POSITION PAPER

RECOGONIZING AND MITIGATING ASSOCIATED RISKS INVOLVING FATIGUE OR STRESS DURING ROTORCRAFT EXTERNAL LOAD OPERATIONS

PRESENTED TO
HAI UTILITIES, PATROL AND CONSTRUCTION SUBCOMMITTEE
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The document represents the opinion of the author based on 40 years of aviation operational, maintenance, accident and safety experience, and research conducted on articles, papers, and accident and incident data of the helicopter industry. The opinions expressed in this document are strictly those of the author and do not represent the opinions of the Department of Energy or any other company. The author is not receiving any compensation or other considerations and the recommendations in this document are only provided to raise the awareness of potential risks associated with stress and fatigue during high-cycle or repetitious external load work.

PROLOGUE

The helicopter is no doubt a unique machine; it is capable of hovering, vertical, sideward, rearward and forward flight. It takes special individuals to want to fly a helicopter, since they are not very fast or stable and generally not considered as glamorous as the aircraft our high-speed jet brethren fly. However, pilots that gravitate to the aerial work industry that involves external load work are unique, in that they grasp the concept that the helicopter, when combined with an experienced pilot and crew, can accomplish work that no other flying machine is capable. The helicopter provides a customer with a "tool" that can provide cost effective and rapid support that no other machine can provide as effectively under certain circumstances.

Generally speaking, all helicopter external load work is "production" work! A typical job requires cargo and personnel to be delivered to specific points within a certain timeframe, in order to keep the project on schedule and within the customer's cost expectations. Sometimes the job requires such precision and concentration by the pilot and construction crew that the minutest miss-placement of the load can turn a simple task into an emergency. This is another reason why it takes a certain individual to specialize in external load work over transportation or other types of industries that use helicopters. There is not much I have not done with a helicopter conducting external load work from rescues, hauling burros from the Grand Canyon (hauling ass), to placement of steel, harvesting timber, or supporting the construction and seismic exploration industry. This type of work has inherent risk and hazards that other helicopter work does not experience on such a continuous basis, and yet I have always found that external load work was the most enjoyable, satisfying, and rewarding work I ever done. I have always piloted aircraft in a safe manner, considering the aircraft, crew, terrain, weather, and my limitations, yet, external load work has inherent risk that must be measured and taken to get the work done. In addition, the shear complexity of the work provides a satisfaction that no other work can provide. It is you, the machine, and the load that become one entity, in order to conduct the work safely and efficiently.

After a 24 year career in operating, maintaining, and managing helicopters I retired from flying after sustaining a series of mechanical failures that depleted my confidence and effects on mental ability to conduct external load operations with the confidence you need to carry out the responsibilities of a pilot in that industry. I now use my civil business, safety, and operating experience to develop policy and conduct oversight of a government agency's aircraft operations. The agency has invested in my continued professional growth by providing training in safety, accident investigation, and management courses. This document will define and discuss the operational environment and work load that contributes to pilot fatigue, physiological factors that effect performance and methods to mitigate the threats and potential errors during these types of operations.

PURPOSE AND OBJECTIVE

This document was developed to inform owners, managers, supervisors, pilots, and crews involved with rotorcraft external load operations of the potential risks associated with physiological factors (fatigue, stress, sleep loss, etc.) and provide recommendations to mitigate those risks. To mitigate the identified risks, the author recommends voluntarily implementation of administrative controls on flight time based on pilot workload. These controls are designed to reduce potential human factor induced errors, incidents, and accidents when conducting repetitive lift external load operations, Class A, B, and C loads (line stringing operations).

SCOPE

This document is applicable to single-pilot operations in small and medium helicopters conducting external load operations in support of construction, utility work, seismic surveys, and timber harvesting. The author did not evaluate the workload when using two-pilots or work in other aerial applications.

TERMS

In order to properly communicate information and reach an understanding of the work process, common terms were established for use in this document. The following terms are defined so that a clear understanding of the operational environment and pilot workload is understood.

- Approach phase means the act of maneuvering a rotorcraft, including any external load, with associated pilot decision making and control inputs to ensure obstacle clearance, dissipation of airspeed and rate of descent, aligning the aircraft with the prevailing wind and its intended point of touchdown for landing or receiving or releasing an external load.

- Calendar day means the period of elapsed time, using Coordinated Universal Time or local time that begins at midnight and ends 24 hours later at the next midnight.

- Climb-out phase means the act of maneuvering a rotorcraft, including any external load, with associated pilot decision making and control inputs to achieve a positive vertical assent, alignment for clearing departure path obstacle(s), and achieving translational lift for transition to cruise flight.

- Climb-out speed, with respect to rotorcraft, means a referenced airspeed, which results in a flight path clear of the height-velocity envelope during initial climb-out.

- Cruise flight phase means the act of maneuvering a rotorcraft, including any external load, with associated pilot decision making and control inputs, between one geographic point to another that includes achieving level flight, adequate forward speed to prevent external load oscillations, altitude to clear terrain and obstacles, and provide the opportunity to execute emergency procedures, if necessary.

- Cycle means the departure from one geographic point to another point that includes all of the pilot decision making and aircraft control actions to execute a take-off, climb-out, cruise, approach, and landing phases of a rotorcraft with or without an external load.

- Duty period means the period of elapsed time between reporting for an assignment involving flight time and release from that assignment by the certificate holder. The time is calculated using either Coordinated Universal Time or local time to reflect the total elapsed time.

- External load means a load that is carried, or extends, outside of the aircraft fuselage.

- Fatigue means a state of diminished physical and/or mental efficiency.

- Flight time means pilot time that commences when an aircraft moves under its own power for the purpose of flight and ends when the aircraft comes to rest after landing.

- Human Error is a social label that is generally agreed when an individual should have taken an action other than what they did and in the course of the action inadvertently caused or could have caused an undesirable outcome.

- Landing phase means the act of maneuvering a rotorcraft, including any external load, with associated pilot decision making and control inputs in order to land the aircraft on the ground or place an external load on a geographic point, including achieving obstacle clearance, adequate power for hovering flight, and other maneuvers (sideward, forward, rearward, vertical) to accurately place the external load or land the aircraft.

- Rest period means the period free of work or duty.

- Rotorcraft-load combination means the combination of a rotorcraft and an external-load, including the external-load attaching means. Rotorcraft-load combinations are designated as Class A, Class B, Class C, and Class D, as follows:
  (1) Class A rotorcraft-load combination means one in which the external load cannot move freely, cannot be jettisoned, and does not extend below the landing gear.
  (2) Class B rotorcraft-load combination means one in which the external load is jettisonable and is lifted free of land or water during the rotorcraft operation.
  (3) Class C rotorcraft-load combination means one in which the external load is jettisonable and remains in contact with land or water during the rotorcraft operation.
  (4) Class D rotorcraft-load combination means one in which the external-load is other than a Class A, B, or C and has been specifically approved by the Administrator for that operation.

- Take-off phase means the act of maneuvering a rotorcraft, including any external load, with associated pilot decision-making and control inputs in order to depart the surface with adequate power to attain a positive rate of climb to ensure clearance of obstacles, adequate power for hovering flight, and/or other maneuvers necessary for safe flight.

- Turn means the departure from one geographic point to another point and return to the original point of departure. One turn equates to two cycles generally. (This term is generally applicable to Class A and B loads)

- Vertical reference longline work means rotorcraft load operations conducted by a pilot when the sole visual reference to the external load is maintained by the pilot's line of sight and not by use of a mirror or directions from another crewmember.

