To the Graduate Council:

I am submitting herewith a thesis written by Kathy Michele Wallace entitled "Corrective Measures for Inadvertent Helicopter Flight into IMC." I have examined the final 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.

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CORRECTIVE MEASURES FOR INADVERTENT HELICOPTER FLIGHT INTO IMC

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Kathy Michele Wallace
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DEDICATION

This thesis is dedicated to my parents

Mr. Larry Wallace

and

Mrs. Melissa June Wallace

whose love and support made this possible.

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Abstract

Helicopters have become a vital means of transportation today. Unfortunately, as the number of helicopter operations have increased so have the number of accidents. Most of these accidents are the result of inadvertent flight into instrument meteorological conditions (IMC). The purpose of this study is to find out why these accidents happened and how they can be prevented in the future.

This study included a review of all pilot error helicopter accidents from 1979 until 1994. Findings showed that most of the inadvertent IMC accidents where the result of spatial disorientation and/or collisions with obstacles.

To get to the root causes of the accident certain areas were investigated. These areas include: human factors of helicopter flight, pilot training methodology, and the National Airspace System.

Human factors such as fatigue, stress, and workload play a significant role in these accidents. Pilots that are fatigued and stressed for whatever reasons often find it difficult to make decisions concerning the flight.

Another root cause of these types of accidents is inadequate pilot training. Effective helicopter pilot training in the United States is minimal. Helicopter pilots are not being trained to deal with the challenges of helicopter flight. Over the past few years, programs have been developed to help increase pilot situational awareness. Unfortunately these programs are costly and are not offered to all helicopter pilots.

Finally, the National Airspace System was created for fixed wing airplanes. As the complexity and needs of the airplane have changed, so has the National Airspace System, but not for the benefit of helicopters. For the last 50 years, regulations for helicopters and helicopter operations have not change significantly, while helicopters have improved. Included in the National Airspace System are such topics as: weather minimums, navigational aids, radio communication, and aircraft certification. Until changes are made to this current system, the accident rate may not decrease.

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LIST OF ABBREVIATIONS

ATC	Air Traffic Control
EMS	Emergency Medical Service
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FSS	Flight Service Station
GA	General Aviation
GPS	Global Positioning System
HAI	Helicopter Association International
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
MEA	Minimum Enroute Altitude
MOCA	Minimum Obstacle Clearance Altitude
NAS	National Airspace System
NWS	National Weather Service
NEMSPA	National EMS Pilot Association
NTSB	National Transportation Safety Board
VFR	Visual Flight Rules
VHF	Very High Frequency
VOR	Very High Frequency Omni-directional Range

CHAPTER I

INTRODUCTION

Who would believe that the helicopter that Igor Sikorsky flew in 1939 would develop into a vital means of transportation? Today commercial helicopter operations range from transporting patients, to herding cattle, and even to stringing power lines in mountainous areas. The helicopter's unique characteristics, including slow speed, hover and vertical flight, make it an invaluable means of transportation.

Unfortunately the increase in the number of helicopter operations has caused an increase in the number of accidents. Helicopter accidents surpass general aviation (GA) fixed wing accidents by more than 40%, the alarming fact is that 30% of the GA fixed wing pilots have considerably less flight time than the helicopter pilots.[1] During the last fifteen years restricted visibility has been the main culprit of helicopter weather related accidents.[2] It has been estimated that emergency medical service (EMS) pilots fly inadvertently into instrument meteorological conditions (IMC) on the average of 1.3 times a year.[3]

The goal of this study is to provide an understanding of why inadvertent IMC accidents occur, so that solutions to this problem can be developed and eventually implemented. Contributing factors to these accidents include: the human factors of helicopter flight, the lack of adequate pilot training, the problems associated with the National Airspace System (NAS), and the requirements for helicopter IFR certification.

Current training programs available to helicopter pilots do not include many of the necessary ingredients for safe helicopter flight. Many pilots are flying unaware that the human body has certain limitations, especially during instrument conditions and at night. Factors such as stress and fatigue significantly affect the pilot decision making skills and motor skills. Management and employers often increase the level of fatigue by imposing demanding schedules and creating unattainable goals. In addition, flight instruction does not always prepare the pilot for the challenges that he is likely to encounter at lower altitudes.

Helicopters are able to be operated effectively in the NAS, however when they do the full potential of the helicopter is not being realized. When pilots choose to operate at altitudes below the minimum enroute altitude, navigation and communication are difficult, if not impossible. This significantly increases the pilots workload since he must be aware of his position at all times.

Another area that contributes to inadvertent IMC accidents includes the current regulations. It appears as though the current Federal Aviation Regulations (FAR) discourage helicopter instrument flight. This is because the Federal Aviation Administration (FAA) has imposed confusing regulations on the helicopter community. For example, the certification requirements for helicopters used in instrument flight rules (IFR) are stringent, while the altitude and visibility requirements for visual flight rules (VFR) flight are relaxed.

CHAPTER II

BACKGROUND

The reason for undertaking this study is to help reduce the number of inadvertent IMC accidents by increasing the awareness of the problem. The industry has many different viewpoints as to why experienced helicopter pilots with a mean flight time of 5500 hours find themselves flying inadvertently into instrument weather.[4] But one thing remains clear; all involved would like to see the accident rate decrease. Bringing attention to the types of accidents and understanding why they occur will help in reducing the number of inadvertent IMC accidents.

2.1 Inadvertent IMC Resulting in Spatial Disorientation

In 1988, the National Transportation Safety Board (NTSB) conducted a study of 59 EMS helicopter accidents. Of these 59 accidents, 15 were the result of the pilot becoming spatially disorientated after penetrating adverse weather; 11 of these accidents were fatal.[5] This sections includes an analysis of one such accident and the current efforts being made to rectify this problem.

2.1.1 Accident Scenario

On the night of 20 January 1985, an EMS configured Bell 106L-1 (Longranger) took off from a hospital helipad in Carson, New Mexico to pick up a patient. The weather report at the time of flight indicated a 100 foot overcast ceiling with 3 miles visibility and fog. After inadvertently flying into the weather, the pilot failed to maintain directional control and crashed into the terrain next to a power line. The pilot and two medical personnel where fatally injured. The pilot held an Airline Transport Pilot rating and had 14,000 hours in both helicopters and airplanes. He had more than 1500 hours in this particular helicopter.[6]

Human error was cited as the cause of this accident. The pilot exercised poor judgment in undertaking the flight. The pilot was unable to maintain aircraft control as a result of spatial disorientation.

EMS pilots face many stresses associated with their jobs. Chapter 3 contains a more detailed discussion of these stresses and their effects. Poor decision making and impaired judgment are usually the result. Initial training programs and recurrent training programs that deal with these issues and address the human factors problems will reduce this type of accident.

2.1.2 Flight Safety International's EMS Training Program

Flight Safety International has recognized the challenges associated with EMS helicopter flight and has created a safety program for EMS pilots, entitled: "Handling Clouds and Stress". Joel Harris, chief flight instructor for Flight Safety International, heads up this program. The program runs for four days and addresses issues such as: night flying, weather, spatial orientation and illusion, EMS flight hazards, and the problems associated with flying into confined areas. In addition to classroom time, pilots spend nine hours in a Sikorsky S-76 simulator where they are taught how to survive inadvertent IMC. Harris says that this course offers the only specialized training that EMS pilots receive.[7]

2.1.3 "Heliprops" Program

Bell Helicopter, with the help of the FAA, Aircraft Owners and Pilots Association, Helicopter Association International (HAI), Ohio State University, and Systems Control Technology and Transport of Canada, has also performed research in this area. They have developed a program entitled "Heliprops" to increase safety awareness. The focus of this effort was to study the human factors aspects of helicopter accidents. Findings showed that decision making training can reduce pilot mistakes up to 50%. Bell Helicopter strongly recommends that pilots and employers take advantage of all available training programs.[8]

2.2 Inadvertent IMC as the Result of Scud Running

The current regulations have made helicopter IFR certification difficult. Many companies and helicopter owners choose not certify their helicopters for IFR flight because of the time and cost involved. Often times pilots choose to scud run, that is, they fly at lower than normal altitudes to avoid deteriorating weather. This section includes a look at a scud running accident and attempts to explain how the regulations practically dare pilots to take the risk.

