and encouragement this research would not have been possible.

ACKNOWLEDGEMENTS

I would like to acknowledge those individuals who provided encouragement throughout this endeavor. In particular, I would especially like to thank, Dr. Ralph Kimberlin for his instruction and guidance in this area of aviation study and Professor Fred Stellar. Additionally, I would like to thank my family, friends and especially God for support during this research.

ABSTRACT

Rural areas do not receive the same emergency medical services as metropolitan and suburban areas due to their remote locations. In the event of a life-threatening medical emergency, citizens in rural areas cannot be transported to a level-one trauma center within the critical Golden Hour. The Golden Hour is the hour during which the mortality rate can be reduced by 50% if a patient can reach a trauma center. The inability of helicopter EMS operations to fly in poor weather lessens a patient's chances for surviving a medical emergency. Helicopter air ambulance operations enable hospitals to provide comparable service to rural locations. Low cloud cover and reduced visibility often prevent or hamper air ambulance service to rural areas. This thesis attempts to determine *how* and *where* to locate non-precision GPS instrument approach procedures in Middle and East Tennessee so that the area could be served by instrument-certified EMS air ambulance operators during instrument meteorological conditions (IMC). The objective of the thesis is to systematically survey the Middle and East Tennessee area in order to identify proposed locations for GPS approaches to provide 95% EMS coverage. Appropriate maps and statistics are provided to document this survey.

Alternatives on how to implement EMS instrument approaches are:

(1) Allow continued haphazard commercial development.

(2) Wait on the FAA to develop the infrastructure.

(3) Press for early development of a publicly-funded integrated system of instrument approaches.

The author recommends the development of a publicly funded, integrated system of instrument approaches as an experimental test project in the Middle and East Tennessee area and provides a roadmap for the steps required to implement this project. The concept of an integrated system of publicly funded instrument approach procedures is expounded. This system involves instrument approach procedures (IAPs) either based on a particular hospital helipad or on an existing airport approach which is within three nautical miles of a medical center. Such a system would involve the development of 33 instrument approach procedures located at the approximate locations specified in *Figure 2.4 page 43.* Additional emerging free-flight technology could, and should, be included in this proposed instrument approach system.

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ABBREVIATIONS

AC	Advisory Circular
ADS-B	Automatic Dependent Surveillance-Broadcast
AGL	Above Ground Level
AWOS	Automated Weather Observing System
ASOS	Automated Surface Observing System
CFIT	Controlled Flight Into Terrain
CFR	Code of Federal Regulations
DGPS	Differential Global Positioning System
DA	Decision Altitude
EFIS	Electronic Information System
EMS	Emergency Medical Services
FAA	Federal Aviation Administration
FAF	Final Approach Fix
FAR	Federal Aviation Regulation
FIS	Flight Information Services
GPS	Global Positioning System
HALS	Helicopter Approach Lighting System
HILS	Helicopter Instrument Lighting System
HAT	Height Above Touchdown
HITS	Highway In The Sky
IAP	Instrument Approach Procedures

IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
LAAS	Local Area Augmentation System
MAP	Missed Approach Point
MDA	Minimum Descent Altitude
MEA	Minimum En-route Altitude
MEDCOM	Medical Communications Center
MOCA	Minimum Obstruction Clearance Altitude
MSL	Mean Sea Level
NAVAID	Navigation Aid
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
OROCA	Off-Route Obstruction Clearance Altitude
RNAV	Area Navigation
RNP	Required Navigation Performance
RTCA	Radio Technical Committee on Aviation
SIAP	Special Instrument Approach Procedure
VFR	Visual Flight Rules
VTOL	Vertical Take-off and Landing
WAAS	Wide Area Augmentation System

CHAPTER 1

BACKGROUND

Introduction

In March 2000, a helicopter air ambulance flight from Amarillo, Texas, crashed on a mission to rural Boise, Oklahoma en-route to pick up a 4-month old girl with breathing problems. Because of fog, an ambulance had to meet the EMS helicopter at a transfer site just south of the Texas border. After the child was placed aboard, the aircraft took off in fog to return to Amarillo. The helicopter was following power lines along a roadway. The aircraft crashed shortly thereafter killing the baby and the three person aircrew. The wreckage was discovered less than a mile away from the pick-up site and was scattered over a 400 by 100 foot area *(*Associated Press 2000).

This flight ran into IMC (instrument meteorological conditions) and continued on under visual flight rules (VFR) because of the urgency of the mission the aircraft was performing. Similar situations are all too common in the emergency medical services (EMS) community where time literally may mean the difference between life and death. Fortunately, with improvements in technology this is preventable. Relatively low-cost IFR avionics and GPS IFR approaches are available to help prevent incidents similar to the Texas accident.

Of the civil helicopter mishaps reported in the last two years only 10 of 387 have involved aircraft flying under Instrument Flight Rules. In 2002, 40% of civil helicopter accidents occurred during the cruise or en-route phase of the mission. This was a 54% increase over the previous year (Helicopter Association International 2002). Many of these accidents are the result of inadvertent IMC and the resultant loss of aircraft control or controlled flight of the aircraft into terrain (CFIT). The en-route and approach portion of the air ambulance mission are the portions of the air ambulance mission where the use of new technology would provide the most advantage and increase safety. The ability to climb into controlled airspace under instrument flight rules and recover to a suitable IFR hospital helipad or airfield is critical and could prevent aircraft accidents and save lives.

This thesis begins with a description of the background research conducted and then delves into several of the current problems and issues facing the helicopter air ambulance community. The first chapter describes the status of GPS approaches in the Tennessee area and the direction that the local EMS and government policy are headed.

In Chapter 2, options are presented on how to introduce this network. The author presents the alternative that he believes is the most viable solution to provide comparable healthcare to rural areas. A network of IFR approaches that provides 95% IFR EMS coverage of the Tennessee research area is proposed. The proposed EMS helicopter coverage is within specified IFR weather and distance constraints. In addition to defining the location and number of proposed instrument approaches, this document outlines additional features which could, or should, be included in a future IFR network to enhance and enable efficient operation.

Background Research

During the course of this study, a considerable amount of background literature research was conducted. The focus of the research was primarily on helicopter GPS/IFR approaches and infrastructure and the applicable FAA rules and regulations pertaining to instrument approach development. Additionally, emerging technology in air navigation and helicopter instrument flight capabilities were researched.

The University of Tennessee Space Institute presented some early research into the concept of an integrated EMS network in the Tennessee area and also into the unique IFR capabilities of the helicopter. The majority of this research can be found in two documents. The first is *A Demonstration Project for an infrastructure Delivering Health Care to Rural Communities by Helicopter* (Kimberlin 1998). It is essentially a proposal that introduces the basic concept upon which many of the themes in this thesis are based. The second document is *A Program Plan for the Development of Helicopter Terminal Instrument Procedures (TERPS)* (Kimberlin 1993). The plan focuses on the requirements for helicopter IFR approach and introduces innovative ideas regarding helicopter and vertical takeoff and landing (VTOL) aircraft and their integration into the national airspace system (NAS). The thesis is involved intimately with the current and future airspace and the national airspace system (NAS).

Several Helicopter EMS operations make use of GPS approaches. Some even have developed their own private IFR approach networks. One of the most notable of these is Erlanger Medical Center, located in Chattanooga, Tennessee. Because the Erlanger Medical Center is reasonably close to the University of Tennessee Space Institute, the Erlanger EMS operation, *LifeForce,* was visited and studied extensively. Erlanger Medical Center is a level I trauma center which anchors one corner of the research area described in this document. Erlanger Medical Center is a leader in utilizing new aviation technology to enhance patient care. A level I trauma center has the capability of providing leadership and care for every aspect of injury. Most level I trauma centers also are responsible for leadership in education and research. Because of this, many level I trauma centers are associated with either universities or larger metropolitan areas.

Erlanger Medical Center's *LifeForce* flies two Bell 412 helicopters in their helicopter EMS operation. The Bell 412 is single pilot, IFR-equipped aircraft. These two aircraft are based out of the hospital helipads in downtown Chattanooga and Sparta Base in Sparta, Tennessee. These aircraft have KLN-900 GPS receivers (Erlanger Medical Center). The avionics enable the aircrews to conduct GPS and RNAV approaches into airports or hospital helipads which have approved Instrument Approach procedures (IAPs). Erlanger was the first medical facility in the nation to have a non-precision instrument approach procedure approved to the hospital helipad

Erlanger also operates a medical communications center (MEDCOM) from their flight operations facility at the hospital. The MEDCOM serves as a flight operations and dispatch center for both air and ground-based emergency medical services. This communications center coordinates the Regional Emergency Medical Services Alliance (REMSA) in order to provide comprehensive EMS service to communities in a three state area. The Erlanger MEDCOM incorporates many innovative tracking and coordinated aviation EMS operations discussed later in this document (Erlanger Medical Center 2003). Erlanger currently has ten instrument approach procedures into local hospitals. They have contracted for the development of a total of 18 instrument approach procedures into the southeast Tennessee area (Satellite Technology Implementation 2003).

Vanderbilt University Medical Center lies in the western portion of the research area. The VUMC flight operation, *LifeFlight,* is equipped with American Eurocopter BK 117 helicopters. These aircraft operate out of three bases in Middle Tennessee. *LifeFlight 1* is an IFR-equipped BK-117 that is based out of Vanderbilt Medical Center in downtown Nashville. At this writing, Vanderbilt University Medical Center only has one aircraft, *LifeFlight 1,* which is single-pilot IFR-certified and is currently working on certification for a GPS approach into the Vanderbilt Medical Center helipad. An additional two BK-117s, *LifeFlight 1* and *LifeFlight 2* are located at Clarksville, Tennessee, and at Shelbyville, Tennessee. Vanderbilt also operates an office of emergency communications which performs functions similar to those performed by the MEDCOM at Erlanger Medical Center (Vanderbilt University).

In the east, is the University of Tennessee Medical Center at Knoxville (UTMCK). This level I trauma facility is located several miles north of McGhee Tyson Airport. UTMCK *LifeStar* operates two single-pilot IFR-certified Bell 412 helicopters (University of Tennessee Medical Center).

The three aforementioned air ambulance operations would be the basis for the proposed air ambulance coverage. It should be noted, that these three operations are not independent EMS operations, but are affiliated with a local level I trauma center.

One of the commercial leaders in the area of EMS helicopter approaches is Satellite Technology Implementation (STI) LLC. STI is an independent company headquartered in Orange Beach, Alabama. STIGPS specializes in developing helicopter IFR approaches primarily for EMS purposes. In 1998, STI received authorization from the FAA to develop instrument approach procedures (Satellite Technology

Implementation). This is essentially a new policy whereby the FAA is allowing commercial entities to develop instrument approaches. The approaches are then flight checked and reviewed by the FAA before approval. This outsourcing of work by the FAA is efficient and results in faster integration of GPS approaches into the national airspace system. STI has developed over 110 approaches during the last ten years, including approaches for the Maryland State Police and for the 1996 Olympics in Atlanta (McAdams 1999). A personal interview was conducted with the staff of STI. The staff emphasized the complexity of developing instrument approaches into helipads and the relative difficulty in getting these approaches approved by the FAA. The future of developing low-cost instrument approach procedures lies with companies like STI who have authorization from the FAA to survey and develop approaches.

Throughout the country there are several EMS operations that make extensive use of GPS instrument approaches. STAT MedEvac is a company that conducts air ambulance operations in the Pennsylvania area. As of this writing, STAT MedEvac operates 16 helicopters and utilizes 25 GPS instrument approaches (STAT MedEvac). This air medical evacuation company has benefited from the GPS approaches plotted by STI. STAT MedEvac has led the way in using GPS approach technology to improve healthcare availability in the Pennsylvania area. Their helicopter fleet includes IFR equipped EC 135s, Dauphins, AS 365N, BK117 and Bell 430s.