ACCIDENT BACKGROUND

How many accidents have been directly attributed to pilot fatigue in the helicopter industry? A search of the National Transportation Safety Board (NTSB) accident and incident database reveals four accidents over a 32-year time span (1975 – 2007). None of the four incidents involved "rotorcraft external load" operations. Then one would have to ask, "Where is the risk associated with crew fatigue and external load operations?" I would ask the reader this question, "How does a pilot with over 7000 flight hours, of which 3000 hours are conducting external load operations (vertical reference longline), take-off with his longline still attached destroying the aircraft and killing himself?" "How does an experienced pilot who has pulled wire over a three mile distance suddenly strike a tower and crash?" Could the answers to either one of above scenarios be "complacency" or "loss of situational awareness," or was it "fatigue?" It could be a combination of all three because fatigue causes both a loss of situational awareness and complacency.

Fatigue is difficult for the NTSB to prove empirically so it is rarely listed as a primary cause factor. Evidence regarding the existence and extent of fatigue in aviation has been gathered from several different sources and environments, including aviation operations, laboratory studies, high-fidelity simulations, and surveys. Studies have been consistent in showing that fatigue is an issue with complex, diverse causes and potentially critical consequences. Field studies specific to different aviation environments and using a range of measures (e.g., performance, physiology, and behavior) have revealed a number of factors related to fatigue.

Other evidence of fatigue has been obtained from flight crew surveys and researcher observations in the field. Flight crews routinely respond that fatigue is a concern, often admitting to having nodded off during a flight and/or arranging for one pilot to nap in the cockpit seat. The presence of fatigue has been acknowledged by flight crews for many years. A 1980 study of voluntary reports made to NASA's Aviation Safety Reporting System (ASRS), which we operate under FAA funding, found that 21% of reported incidents mention fatigue-related factors. Fatigue continues to show up in these reports, as evidenced by recent ASRS database reports even though it is absent from the NTSB reports.

As a professional helicopter pilot and safety professional that accumulated 9985 total hours of which 3975 hours were conducting external load operations in my career, I am certain, as most professional pilots are, that fatigue has been a major factor in many external load operations, but was not identified by accident boards or misidentified as "complacency" or "loss of situational awareness." To be honest no one will ever really know, because the one person that could provide the facts of their physiological state at the time of the accident is dead.

After an accident, accident boards normally look at flight records and conduct interviews to reconstruct the 24 to 36 hour period prior to the accident. The accident board traditionally, has tried to determine the amount of rest or sleep the pilot had prior to the accident to determine if "fatigue" was a factor. In addition, the accident investigation team is trying to determine the pilot's eating habits to determine the impact of blood sugar imbalances or if alcohol may have been a factor, but until 2007 the reports have not mentioned the number of "turns" or "cycles" the pilot had completed prior to the accident. Nor have many accident boards before 2004 used the more recently accepted Human Factors Ranking/Risk Factors in evaluating causal factors of accidents.

When the NTSB and FAA are investigating component or airframe failures, accident boards spend a lot of resources to determine the cycles and hours on a component or airframe. Obviously, a determination of a "fatigue failure" in a component or airframe has far-reaching impacts on safety to operators and the public; therefore, it is important to determine the cause of these failures. However, until recently, the same was not true when it came to determining the pilot's workload prior to the accident or incident or in other words, "how many cycles or turns did the pilot accomplish?" Was this a factor? Since the NTSB and FAA focus their investigations around the regulatory environment of the operation at the time of the accident, regulations have a bearing on why flight time or rest may not be considered as a contributing causal factor.

REGULATORY BACKGROUND

Rotorcraft external load operations associated with construction, logging, seismograph exploration, firefighting, and the power line repair industry are governed by Title 14 Code of Federal Regulations (CFR), Chapter 1, Parts 91 (General Operating Rules, 119 (Certification of Commercial Operators), and 133 (Rotorcraft External Load Operations). Part 119 exempts certain aerial work activities from complying with the stricter safety standards set for transportation operations embodied in Parts 121 and 135 of Chapter 1. This exception found in Part 119 allows aerial work such as external load and construction operations to be conducted under Parts 91 or 133 operational rules. Neither Part 91 nor 133 operational regulations establish pilot duty time, rest or flight time limitations for these aerial work operations. Essentially these operations rely on the pilot's authority to determine the safety of the operation. Nevertheless, if during an external load operation a pilot "transported" the crew from the job site into town, then he or she would have to be certificated to operate under Part 135 and adhere to the flight and duty time limitations or a violation would have been committed. Part 135 allows a maximum of 8 hours of flight time per consecutive 24-hour period, with additional flight time permitted when the anticipated duty period will not exceed 14 hours and is preceded and followed by rest periods of at least 10 hours.

By comparison, military (U.S. Army) flight regulations recommend that a helicopter pilot's flight time be limited to 8 hours per 24-hour period, which is similar to the civil Part 135 requirements. However, the military has recognized the stresses and workload associated with helicopter flying, and its regulations recommend that maximum flight times be reduced to 6.1 hours for day contour flight or low-level flight at or below 200 feet above ground level. Military regulations also contain a broader definition of flight time. Military regulations consider a pilot's flight time to begin when a helicopter lifts off the ground and ends when it lands and either its engines are stopped or the flight crew changes. The reduction in flight time was based on human factors involved with the increased workload stress and fatigue in low-level flight operations. The military also impose further flight time reductions if night vision goggle operations are part of the low-level flight regime.

In the civil helicopter industry, it was common in the 1970s thru the 1990s, and may still be prevalent in today's operating environment, for pilots to fly 6 - 10 hours of external load operations during a 16 to 17 hour duty day, working 20 days on and 10 days off in the seismic, logging, and construction industries. There is nothing illegal or unethical about this operational pace, because it was, and still maybe, accepted practice, the normal expectation of customers, pilots, and the helicopter industry, and allowed by regulation.

Since the majority of FAA operational regulations relate back to one rule, 14 CFR Part 91 section 91.3, Responsibility and authority of the pilot in command, paragraph (a) "The pilot in command of an aircraft is directly responsible for, and is the final authority as to, the operation of that aircraft." Regardless of the regulatory limitations on flight time, or lack thereof, the decision to fly or not fly rests with the pilot-in-command.

"Whenever we talk about a pilot accident, we should all keep one thing in mind; they made a judgment. They believed in it so strongly that they knowingly bet their lives and those of others on it. That they may have made an error and their judgment was faulty is a tragedy. Some of us here today had the opportunity to influence their judgment, so a little bit of all of us goes with every pilot we lose."

"Author Unknown"

OPERATIONAL ENVIRONMENT BACKGROUND

In this section the work environment, elements, and tasks will be broken down in order for the reader to appreciate the operational differences between airport-to-airport transportation and most aerial work (helicopter external load work) environments. This section will also describe the cockpit and seating environment and the operational phases that contribute to pilot stress and fatigue.

In the following scenarios, the helicopter pilot and crew are essential to or associated with the work performed and the helicopter is essential to performing the work. The aircraft activity is conducted from a landing zone or staging area where the loads and crews are pre-positioned. No transportation subject to

14 CFR Chapter 1 Part 135 regulations is conducted in these scenarios. Therefore, 14 CFR Chapter 1, Parts 91 and 133 govern the work.

Exploration Work (Class B Loads)

The customer's objective is to record 4 miles of data or more each day over a surveyed line that runs 60 miles through mountainous terrain at elevations starting at 5,000 feet Mean Sea Level (MSL) to 10,000 feet MSL. The customer has 2.5 miles of gear on the ground with 440 feet spacing for each cable and geophone array. The recorder weighs 1000 pounds and has a generator that weighs 600 pounds, which is a separate load. It takes 12 equipment bags for each mile and each equipment bag contains a cable and geophones for each 440-foot layout that weighs 100 pounds. The exploration survey requires the use of explosives to provide the "sounding" for the array to record the geological structure below the array. Each bag of explosives weighs 100 pounds.