2.2.1 Accident Scenario

A helicopter pilot was asked to transport a piece of equipment to a location approximately 150 miles from his home base. The pilot obtained a weather briefing at midnight that indicated deteriorating weather along his chosen flight path. The pilot departed at 3:00 a.m. ignoring the warnings of poor weather. He made initial contact with the Air Force Tower and a police helicopter. He told them that he intended to follow the highway at a low level to stay below the weather. The helicopter impacted a 75 foot tree at the 50 foot level about 135 miles from his home base. The pilot had 3166 hours of helicopter time with 135 in that particular make and model.[9]

This is another accident that occurred as a result of poor pilot judgment. Because the helicopter has the ability to fly at slow airspeeds and at low altitudes, the pilot believed that he could avoid the weather. This attitude is far to common and is extremely dangerous.

2.2.2 IFR Certification for Helicopters

The logical solution to reducing scud running is to certify helicopters and pilots for IFR and incorporate them into the National Airspace System. Parts 27 and 29 of the Code of Regulations incur a large design and cost penalty for helicopter manufacturers who wish to certify their helicopters for IFR flight. In fact, the requirements for certifying a helicopter for IFR flight are more complex then the requirements to certify a fixed wing aircraft for IFR flight. Chapter 5 contains a full explanation. In most cases certifying a helicopter for IFR flight may require extensive modifications. The University of

Tennessee Space Institute was recently involved in an IFR certification of a McDonnell Douglas MD-369E. The owner, a cardiac surgeon who provides continuing education for surgeons around his home state, wanted the helicopter certified for single pilot instrument flight so that he could fly to his lectures. This particular helicopter required significant modifications that cost approximately $100,000 and took two years to complete.[10] "These modifications include:

1. Modification of the center instrument console to place all avionics within reach of the pilot in the upright sitting position.

2. Installation of an emergency electrical bus and a second aircraft battery. this battery installation was so designed that it could be used to provide additional electrical power for starting the engine. The emergency bus automatically shed load upon being selected.

3. Installation of a dual pitot-static system: one for the aircraft systems and one for the autopilot.

4. Installation of a stand by attitude indicator that met the requirements of FAR Part 27, Appendix B.

5. Reduction of the size of the center of gravity envelope and reduction of the maximum altitude approved for single pilot IFR to provide the required static stability.

6. Establishment of IFR airspeeds.

7. Installation of a radio select switch on the collective control.

8. Installation of a second inverter.

9. Modification to the autopilot to allow independent operation of the yaw SAS."[11]

The doctor can now fly his helicopter without fearing what the weather will hold.

2.2.3 Part 135 Weather Minimums

An increase in the current weather minimums would help reduce scud running and would increase the number of IFR certified pilots and helicopters. Raising these current visibility minimums is of concern to many people in the helicopter industry. In fact, Dan Norman, Chief Pilot for Erlanger Medical Center, addressed this same issue in a letter to the FAA, dated 11 December 1986.[12] He urged the FAA to increase these minimums, saying that it would encourage IFR helicopter flight. The NTSB supports this argument and has made similar recommendations. Additionally, the NTSB believes that the current alternate airport regulation that requires enough fuel for flight to the destination airport and alternate airport, plus 30 minutes reserve increases the problem.[13] They feel this requirement is too restrictive for helicopters because it does not consider that helicopters are relatively slow aircraft and have a limited endurance due to high fuel consumption.

The Helicopter Association International encourages EMS operators to enforce their own minimums since the FAA has not made the recommended changes. They propose the following altitude minimums for safe VFR operations:

Table 1. HAI Minimum Altitude Recommendations[14]

	Above the Ground	Horizontal Distance
Day - Local (25 miles)	500 feet	1 mile
Day - Cross Country	1000 feet	1 mile
Night - Local (25 miles)	800 feet	2 miles
Night - Cross Country	1000 feet	3 miles

2.3 Safety Programs in Action

The NTSB visited two EMS programs located in the mountains that have chosen to certify their helicopters and pilots for IFR flight. Both EMS operators feel that the benefits definitely outweigh the cost. Pilots are safely able to transport patients that they otherwise would not have been able to do.[15]

2.3.1 EMS Program 1

The first EMS operation is located in a mountainous area of Tennessee. It operates two IFR certified Bell 222's. The operator says that 23% of flights are scene related, while 77% are interfacility transfers; 32% of these flights involve some IFR flying. In order to insure safety, management has set the following VFR weather minimums:

day - 800 foot ceiling and 2 miles visibility
night - 1000 foot ceiling and 3 miles visibility.

Management stresses that if there are any questions as to the flight being completed VFR, an IFR flight plan is to be filed. This is easily achieved, since a desktop computer containing all pertinent information for the flight, including most common routes, has been installed. To obtain weather information along a specific route the pilot simply needs to identify the route.

A typical flight scenario at this operation involves patient transfers from a remote hospital. If IFR conditions exist then a flight plan is filed. The facility requesting the transfer prepares the patient while the helicopter is enroute. If weather permits, the pilot cancels the flight plan and lands at the hospital helipad. If weather does not permit, the pilot continues the flight as planned to the local airport, where the patient arrives by ambulance.

This program also uses IFR flight plans for segments of flight. For example, a small city hospital on the other side of the mountain makes a patient transfer request. Often weather is good on either side of the mountain, however, fog prevails on the mountain range. The pilot files a flight plan, crosses the mountain and descends under Air Traffic Control (ATC) until he reaches VFR. He then cancels the flight plan and continues the flight VFR. The same is done for the reverse trip.[16]

Since 32% of the flights encountered by this operation involve some sort of instrument flight, it seems that IFR capability is an asset to this operation. The program administrator feels that many of these flights could not be made safely without this capability.

2.3.2 EMS Program 2

The second EMS operation is located in the Rocky Mountains. This program operates a Bell 222 and a Bell 206, both certified for IFR. Management has also set their own VFR weather minimums, listed below:

Local flight:
- day: 500 foot ceiling, 1 mile visibility
- night: 800 foot ceiling, 2 miles visibility

Cross country flight:
- day: 500 foot ceiling, 2 miles visibility
- night: 1000 foot ceiling, 3 miles visibility.

Again, pilots are required to file a flight plan if these weather minimums cannot be maintained.

Typical weather conditions in the winter are the result of temperature inversions. Usually IFR conditions prevail at the surface, but at altitude VFR conditions exist. Therefore this program uses flight plans as a means to get to altitude and climb through the inversion layer.[17]

The company president feels that certifying the helicopter for IFR and having instrument rated pilots is not only beneficial, it is mandatory. He says that pilots do not always have to fly into the cloud to lose ground reference, and his pilots are able to face these challenges.

CHAPTER III

HUMAN FACTORS

In today's helicopter environment, pilot error makes up roughly 67% of all helicopter accidents.[18] This is most likely a result of inadequate training and lack of IFR certification requirements for helicopter pilots.

When a pilot chooses to "scud run" he increases the likelihood of flying into deteriorating weather. If an understanding of what motivates the pilot to make risky decisions can be gained, then solutions to the problem can be explored. In addition, it is important for pilots and employers to be knowledgeable about the effects of human factors such as fatigue, stress, spatial disorientation, excessive workload, and visual deficiencies.

3.1 Fatigue

Throughout the years, fatigue has remained one of the greatest hazards to the safety of helicopter flight.[19] It can severely impair the pilot's decision making, judgment, motor skills, visual perception, and coordination.[20] Improving working conditions can help to reduce the level of pilot fatigue.

There are two types of fatigue that pilots generally experience: acute fatigue and chronic fatigue. Acute fatigue is usually the result of a poor night's rest or pressures associated with everyday life. Characteristics ordinarily associated with acute fatigue include: errors in timing, need for greater stimuli, neglect of secondary tasks, loss of accuracy, and an unawareness of error accumulation.[21] Chronic fatigue, on the other hand, is much more serious. It is usually caused from lack of sleep and excessive mental and physical activity.[22] Symptoms common to chronic fatigue include: insomnia, depression, irritability, poor judgment, and slowed reaction time.[23]

Of all helicopter pilots, EMS pilots experience the highest level of fatigue. This is primarily due to their demanding schedules. Because EMS operations provide around the clock service, 365 days a year, shift work is necessary. This type of work often disrupts a persons normal sleep patterns, thereby inducing fatigue. Studies show that many EMS pilots work shifts in excess of 24 hours, some as high as 72 hours.[24]

When a pilot inadvertently enters inclement weather, his workload significantly increases. If the pilot has just worked a 24 hour shift with little rest, chances are he is experiencing a high level of fatigue; thereby reducing his decision making skills. The likelihood that this pilot would escape an encounter with deteriorating weather after working his shift is slim.