Another innovative air ambulance service is REACH MedEvac of California. REACH has implemented a low-level IFR en-route network to help facilitate their operations in California. REACH makes extensive use of GPS approaches and is an industry leader in this area (Reach Air Ambulance Service 2003).

A variety of sources were used to compile safety information used in this research. Safety data for civil helicopters was obtained at the Helicopter Association International (HAI) website and from the NASA Aviation Safety Reporting System (ASRS). Another source of useful information was the Helicopter Safety Advisory Committee (HSAC). HSAC is a consortium which is interested in improvements in aviation safety in the Gulf of Mexico region.

An invaluable source of information for this document was data from the Federal Aviation Administration (FAA) and their associated websites and publications. Particularly useful, were the websites associated with the FAA Satellite Navigation Product Teams, Flight Procedures Office and the FAA free-flight projects in Alaska (Capstone) and in the Gulf of Mexico (GOMEX).

A state government entity that would prove critical in the development of an IFR approach network is the Tennessee Department of Transportation (TDOT) Aeronautics Division. This organization is the state equivalent of the FAA and conducts inspection and certification of helipads in Tennessee. The state aeronautical chart used as a template for this research is developed by the Aeronautics Division. TDOT is also the certification authority for helipads in Tennessee.

Regulations and Limitations of IFR Flight

In order to fully understand the problems and issues associated with helicopters and instrument flight, one must understand the regulations and limitations inherent to helicopters and how these relate to the helicopter air ambulance mission in particular. Flying under instrument flight rules is essentially flying without reference to the ground or the visual horizon. The pilot depends solely on aircraft instruments and avionics to navigate and remain oriented. An aircraft must be equipped and certified for instrument flight, and the pilot must have an additional rating to be qualified for IFR flight. In most cases, it is much safer to fly under instrument flight rules than trying to dodge poor flying weather at low altitudes. This dodging of bad weather is sometimes referred to as "*skud-running*". Dodging clouds at low altitude is dangerous because weather conditions can change rapidly and the pilot can lose reference to the ground or horizon at low altitude and lose control of the aircraft, or the aircraft may run into terrain or obstructions that suddenly are not visible. The ability for EMS helicopters to fly in uncontrolled airspace under visual flight rules (VFR) and remain clear of clouds although legal and convenient, can be problematic since weather conditions can deteriorate quickly and the aircraft can inadvertently enter the clouds or fog and inadvertently go into instrument meteorological conditions (IMC).

Helicopters operate under Federal Aviation Regulations (FARs) specified in the Code of Federal Regulations (CFR) Title 14, Part 91 and Part 135. When an air ambulance service is not actively transporting a patient the air ambulance operation falls under Part 91 of Title 14. When transporting patients or passengers, the aircraft and pilots must work under the guidance and regulations specified in Part 135, Title 14 of the CFR.

VFR Weather Requirements

For a helicopter to operate outside of controlled airspace (Class G airspace), the aircraft is required to remain clear of clouds and maintain an airspeed that allows the pilot to avoid obstacles or other aircraft. In East Tennessee, the uncontrolled airspace typically goes from the ground to 700 or 1200 feet above ground level (AGL). This altitude is dependent on whether the uncontrolled airspace is associated with an airport or approach procedure. Basically, a helicopter can fly under visual flight rules (VFR) at less than 1200 feet above the ground as long as the aircraft remains clear of the clouds. The aircraft is thus operating close to the ground and obstacles at relatively high speeds. This can potentially be an unsafe condition. In controlled airspace (any class other than class G below 10,000 MSL), the VFR weather requirement is to remain 500 feet below clouds, 1000 above any clouds or 2000 feet horizontally from any clouds. Additionally, three statute miles of visibility are required. If the weather is good, it is more efficient and convenient to fly using visual flight rules. VFR is generally more direct and thus saves time and fuel. A controlled airfield is considered under instrument flight rules if the weather conditions fall below 1000-foot cloud ceilings and three statute miles visibility. *Figure 1.1* depicts the Classes of Airspace as defined by the Federal Aviation Administration.

IFR Weather Requirements

In order to fly under instrument flight rules (IFR) the aircraft and the pilot must be IFR certified. Additionally, IFR aircraft must meet certain weather and fuel criteria in order to ensure a margin of safety during the flight. These weather requirements are based on the reported ceiling and visibility at an airport. A cloud ceiling is defined as the lowest layer of clouds or obscuring phenomena that is classified as broken, overcast or obscured that is not classified as thin or partial (*FAR/AIM* 2002).

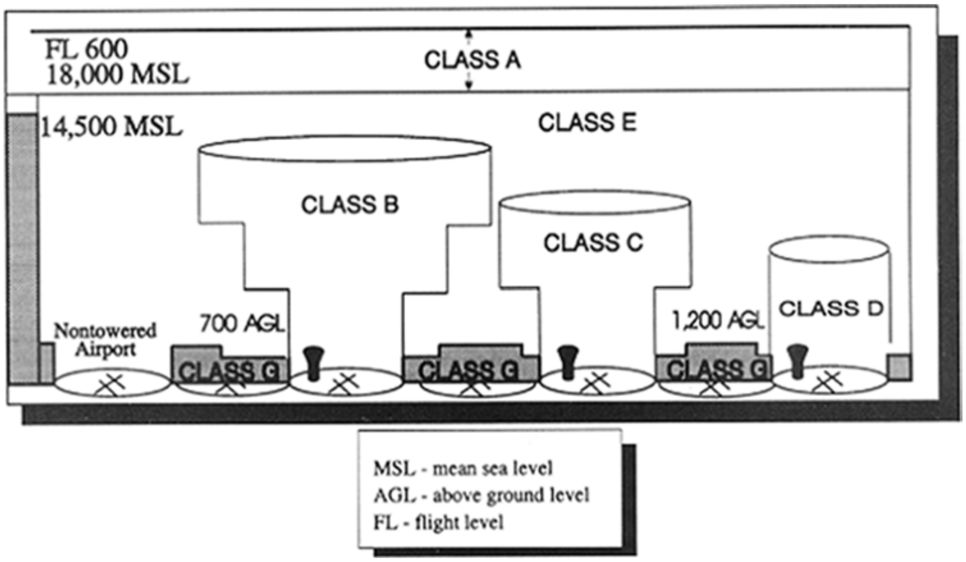


Figure 1.1 Airspace Classes

Source: *FAR/AIM* (2002). Newcastle, WA: Aviation Supplies and Academics Inc.

Weather requirements for IFR flight are relatively complicated. The following discussion is not all inclusive and is meant as a general overview for the purpose of providing background information to the reader. This is not an authoritative source on instrument flight regulations or procedures.

Civil helicopters must have ½ mile visibility in order to take off under instrument flight rules. A helicopter must meet the minimum weather requirements specified for the instrument approach procedure to be flown. These consist of a specified ceiling in feet AGL and visibility in statute miles. Helicopters are allowed to reduce the visibility minimum by one-half but no less than ¼ mile or 1200 ft runway visual range (RVR). Helicopter-only approaches must be flown at 90 knots or less. A reduction of the visibility minimum is not allowed.

In order for helicopters to fly IFR, the pilots must designate an alternate airport. The alternate is the airport to be used if the aircraft does not breakout of the weather at the destination airport. In order to qualify as an alternate, an airport must have cloud ceilings at least 200 feet above the minimums for the approach to be flown and have at least 2 miles visibility. These requirements for alternates are not applicable if the aircraft can descend from the minimum en-route IFR altitude (MEA) under visual flight rules.

Fuel requirements are also tied to weather requirements. If the weather at the destination has a ceiling that is less than 1000 feet above the airport or 400 foot above the lowest approach minimum or less than two miles visibility, a 30 minute fuel reserve is required after reaching the alternate. This is rather restrictive and limits the operational mission time available for helicopter IFR flights.

En-route to a destination under instrument flight rules, a helicopter typically flies the Minimum En-route Altitude (MEA) for instrument flight. The MEA is the altitude along an IFR route which ensures NAVAID reception and clearance from obstructions. The obstruction clearance requirements for IFR flight are that the aircraft maintain an altitude 2000 foot above the highest obstacle within four nautical miles of a route in mountainous terrain and 1000 foot above the highest obstacle in non-mountainous terrain. This altitude is referred to as the Minimum Obstacle Clearance Altitude (MOCA). Aircraft using GPS for en-route navigation can use this lower less-congested altitude, because GPS navigation doesn’t require reception from conventional line-of-sight radio-based NAVAIDS.

FAR Part 135 is more restrictive regarding IFR weather requirements. This is because the FAA wants an added safety margin since passengers are being transported.

Part 135 specifies that weather at the destination be forecast above IFR minimums prior to take-off. Additionally, Part 135 has a stipulation that the weather at the take-off airport must be at or above authorized IFR landing minimum unless there is an alternate airport within one hour flying time of the airport. With the limited range of most helicopters, this regulation can pose a problem. Most low ceiling and visibility associated with a weather pattern would still be predominant in the relatively short distances a helicopter could fly in one hour at cruise speeds.

Part 135.225 also requires that in order to begin an instrument approach an aircraft must obtain a weather report from the U.S. National Weather Service or another approved source by the FAA administrator. That report must indicate that weather conditions are above IFR minimums for the approach to be flown. Helicopter EMS operations typically use local Automated Weather Observation Station (AWOS) and area forecasts to get their flight weather. (*FAR/AIM* 2002)

The National Airspace System and GPS

The current instrument infrastructure utilized in the National Airspace System (NAS) is predicated mostly on ground-based navigation aids (NAVAIDS). These NAVAIDS are primarily very high frequency omni-directional receivers (VORs) and non-directional beacons (NDBs).

The conventional instrument infrastructure conceived in the 1940s and implemented in the 1950s is hardware and maintenance intensive. In addition, this system was conceived and built with fixed-wing aircraft envisioned as the primary users. In many cases, this has proven a hindrance to helicopter operations. Regulations and procedures based on fixed-wing aircraft performance frequently fail to take into account the unique abilities of the slower and more maneuverable helicopter.

The National Airspace System is rapidly changing to a space-based GPS system. The spaced based, or GPS system, is not as infrastructure intensive as the conventional system. The Global Positioning System (GPS) is a navigation system based on a constellation of 24 satellites. The GPS navigation system provides horizontal guidance accuracy of 100 meters with a probability of 95% in the non-secure or standard positioning service (SPS) mode. GPS was developed in the late 1980s and early 1990s by the Department of Defense (DOD). Since its inception, GPS has become a public asset, and the more accurate precise positioning service (PPS) is available to all users (*FAR/AIM* 2002).

The GPS satellites are in an orbit roughly 11,000 miles above the earth. The GPS system consists of three major components. The first is a user component that consists primarily of a GPS receiver. The second is a satellite component which consists of the GPS satellite and includes the satellite support systems. The third component is a ground segment which consists of stations that provide positioning and timing corrections to the satellites. There are five monitoring stations located around the world and one master control station located in Colorado Springs, Colorado. The satellites use very precise atomic clocks to measure the time between sending a signal from the satellite to the receiver. From this time and the known position of the satellite, the distance to the satellite is determined. GPS uses triangulation through precise timing to determine precise location and height above the earth. The GPS must know the exact location of the satellite in order to triangulate the position of the receiver. This position is called the ephemeris. Signals from four satellites are required to determine a location in three dimensions.

Differential Global Positioning System (DGPS) is an augmentation to the standard GPS. DGPS uses specially located ground based stations which are very accurately surveyed. These stations provide updates to the GPS signal and thus increase the accuracy of the system. The two types of DGPS are the Wide Area Augmentation System (WAAS) and the Local Area Augmentation System (LAAS). WAAS uses very precisely surveyed ground stations to measure the accuracy of GPS signals. A correction is developed and sent back to a communications satellite. The communications satellite sends corrections to GPS users on the same frequency as the GPS. LAAS provides more accuracy and augments the GPS in the terminal area and provides for the accuracy required for precision GPS approaches.