The helicopter uses a 125 feet of longline to maintain obstacle clearance and has an 8-point remote hook to place the loads at the designated drop points along the surveyed line. The aircraft is capable of carrying 800 pounds of gear with 1.5 hours of fuel, with 20-minute fuel reserve onboard and can move the recorder with 1 hour of fuel, with a 20-minute fuel reserve onboard.

In this hypothetical scenario the job is just starting. The pilot flies out the complete crew (15 personnel) to start laying out the array, five personnel at a time; a total of 3 turns or 6 cycles in less than 40 minutes. The pilot then refuels and starts hauling equipment bags, 48 bags at 8 bags per load. It takes two flight hours to drop all 48 bags. The pilot has accumulated 6 turns and 48 cycles, since each turn you are placing 8 equipment bags and each placement requires the pilot to perform a take-off, climb out, cruise, approach and landing (load drop). This equates to a pilot workload of 24 cycles per flight hour. However, it is important to note that the aircraft is at or near its limits during the first three drops and mountain flying, timber cover, or other obstructions add their own unique stresses on the pilot's physiology that can affect decision-making and judgment.

It is common to fly 7 to 8 hours during a 16-hour duty day. The flying is not continuous, so there are opportunities for rest breaks, but the cumulative effects of stress over the length of the project can cause fatigue to the point of affecting the pilot's abilities to function effectively.

Construction (Class B Loads)

The customer's objective is to set 60 ventilation units on a three story manufacturing plant in one morning. The plant is at 6,000 feet MSL. The ventilation units weigh 2000 pounds each. The helicopter uses a 100 feet of longline to maintain obstacle clearance and has a single-point remote hook to place the loads at the designated drop points. The aircraft is capable of carrying 2700 pounds of gear with 1hour of fuel, with 20-minute fuel reserve, on board. Each ventilation unit must be placed over the prepared opening and will have two ground crew to assist in placement, once the pilot has centered the load over the opening. After the placement, the ground crew will disconnect the rigging to be recycled back to the staging area.

In this hypothetical scenario, the pilot accumulates 60 turns or 120 cycles, since each turn, you are placing a ventilation unit and each turn requires the pilot to perform two take-offs, climb outs, cruises, approaches and landings (load drop and pick-up). The work is completed in 1.5 flight hours over a 3-hour period, since the ground crews cannot keep up with rigging recycling at the same tempo as the helicopter. This equates to a pilot workload of 40 cycles per flight hour. However, it is important to note that the aircraft is at or near its limits during the operation and the precision required to place the loads and caution required to ensure the ground crew is not placed in jeopardy during the placement adds their own unique stresses on the pilot's physiology that can effect decision-making and judgment.

During a typical Class B external load operation the pilot averages 20 turns[1] per flight hour or 40 cycles[2]. Half of these cycles the aircraft is at or near gross weight and the other half of the cycles the aircraft is empty, except for the longline and remote hook(s). However, in the logging and construction industry it is not uncommon to achieve 40 turns (80 cycles) or more per flight hour or as high as 60 turns (120 cycles) during some operations. Depending on the job flight time can be as low as 1.5 hours and as high as 8 to 9 hours per day.

Power line Construction or Repair (Class A and B Loads)

The customer's objective is to complete 50 miles of installing conductor on a 345-Kilovolt (KV) power line. Each structure holds three conductors, a center phase and two outside phases, and there are six steel structures per mile, at an average 150 feet above ground level. To complete the task the helicopter must first place and secure "fly-blocks" for each phase and on each structure. The structures are 880 feet apart. The power line is in hilly terrain and starts at 4,800 feet MSL and reaches the highest point at 8,500 feet MSL before dropping back to 4,800 feet MSL.

This work will primarily start as Class A loads. The pilot will first transport crews, three persons at a time and place one person on each structure, by landing on the structure and transferring a crewman on to the structure by landing atop the structure. Once the support crews are set, the aircraft returns and loads "fly-blocks" in the rear of the cabin and one crewman, who will sit on a platform that extends just past the skids or stand on the skid strapped to the aircraft, to install the "fly-blocks" onto the outside phases of each structure,. The pilot will complete a cycle to the first structure and then maneuver to the next structure and the next until all of the fly-blocks are installed. The center phase fly-blocks are handed off to the worker on the structure to install. In this hypothetical scenario, the pilot accumulates 15 to 20 turns or 30 to 40 cycles, since each turn you are placing a fly-block and each placement requires the pilot to perform a take-off, climb out, cruise (hovering), approach and landing (load drop). The work can continue up to 6 hours or more. However, it is important to note that the aircraft is well within its limits, but the continual vigilance to ensure obstruction clearance and precision required by the pilot to place the workman near the structures to conduct his work, along with continual leaning out the door places physical and mental stresses on the pilot's physiology that can affect decision-making and judgment.

The alternate procedure is to place the crews on the towers and the pilot uses a longline to bring fly-blocks to the crewmen who then attach the fly-blocks to the structure. Once the crewman is done, they are moved via the longline to the next structure. This operation is a Class B load and generally, the pilot will average 50 to 60 cycles per flight hour.

During a typical Class A external load operation in support of power line construction or repair work the aircraft may have a platform installed for the worker to sit or the worker may be working from the open door in the back seat. This type of operation is unique when compared to Class B or Class C operations in that the pilot generally spends most of the flight time at a hover after take-off. However, when moving the worker from one point of the power line infrastructure to another point, the pilot uses the departure and approach phases, but may not ever actually achieve the climb-out or cruise phases as in Class B loads.

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[1] Turn means the departure from one geographic point to another point and return to the original point of departure. One turn equates to two cycles generally.

[2] Cycle means the departure from one geographic point to another point that includes all of the pilot actions to execute a take-off, climbout, cruise, approach, and landing phases of a rotorcraft, and may include an external load that extends below the landing gear.

The pilot will average .41 turns per flight hour or .82 cycles, but during that flight hour accomplished 30 to 40 approaches and departures to various points along the power line. The operational stress and fatigue for these operations is not brought on by repetitive cycles, as much as continuous hovering flight and concentration to maintain obstacle clearance (power line or structure). In addition, obstacle clearance, wires and structure, require constant vigilance and induce stress compared to Class B operations where obstacle clearance is normally an approach, landing, and departure issue.

This type of work also involves long duty days, on average 16 hours, and the pilot may log upwards of 6 to 8 flight hours per day. This equates to 300 to 360 cycles per day.

Sockline Pulling (Class C Loads)

The customer's objective is to complete 50 miles of installing conductor on a 345-Kilovolt (KV) power line. Each structure holds three conductors, a center phase and two outside phases, and there are six steel structures per mile, at an average 150 feet above ground level. To complete the task the helicopter must pull "sockline" off a puller-tensioner reel machine and place the line into the fly-blocks located on the structure. This work requires complete coordination and communication between the puller-tensioner operator and the pilot. It also requires complete concentration and skill on the pilot's part to maneuver clear of the structures and placing the sockline into the fly-blocks. The center phase generally requires the pilot to use a "needle" to thread the sockline through the center portion of the structure. This work is intense and very repetitive. This type of work also involves long duty days, on average 16 hours, and the pilot may log upwards of 6 to 8 flight hours per day.

In Class C operations, certain models use a "side-puller" see Figure 1 or a longline with ballast weight see Figure 2.