Because pilots are poor judges of when they are experiencing fatigue, the National EMS Pilots Association (NEMSPA) has set guidelines for EMS operations. NEMSPA recommends that pilot work shifts no greater than 12 hours and that there be a minimum of four pilots on staff per aircraft.[25]

3.2 Stress

Stress effects the human body in much of the same ways as fatigue. Again, judgment is impaired and motor skills are greatly reduced. Pilot stress is often self induced, but work environment and employers can significantly contribute to the level of stress.

A study performed in 1980 to determine the typical helicopter pilot profile showed that pilots are usually goal-oriented and have a strong need for achievement.[26] Because of these traits, helicopter pilots often feel compelled to meet demanding schedules, complete flights as planned, and please employers, family and, peers; thereby inducing stress.[27]

Pilots working for EMS or Law Enforcement must often deal with emotional stress. For example, an EMS pilot is faced with the family of a dying patient and deteriorating weather. He must chose whether to risk his life and the crews life to save the patient or tell the family he is unable to transport their loved one. When the flight cannot be completed the pilot may be faced with feeling of guilt and failure.

Employers often add to pilot stress. Unaware of the rigors of flying, they often set unrealistic goals based on profit margin and time demand. As mentioned earlier, since pilots have a need for achievement, they take unnecessary risks, such as "scud running", to please the employer and get the job done.

3.3 Spatial Disorientation

Spatial disorientation is one of the leading causes of fatal helicopter accidents.[28] It is generally the result of a pilot losing the outside horizon, most often at night and/or in poor weather. Early detection of spatial disorientation increases the likelihood over coming it.

Spatial disorientation occurs when the brain receives conflicting information from the sensory organs. The sensory systems responsible for orientation are the visual system, vestibular or motion sensing system, and the propriocepter or position sensing system. The inner ear, which provides information to the vestibular system is the primary culprit of spatial disorientation.[29] Spatial disorientation can occur when a pilot initiates an accelerated turn to the right without reference to a fixed horizon. Upon reaching the desired heading the pilot attempts to bring the aircraft to wings level. Due to the unequalizing of the fluids in the inner ear, the pilot feels as though he is still in the turn and continues banking in the opposite direction.[30] Figure 1 shows the various sensations experienced with spatial disorientation.

Tests show that it takes an experienced, current instrument rated pilot approximately thirty-five seconds to shift focus from outside the cockpit to inside the cockpit and to reestablish control of the aircraft using the instruments. Since most helicopter pilots do not hold a current instrument rating, rarely are they able to overcome the effects of spatial disorientation after inadvertently flying into IMC.[31]

A typical scenario of spatial disorientation accident would involve a non-instrument rated pilot who flies into marginal weather. He inadvertently flies into a cloud and attempts to fly by his instruments. Because of his lack of training he allows his motion sensing organs to take over. He then becomes disoriented and ultimately crashes his helicopter into the terrain. This pilot could have overcome the effects of spatial disorientation if he had followed the guidelines listed below:

1. Rely on instrument indications and develop a good cross-check.

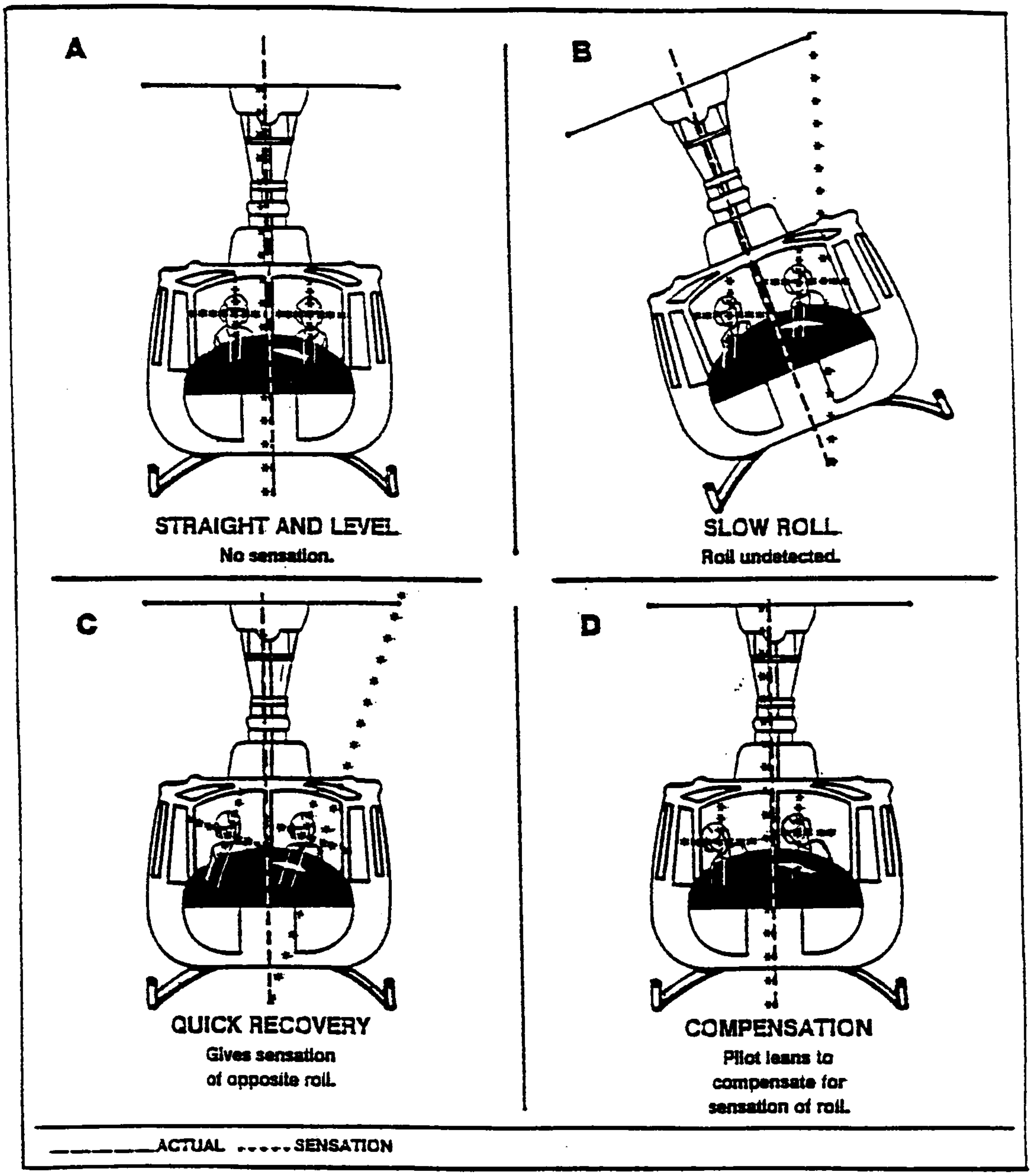

Figure 1. Comparison of Actual Attitude and Body Sensation in Various Angular Motions[33]

2. Never attempt to fly IFR and VFR at the same time.

3. Do not rely on intuitive actions until visual and instrument references are checked.[32]

3.4 Workload

A helicopter pilot has an extreme workload. He must deal with the typical cockpit duties, the unique flying qualities of the helicopter, and the obstacles outside of the helicopter. When poor weather is encountered the workload significantly increases due to lack of good visual cues.