GPS Instrument Approach Procedures

An instrument approach procedure is a procedure an aircraft flies in order to safely transition from the en-route portion of the instrument flight to the airport and to visual references. En-route to a destination under instrument flight rules, a helicopter typically flies the Minimum En-route Altitude (MEA) for instrument flight. This is the altitude along an IFR route which ensures NAVAID reception and clearance from obstructions. During the instrument approach procedure, the aircraft descends to an altitude where the pilot expects to break out of the clouds and acquire the airport or landing environment. This altitude is referred to as the minimum descent altitude (MDA) for non-precision instrument approaches. For approach procedures with a glide slope, such as the instrument landing system (ILS), this altitude is referred to as the decision altitude (DA). The MDA and DA are expressed in feet above mean sea level (MSL). The actual height above ground level (AGL) is referred to as the height above touchdown (HAT).

If the pilot does not breakout at this altitude over a specified point called the missed approach point (MAP), then the pilot climbs and either flies to his alternate or attempts another approach. An example of the format for a typical standard instrument approach procedure is shown in *Figure 1.2.* Public instrument approach procedures are prescribed in 14 CFR Part 97. Non-public special instrument approach procedures (SIAPs) are not published in Part 97 of the FAR.

Many GPS approaches presently in use in the National Airspace System, are part of the GPS approach overlay program. The overlay program uses GPS avionics to fly existing non-precision approach procedures. These instrument approach procedures (IAPs) are predicated on ground-based navigation aids (VORs or NDBs). Overlay instrument approaches can normally be identified by instrument approaches which have designations such as VOR or GPS RWY 36 indicating that either VOR instrumentation or GPS avionics can be used to complete the approach. New GPS approaches are referred to as area navigation RNAV approaches. For the purpose of this paper RNAV and GPS approaches are almost synonymous.

Area Navigation

In contrast to using just one type of sensor such as GPS or VOR, Area Navigation (RNAV) uses a combination of navigation sources to obtain a level of navigation accuracy.

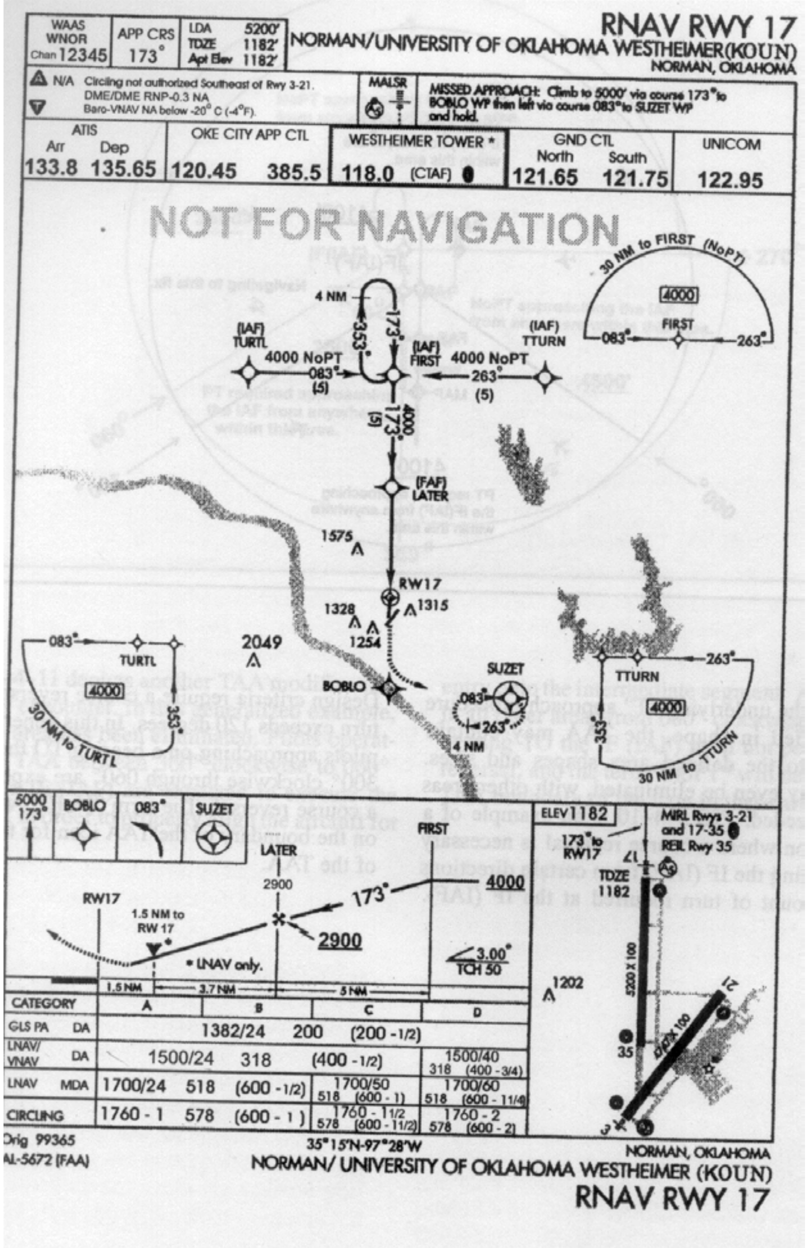


Figure 1.2 Typical Instrument Approach Procedure

Source: Airman's Information Manual

This accuracy is measured in terms of required navigation performance (RNP). RNP differs depending on the phase of flight one is involved in. The values indicate how far from the desired track the navigation system could theoretically allow the aircraft to stray. RNP values in the U.S are .3 nautical miles on an instrument approach. En-route the RNP value expands to two nautical miles. In the airport environment, the RNP is one nautical mile. Many EMS operations use RNAV navigations systems.

Available stand-alone GPS-based approaches are the LNAV (lateral navigation) and the LNAV/VNAV (vertical navigation approaches). LNAV/VNAV approaches are similar to precision approaches in that they provide a glide-slope-like gradual descent instead of the old method of step down fixes. By using “baro Vnav” a vertical descent profile is used instead of a step-down. This reduces the airspace required to develop instrument approach procedures (McAdams 1999). Non-precision LNAV/VNAV approaches allow descents to heights that are 250 feet HAT (FAA *Airport Design* 2000). The future involves GLS (Global navigation satellite system Landing System) approaches. GLS approaches are DGPS-based precision approaches similar to an instrument landing system (ILS) approach. GLS approaches are GPS approaches augmented by LAAS and WAAS and allow descents to much lower altitudes.

The Airman’s Information Manual (AIM) discusses helicopter point-in-space approaches (PinS). These are approaches that do not terminate with the aircraft descending directly to the landing area. PinS approaches are developed for heliports that do not meet the standards required of an IFR heliport or the particular heliport is not located within 2,600 feet of the missed approach point (MAP). The point in space (PinS) approach includes a visual flight portion between the MAP and the landing area. There are two types. One is based on a distance of less than 10,500 feet from MAP to the landing area. The other is for distances greater than 10,500 feet.

If the distance is greater than 10,500 feet, then the pilot must execute a missed approach procedure if he or she cannot acquire the landing site at or prior to the MAP. If the distance is greater than 10,500 feet from the MAP to the landing site, regulations require the pilot to determine if he or she can meet VFR weather requirements and transition to VFR flight. In either case, IFR obstruction clearance areas are not applied to the portion from the missed approach point to the landing area (AIM/FAR 2002). Many instrument approaches to hospital helipads require point-in-space approaches because of obstruction and clearance conflicts in the hospital area. Because of stringent requirements for the development of PinS approaches very few are currently in use.

Regulatory guidance for how to develop instrument approach procedures is found in the U.S. Standard for Terminal Instrument Approach Procedures or commonly called TERPs (FAA Handbook 8260.3B). Helicopter specific GPS approach TERPs are found in FAA Order 8620.42A. FAA Advisory Circular 5390/2A Heliport Design enumerates the requirements for heliport instrument approach procedures in chapters 7 and 8. Although some background research was conducted in the intricacies of TERPs procedures, the process of actually developing a certified instrument approach is a time intensive process, and the development of numerous approaches for a network is well beyond the scope of the thesis.

The Air Ambulance Mission

The majority of flights performed by helicopters in the Emergency Medical Services community are under visual flight rules. Not all air ambulance operations are IFR certified. Many services operate only in visual meteorological conditions. Additionally, most flights are inter-facility transfers that involve flight from a referring hospital to a receiving trauma hospital after the patient has been stabilized.

The local or referring hospital typically calls the receiving hospital to initiate this transfer. The decision as to which EMS operation is called revolves around a variety of factors including weather conditions, distance, and which hospital is best equipped to treat the patient. Some hospitals are in the service area of multiple EMS operations while others are limited to one particular service. From interviews with personnel at Erlanger Medical Center, most EMS operations conduct 70% inter-facility flights and only about 30% on-scene pickups (S. Stron,Life Force Operations Officer, personal communication February 2003). A year 2000 study in *Airmed* magazine, determined that 72% percent of all hospital based helicopter transport missions were inter-facility missions while only 28% percent were on-scene missions (Rau 2001). In essence, what this data indicates is that most flights are from one fixed base to another. This condition is uniquely conducive to instrument flights providing the IFR infrastructure and equipment is available and quickly accessible.

The addition of an IFR flight capability enhances the ability of an air ambulance operation to effectively reach patients that may not have been reached due to poor weather or to reach them more quickly thus increasing their survival rate. At Erlanger Medical Center, it was estimated that 10% of their yearly missions, or approximately 150 flights per year, are under instrument flight rules or require portions of IFR flight (S. Stron, Life Force Operations Officer, personal communication February 2003). Stat MedEvac estimated a 15 to 20 percent increase in capability (Satellite Technology Implementation 2003).

A two-year study by Erlanger Medical Center determined that with 24 hospitals, 451 flights had been missed due to weather. Erlanger extended this using a historical data base and determined that 377 of these flights could have been accomplished with GPS approaches in place. Over an 18-month period with 14 approaches installed, 251 approaches were flown (Forgy, 2001). The chief pilot at the University of Tennessee Medical Center estimates that LifeStar flies approximately 5 % to 6 % of their missions under instrument conditions (M. Englebert, (personal communication, April 03). These IFR flights may have been mission turn-downs and could have resulted in the patients not arriving at the level I trauma center at all, or at least not as expeditiously as under instrument flight rules. In any event, these flights may have been conducted under visual flight rules in marginal weather thus increasing the risk to the patients and the flight crew. The integration of GPS IFR capability into flight operations has an immediate positive impact on operations.

Safety Statistics

In a study conducted by the NTSB from 1978 to 1986, it was determined that the accident rates for EMS helicopter operations were 3.5 times those for other unscheduled Part 135 operations (Connell and Patten 1993). The majority of helicopter accidents (mishaps) occur because of collision with terrain or obstacles during the en-route portion of the mission. An NTSB survey found that inadvertent IMC at low altitude was the single most common factor in fatal EMS accidents. Most incidents occur at low altitude in uncontrolled airspace. In-flight weather encounters were also determined to occur most often during cruise flight (Connell and Patten 1993). In many cases, this is due to deteriorating weather. Over the last 10 years, 3 % of helicopter accidents occurred in the air medical service. These numbers have increased significantly over the last ten years from 2 in 1992 to 12 in 2002 (Helicopter Association International 2002). This data makes a strong statement in support of the integration of instrument flight operations into the air ambulance industry.

Weather Data

Weather data from three Automated Surface Observation Systems (ASOS) in the Middle and East Tennessee area is presented in *Figures 1.3-1.5*. The three stations represent a cross-section of ceiling and visibility data in the year 2002. The data was collected from the National Climatic Data Center database. The charts indicate the number of days where IFR weather was present in a particular month. The charts also show where extremely poor IFR weather was present. This was when the weather deteriorated to less than 500-foot ceilings, and the visibility was less than half of a mile.