Figure 1

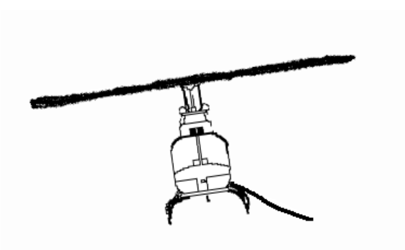
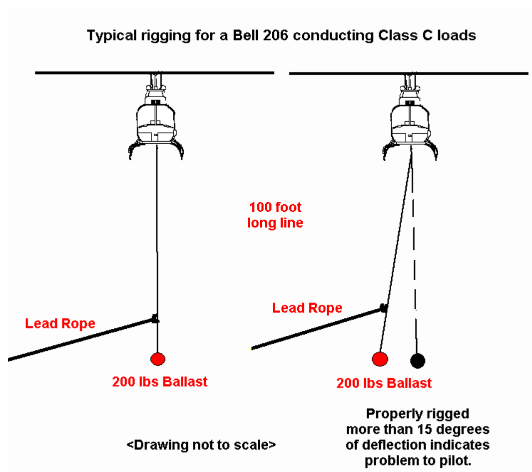


Figure 2



During a typical Class C external load operation the pilot averages .9 turns[3] per flight hour or 1.8 cycles[4]. In these operations, it places operational stress and fatigue on the pilot because of the continuous

[3] Turn means the departure from one geographic point to another point and return to the original point of departure. One turn equates to two cycles generally.

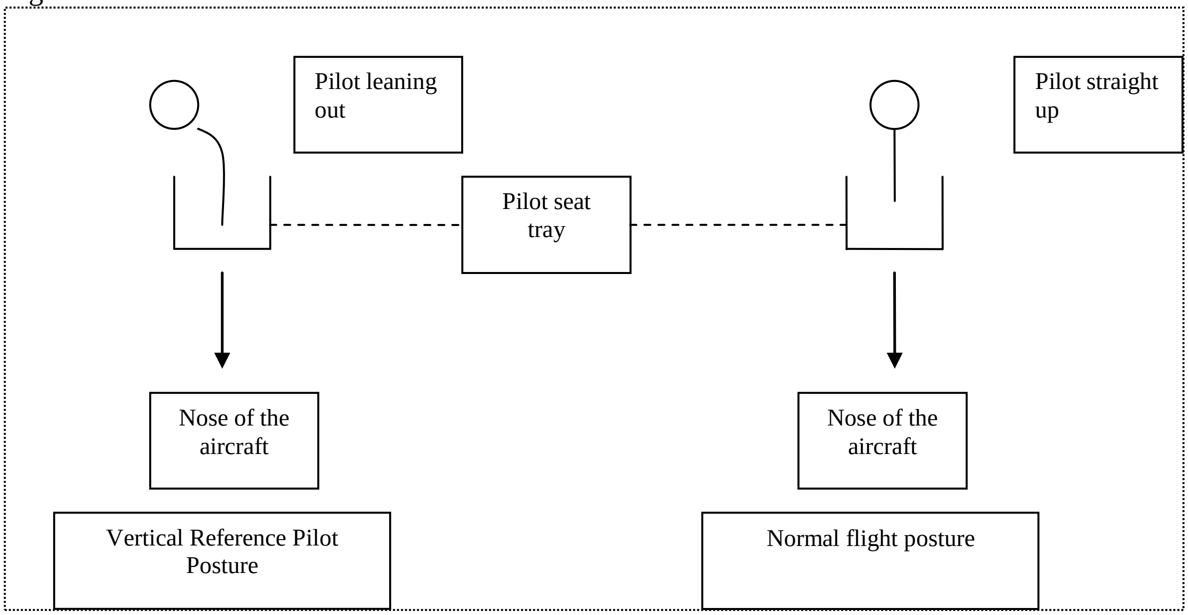
[4] Cycle means the departure from one geographic point to another point that includes all of the pilot actions to execute a take-off, climbout, cruise, approach, and landing phases of a rotorcraft, and may include an external load that extends below the landing gear.

extension of the pilot outside to monitor the load. In addition, obstacle clearance, wires and structure, require constant vigilance and induce stress compared to Class B operations where obstacle clearance is normally an approach, landing, and departure issue.

Cockpit Seating and Pilot Posture

A typical small or medium helicopter utilizing a single pilot, the pilot must be able to see the load to conduct vertical reference longline external load operations. To accomplish this, the pilot has to lean out far enough to observe the load during the take-off, climb-out, approach, and landing phases of flight. When you compare the pilot's posture to a normal flight posture, it is easy to see the spinal column, ribs, and neck are under stress when compared to the normal flight posture. Depending on the make and model of aircraft, the pilot may have to lean or look out to the left side or right side, either case places physical stress on the pilot's neck, spine, and lower back. In addition, the pilot normally wears a protective helmet that adds stress to the neck and spine because of the additional weight and vertical-moment the helmet adds when leaning to one side. See figure 3.

Figure 3 Pilot Posture



Pilot Workload

When you compare the pilot's workload during aerial work such as external load operations, to the pilot workload in the transportation industry, based on FAA and NTSB data, you find an average 1.2 cycles per flight hour in the emergency medical services industry and .75 cycles per flight hour in commuter and Flag air carrier operations. The pilot workload for most external load operations (40 to 80 cycles per flight hour) has no comparison in the aviation transportation industry. Generally, in a high turn environment or wire stringing operations the pilot rarely is able to sit straight in the seat to relieve the physical stress and is under constant mental vigilance (stress). Therefore, I believe the workload experienced by a helicopter pilot to be one of the most overlooked aspects contributing to pilot fatigue in our industry and a major contributing causal factor in accidents.

As discussed in the physiological section of this document the normal functions of the brain, biological chemistry, and effects on the brain functions required to accomplish these tasks can and do contribute to fatigue and capability of the pilot to sustain operations involving multiple tasking.

It also important to understand at this stage in a typical pilot's career flying the aircraft has become an instinctive ability. In other words, the mechanical aspects of manipulating the controls have become so ingrained in our subconscious that the workload of "operating the aircraft" is minimal. This is due to the repetitive nature of the training most pilots receive and the proficiency achieved over a hundreds of hours of flying. In external load operations, the pilot is "flying the load" and that is where all of the concentration, stress, mental and physical effort is placed. This topic will be discussed further in the Physiological section of this document.

> *Life experience. I once flew a contract in Alaska hauling salmon from boats located a quarter of mile offshore to trucks on shore, using 50 feet of longline and two remote hook(s). One remote hook released the basket from the end of the longline and the other hook released the purse strings allowing the fish to be dropped into the containers on the truck trailer. During that time of year in Alaska, there are 20 hours of daylight. The pilots alternated shifts by flying a fuel load (2.4 flight hours) and then resting while another pilot flew a fuel load. There were two aircraft flying at all times and four pilots to accommodate the work flow. We were averaging 65 turns per flight hour or 130 cycles per flight hour. The flight stress, physical and mental fatigue, and*

sleep disruptions were overwhelming, but we did not have any "accidents." However, we did encounter an occasional inadvertent dropped load, minor entanglements with boat infrastructure, occasional load skipping across the water (pilot failed to maintain altitude), but no injuries or damage. Think about the mental and physical stresses we were under! Looking back, we did not have any serious or costly incidents, and that was primarily because we did shifts, we had rest periods, and the job only went for three weeks.