Cockpit duties include: monitoring instruments and gauges, communicating with ATC, navigating, and flying the helicopter. Under VFR these duties are not too demanding, however when a pilot flies inadvertently into IMC demand on the pilot increases due to instrument limitations. Without outside visual references, maintaining attitude is difficult. This stems from the fact that the attitude indicator was designed for fixed wing aircraft and not helicopters. In a fixed wing aircraft the attitude indicator always indicates a nose down attitude during a descent and a nose up attitude during a climb. In helicopter flight this is not true. Depending on the speed of the helicopter, the indicator can provide false information. For example, in a descent the helicopter may be in a nose up position, however, the attitude indicator will shows climb. Figure 2 further shows the misleading information on the attitude indicator. A cross check of other instruments will help the pilot to get a sense of his true direction.[34]

The helicopter's unique flying qualities also increase the pilot's workload. Typically civil helicopters are inherently unstable. Therefore at airspeeds below 40 knots it is difficult to accurately fly the helicopter. It is likely that a pilot will slow the helicopter down to avoid entering a cloud. Eventually the helicopter will slow to the point that it will begin to back up. Due to directional stability the helicopter will tend to weather cock. This will cause the pilot to experience such severe spatial disorientation that it is highly unlikely that he will not overcome it. The addition of a stability augmentation system makes slow flight possible.

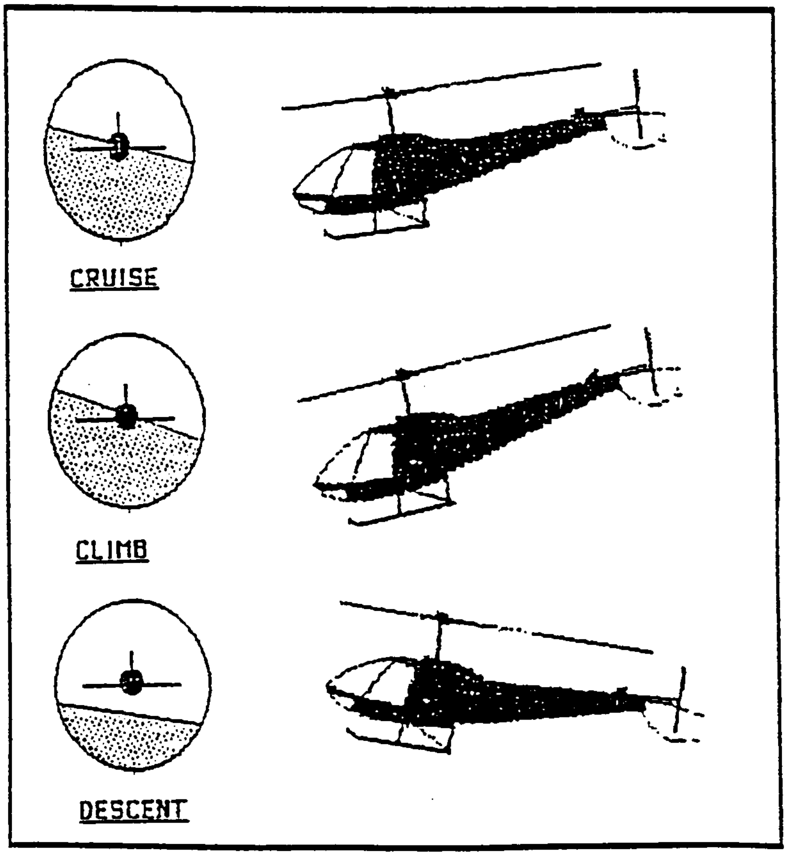

Figure 2. Misleading Helicopter Attitude Information[35]

Because the helicopter is most effectively used at lower altitude and slower airspeeds, encounters with obstacles are more likely to occur. Therefore a high level of situational awareness is required, when flying IFR. For example, assume that a pilot has flown into poor weather at a groundspeed of 20 knots. It will take the pilot approximately five seconds to realize that the aircraft must be stopped. The distance covered in this time is about 170 feet. Another 170 feet is required to decelerate the aircraft and bring it to rest. The pilot has just covered 340 feet of unknown territory that may include trees, powerlines, etc.[36]

As the number of factors increase so does the pilot's workload. Proper training can teach pilots how to deal with workload issues and increase the likelihood of overcoming the challenges faced when flying a helicopter inadvertently into IMC.

3.5 Vision

The primary sensory organ used in flight is vision. At night, vision is critically reduced. Understanding the limitations of the eye can better prepare the pilot for the illusions he may encounter.

3.5.1 Night Blind Spot

The night blind spot is the result of the loss of cone cell sensitivity in reduced light. It generally covers an area of five to ten degrees wide from the center of the visual field, as illustrated in Figure 3. It is likely that objects viewed directly may go unnoticed. As the viewing distance increases, so does the blind spot. Figure 4 shows that larger objects may go undetected at distances as short as 3000 feet.[37] The use of peripheral vision will allow obstacles to be viewed at night. This is of great importance to helicopter pilots flying at night since they are likely going to encounter obstacles.

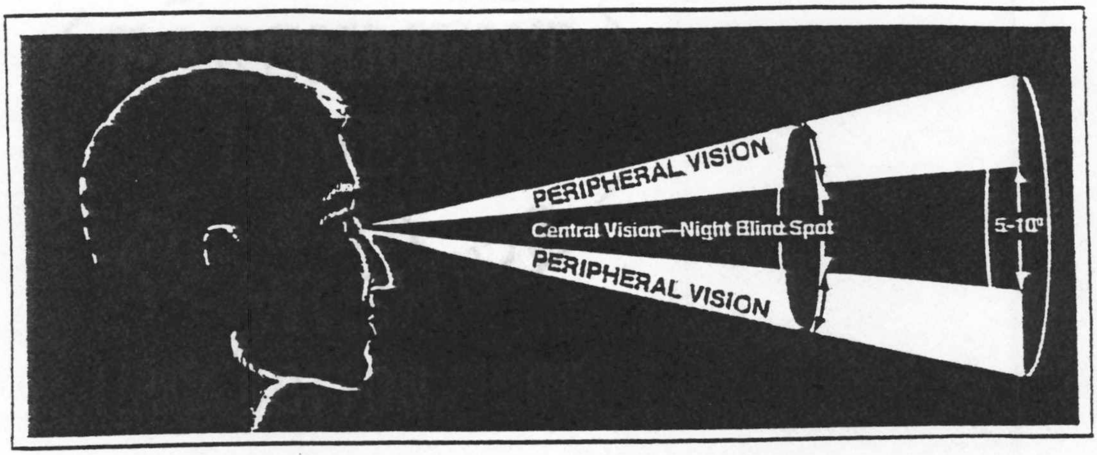

Figure 3. Night Blind Spot[38]

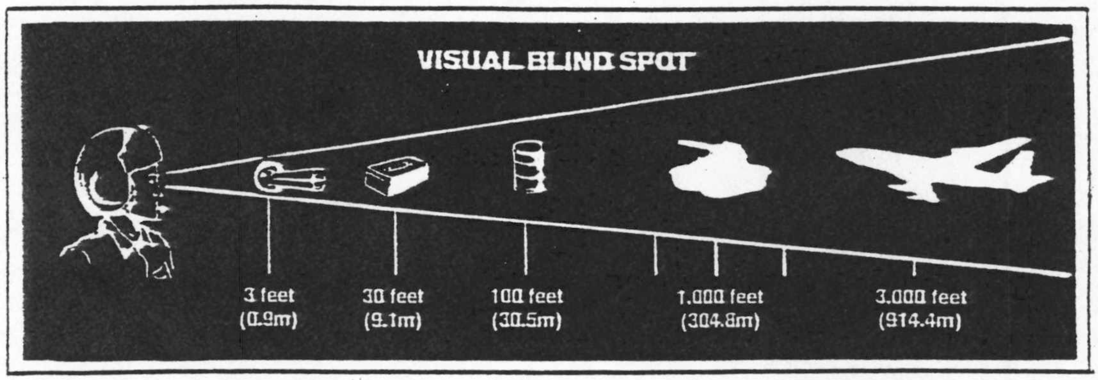

Figure 4. Effects of a Night Blind Spot[39]

3.5.2 Visual Illusions

Visual illusions are most prevalent at night and can give the pilot false impressions. These impressions increase the likelihood of spatial disorientation (section 3.3). Since pilots rely on outside references, an understanding of visual illusions is important for safe helicopter flight.

There are three illusions that a helicopter pilot flying at night is likely to encounter. They are as follows:

1. Because at night the pilot has little outside attitude reference, lights on the ground and stars can be mistaken for one another.