Combining the data from the three stations, the mean number of days per month that IFR weather was present was 12.25 days. The number of days of low IFR per month is indicated by dark bars on the charts. The combined mean number of days with the very low IFR weather (less than 500-1/2) was 5.39 days.

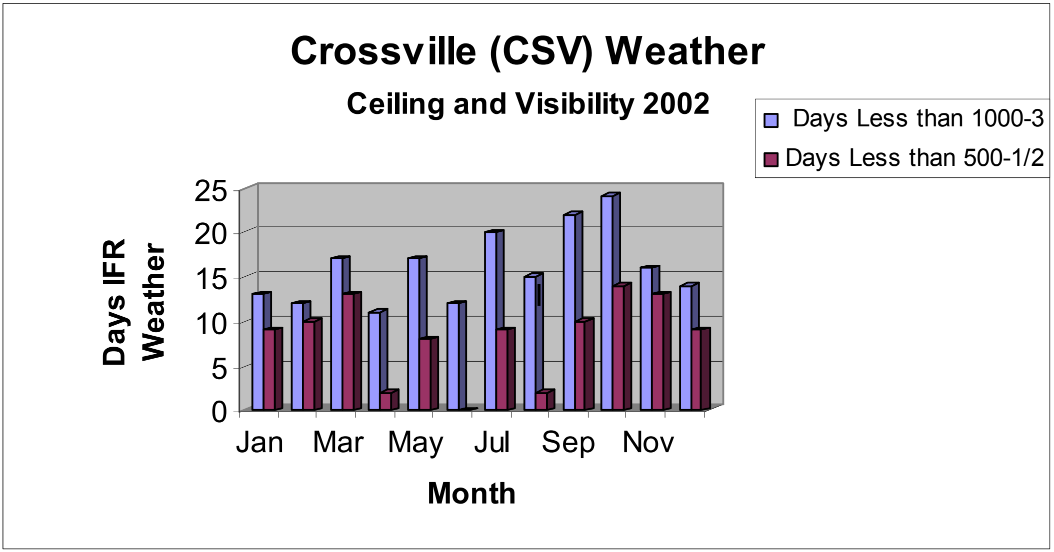


Figure 1.3 Ceiling and Visibility-Crossville

Source: Local Climatological Data-Hourly Observation Table CSV (2002). Asheville NC: National Climatic Data Center. Available from www.ncdc.noaa.gov/oa/ncdc.html

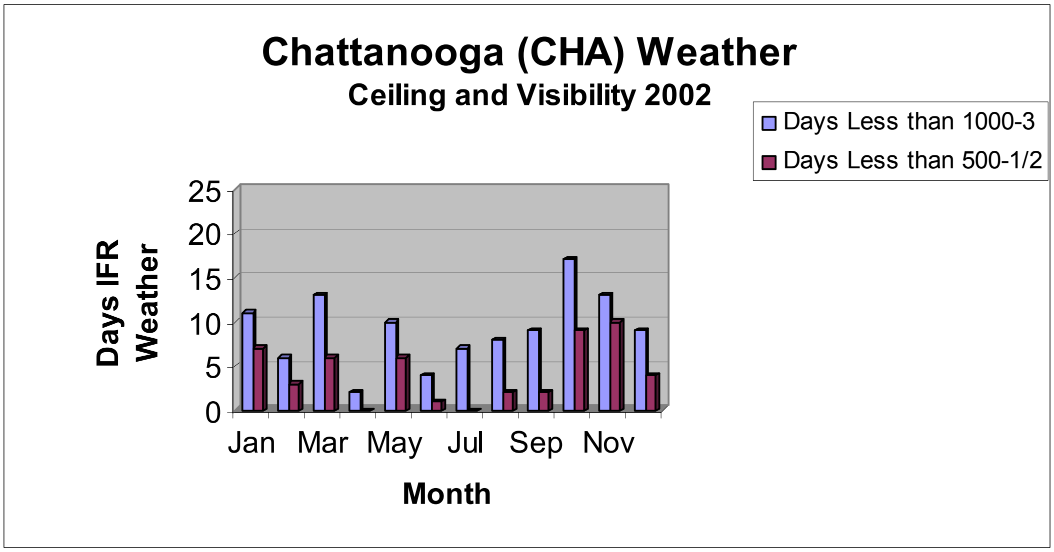


Figure 1.4 Ceiling and Visibility-Chattanooga

Source: Local Climatological Data-Hourly Observation Table-CHA, (2002). Asheville NC: National Climatic Data Center. Available from www.ncdc.noaa.gov/oa/ncdc.html

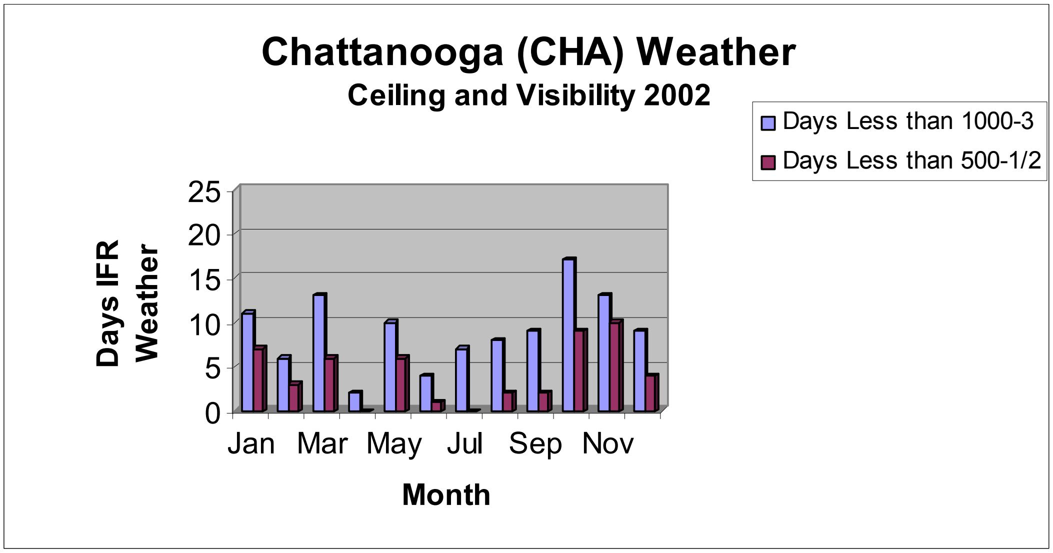


Figure 1.5 Ceiling and Visibility-Nashville

Source: Local Climatological Data-Hourly Observation Table-BNA, (2002). Asheville NC: National Climatic Data Center. Available from www.ncdc.noaa.gov/oa/ncdc.html

This data is significant because it shows that on a significant number of days each month the weather is below VFR minimums and would require instrument flight in controlled airspace. The data demonstrates that instrument approaches with minimum descent altitudes less than 500 feet are not particularly imperative. Most non-precision approaches have minimum descent heights that average to around 500 feet above ground level (AGL). In only approximately five days of the month would an approach with a MDA less than 500 feet AGL be of utility. Non-precision GPS approach MDA should be sufficient in most situations encountered by an EMS operation. Thus, this added technological capability is probably not critical at this juncture. Further study into weather conditions and the need for lower helicopter IFR descent altitudes is required. It should be noted, that this weather data applies only to three locations in the research area.

Also, this data indicates that during a particular day a certain IFR weather condition was present, but in no way asserts that that condition was present throughout the entire day.

IFR Issues

There are several problems concerning helicopter air ambulance operations and instrument flight. One of these issues, is the inherent fact that an air ambulance operation is a business and is not an altruistic public service. Although frequently a life or death issue, like many parts of health-care, a driving factor is money. From year 2000 statistics, the base rate in the Tennessee research area for a medical helicopter transport was $2028 (Rau, 2000). Obviously, an air ambulance operation can be a lucrative. In some ways, this is problematic since a holistic approach to public health care is not a driving force in decisions. This is one compelling reason for some form of public integrated instrument EMS network.

The air ambulance business has had an influx of VFR-only EMS operators. Because of their relatively low cost per flight hour, these operations are taking a large portion of the EMS business. While the addition of more air ambulance services does constitute an improvement in overall health care, there are significant safety consequences. These operators are unwilling to invest in technology associated with IFR avionics and certification. These VFR-only EMS operations would not advocate, nor benefit from a network as proposed in this paper.

Federal Aviation Regulation Part 135 requires aircraft to have weather reporting at the airport or helipad that the aircraft is landing or taking off from. This proves problematic for EMS operators who are frequently operating out of remote locations or hospital helipads. Fortunately, many of the rural communities in the research area have remote weather reporting stations called Automated Weather Observation Systems (AWOS). *Figure 1.6* shows the locations of Automated Weather Observation Systems in the Middle and East Tennessee area. The Helicopter Association International (HAI) and the Association of Air Medical Services (AAMS) have obtained an exemption allowing EMS operations to conduct instrument departures without on-site weather forecasting as long as VFR minimums are met (Lacey 1999). Research into approved portable weather observation equipment is warranted and would benefit the EMS community.

FAR Part 135 includes an additional requirement that an aircraft taking off IFR must have an airport within one hour of flight from the takeoff airport which is above IFR minimums specified in Part 97 of the Federal Aviation Regulations (FARs). As was mentioned previously, this presents a helicopter specific problem due to the limited range of helicopters.

A systemic issue that is facing the air ambulance industry and aviation in general is the slow methodical pace taken by the FAA in developing and implementing new technology into the national airspace system. The FAA is still in the testing stage of integrating much of the technologies mentioned in this paper.

Capstone which is a FAA initiative to test new airspace architecture and technology into the National Airspace System is entering its second phase. Full-scale implementation of free flight technology such as automatic dependent surveillance-broadcast (ADS-B) and RNAV is probably up to ten years in the future.

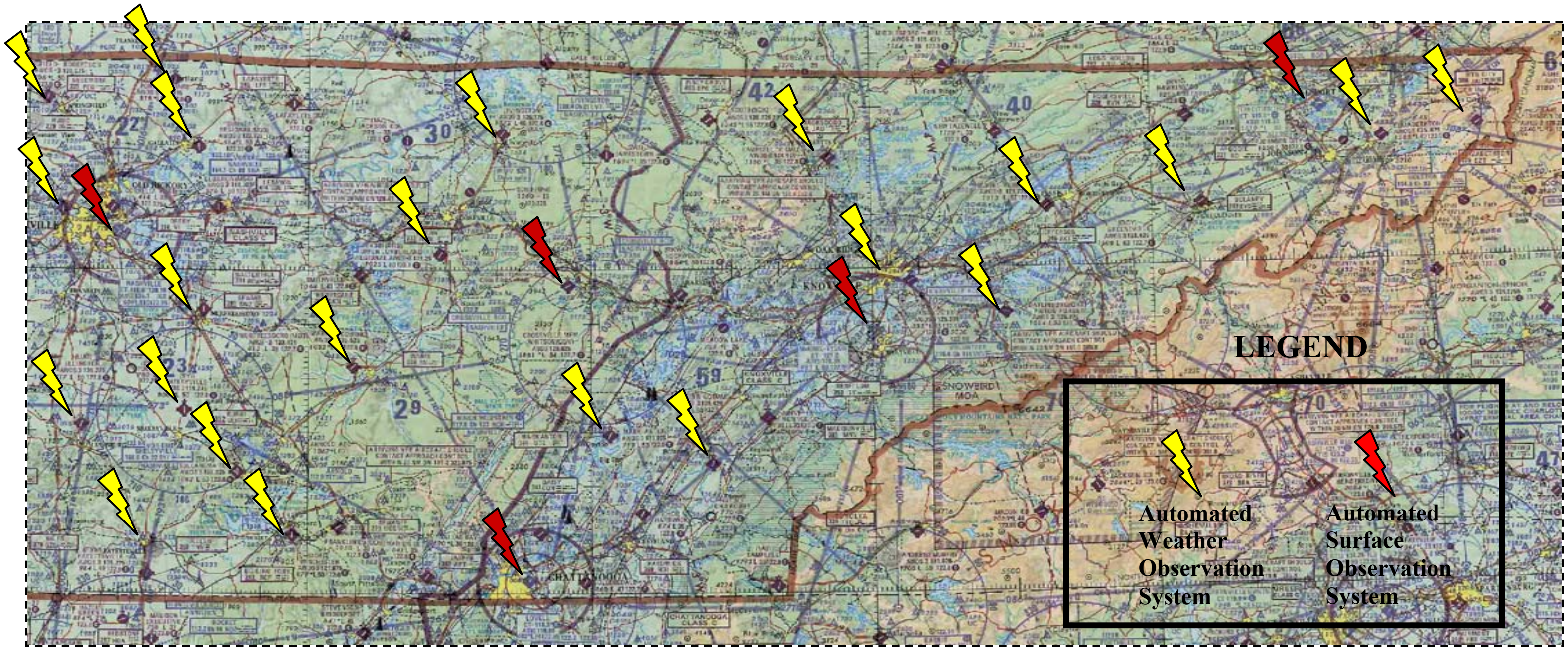


Figure 1.6 AWOS and ASOS Locations

Source: Federal Aviation Administration (n.d.). *Site Map Tennessee*. Retrieved April 16, 2003, from http://www1.faa.gov/asos/map/tn.cfm.