PREVIOUS STUDIES AND RECOMMENDATIONS

If you conduct a search of the internet on the topic of "pilot fatigue", you will get about 1,160,000 related articles, studies, and books on this subject. If you search on the internet for the same topic "pilot fatigue", include, "AND" "helicopters" you will get about 940 related articles, studies, and books on this subject. Not surprisingly of the 200 articles and studies this author read, the common theme was the airline transportation industry and the disruption of sleep patterns, referred to as Circadian Rhythm Disruption. The major theme of the articles and studies done on helicopters was generally on the effects of noise and vibration and their contribution to fatigue. The second common theme for helicopters was the same as the airline industry, Circadian Rhythm Disruption. What surprised me the most was not one article, although I admit I did not read all 1,160,000 articles due to the fact at age 57 there is not enough time left to read all the 1,000,000 plus articles and studies, referenced pilot work load during external load operations. Only one reference that looked at helicopter pilot workload could be found and that was referenced in the FAA Administrator's statements to address NTSB Safety Recommendation A-07-18 through -26, dated February 27, 2007 to an A.V. Stave study dated 1977. *His research on pilot fatigue in a noisy, vibrating helicopter simulator found considerable increases in subjective fatigue after 6 hours of short repetitive flights. At the end of this period, some helicopter pilots who participated in the study said they were so fatigued that they did not feel safe to fly a real helicopter. As subjective fatigue increased, study pilots demonstrated increasingly frequent "lapses" in performance. The study also found that routine, hourly rest breaks outside the cockpit reduced the buildup of pilot fatigue to manageable levels, even when flight periods were extended to 8 hours.*[5]

The National Transportation Safety Board (NTSB) has made recommendations for establishing flight time and duty time limitations for Part 91 air tour operations and Part 121 operations previously. The Federal Aviation Administration (FAA) took action on the NTSB recommendation through the Notice of Proposed Rule Making (NPRM), but due to the numerous comments (2000+) removed the proposed rule from consideration. The Air Transport Association, Helicopter Association International, National Business Aircraft Association, and several others objected to the proposed rules based on the lack of evidence supporting fatigue related accidents and the cost to owners and pilots, if new limitations were enacted. Many airlines and some operators in the helicopter industry provide pilots additional pay for hours flown as a way of controlling payroll costs and motivating employees. I can understand why owners and pilots may not want the new rules enacted, because it influences their payroll costs or income. As a person that owned and operated helicopters in Part 133, 135 and 137 operations, I am sympathetic to these concerns, but I also know the cost of an accident is far greater.

There is one other reason why Part 91, 133, and 137 operations have not been addressed as far as flight and duty time limitations, and that is exposure! In the aerial work arena, there is very little exposure to the flying public, since the crews are all essential to or associated with the work that is being performed. In addition, when a fatal accident does occur the loss in life generally involves the pilot. It is not mean spirited that I say this, it is just an unpleasant fact in our regulatory environment, and all rules are generally made based on "exposure to loss of life and exposure to the traveling public." In our industry,

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[5] A.M. Stave, "The Effects of Cockpit Environment on Long-Term Pilot Performance," *Human Factors*, Vol. 19 (1977): 503-514.

we fall short on both these levels, but it should not stop us from implementing controls to prevent fatal accidents that may cause the loss of a friend. I have lost many in this industry over the last 30 years.

PHYSIOLOGICAL ASPECTS OF FATIGUE AND STRESS

The following material in this section is attributed to the California Training Institute and Craig Geis who provides training on Human Error: Threat and Error Management. All copyright material is in italics and the author's notes are in normal print.

Stress and Performance

What is stress? When we think of the word "stress", mental-emotional strain usually comes to mind. Anxiety, fear, anger, and frustration do, indeed, qualify as stress. Excessive levels of any of the following are also types of stress: sound, light, certain chemicals, fatigue, starvation, acute illness, pain, tissue injury (with or without pain), trauma, surgery, long airplane flights, heat, cold, and deviations from normal blood sugar levels. The thing that qualifies all these as stress is their common ability to activate the body's stress response. It does not matter if the stress is mental-emotional, physiological or environmental. The body responds the same way to stress only the intensity of the response varies depending on whether it is chronic or acute stress.

A lecturer, when explaining stress management to an audience, raised a glass of water and asked, "how heavy is this glass of water?"

Answers called out ranged from 6 to 12 ounces.

The lecturer replied, "The absolute weight doesn't matter. It depends on how long you try to hold it. "If I hold it for a minute, that's not a problem. If I hold it for an hour, I'll have an ache in my right arm. If I hold it for a day, you'll have to call an ambulance. "In each case, it's the same weight, but the longer I hold it, the heavier it becomes."

He continued, "And that's the way it is with stress management. If we carry our burdens all the time, eventually, as the burden becomes increasingly heavy, we won't be able to carry on."

"As with the glass of water, you have to put it down for a while and rest before holding it again. When we're refreshed, we can carry on with the burden. Whatever burdens you are carrying now, let them down for a moment if you can. Relax; pick them up later after you've rested."

Information Processing Modes

Most pilots go their entire careers without ever having to deal with a catastrophic emergency. V/hen we are faced with this challenge we must be able to deal with it effectively. When faced with a serious emergency we tend to react without thought. We can be trained to overcome this natural tendency. Humans have two distinctly different modes of processing information. These are the rational-thinking mode and the experiential-thinking mode.

***Rational-Thinking Mode**: When people are not under high levels of stress, they have the ability to calmly engage in the conscious, deliberative, and analytical cognitive processing that characterizes rational thinking. The rational-thinking mode happens during low emotional arousal states.*

***Experiential Thinking Mode**: However, when people become angry, or frightened, they stop thinking with their forebrain (the rational thinking mode) and start thinking with their midbrain (the experiential* *mode, which is indistinguishable from the mind of an animal). They are literally "scared out of their wits". The experiential-thinking-mode occurs during states of <u>high stress and emotional arousal,</u> such as would occur in a serious emergency. When a perceived emergency requires quick action, they cannot afford the luxury of thinking. Instead, their cognitive processing system automatically switches over to experiential thinking. People are angry, sad, or frightened not as a direct result of what objectively occurs but because of how they interpret what happens. The automatic, preconscious processes that are the effective instigators of such emotions are made so automatically and rapidly as to preclude the deliberative, sequential, analytical thinking that is characteristic of the rational system.*

I have found during external load operations that I never found myself "scared out of my wits" but there were certain jobs that due to their complexity or precision caused a great deal of anxiety. Even though the ground crew and I accomplished all of the pre-mission planning and briefings, weight and performance planning, weather checks, etc., the job stress came from the complete understanding that very little margin for error existed. The job may have lasted for less than one and half flight hours, consisting of 30 turns (60 cycles), but at the end I felt as if I had flown for eight hours or more.

<u>Acute Stress</u>

The situation changes significantly when we are subjected to acute stress. Since the stressor is extremely high and occurs rapidly the nervous system intervenes to help us immediately. In the case of acute stress, the "Fight or Flight Response" is triggered. Acute stress is the rapid exposure to a high stressor. Our ancestors experienced acute stress when they were chased by a lion. Today we experience acute stress if we are put in a "perceived" stressful situation quickly. To be considered acute stress, the stress must be perceived high by the individual and occur quickly. Remember it is not the stressor but the individual's perception of the stressor that makes it high. This is often a function of the experience level of the individual and their previous exposure to stress. See graph next page.