2. Due to a lack of a natural horizon cloud formations can be misinterpreted for a horizon.

3. Double vision can be induced when weather conditions such as rain, sleet, and snow prevail. For example, a wingtip light may appear as two lights when viewed through rain showers.[40]

3.5.3 Night Vision and IMC

At night clouds are difficult to see, it is then that pilots inadvertently enter IMC. As previously mentioned, deteriorating weather conditions increase pilot workload. This workload can be reduced if pilots are taught to be aware of changing conditions. Some of these conditions include:

1. A reduction in the level of light and a loss of visual acuity and contrast of the terrain.

2. The inability to see the moon and the stars.

3. Shadows being produced as the result of clouds obscuring the moonlight.

4. A decrease in the intensity of ground lights usually means that there is a presence of ground moisture.

5. Fog over water areas usually indicates that there is a small temperature/dewpoint spread and the possibility of ground fog exists.[41]

3.6 Summary

Fatigue and stress experienced by helicopter pilots are usually the result of pressures associated with work, family and peers. It is imperative that a pilot not let these pressures interfere with flying. When this happens, so do mistakes. Reducing pilot workload can help reduce stress and fatigue. With the help of employers and management, realistic goals can be set and work environments improved.

CHAPTER IV

PILOT TRAINING

Are pilots receiving adequate training? Given that the present criteria for helicopter training and certification were developed under the Civil Aeronautics Administration in 1946, the answer is most likely no. Considering that helicopter safety has not improved over the last 15 years, one would think that the FAA would set higher training standards.

After examining the human factors of helicopter flight, one would assume that training methods would examine methods for dealing with the challenges of helicopter flight.

4.1 Initial and Recurrent Training

Flight instruction in helicopters is lagging behind where it should be. In fact, the FAA requires that a fixed wing private pilot receive more instrument flight training than a commercial helicopter pilot flying at night.[42] This is mainly the result of a decline in training resources, a lack of interest on the part of the FAA, and an increase in training costs.[43]

Because of the dangers associated with helicopter flight and inadvertent IMC, an effective training program should consist of actual instrument training. Learning to fly at altitude under the simulated instrument conditions does not prepare a helicopter pilot for the challenges he is likely to encounter. As previously stated, when a pilot inadvertently enters IMC he must shift his focus from outside the helicopter to his instruments. Since the instruments can be misleading a great deal of skill is required. This type of skill can be acquired through training and practice. Additionally, a high level of situational awareness is required at low altitudes. Again this must be learned.

Initial and recurrent training should include a study of the human factors of flight. A pilot should have an understanding of how areas such as fatigue, stress, spatial disorientation, visual deficiency, and workload affect flying capabilities. Instruction needs to be given to help teach pilots to overcome the effects of spatial disorientation and visual illusions.

4.2 Behavior Modification and Judgment Training

Another important item to be included in a helicopter pilot training program is behavior modification and judgment training. In 1981, the NTSB Special Study attributed 40.8% of pilot related accidents to poor judgment.[44] Because pilots have that "stress for success" mind set, they often feel obligated to take unnecessary risks. Behavior modification and judgment training can teach the pilot to be able to identify hazardous thought processes and to replace them with safe thought processes, as suggested in Figure 6. This type of training can increase the pilot's awareness of dangerous situations such as "scud running". The two accidents cited in the background are prime examples as to why there is a need for this type of training.

HAZARDOUS ATTITUDE	SAFE ATTITUDE
ANTI AUTHORITY:	
"Don't tell me."	"Follow the rules, they are usually right."
IMPULSIVE:	
"Do something - quickly!"	"Not so fast, think first."
INVULNERABILITY:	
"It won't happen to me."	"It could happen to me."
MACHO:	
"I can do it."	"Taking chances is foolish."

Figure 5. Thought Patterns[45]

4.3 Summary

Initial and recurrent training are essential for safe helicopter flight. People learn by two ways: repetition and experience. Training fulfills both of these requirements. For commercial operations, management should enforce policies requiring their pilots to have recurrent training at the time of their biannual flight review. Flying should be viewed as a learning process that never ends.

CHAPTER V

NATIONAL AIRSPACE SYSTEM

The National Airspace System (NAS) was designed around the needs of fixed wing aircraft and the needs of helicopters have not been considered. This is due to the fact that helicopters came into being long after this system was in place and generally operate at lower altitudes and airspeeds than do fixed wing airplanes. Also, the range and endurance of the helicopter is much less than that of the airplane.

The dilemma that many companies and private owners are faced with is whether or not to buy helicopters that are certified for IFR. Most are choosing not to because current navigation and communication systems are not adequate for flight at lower altitudes. In addition, the Federal Aviation Regulations (FAR) allows the pilot to operate under VFR with very low weather minimums.

5.1 Navigation

The primary means of navigation for IFR is the very high frequency omni-directional range (VOR). This system transmits very high frequency (VHF) navigation signals from a ground based station. Signals are received by line of sight, which means that the aircraft needs to be at minimum enroute altitude (MEA) to receive the signal. In most cases helicopter pilots fly at the minimum obstacle clearance altitude (MOCA) which is usually lower than the MEA. Therefore, in the event that the pilot would encounter adverse weather at the lower altitude and want to transition to IFR, he would need to determine what VOR to tune too, climb to the MEA, and make the necessary instrument adjustments. While he is doing all of that, he also needs to fly the helicopter, establish radio communication, and be aware of obstacles.

The advent of the Global Positioning System (GPS) will help alleviate this problem. GPS is a satellite based system that provides point to point navigation based on tracking. This system allows for navigation from the surface to high altitudes, making navigation for helicopters at low altitudes possible.[46] Currently work is being done to create non- precision GPS approaches. Once the full potential of GPS is realized, lack of navigation for helicopters operating at low altitudes will no longer be an issue.

5.2 Radio Communication

Aircraft radios are also based on line of sight which is another obstacle making IFR flight difficult for helicopter pilots who fly at the MOCA. With today's satellite technology, a similar system could be created for radio communication. A system of this nature would allow the pilot to request flight following, file an IFR flight plan, or obtain weather information if it appears conditions are worsening.

5.3 Weather Minimums

Because helicopters can operate safely at lower altitudes and airspeeds, it is understandable why their weather minimums are lower than those of fixed wing aircraft. However, the current weather minimums set forth by the FAA (see below) are too low for safe operation. Additionally, these minimums discourage helicopter instrument flight since they are lower than some of the minimum descent altitudes on an approach. Given below are the regulations for Air Taxi Operations under FAR Part 135, for altitude and visibility requirements.

The minimum flight attitudes for cruise flight under FAR Part 135.203 for airplanes are as follows:

> Day: a minimum altitude of 500 feet above the surface and horizontal distance of 500 feet from the closest obstacle,
>
> Night: a minimum altitude of 1000 feet above the highest obstacle and 5 miles horizontal distance from the nearest obstacle.

For helicopter operations part (b) of the section simply states that an altitude of 300 feet must be maintained over congested areas.

FAR Part 135.207 states that the visibility requirements for helicopter VFR flight are 1/2 mile for day operations and 1 mile for night operations. Originally these minimums were set because most helicopters were unable to exceed 80 knots. However, helicopters are now able to fly at speeds in excess of 130 knots. The following example shows why the current weather minimums are unsafe. It takes a pilot approximately 5 seconds to notice that poor weather is ahead of him and to determine what appropriate actions should be taken. If the helicopter is flying at 120 knots it will cover 1012 feet in this time. If the pilot maintains 120 knots and executes an 30 degree turn it will take him another 2208 feet to completely turn around and begin moving away from the weather. This is assuming that the pilot maintains a constant airspeed and altitude, which is not likely. The total distance, that it took this pilot to turn away from the weather, 3220 feet or 3/5 mile, exceeds the 1/2 mile day visibility for VFR flight. It is possible that a helicopter at cruise speed can overrun the pilots ability to see and avoid deteriorating weather.[47]

5.4 Weather Forecasts

The regulations concerning weather briefings prior to flight may encourage pilots to risk flight into potentially dangerous weather. According to FAR Part 135.312, the FAA requires that a weather briefing be obtained from the National Weather Service (NWS) or an approved weather source prior to flight, if a briefing is not available then the pilot may use his own discretion as long as visual meteorological conditions (VMC) prevail. So basically the FAA is saying that a helicopter pilot may take off on a VFR commercial flight during the day with only 1/2 mile visibility and without receiving a current weather briefing. Considering that commercial helicopter flights usually carry passengers, the FAA has entrusted the pilot with a significant responsibility, which ultimately adds to their stress. Given the present weather minimums, pilots on commercial flights should be required to receive a weather briefing prior to flight, if conditions are marginal.