There is an inherent *airplane-first* attitude imbedded in the IFR infrastructure. This should be expected since the majority of air traffic is fixed-wing. With the increase in overall air traffic in recent years the National Airspace System (NAS) has become burdened. A shift toward helicopter and vertical flight operations may become inevitable as traditional airports become more crowded. Point-to-point transportation is more accessible and affordable. Hopefully, a new emphasis on helicopter capabilities will evolve that allows the full realization of the unique advantages of vertical flight.

CHAPTER 2

CONCEPT: AN INTEGRATED IFR EMS APPROACH NETWORK

The Problem

The basic problem addressed in this thesis is to determine the best way to improve the health care of rural residents of Tennessee by the implementation of emerging GPS instrument approach technology. In order to solve this problem, a general method of how to implement an IFR system must be analyzed.

A Systems Engineering Approach

To determine how to implement the IFR system a systems-engineering approach was used. This was primarily a logical thought process used to look at the advantages and disadvantages of the alternatives available to address a particular problem.

The Stakeholders

The stakeholders in this process are, first and foremost, the citizens of the state of Tennessee. The taxpayers will eventually pay the bill should a project such as this come to fruition. Additionally, the taxpayers will be the individuals who will benefit from the improvements in healthcare availability provided by an IFR EMS network.

A second major group of stakeholders is the helicopter EMS community, the medical centers, and to some extent, the smaller local hospitals. The current system is a largely commercial endeavor and a public system may, or may not, be a welcomed addition to include in their operations schemes. A third interested participant would be government entities such as the FAA and Tennessee state government. These agencies would incur increased workload, responsibilities and costs with the advent of an additional instrument approach network.

Assumptions and Constraints

Any aviation IFR network would have to fall under the purview and regulations established for aviation and navigation by the FAA. Thus the constraints outlined in Part 91 and 135 of the FAR as well as the U.S. Standard for TERPs would weigh heavily on the design and composition of any such system.

It is assumed that a twenty nautical mile radius from a pick-up site with an approved instrument approach procedure would allow sufficient time for critical patients to reach a level I trauma center within the critical first hour following an accident. Since 100% helicopter EMS percent coverage of the entire state of Tennessee is not a feasible goal this research set 95% EMS coverage as an attainable goal. Certain remote areas, in particular those around state and national parks, or those including large bodies of water probably would not allow complete EMS coverage. Some objective, judgment-based decisions must be made regarding what areas fall into this category. Also, a more in-depth cost-benefit analysis would be a prudent step to take to ascertain inclusion or not. This cost-benefit analysis could help determine areas of coverage that require more coverage focus due to their population density. In addition to the basic instrument approach, it is assumed that applicable missed approach procedures are developed even for possible VFR portions of point-in-space approaches.

The Alternatives

Several alternatives exist as to how to implement such a system in Tennessee. The first alternative would be to continue with haphazard commercial development of an IFR approach system. An obvious advantage to this alternative it is that is already partially in effect and development is ongoing. This alternative would not burden the state budget or add additional requirements to local, state or federal agencies. This option is dependent upon the haphazard, often laissez faire, development of the EMS operators. Inevitably, this approach would not provide inter-connectivity or provide IFR capability to all EMS providers or government emergency management personnel. In reality, competition among health care facilities may actually hamper timely development of any such commercial system and introduce safety concerns. Additionally, lower cost EMS operators which operate primarily under visual flight rules take a significant share of the business and thus decrease the impetus for further advances in IFR flight. The limited number of IFR operations also creates a limited amount of competition thus driving up the cost of patient transportation.

Another viable alternative is to wait on FAA development of GPS IFR infrastructure. This alternative is similar to the first alterative, but implies that once the technology is available through the FAA, a network of IFR helicopter GPS approaches would be publicly developed. As before, one of the distinct advantages of such a system is that this alternative would not cost anything to local taxpayers, and technological development will undoubtedly occur without any intervention. As was mentioned previously, the primary focus of the FAA is on airplane IFR improvements. A helicopter-based system would probably not have much priority. The major shortcoming of this option is the long wait for FAA mandated improvements. The wait may be deemed unacceptable and certainly doesn't indicate a proactive approach to problem solving.

The final alternative would to be to develop a publicly funded, comprehensive system of EMS helicopter GPS instrument approaches. Such an integrated IFR network would place Tennessee at the forefront of emerging aviation free-flight technology. The network would demonstrate the feasibility of the system and set a precedent for EMS networks nationwide. Without a doubt, the system would provide immediate improvements in health care availability to the citizens of Tennessee. Furthermore, the development of a public system would also provide impetus for helicopter air ambulance operators to fly IFR equipped aircraft. An added benefit is that such a system would add a disaster relief capability for emergency management personnel during inclement weather.

The Best Alternative

The author believes that the best solution is to advocate a comprehensive network based on a combination of airport GPS approaches and approved hospital IFR approaches. The system focuses primarily on GPS instrument approaches to medical facilities with reliance on already established IFR approaches to local airports within three nautical miles of medical center. The system would initially be a proof of concept type network. Such a system would set the precedent for similar systems throughout the country.

Concept

This chapter outlines the concept of a publicly developed and managed system of helicopter GPS instrument approaches which is interconnected and available for use by all appropriately-equipped EMS aircraft. Several similar systems exist throughout the country. There is a low-level helicopter IFR structure in the northeast corridor of the United States. These are RNAV airways between Washington DC and New York City. These routes have altitudes between 1800 and 5000 feet (McAdams 1999). Also there exists a relatively new instrument grid system in the Gulf of Mexico. Other precedents for helicopter low-altitude IFR networks are commercial networks developed by REACH MedEvac in California, STAT MedEvac of Pennsylvania and Erlanger Medical Center of southeast Tennessee.

The Middle and East Tennessee area is uniquely suited to host such a system. There are a numerous reasons why this area is conducive to the development of an experimental public instrument approach network. The Middle and East Tennessee area has representative terrain and weather similar to much of the United States. The weather is not extremely harsh, nor is it extremely benign. With a wide diversity of terrain, the geography and topography is analogous to much of the 48 contiguous states. There are four distinct seasons which provide challenging flight conditions throughout the year. While blessed with many local airports, the airspace at low altitudes is not extremely crowded and does not contain numerous complicated areas of controlled airspace. The only controlled airfields in this research study area are at Knoxville, Tri-Cities, Chattanooga and Nashville/Smyrna.

A factor which would contribute favorably to the choice of this area is that there is the triad of well-equipped, well-funded air ambulance operations. These operations already conduct IFR operations and would not require extensive training to integrate additional IFR flights into their operations. Also the relative availability of IFR air ambulance service in the area allows for a level of competition among operations. Competition could assist in lowering the cost of using the system.

A distinct advantage of the Tennessee area for this project is the availability of good aviation research and development facilities nearby. While not specifically involved in similar research, facilities such as the University of Tennessee Space Institute, Redstone Arsenal, NASA Huntsville, and Arnold Engineering Development Center could provide a technical base that may be invaluable in the development of an IFR system. The Tennessee Valley high technology corridor extends from the Tri-cities of Johnson City, Bristol and Kingsport southwest through Oak Ridge, Knoxville, and Chattanooga and continues further south into Alabama to terminate in Huntsville.

The entire state could eventually be included in an IFR EMS network. For the purpose of this paper only the Middle and East Tennessee area were included. This was done primarily to ensure a sufficient amount of attention to detail.

The Research Area

The research area defined in this study is essentially Tennessee east of Nashville. To be precise, it encompasses the area from the eastern border with North Carolina to the southern border with Georgia and Alabama, westward to the 87 degree line of longitude west of Nashville and north to the state border with Kentucky. *Figure 2.1* outlines the Research Area and the three primary IFR certified level I trauma centers.

The research area has an established triad of IFR equipped helicopter EMS operators. There are four level I trauma centers that provide air ambulance service within this defined research area. Other trauma centers in the research area are identified in *Table 2.1*. The Tri-cities, Bristol, Kingsport and Johnson City, have two level I trauma centers in that metropolitan area. Currently, there is not an IFR-equipped air-ambulance operation that works out of the Tri-Cities area. *Table 2.1* is a list of trauma centers available in the designated research area.

The majority of the airspace in the research area is classified as Class G (uncontrolled) below 700 feet AGL. Minimum en-route altitudes (MEAs) in the area typically run from as low as 3000 MSL to as high as 9000 feet in the extreme northeastern portion of the research area. The off-route obstruction clearance altitudes OROCA altitudes range from 4000 feet to 9000 feet MSL. Erlanger Medical Center in Chattanooga has an approved IFR approach to the medical center helipad.

Methodology

To develop the desired instrument air ambulance coverage a Tennessee Aeronautical Chart (2002) was used. This map was used as a template upon which current and proposed locations of instrument approaches were placed. A twenty nautical mile ring was used to depict the coverage associated with a particular instrument approach.