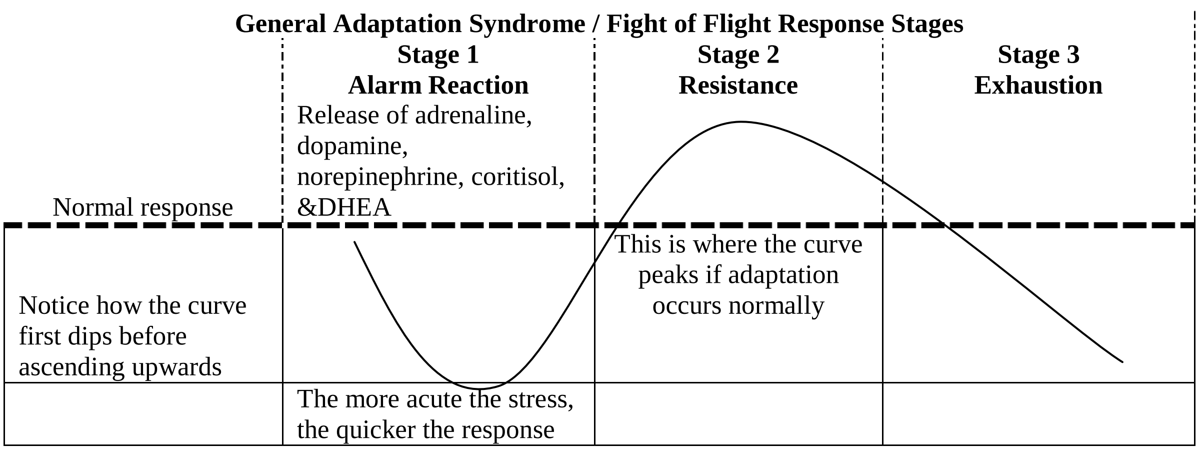

Figure 4

It is the author's belief the majority of pilots still operating in the aerial work industry have developed a "tolerance" to these stressors due to our operational experience. As stated above, ". . . it is not the stressor but the individual's perception of the stressor that makes it high. This is often a function of the experience level of the individual and their previous exposure to stress." The operational experience I am speaking of was honed during the Vietnam War, where long duty days and high flight hours, exposure to constant threats of "life or death" situations, and sleep disruptions contributes to a high tolerance to stress for most of us. In addition, most helicopter pilots that engage in aerial work similar to what is discussed in this document have spent many years in the industry and have developed a "tolerance" to the stress in this line of work. However, as the workforce is replaced by pilots who have not been exposed to high stress levels; external load work provides an environment where stress related fatigue may become more of a factor in accidents.

The best way to envision the effect of acute stress is to imagine oneself in an emergency situation. Let's take a look at the brain's response to this.

Stage I: Alarm Reaction - When stress is high and occurs quickly the fight or flight response is activated. This is shown in the figure above where the curved line falls below the normal response to stress. The high stress is detected by the nervous system and it signals the endocrine system to release chemicals to help. The Alarm Stage is the initial result of the chemicals being released to fight stress. This is shown in the figure above where the curved line moves up quickly. As you can see, the individual can now respond to more stress than normal. They are charged chemically and you can see and feel this in heartbeat, flushness, pupil dilation, etc. The release of hormone is what helps us when the brain signals the release of adrenaline, dopamine, norepinephrine, coritisol & DHEA.

> Adrenaline: Give us energy and strength
> Dopamine: Increases alertness & anxiety
> Norepinephrine: Enhances automatic responses
> DHEA: Restores calm & performance
> Cortisol: Helps us respond to stress & change

Cortisol: Cortisol is a normal hormone produced in the outer portion, or cortex, of the adrenal glands, located above each kidney. The normal function of cortisol is to help the body respond to stress and change. It mobilizes nutrients, modifies the body's response to inflammation, stimulates the liver to raise the blood sugar, and it helps control the amount of water in the body. While helping us, too much cortisol impairs a particular aspect of the memory process in humans.

Short-Term Memory (STM): Cortisol impairs the transfer of information from short term to long-term memory. It interferes in the encoding and consolidating process. This results in information being lost or information not being transferred to long-term memory. Since STM is limited in capacity (6-8 chunks of information), in a stressful situation information overload occurs and pieces are lost and not transferred to LTM.

Long-Term Memory (LTM): It is thought that cortisol (and by extension, stress) impairs memory retrieval specifically, without more general effects on thinking or intellectual function. It's not that we lose information from long-term memory but that we have difficulty finding and retrieving it. This finding may have implications for the reliability of courtroom testimony, performance in combat, aircraft, police, and medical emergencies, and any other situations where people must remember important information under stress.

- *Frontal Lobe: Cortisol also affects the frontal lobe of the brain. The frontal lobes are considered our emotional control center and home to our personality. The frontal lobes are involved in motor function, problem solving, spontaneity, short-term memory, rational thought, language, initiation, judgment, impulse control, and social and sexual behavior. During a stressful event, cortisol suppresses activity in areas at the front of the brain that control short-term memory, concentration, inhibition, and rational thought. These sequences of mental events allow a quick reaction to the lion - fight or flee from it. But, it hinders the ability to handle complex social or intellectual tasks and behaviors. This may result in irritability and aggressive behavior.*

While acute stress triggers the Fight or Flight Response immediately, continued exposure to moderate level of stress leads to chronic stress. Chronic stress does not trigger the Fight or Flight Response but in the long run it mimics acute stress by the gradual production of stress hormones.

How do the above chemical reactions affect the pilot during external load operations? I believe pilots experience most, if not all of these effects, when conducting high cycle repetitive lift operations. The mind does not get to the level of stress of "fight or flight," but the stress is high enough to experience many of these physiological reactions. Think of about the numerous bits of information a pilot's brain is processing when placing an external load that is on the end of a 150 feet of longline in heavily timbered area or area with multiple obstructions. If six to eight bits of information is all the STM can process, then we must experience in some cases a "loss of situational awareness" because of the overload or focus on only those threats that are immediate such as obstacle clearance and power management.

Stage II: Resistance Stage - is where the body adapts to the new stress and continues to produce chemicals to deal with it. Over time if the stress is too high the body cannot keep up the chemical production and the line starts to fall. If the stress is removed, the body goes into the relaxation response where it returns to normal. Note that if the stressor is removed quickly when the body is chemically charged the chemicals no longer have any stress to work on. This can result in excess adrenalin and muscular problems (shakes, nervousness, etc.) Acute stress in short episodes is usually fine. Once the threat has passed and the stressor has been resolved, the stress hormones return to normal. This is known as the relaxation response. The body's systems also normalize.

In the Exhaustion Stage the line moves below the normal response to stress and our performance suffers. This does not mean we are physically exhausted only that the body exhausts its ability to continue to produce the required chemicals.

Types of Stress We Face

Concept Shifting: Another type of mental stress called concept shifting or multi-tasking is an important type of stress experienced by many pilots and crewmembers on a daily basis. Concept shifting is the action of changing the focus of your attention from one thing to another or shifting our attention too frequently. The constant forcing of the brain to shift attention from one stimulus to another not only causes stress but also results in a negative impact on your hormone and immune systems. External load operations require us to constantly shift our attention and make us susceptible to to concept shifting.

While it does not meet the definition of acute stress, concept shifting and multi-tasking, can lead to chronic stress. Many of us experience concept shifting daily, for example, when we try to complete a complicated task while making or answering a radio call. Throughout a school day, students constantly shift their focus, studying math during one period and history the next, so on and so forth, to a point of diminished returns in the learning process. It's a good thing to be able to think on your feet, but not to a point of collapse! To minimize this stress, try to organize your schedule so that concept shifting is kept to a minimum. Another alternative is to adopt behaviors that improve cortisol levels and reverse overload. This includes performing exercise and relaxation techniques; of course, keeping your blood sugar stable by eating right helps too. A positive mental attitude is paramount to optimum health.