More often that not helicopter pilots are taking the risk of not getting a weather report before flying, this is due to the closing of many remote Flight Service Stations (FSS). The FAA has decided to close the smaller FSS facilities and centrally locate them in larger metropolitan areas. This makes talking to an actual weather briefer even more difficult.[47] Commercial operations such as EMS must depart within a moments notice and waiting to talk to a briefer is not always possible. The advent of the automated weather reporting has helped this problem, however direct route information and weather for remote sites cannot be obtained. Therefore, other weather sources need to be available to helicopter pilots in this type of situation.

5.5 Summary

Extremely low weather minimums and the lack of available weather reporting stations encourage pilots to "scud run." Unfortunately when pilot's "scud run" they increase the likelihood of inadvertently entering IMC. Because of the lack of appropriate navigation and communication systems, the pilot is faced with a difficult situation. With the advent of better navigation aids, hopefully more helicopter owners and operators will decide that IFR operations are safer and equip their helicopter accordingly.

CHAPTER VI

AIRCRAFT CERTIFICATION

The certification requirements for IFR helicopter flight are one of the significant reasons why manufacturers of helicopters do not certify their helicopter for IFR flight. These regulations may require significant modifications to helicopters. The MD-369E discussed in the background is a prime example of this. This increases the cost of the helicopter significantly

The current certification requirements for helicopters are under FAR Parts 27, Normal and Utility Rotorcraft, and Part 29, Transport Rotorcraft. Appendices of FAR Parts 27 and 29 relating to certification for IFR flight can be found in Appendix A and B of this thesis, respectively.

6.1 IFR Certification

There are different certification regulations for helicopters to fly VFR and IFR. Arguments for not certifying helicopters for IFR flight are that these regulations are more stringent than those for VFR flight; this results in a more expensive helicopter. In addition, since the visibility and altitude requirements are so low for VFR flight, there is less of a desire to undergo the burdens of IFR certification.

The requirements for fixed wing aircraft are much different. The only additional requirement for IFR certification of an airplane is the installation of approved instrumentation and radios.

In addition to the above, the dynamic stability requirements for helicopter IFR flight are much more severe than for fixed wing aircraft. Also, there are separate requirements for single-pilot and dual-pilot operations. An excerpt from the regulations is given below to show the differences.

FAR Part 23, Normal Utility Airplane, dynamic stability requirements are:

> "(a) Any short period oscillation not including combined lateral-directional oscillations occurring between the stalling speed and the maximum allowable speed appropriate to the configuration of the airplane must be heavily damped with the primary controls-
> (1) Free; and
> (2) In a Fixed position.
> (b) Any combined lateral directional oscillations ("Dutch Roll") occurring between the stalling speed and the maximum allowable speed appropriate to the configuration of the airplane must be damped to 1/10 the amplitude in 7 cycles with the primary control-
> (1) Free; and
> (2) In a Fixed position.
> (c) If it is determined that the function of a stability augmentation system is needed to meet the flight characteristic requirements of this part, the primary control requirements of paragraphs (a)(2) and (b)(2) of this section are not applicable to the tests needed to verify the acceptability of that system."[48]

FAR Part 27, Normal Utility Rotorcraft, dynamic stability requirements are:

> "VI. *Dynamic stability*. (a) For single-pilot approval-
> (1) Any oscillation having a period of less than 5 seconds must damp to 1/2 amplitude in not more than one cycle.
> (2) Any oscillation having a period of 5 seconds or more but less than 10 seconds must damp to 1/2 amplitude in not more than 2 cycles.
> (3) Any oscillation having a period of 10 seconds or more but less than 20 seconds must be damped.
> (4) Any oscillation having a period of 20 seconds or more may not achieve double amplitude in less than 20 seconds.
> (5) Any aperiodic response may not achieve double amplitude in less than 6 seconds.
> (b) For helicopters approved with a minimum crew of two pilots-

(1) Any oscillation with a period of less than 5 seconds must damp to 1/2 amplitude in not more than two cycles.
(2) Any oscillation with a period of 5 seconds or more but less than 10 seconds must be damped.
(3) Any oscillation having a period of 10 seconds or more may not achieve double amplitude in less than 10 seconds.'"[49]

Since helicopters operate similar to fixed wing aircraft in forward flight the regulations should be similar and the additional single pilot regulations should be excluded. After all, airplanes with one pilot operate efficiently in both VFR and IFR flight. If the FAA required that helicopters meet the same criteria as airplanes, more manufacturers would be open to certifying their helicopters for IFR flight.

6.2 Summary

The current regulations discourage manufacturers from certifying their helicopters for IFR flight because of the stringent requirements imposed on the helicopter. The time and cost involved in certifying helicopters for IFR flight may not always seem to be worth it when one considers the low VFR altitude and visibility requirements. However, increasing the certification requirements for VFR and eliminating the current IFR requirements will force manufacturers to make a safer helicopter.

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

To reduce the number of inadvertent IMC accidents, changes to the current system need to be made. The utilization of the helicopter has change significantly over the last 50 years, however the regulations and standards have not. Improving these standards will help increase the level of safety for helicopter flight.

Based upon the findings of this study, the following conclusions regarding helicopter flight and inadvertent IMC have been reached:

1. Some helicopter pilots must deal with a large amount of stress and fatigue therefore increasing the likelihood of mistakes occurring in flight.
2. If a non-instrument rated pilot or a non-proficient instrument rated pilot becomes spatially disorientated after inadvertently entering IMC, chances of overcoming it are slim.
3. Because of the nature of helicopter flight, pilots have a high workload. When they encounter poor weather, their workload increases significantly, sometimes more than they are able to handle.
4. Helicopter pilots are not receiving adequate training to prepare them for encounters with inadvertent IMC and the challenges faced at low altitudes.
5. There is a lack of decision making and behavior modification training offered to helicopter pilots.

6. Instrument navigation (VOR) and radio communication is difficult if not impossible at altitudes lower than the MEA. Once fully utilized, GPS will meet the needs of helicopter navigation.

7. The current altitude and visibility requirements are too low for safe operations. They increase the likelihood of "scud running."

8. Certifying a helicopter for instrument flight is far more complex than certifying an airplane for instrument flight, which discourages IFR helicopter certifications.

6.2 Recommendations

Based on the conclusions stated in section 6.1, the following recommendations are submitted:

1. The FAA should increase the standards for helicopter training. Effective training programs should consist of some actual instrument time instead of simply simulated instrument time. In addition, since helicopters operate at low altitudes, training programs need to be designed so that the challenges faced at lower altitudes are addressed. For commercial helicopter pilots, topics such as behavior modification and judgment also need to be included in training programs.

2. The FAA should enforce proficiency training biannually for helicopter pilots. Since pilots are required to have a biannual flight review, proficiency training should be made a part of the process.

3. The Global Positioning System should be used as the primary means of navigation for helicopters.

4. Research and development should be done to develop a satellite based communication system, for civil helicopters.

5. The FAA should raise the altitude and visibility requirements under Part 135 as recommended by the Helicopter Association International to ensure safe flight.

6. Helicopter certification regulations under Parts 27 and 29 should be changed to resemble those of fixed wing aircraft. VFR standards should be increased and the current IFR requirements eliminated. If IFR standards for helicopters are to be imposed, then the requirements should include better and larger instrumentation. An example would be to increase the size of the attitude indicator, so that the viewing the instrument is easier.

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APPENDICES

APPENDIX A

FAR Part 27

APPENDIX A

The regulations for certification of a Normal Utility Rotorcraft for IFR can be found in FAR Part 27, Appendix B. These requirements are:

"I. *General.* A normal category helicopter may not be type certificated for operation under the instrument flight rules (IFR) of this chapter unless it meets the design and installation requirements contained in this appendix.