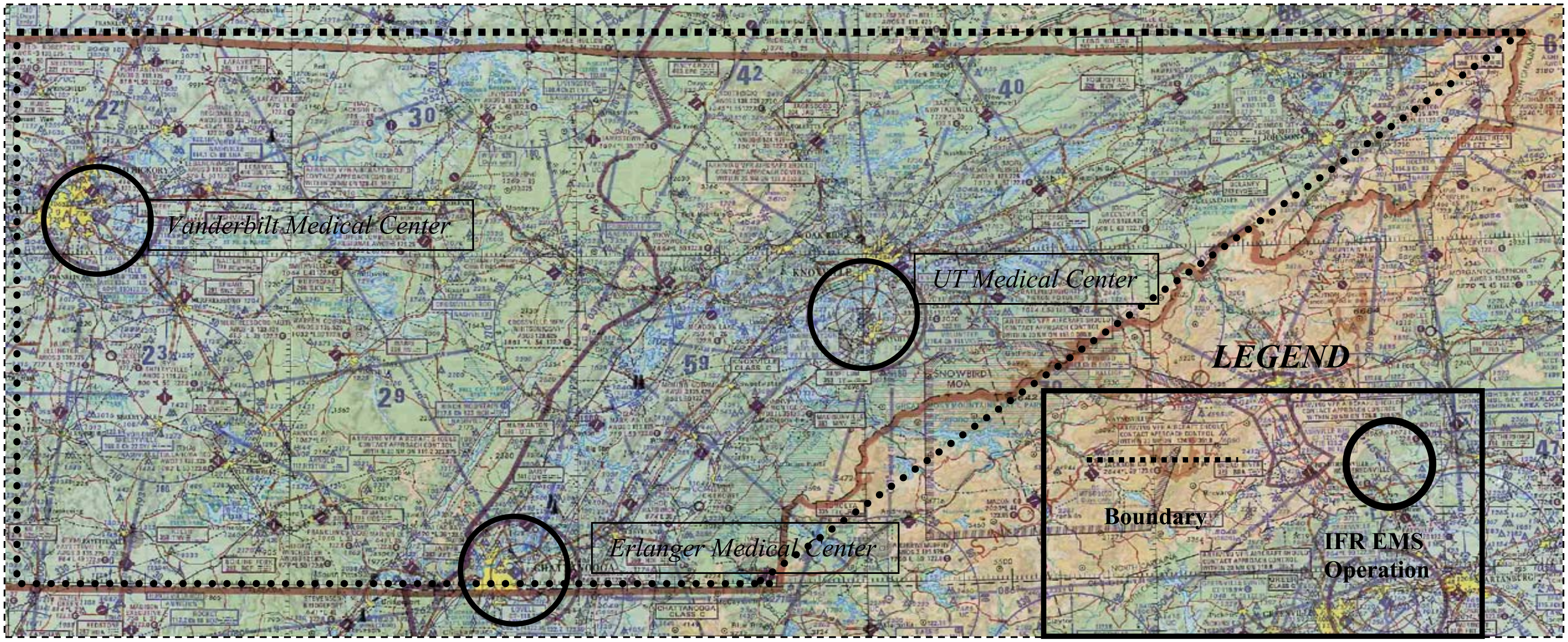


Figure 2.1 Research Area

Table 2.1 Designated Trauma Areas in the Research Area

Trauma Center	**Location**	**Level**	**Helicopter EMS Operation**	**IFR Certified**
Vanderbilt University Medical Center	Nashville	I	Y	Y
University Health Systems Inc	Knoxville	I	Y	Y
Erlanger Medical Center	Chattanooga	I	Y	Y
Wellmont Holston Valley	Kingsport	I	N	N
Johnson City Medical Center	Johnson City	I	Y	N
Wellmont Bristol Regional Medical Center	Bristol	II	N	N
Blount Memorial Hospital	Maryville	III	N	N
Athens Regional Medical Center	Athens	III	N	N
Woods Memorial Hospital District	Etowah	III	N	N
Bradley Memorial Hospital	Cleveland	III	N	N

Source: Tennessee Department of Health (2001). *Designated Trauma Centers in Tennessee*. Retrieved on May 22, 2003 from http://www2.state.tn.us/health/HCF/facilities_listings.

A twenty nautical mile radius from a pickup site would allow ground transportation to the respective helipad with sufficient time remaining for air transport to the trauma center within the desired Golden Hour.

Hospital locations were determined by a list of hospitals and healthcare facilities provided from the Tennessee Department of Health. A list of approved/certified helipads was obtained from the Tennessee Department of Transportation-Aeronautics Division. This list was instrumental in determining locations for additional required instrument approaches. By analyzing appropriate topographic maps it was determined whether airports with instrument approach procedures were within three nautical miles of a medical facility. Hospital locations within three miles of IFR airports were combined with already established hospital helipad IFR approaches to develop a current coverage map.

The next logical step was to determine how to provide instrument air ambulance coverage to the areas not within 20 nautical miles of either an existing hospital IFR approach or a hospital located near an airport. This required an analysis of local medical facilities, government infrastructure and facilities and topography. Following this analysis, approximate locations for approaches were determined and placed upon the template map. If an appropriate medical facility with a certified helipad was available in a particular area, this location was chosen as the approximate location of the instrument approach. If a medical facility was not available, other government infrastructure such as law enforcement facilities were analyzed. Lastly, private infrastructure such as private airports and heliports were investigated.

GPS Approaches at Local Airports

Within the state of Tennessee there are currently 61 airports with instrument approaches. There are 35 airports with FAA-approved GPS non-precision approaches in the designated research area. Many of these instrument approach procedures are GPS overlay approaches of existing conventional NAVAID approaches and are not stand-alone GPS approaches. These approaches do not have an associated medical facility. Local airports and their associated instrument approaches are useful to the helicopter air ambulance operations because they provide safe pick-up zones for patients when accidents occur in relatively rural areas located near these airports. *Figure 2.2* identifies those airports with GPS approaches and shows their respective Heights above touchdown (HAT). The average height above touchdown (HAT) for GPS approaches in the research area is 602 feet.

Hospitals with IFR Approaches within Three Nautical Miles

Many airports with certified GPS approaches are located close enough to an existing hospital that an additional approach to a hospital helipad would not be warranted. In the research area, there are 16 hospitals within three nautical miles of an airport with a FAA-approved GPS instrument approach. No distinction was made between stand-alone or overlay GPS approaches. Airport GPS approaches would permit instrument approaches to the local airport and then the helicopter could easily transition to visual flight rules (VFR) and fly a known route to a state-certified hospital helipad

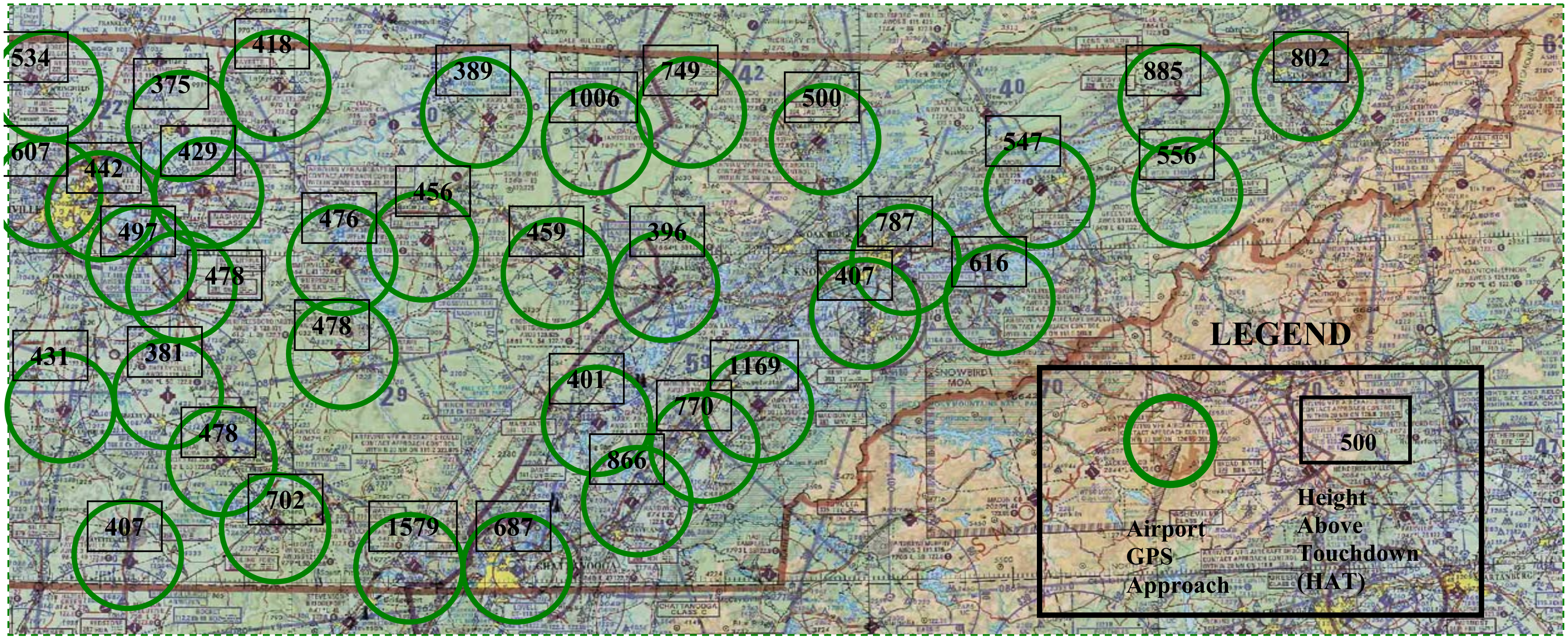


Figure 2.2 GPS Instrument Approaches

Source: U.S. Department of Transportation (2003). *U.S. Terminal Procedures Southeast Volume 1 of 4 United States Government Flight Information Publication.* Federal Aviation Administration, National Aeronautical Charting Office

Lead-in lighting and GPS-assisted VFR would help ensure safe arrival of the aircraft at the associated hospital helipad. If the ceiling was greater than 500 feet above ground level (AGL) a transition to visual flight would be relatively easy. EMS operations with a preponderance of high ground in their operations areas would benefit significantly by this network by not having to "scud run" during the en-route or cruise phase of the flight. *Figure 2.3* identifies airports with GPS approaches that are within three nautical miles of a medical facility with a 20 nautical mile ring.

Hospital Helipads with Instrument Approach Procedures

Erlanger Medical Center already has 11 approved instrument approach procedures into hospital helipads within their area of operations. The 11 approaches include the pad at the medical center. Additionally, the University of Tennessee Medical Center has funded the development of four GPS approaches to enhance their operations. These procedures are indicated in *Figure 2.3* by segmented rings. These special instrument approaches (SIAPs) are proprietary and at the present time can be used only by personnel from the respective organizations.

Required Approaches to Hospital Helipads

In order to obtain the desired 95% coverage, twenty-three (23) approaches would be required to hospital helipads. Hospital helipad approaches are the backbone of an IFR approach network. These IFR hospital helipads would allow inter-facility flights in the vast majority of weather conditions experienced in Middle and East Tennessee.

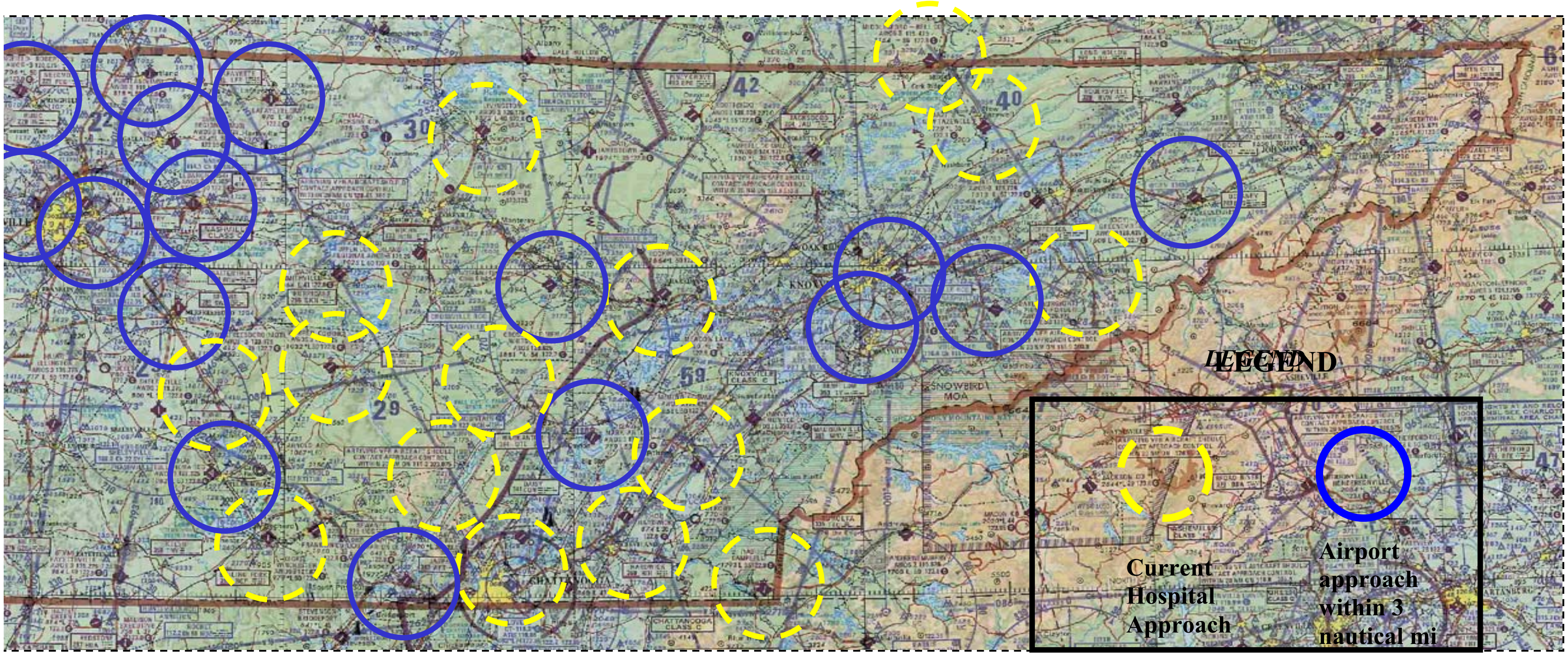


Figure 2.3 Current Hospital Helipad Approaches

Most of these approaches would terminate at a helipad approved by Tennessee Department of Transportation-Aeronautics division. A state-certified helipad is a 20 foot by 20 foot helipad with an 8 to 1 approach angle. An obstruction free clear zone of 50 feet by 50 feet is also required (B. Hadley-Tennessee Department of Transportation, personal communication, March 2003). The FAA advisory circular (AC) for helipad construction and design is AC 150/5390-2. This Advisory Circular stipulates very stringent guidelines for helipad design which most hospital helipads cannot conform to because of cost and space/obstruction constraints.