Workload (Boring & Repetitious: Research at the Aeromedical Institute of Research in Oklahoma City found that boredom and monotony are widely recognized as undesirable side effects of repetitious work. Boredom and monotony are in fact stressors that may be as potentially harmful to the individual as are the same commonly acknowledged effects of exposure to aver stimulating conditions. These factors can be detrimental to morale, performance, and eventually to the quality of work. Typical examples of under stimulation include sensory and perceptual deprivation, vigilance (monitoring) tasks, repetitive tasks, and *unsatisfying work. Too little work, for your required level of mental activity, will be stressful. External load operations require extreme vigilance, are often repetitious, and become boring. This leads to fatigue and a loss of situational awareness.*

Other Factors Causing Stress:
(1) Prolonged Work: Usually leads to fatigue because of cumulative sleep loss
(2) Lack of Satisfaction: Fatiguing and boring
(3) Circathan Rhythm Disruptions: Night Shift Work, travel, etc.
(5) Emergencies: Intense, unplanned acute stressors

Chronic Stress

Chronic stress is caused by a stressor of moderate intensity which continues for a prolonged period of time. Chronic stress is not unfamiliar to any of us these days. We have too much stress in our lives, and it is coming from all directions. Our jobs, financial situations, family responsibilities, relationships, and even ova' health concerns are just a few of the things that may be causing stress in our lives. Over time, this chronic stress can really take its toll on our hormones, and our bodies and lead to burnout. When you face chronic stress or normal daily stressors the body responds in a predictable way to help you.

1. The hormone cortisol (a derivative of cortisone) is released by the adrenal cortex and floods your system. Cortisol is a stressed-induced hormone that helps your body have the energy to get through the situation.

2. Once the stressful situation is past, the cortisol is shut off, and dehydroepiandrosterone (DHEA) is produced to restore calm and balance to your body and return it to equilibrium.
3. Cortisol and DHEA work as a team to get you through stressful situations.

4. However, if you are constantly under stress, whether it is from a struggle to make ends meet or from the stress of your job, these hormones are constantly in your system. Too much can cause your adrenal glands to be overburdened and become worn out. If this goes on for a long period of time it can have serious affects on your body and overall health.

5. When chronic stress continues, cortisol production increases and your overall levels of DHEA will decrease- The cortisol still being produced then causes negative side effects. Empirical evidence shows that the DHEA Cortisol ratio level may determine the degree to which an individual is buffered against the negative effects of stress. Constant exposure to chronic stress produces lower levels of DHEA and the balance is upset. This imbalance can lead to many health problems that may be as insignificant as a cold or as serious as a heart attach. Individuals with high cortisol and low DHEA levels can also have panic attacks, anxiety, and suffer from exhaustion.

Signs of Excessive Stress

1. *Confusion in thinking*
2. *Difficulty making decisions*
3. *Increased heart rate*
4. *Rapid breathing*
5. *Depression*
6. *Change in eating habits*
7. *Feeling overwhelmed*
8. *Inappropriate tiredness*

9. Headache
10. Sleep disturbances
11. Difficulty in concentrating
12. Short temper
13. Upset stomach
14. Job dissatisfaction

Stress and Performance

Stress affects the way we process information, what we remember, our perceptions, and the decisions we make. Arousal of the nervous system is a consequence of stress. Stress has two effects on us:

- *Energizing + Increases Performance*
- *Interfering + Detracts from Performance*

The effects of stress are cumulative. Furthermore, some amount of stress is desirable, it keeps us alert and on our toes. However, higher stress levels, particularly over long periods of time can adversely affect performance. Thus, performance will generally increase with the onset of stress, but will peak and then begin to fall off rapidly as stress levels exceed your ability to cope. Each person has an individual optimum level of stress that results in an optimum level of performance for a given task. This is shown in Figure 5..

LOW STRESS: Low levels of stress result in inattention, low information processing, complacency, boredom, and overall feeling of "fat, dumb, and happy (FDAH)."

MODERATE STRESS: Moderate stress results in vigilance and optimal performance. This is universal but what moderate stress is for a particular individual differs. Keep in mind that for a given task the individual's perception of the stress will vary based on their experience, training, etc.

HIGH STRESS: High stress results in low information processing and very often "defensive avoidance" behavior. You will often see individuals avoid additional information that is stressful. It can also lead to hypervigilance, panic, confusion, tunnel vision, and tunnel hearing.

Our Equilibrium Level

Our nervous system is designed to keep us in equilibrium. This also applies to mental functioning and the mind seeks a comfortable level, leaving something in reserve for emergencies. The body therefore seeks a level slightly to the left of moderate stress.

Performance Curve

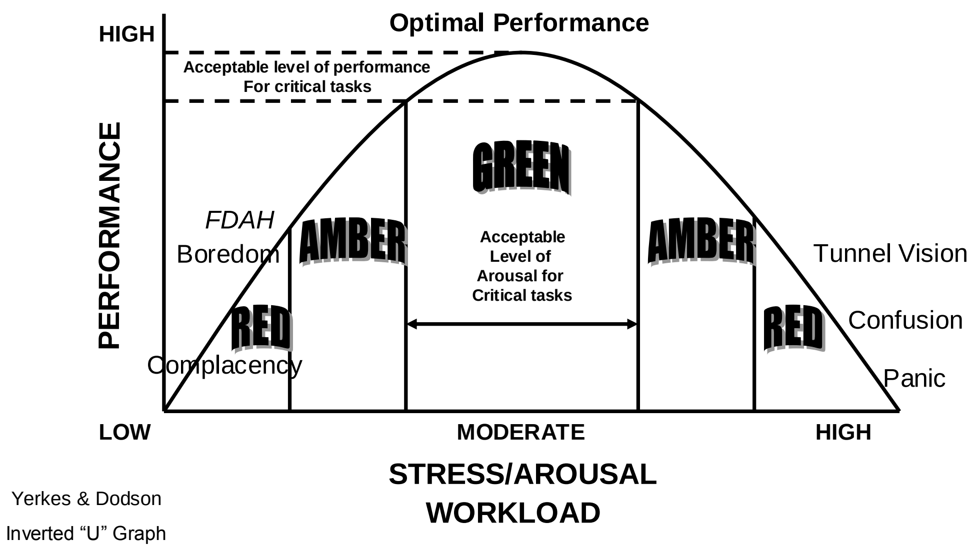

Figure 5

<u>Figure 5 Interpretation:</u>

- *As individual arousal stress/workload increases from low to moderate, performance increases.*
- *As individual arousal/stress/workload increases from moderate to high, performance decreases.*
- *Each individual has his/her own curve defining what is low, moderate, and high for them. Experience, level of proficiency, and training all play an important part in this. What is low for one person may be high for another.*
- *An individual desiring optimal performance must be aware of his or her moderate level and where they are on the curve in a given situation.*

<u>Task Complexity</u>

In understanding this relationship a little better, let's look at what happens when we consider the complexity of the task we are performing. Figure 6 shows the level of stress/arousal and associated performance as it applies to the tasks of varying complexity.