II. *Definitions.* (a) V_{YI} means instrument climb speed, utilized instead of V_Y for compliance with the climb requirements for instrument flight.
(b) V_{NEI} means instrument flight never exceed speed, utilized instead of V_{NE} for compliance with the maximum limit speed requirements for instrument flight.
(c) V_{MINI} means instrument flight minimum speed, utilized in complying with minimum limit speed requirements for instrument flight.

III. *Trim.* It must be possible to trim the cyclic, collective, and directional control forces to zero at all approved IFR airspeeds, power settings, and configurations appropriate to the type.

IV. *Static Longitudinal Stability.* (a) *General.* The helicopter must possess positive static longitudinal control force stability at critical combinations of weight and center of gravity at the conditions specified in paragraph IV (b) or (c) of this appendix, as appropriate. The stick force must vary with speed so that any substantial speed changes results in a stick force clearly perceptible to the pilot. For single-pilot approval, the airspeed must return to within 10 percent of the trim speed when the control force is slowly released for each trim condition specified in paragraph IV (b) of this appendix.
(b) *For single-pilot approval:*
(1) *Climb.* Stability must be shown in climb throughout the speed range 20 knots either side of trim with-
(i) the helicopter trimmed at V_{YI};
(ii) Landing gear retracted (if retractable);
(iii) Power required for limit climb rate (at least 1000fpm) at V_{YI} or maximum continuous power, whichever is less.
(2) *Cruise.* Stability must be shown throughout the speed range from 0.7 to 1.1 V_H or V_{NEI}, whichever is lower, not to exceed $\pm$ 20 knots from trim with-
(i) The helicopter trimmed and power adjusted for level flight at 0.9 V_H or 0.9 V_{NEI}, whichever is lower; and
(ii) Landing gear retracted (if retractable)

(3) *Slow Cruise.* Stability must be shown throughout the speed range from 0.9 V_{MINI} or 20 knots above trim speed, whichever is greater, with-
(i) the helicopter trimmed and power adjusted for level flight at 1.1 V_{MINI}; and
(ii) Landing gear retracted (if retractable).
(4) *Descent.* Stability must be shown throughout the speed range 20 knots either side of trim with-
(i) The helicopter trimmed at 0.8 V_H or 0.8 V_{NEI} (or 0.8 V_{LE} for the landing gear extended case), whichever is lower;
(ii) Power required for 1000 fpm descent at trim speed; and
(iii) Landing gear extended and retracted, if applicable.
(5) *Approach.* Stability must be shown throughout the speed range from 0.7 times the minimum recommended approach speed to 20 knots above the maximum recommended approach speed with-
(i) The helicopter trimmed at the recommended approach speed or speeds;
(ii) Landing gear extended and retracted, if applicable; and
(iii) Power required to maintain a 3° glide path and power required to maintain the steepest approach gradient for which approval is requested.
(c) Helicopters approved for minimum crew of two pilots must comply with the provisions of paragraphs IV(b)(2) and IV(b)(5) of this appendix.

V. *Static lateral-directional stability.* (a) Static directional stability must be positive throughout the approved ranges of airspeed, power, and vertical speed. In straight, steady sideslips up to ±10° from trim, directional control position must increase in approximately constant proportion to angle of sideslip. At greater angles up to the maximum sideslip angle appropriate to the type, increased directional control position must produce increased angle of sideslip.
(b) During these sideslips up to ±10° from trim throughout the approved ranges of airspeed, power, and vertical speed, there must be no negative dihedral stability perceptible to the pilot through lateral control motion or force. Longitudinal cyclic movement with sideslip must not be excessive.

VI. *Dynamic stability.* (a) For single-pilot approval-
(1) Any oscillation having a period of less than 5 seconds must damp to 1/2 amplitude in not more than one cycle.
(2) Any oscillation having a period of 5 seconds or more but less than 10 seconds must damp to 1/2 amplitude in not more than 2 cycles.
(3) Any oscillation having a period of 10 seconds or more but less than 20 seconds must be damped.
(4) Any oscillation having a period of 20 seconds or more may not achieve double amplitude in less than 20 seconds.
(5) Any aperiodic response may not achieve double amplitude in less than 6 seconds.
(b) For helicopters approved with a minimum crew of two pilots-

(1) Any oscillation with a period of less than 5 seconds must damp to 1/2 amplitude in not more than two cycles.
(2) Any oscillation with a period of 5 seconds or more but less than 10 seconds must be damped.
(3) Any oscillation having a period of 10 seconds or more may not achieve double amplitude in less than 10 seconds.

VII. *Stability augmentation system (SAS).* (a) If a SAS is used, the reliability of it must be related to the effects of its failure. The occurrence of any failure condition which would prevent continued safe flight and landing must be extremely improbable. For any failure condition of the SAS which is not shown to be extremely improbable-
(1) The helicopter must be safely controllable and capable of prolonged instrument flight without undue pilot effort. Additional unrelated probable failures affecting the control system must be considered; and
(2) The flight characteristics requirements in Subpart B of Part 27 must be met throughout a practical flight envelope.
(b) The SAS must be designed so that it cannot create a hazardous deviation in flight path or produce hazardous loads on the helicopter during normal operation or in the event of malfunction or failure, assuming corrective action begins within an appropriate period of time. Where multiple systems are installed, subsequent malfunction conditions must be considered in sequence unless their occurrence is shown to be improbable.

VIII. *Equipment, systems, and installation.* The basic equipment and installation must comply with 29.1303, 29.1431 and 29.1433 through Amendment 29-14, with the following exceptions and additions:
(a) *Flight and Navigation Instruments.* (1) A magnetic gyro-stabilized direction indicator instead of a gyroscopic direction indicator required by 29.1303(h); and
(2) A standby attitude indicator which meets the requirements of 29.1303(g). For two-pilot configurations, one pilot's primary indicator may be designed for this purpose. If standby batteries are provided, they may be charged from the aircraft electrical system if adequate isolation is incorporated.
(b) *Miscellaneous requirements.* (1) Instrument systems and other systems essential for IFR flight that could be adversely affected by icing must be adequately protected when exposed to the continuous and intermittent maximum icing conditions defined in Appendix C of Part 29 of this chapter; whether or not the rotorcraft is certified for operation in icing conditions.
(2) There must be means in the generating system to automatically de-energize and disconnect from the main bus any power source developing hazardous overvoltage.
(3) Each required flight instrument using power supply (electric, vacuum, etc.), must have a visual means integral with the instrument to indicate the adequacy of the power being supplied.

(4) When multiple systems performing like functions are required, each system must be grouped, routed, and spaced so that physical separation between systems is provided to ensure that a single malfunction will not adversely affect more than one system.
(5) For systems that operate the required flight instruments at each pilot's station-
(i) Only the required flight instruments for the first pilot may be connected to that operating system;
(ii) Additional instruments, systems, or equipment may not be connected to an operating system for a second pilot unless provisions are made to ensure the continued normal functioning of the required instruments in the event of any malfunction of the additional instruments, systems, or equipment which is not shown to be extremely improbable;
(iii) The equipment, systems, and installations must be designed so that one display the information essential to the safety of flight which is provided by the instruments will remain available to a pilot, without additional crewmember action, after any single failure or combination of failures that is not shown to be extremely improbable; and
(iv) For single-pilot configurations, instruments which require a static source must be provided with a means of selecting an alternate source and that source must be calibrated.

IX. *Rotorcraft Flight Manual.* A Rotorcraft Flight Manual or Rotorcraft Flight Manual IFR Supplement must be provided and must contain-
(a) *Limitations.* The approved IFR flight envelope, the IFR flightcrew composition, the revised kinds of operations, and the steepest IFR precision approach gradient for which the helicopter is approved;
(b) *Procedures.* Required information for proper operation of IFR systems and the recommended procedures for the event of stability augmentation or electrical system failures; and
(c) *Performance.* If V_{YI} differs from V_Y, climb performance at V_{YI} and with maximum continuous power throughout the ranges of weight, altitude, and temperature for which approval is requested."

APPENDIX B

FAR Part 29

APPENDIX B

The regulations for certification of a Transport Rotorcraft for IFR can be found in FAR Part 29, Appendix B. These requirements are:

"I. *General.* A normal category helicopter may not be type certificated for operation under the instrument flight rules (IFR) of this chapter unless it meets the design and installation requirements contained in this appendix.