Approved helipads are identified in *Figure 2.4* with bold "H's". There are currently 100 approved hospital helipads in Tennessee and 67 approved helipads in the research area. From the weather data collected, there would only be five to six days a month that had some portion of the day with weather less than most non-precision approach minimums. The locations for these instrument approaches are tentative and are not surveyed. The criteria described in the U.S. Standard for Terminal Instrument Approach procedures, TERPS, analyzes the topography, obstructions, and noise-sensitive areas around a facility requiring an approach. From this information, appropriate altitudes, and headings, as well as limitations for an approach, are developed (AIM/FAR 2002).

The actual development of FAA-approved instrument approach procedures is a detailed complicated process and is beyond the scope of the study. The locations specified in *Figure 2.4* are approximate locations and would be adjusted as required to obtain airspace and obstruction clearance requirements as specified in U.S. TERPS.

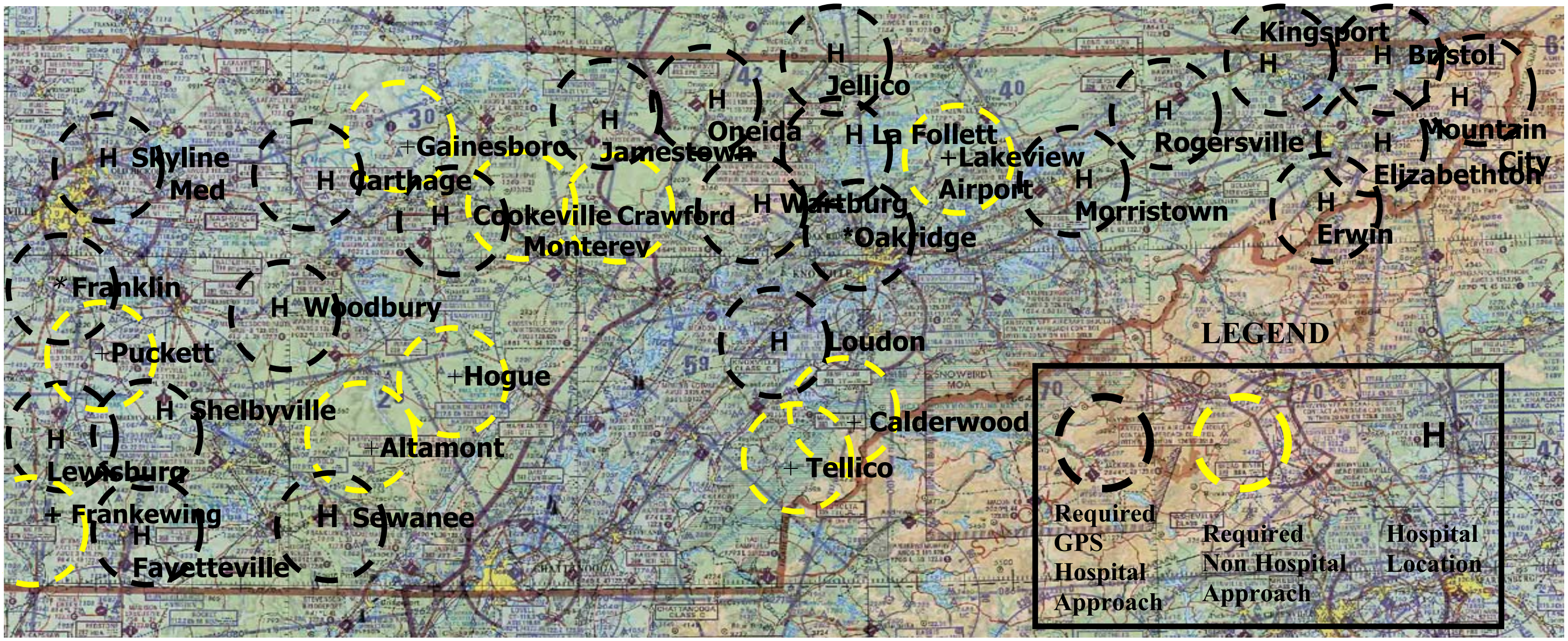


Figure 2.4 Required Approaches

Hospital helipad GPS approaches developed by companies like Satellite Technologies Implementation are the property of the hospital or EMS air ambulance operation which funds their development. Only the members of the organizations which fund these approaches are authorized and certified to use these approaches. These approaches are not in the public domain and as such are not always available to public servants or other EMS operators.

Approaches to Non-Hospital Areas

In addition to the approaches that would be required into certified hospital helipads, there would be ten approaches to remote areas which would be based either on small airports or in and around small remote communities. The instrument approach procedures at remote locations other than hospitals or airports may be the most problematic approaches to develop because there may not be any associated infrastructure with the approach. These procedures would indeed be true point-in-space instrument approaches. In this research, the effort was made to locate these approaches with existing civil infrastructure such as park ranger stations, and law enforcement and or military facilities. These approaches are ringed in a lighter color in *Figure 2.4*. By combining the currently available approaches and the additional, required approaches the coverage area would resemble that depicted in *Figure 2.5* and would provide the desired 95% coverage. As was mentioned previously, a cost-benefit analysis would indicate the true necessity of these approaches.

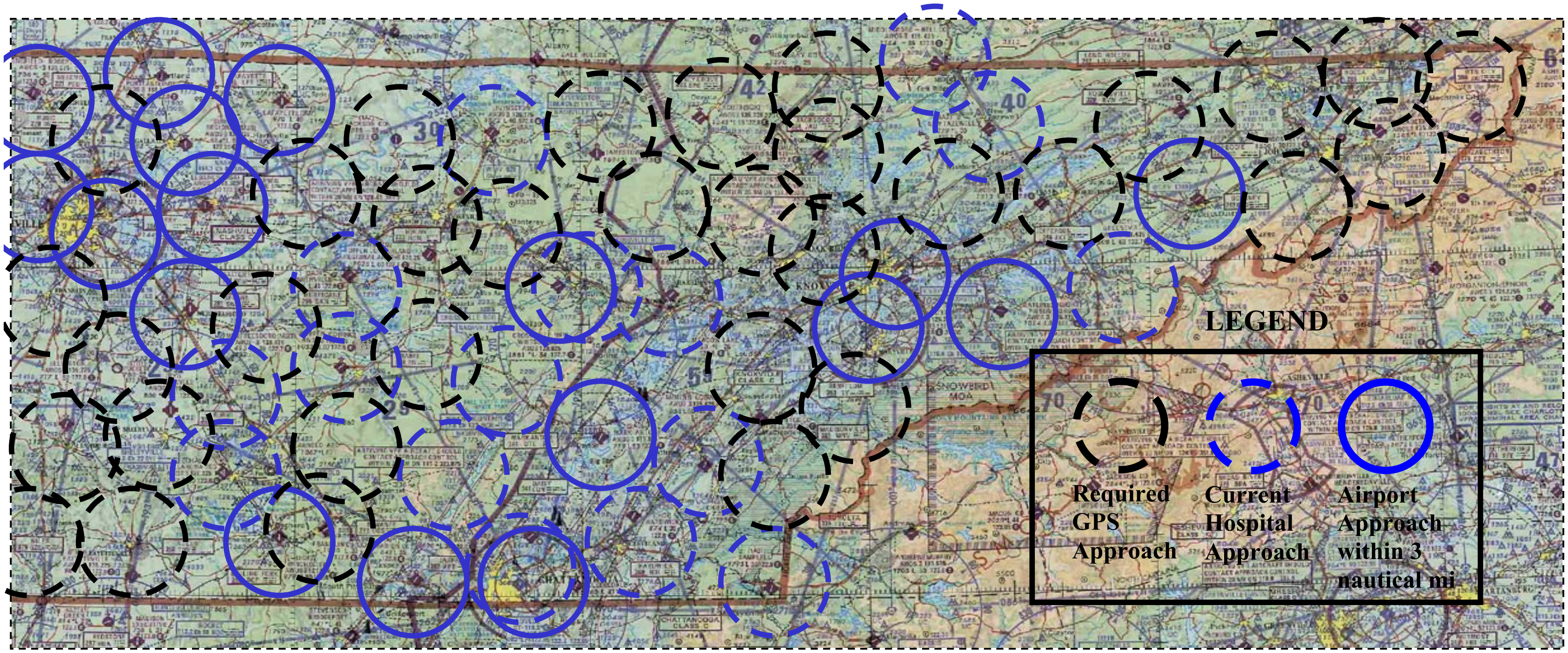


Figure 2.5 IFR Coverage

Costs

The ability to implement an integrate instrument network is now feasible because the cost to implement and operate a GPS approach is significantly less than that for a conventional NAVAID-based approach. The cost to develop one instrument approach is between $5,000 and $11,000 dollars. A flight check of the approach procedure requires an additional $2800 to $4300 (National Aeronautics Charting Office). The true savings is found in the upkeep and maintenance of the approach. The cost of recurrent flight checks is approximately $1800 to $2850 annually. This is significantly lower if a commercial entity develops the approach instead of the FAA. The financial burden for upkeep and maintenance is close to non-existent for GPS/RNAV approaches while it can be prohibitive for conventional approaches. From this study, it is determined that 33 new approaches are required. Using the most conservative values this would cost the funding agency approximately $504,900. This rough order of magnitude estimate constitutes a relatively small investment for the benefit of improvements in healthcare as well as IFR disaster relief capability for the majority of the state. Additional costs would be associated with helipad construction, obstruction surveys and environmental impact reports. Another unknown cost is the amount of money that would be required to accomplish a commercial buy-out of the approaches that have already been developed by EMS operations in the area.

CHAPTER 3

LEVERAGING AVIATION TECHNOLOGY FOR BETTER HEALTHCARE

Several emerging technologies would enable an IFR network to be even more advantageous to EMS users. Fortunately, test projects by the FAA in Alaska and the Gulf of Mexico are already utilizing these technologies. Capstone, a ground-breaking project in Alaska, incorporates many concepts that would prove useful in a future network in Tennessee.