II. *Definitions.* (a) V_{YI} means instrument climb speed, utilized instead of V_Y for compliance with the climb requirements for instrument flight.
(b) V_{NEI} means instrument flight never exceed speed, utilized instead of V_{NE} for compliance with the maximum limit speed requirements for instrument flight.
(c) V_{MINI} means instrument flight minimum speed, utilized in complying with minimum limit speed requirements for instrument flight.

III. *Trim.* It must be possible to trim the cyclic, collective, and directional control forces to zero at all approved IFR airspeeds, power settings, and configurations appropriate to the type.

IV. *Static Longitudinal Stability.* (a) *General.* The helicopter must possess positive static longitudinal control force stability at critical combinations of weight and center of gravity at the conditions specified in paragraphs IV (b) through (f) of this appendix. The stick force must vary with speed so that any substantial speed changes results in a stick force clearly perceptible to the pilot. The airspeed must return to within 10 percent of the trim speed when the control force is slowly released for each trim condition specified in paragraph IV (b) through (f) of this appendix.
(b) *Climb.* Stability must be shown in climb throughout the speed range 20 knots either side of trim with-
(1) the helicopter trimmed at V_{YI};
(2) Landing gear retracted (if retractable);
(3) Power required for limit climb rate (at least 1000fpm) at V_{YI} or maximum continuous power, whichever is less.
(c) *Cruise.* Stability must be shown throughout the speed range from 0.7 to 1.1 V_H or V_{NEI}, whichever is lower, not to exceed $\pm$ 20 knots from trim with-
(1) The helicopter trimmed and power adjusted for level flight at 0.9 V_H or 0.9 V_{NEI}, whichever is lower; and
(2) Landing gear retracted (if retractable)
(d) *Slow Cruise.* Stability must be shown throughout the speed range from 0.9 V_{MINI} to 1.3 V_{MINI} or 20 knots above trim speed, whichever is greater, with-

(1) the helicopter trimmed and power adjusted for level flight at 1.1 V_{MINI}; and
(2) Landing gear retracted (if retractable).
(e) *Descent.* Stability must be shown throughout the speed range 20 knots either side of trim with-
(1) The helicopter trimmed at 0.8 V_H or 0.8 V_{NEI} (or 0.8 V_{LE} for the landing gear extended case), whichever is lower;
(2) Power required for 1000 fpm descent at trim speed; and
(3) Landing gear extended and retracted, if applicable.
(f) *Approach.* Stability must be shown throughout the speed range from 0.7 times the minimum recommended approach speed to 20 knots above the maximum recommended approach speed with-
(1) The helicopter trimmed at the recommended approach speed or speeds;
(2) Landing gear extended and retracted, if applicable; and
(3) Power required to maintain a 3° glide path and power required to maintain the steepest approach gradient for which approval is requested.

V. *Static lateral-directional stability.* (a) Static directional stability must be positive throughout the approved ranges of airspeed, power, and vertical speed. In straight, steady sideslips up to ±10° from trim, directional control position must increase in approximately constant proportion to angle of sideslip. At greater angles up to the maximum sideslip angle appropriate to the type, increased directional control position must produce increased angle of sideslip.
(b) During these sideslips up to ±10° from trim throughout the approved ranges of airspeed, power, and vertical speed, there must be no negative dihedral stability perceptible to the pilot through lateral control motion or force. Longitudinal cyclic movement with sideslip must not be excessive.

VI. *Dynamic stability.* (a) Any oscillation having a period of less than 5 seconds must damp to 1/2 amplitude in not more than one cycle.
(b) Any oscillation having a period of 5 seconds or more but less than 10 seconds must damp to 1/2 amplitude in not more than 2 cycles.
(c) Any oscillation having a period of 10 seconds or more but less than 20 seconds must be damped.
(d) Any oscillation having a period of 20 seconds or more may not achieve double amplitude in less than 20 seconds.
(e) Any aperiodic response may not achieve double amplitude in less than 9 seconds.
(b) For helicopters approved with a minimum crew of two pilots-

VII. *Stability augmentation system (SAS).* (a) If a SAS is used, the reliability of it must be related to the effects of its failure. The occurrence of any failure condition which would prevent continued safe flight and landing must be extremely

improbable. For any failure condition of the SAS which is not shown to be extremely improbable-
(1) The helicopter must be safely controllable and capable of prolonged instrument flight without undue pilot effort. Additional unrelated probable failures affecting the control system must be considered; and
(2) The flight characteristics requirements in Subpart B of Part 27 must be met throughout a practical flight envelope.
(b) The SAS must be designed so that it cannot create a hazardous deviation in flight path or produce hazardous loads on the helicopter during normal operation or in the event of malfunction or failure, assuming corrective action begins within an appropriate period of time. Where multiple systems are installed, subsequent malfunction conditions must be considered in sequence unless their occurrence is shown to be improbable.

VIII. *Equipment, systems, and installation.* The basic equipment and installation must comply with 29.1303, 29.1431 and 29.1433 through Amendment 29-14, with the following exceptions and additions:
(a) *Flight and Navigation Instruments.* (1) A magnetic gyro-stabilized direction indicator instead of a gyroscopic direction indicator required by 29.1303(h); and
(2) A standby attitude indicator which meets the requirements of 29.1303(g) (1) through (7), instead of a rate of turn indicator required by 29.1303 (g). If standby batteries are provided, they may be charged from the aircraft electrical system if adequate isolation is incorporated. The system must be designed of that the standby batteries may not be used for engine starting.
(b) *Miscellaneous requirements.* (1) Instrument systems and other systems essential for IFR flight that could be adversely affected by icing must be provided with adequate ice protection whether or not the rotorcraft is certificated for operation in icing conditions.
(2) There must be means in the generating system to automatically de-energize and disconnect from the main bus any power source developing hazardous overvoltage.
(3) Each required flight instrument using power supply (electric, vacuum, etc.), must have a visual means integral with the instrument to indicate the adequacy of the power being supplied.
(4) When multiple systems performing like functions are required, each system must be grouped, routed, and spaced so that physical separation between systems is provided to ensure that a single malfunction will not adversely affect more than one system.
(5) For systems that operate the required flight instruments at each pilot's station-
(i) Only the required flight instruments for the first pilot may be connected to that operating system;
(ii) Additional instruments, systems, or equipment may not be connected to an operating system for a second pilot unless provisions are made to ensure the continued normal functioning of the required instruments in the event of any

malfunction of the additional instruments, systems, or equipment which is not shown to be extremely improbable;
(iii) The equipment, systems, and installations must be designed so that one display the information essential to the safety of flight which is provided by the instruments will remain available to a pilot, without additional crewmember action, after any single failure or combination of failures that is not shown to be extremely improbable; and
(iv) For single-pilot configurations, instruments which require a static source must be provided with a means of selecting an alternate source and that source must be calibrated.
(c) *Thunderstorm lights.* In addition to the instrument lights required by 29.1381 (a), thunderstorm lights which provide high intensity white flood lighting to the basic flight instruments must be provided. The thunderstorm lights must be installed to meet the requirements of 29.1381 (b).

IX. *Rotorcraft Flight Manual.* A Rotorcraft Flight Manual or Rotorcraft Flight Manual IFR Supplement must be provided and must contain-
(a) *Limitations.* The approved IFR flight envelope, the IFR flightcrew composition, the revised kinds of operations, and the steepest IFR precision approach gradient for which the helicopter is approved;
(b) *Procedures.* Required information for proper operation of IFR systems and the recommended procedures for the event of stability augmentation or electrical system failures; and
(c) *Performance.* If V_{YI} differs from V_Y, climb performance at V_{YI} and with maximum continuous power throughout the ranges of weight, altitude, and temperature for which approval is requested."

VITA

Kathy Michele Wallace was born in Baltimore, Maryland on June 29, 1969. She graduated from Seton High School in June of 1987. She then attended Catonsville Community College in Catonsville, Maryland, where she earned an Associate of Arts Degree in Air Transportation. In May 1990 she received her Private Pilot's License. She earned her Bachelors of Science degree in Aviation Management at Lynn University in Boca Raton, Florida in May 1994, where she graduated Cum Laude. In the summer of 1994 she began her Master of Science Degree in Aviation Systems at the University of Tennessee Space Institute and completed it in May 1996.