Capstone

Capstone is a project of the FAA which is a test-bed for the implementation of National Airspace System (NAS) architecture 4.0. Capstone is being conducted in the Yukon-Kuskokwim (YK) delta and consists of outfitting local aircraft with compatible IFR avionics. The location was selected due to the high number of aviation accidents in that area. The avionics provided to participating aircraft are an IFR-certified GPS navigation receiver, a moving map display, and a multifunction color display. Capstone will include a ground infrastructure for weather observation, data link communications, and flight information services (FIS) (FAA "Capstone"). In addition to outfitting more than 200 aircraft with a similar avionics suite, the project involves the development of a ground-based infrastructure for weather observation data link communications, surveillance, and flight information services (FIS). The system has performed well to date. Ninety percent of the aircraft in the YK delta are equipped with the Capstone avionics suite. Phase I of Capstone did not involve helicopters.

Phase II of Capstone is located in southeast Alaska and began in 2001. This more advanced proof-of-concept incorporates highway in the sky navigational guidance through the use of an advanced electronic flight information system (EFIS). By using WAAS and GPS/RNAV, Capstone Phase II incorporated a new set of en-route IFR altitudes for low level flight (FAA "New Technology"). Because ADS-B does not need line of sight for NAVAID reception, these altitudes are lower and allow access to more airspace for IFR operations.

Capstone Phase II expects to outfit 50 helicopters with GPS/ADS-B technology. The EMS network proposed in this paper would be a viable candidate for similar integration of emerging FAA technologies. ADS-B is one aspect of both Capstone and the operations in the Gulf of Mexico which would be particularly useful in an EMS environment.

ADS-B

Automatic Dependent Surveillance-Broadcast (ADS-B) is a surveillance system similar in function to current transponder and Mode C systems. ADS-B enables pilots and controllers to have an accurate three-dimensional picture of airspace and other aircraft. The system transmits position, velocity, and identification of the aircraft to pilots and air traffic controllers. A common three-dimensional picture of the airspace enhances safety and is a cornerstone of the future free-flight environment. Unlike current transponders and Mode C which require radar and line of sight, ADS-B does not require radar. ADS-B utilizes GPS and digital data-links to provide accurate flight information to pilots and controllers. The ADS-B transceivers transmit the information via digital data-link to ground stations. If ground stations are not available then the data is transmitted directly to satellites. This information is relayed to air traffic controllers and other aircraft.

The FAA in 2002 decided on the two primary hardware components of the ADS-B architecture. One transceiver is for high performance aircraft and the other is for general aviation aircraft. These avionics will be the backbone of the new free-flight infrastructure in the years to come. The decision was in response to a request from the Radio Technical Committee on Aviation (RTCA) free flight steering committee (FAA "FAA announces ADS-B Architecture" 2002). ADS-B works at low altitude and in areas which have little or no radar coverage. This makes ADS-B uniquely suited for the instrument helicopter EMS mission profile.

IFR Grid Network

An integrated instrument network could also expand and evolve into an associated en-route structure such as that in use in the Gulf of Mexico and in the Capstone project in Alaska. Reach Air Ambulance in California has developed a route structure for their system of IFR approaches. In 1999 STI developed a series of off-airway GPS routes for Reach Air Ambulance. These routes were the first stand-alone helicopter GPS routes approved by the FAA (Satellite Technology Implementation "STI Accomplishments and Services"). Portions of this structure are in uncontrolled low altitude airspace. Apparently, the infrastructure developed by STI has proven quite effective.

A major initiative by the FAA was the Gulf of Mexico IFR grid system initiated on October 8, 1998. A project of the FAA's Southwest Region and the Helicopter Safety Advisory Committee (HSAC), it is the world's first IFR grid system and does not use traditional ground-based navigation aids. Instead, the grid system incorporates a semi-free-flight environment with over 300 waypoints allowing aircraft to file IFR to the multitude of offshore helipads in the area. These waypoints use an innovative naming convention which provides for ease of filing. The first three letters designate a geographical area or VOR in the area. The next identifier designates the column in the set either L for left, R for Right, or C for center. The last identifier designates the row. There are just four flight segments required under this system. The required segments are a departure point, a first en-route grid point, a last en-route grid point that corresponds to the start of the instrument approach procedure, and finally a destination point (Karanian 1998).

An IFR grid system would dramatically reduce IFR flight and filing times. A similar grid system would prove very useful in an EMS IFR type network like the one proposed in this document. This would allow for quick direct-route filing to numerous destinations without the cumbersome ground based IFR infrastructure.

Precision Instrument Helicopter Approaches

Precision approach procedures provide vertical guidance during an instrument approach through the use of a glide slope, allowing descents to altitudes lower than current non-precision approaches. By using Local Area Augmentation (LAAS) GLS approaches would significantly lower approach minimums for helicopters. Research into exactly how low these approaches could descend is ongoing. From the weather data presented earlier, the use of these approaches for helicopter helipads may not be required.

Additional research into how to develop precision GPS approaches into helipads is warranted.

Lighting

One critical aspect of helicopter instrument approaches where additional research is needed is in the area of approach lighting systems. Approach lighting systems used at airports for fixed-wing aircraft are not feasible for small hospital helipads or point-in space-approaches. Currently, few approved approach lighting system for helicopters are available. One system, known as the Helicopter Approach Lighting System (HALS), is rather large, expensive, and would not be suitable for most small hospital helipads. *Figure 3.1* demonstrates the size and complexity of HALS.

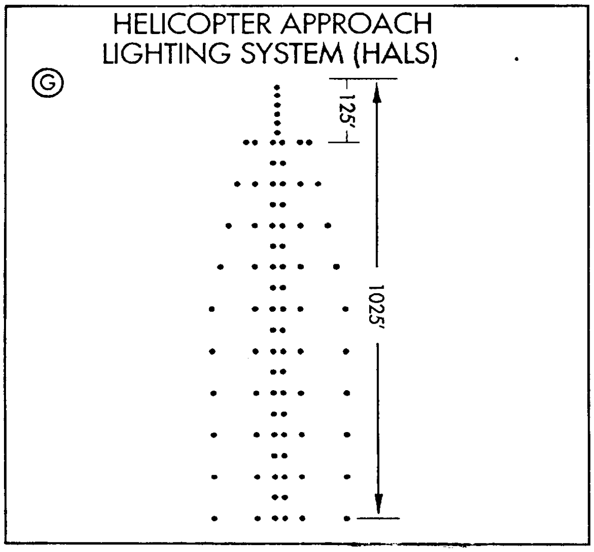


Figure 3.1 HALS

Source: U.S. Department of Defense. (2003). *Flight Information Handbook-Effective 12 Jun 2003*. St. Louis, MO: National Imagery Mapping Agency.

Another system Helicopter Instrument Lighting system (HILS) is designed primarily for non-precision instrument approaches. HILS is smaller, but would still not be very suitable for hospital helipads.

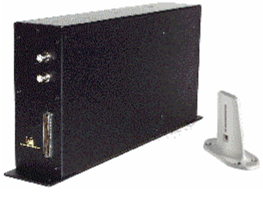
Not only would the IFR system discussed in this thesis be extremely useful in daylight instrument conditions, but it would also be useful during night flight operations. Research done by the University of Tennessee Space Institute in the area of helipad lighting and helicopter GPS approach lighting resulted in an innovative lighting system used during the Olympics in Atlanta and at U.S. National Park Service helipads in Washington D.C. The results of this study determined that helipads with blue-green lighting in the 525 nanometer frequency range were much easier to detect than the amber lighting currently used on helipads. The amber color tends to readily blend into city lights which are similar in color. Another finding of this study was that most of the lighting aids should be positioned on the non-approach side of the take-off and landing area (Kimberlin 1997).

Helipads could be outfitted with new lighting thereby increasing their visibility in inclement weather. By implementing advances in lighting, the safety factor associated with the approaches would increase dramatically. Additionally, advances in lead-in lighting or precision VFR would help improve the safety of the short VFR transition from a local airport or a point-in-space approach to the hospital helipad.

Affordable IFR Avionics

Probably one of the most difficult aspects of implementing the technology described in this document is to make it affordable for the user. The avionics suite utilized in CAPSTONE Phase I cost $15,000 to $20,000 per aircraft (FAA "Capstone Frequently Asked Questions"). The price should drop dramatically following implementation, but will probably still be relatively expensive. The CAPSTONE I avionics suite consists of a transceiver for ADS-B, a multi-function display (MFD) to display terrain, flight information and weather and lastly a GPS receiver (FAA "Capstone Frequently Asked Questions). A picture of the avionics used in CAPSTONE is shown in *Figure 3.2.* The technical specification order for a GPS receiver with the capability to conduct GPS instrument approaches is TSO C-129 (*FAR/AIM* 2002). Unless the needed avionics are relatively inexpensive, or are publicly funded, it could prove difficult to convince EMS services to adopt instrument flight into their operations.

Multifunction Display MX-20



UAT
Universal Access Transceiver

GPS Receiver CX-60

Figure 3.2 Capstone Avionics Suite

Source: Federal Aviation Administration. (n.d.). *Capstone Program*. Retrieved March 29, 2003, from http://www.Alaska.faa.gov/capstone/Capstone.htm .

Highway in the Sky

Highway in the Sky (HITS) is an effort by NASA and members of the aviation industry to develop a virtual highway in the sky. HITS will allow the average person to fly in small, safe, affordable, easy-to-fly aircraft. The HITS team is developing highly intuitive, low-cost flat panel displays that will replace conventional aircraft instrumentation. This program should reduce pilot workload in all weather conditions. The research was meant as a boost to the General Aviation community but, low-cost glass cockpit instrumentation will undoubtedly have applications in the helicopter industry and especially in EMS helicopter operations (Braukus 1999).

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Low cloud ceilings and low visibility conditions currently prevent or hamper air ambulance operations from providing their services to many remote locations. The compelling question driving this thesis is how and where GPS IFR approaches need to be placed in order to provide comparable healthcare to more rural communities. The object of this research was to determine locations of non-precision helicopter GPS instrument approach procedures so that 95% of the Middle and East Tennessee region could be served by IFR-certified EMS air ambulance operators during instrument meteorological conditions (IMC).

A helicopter GPS IFR network would be irreplaceable in emergency management situations or disaster relief operations. This system could provide all weather disaster capability to federal and state emergency management personnel. The network would be useful to the National Guard helicopter assets and state officials in the event of a natural disaster or possible terrorist attack. Current GPS approaches to helipads are private and may or may not be immediately available to local authorities during an emergency. It is irresponsible to allow a haphazard commercial based system to set the standard and effect healthcare of the people of the state of Tennessee. For a relatively low cost, the citizens of Tennessee could receive better access to healthcare and be at the forefront of aviation technology.

In the final analysis, the best way to implement an instrument approach network would be by funding an experimental instrument network in the Middle and East Tennessee Area. The helipad locations specified in *Figure 2.4* are approximate positions for 33 required instrument approach procedures. The network would provide the Middle and East Tennessee area 95% IFR EMS coverage within specified weather and distance constraints.

Recommendations

Based on the research conducted during this thesis, the author recommends that a government entity, either state or federal, fund a program to implement an experimental low-level IFR GPS approach network in Middle and East Tennessee. The focus of this would be on providing GPS approaches to airports within three nautical miles of a hospital with approved helipad or developing GPS approaches directly to hospital helipads. The locations presented in *Figure 2.4* would require the development of new instrument approach procedures. The network could expand to encompass the entire state after a suitable validation period as well as eventually involve a low altitude en-route structure. The following steps must be taken in order to implement this proposed network.

1. An in-depth study of the areas that require approaches must be initiated to check obstruction clearance requirements and ensure feasibility of approaches into the areas specified in this report.
2. Stakeholders would have to be in agreement as to the need and composition of the system.

3. Funding must be appropriated. How and where this funding comes from would be a matter of intense debate.
4. A commercial entity should be contracted to develop the approaches. Commercial development of these approaches would be preferable to ensure timely development of such a system.
5. A suite of relatively low-cost avionics should be developed and approved for helicopter use as well as agreed upon as satisfactory by the EMS users.

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VITA

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