TASK COMPLEXITY

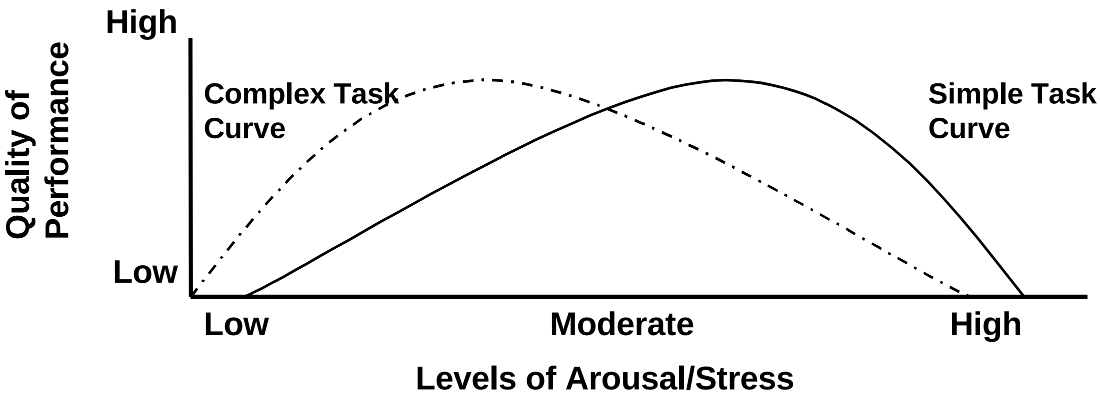

Figure 6

<u>*Figure 6 Interpretation:*</u>

- *Simple tasks are performed better under higher levels of stress. Examples: A pre-flight after major maintenance usually results in more caution, increased situational awareness, better planning, etc.*
- *Complex tasks are performed better under lower levels of stress. Example: We perform better during a check ride if our stress level is lower and we just focus on the basics of the maneuver.*
- *There is a range of moderate stress that will produce Optimal performance in a given situation.*

We often think long-line work is a complex task but it is not because we are experienced and it is very repetitious work. It becomes a simple task that requires habit patterns rather than thinking. The simpler the task and the more that habit patterns are involved, the lower the stress level. We find ourselves on the left side of the simple task curve and susceptible to complacency error.

Figure 7 represents an individual who is experienced, current, and proficient at a specific task. They are able to work over a wide range of low to high stress with little change in performance. The danger comes when they work at too high a level of stress. When stress moves from moderate to high, there is only a small decrease in performance. It is very difficult to detect this change until the curve drops sharply; at that point it's difficult to recover.

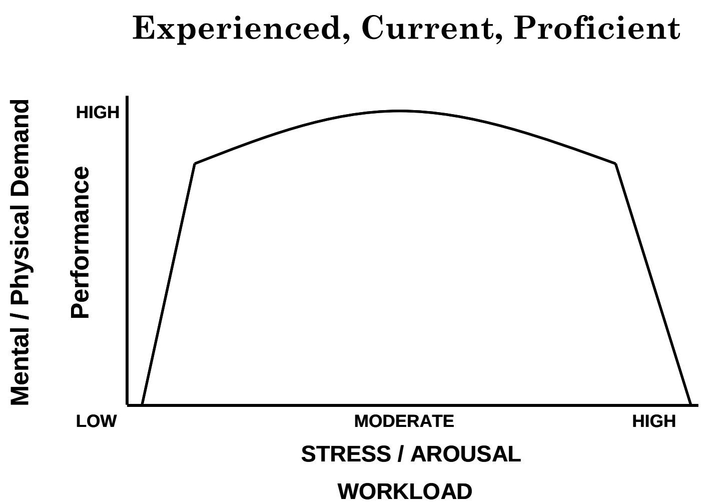

Figure 7

Figure 8 represents an individual who is experience, but not proficient at a particular task. They work well under high levels of stress but are more susceptible to complacency error. They often put themselves in situations that require exceptional proficiency to recover from.

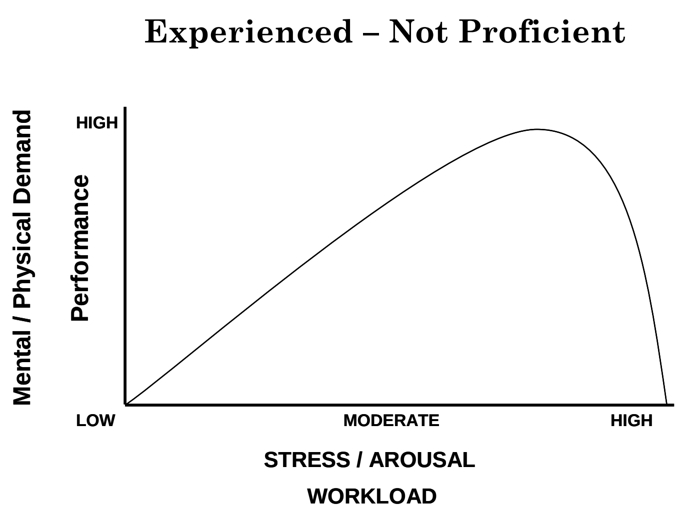

Figure 8

Figure 9 represents an individual who is inexperienced or new to the job or task. They work well under lower levels of stress but are more susceptible to error under moderate to high levels of stress.

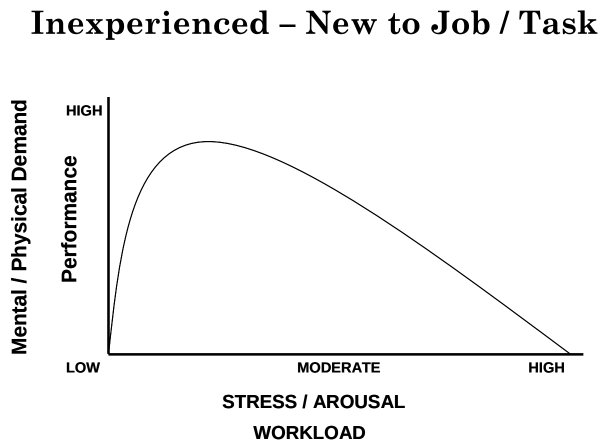

Figure 9

Performance Decrement from Fatigue

Fatigue and stress tend to interact, with stress causing fatigue and fatigue causing stress. As stress and fatigue increase, ones abilities diminish. Fatigue is simply a state of diminished physical and/or mental efficiency. Awake is a stable level of arousal, alertness, and cognitive ability. As fatigue progresses errors of omission increase followed by errors of commission and eventually followed by microsleeps which are involuntary sleep lapses lasting from a few seconds to a few minutes. Fatigue can cause uncontrolled and involuntary shutdown of the brain regardless of the how hard you try, professionalism, or the training level of the person.

As a result of fatigue our mental processes slow down, visual perception (e.g., maintaining proper vigilance) suffers, decision-making and memory tasks suffer, mental arithmetic is difficult and reaction times slow down. It is slow for both simple and complex tasks.

Fatigued individuals are at high risk because they are unable to determine how badly affected they are or when they started being affected by fatigue. Their subjective evaluation of impairment is usually underestimated when compared with the results from objective fatigue testing. Consider this, being fatigued is like being drunk.

Most adults require 8 hours of restful sleep to stay out of sleep debt. With aging there is usually a significant decline in habitual daily sleep due to increased awakenings. This results in more daytime fatigue, sleepiness, dozing, and napping.

Ninteen hours of wakefulness or ninteen hours of wakefulness plus sleep debt equals the mental & performance level of a legally drunk driver in most states (.08 Blood Alcohol Concentration)

Sleep debt has implications for those individuals that don't get a full night's sleep or do shift work. Sleep Debt = # hrs. less sleep per night x # days. For example: 2 hrs less sleep per night for 3 days = 6 hours of sleep debt. Sleep debt is added to hours of wakefulness to get the total time of wakefulness. Remember this is when you wake up, not your duty day time. Sleep debt recovery will not occur after a single sleep period. It usually requires 2 nights of recovery and 10 hours of sleep.

Would you fly legally intoxicated? Consider these numbers:

Hours of Wakefullness	*Blood Alcohol Concentration Performance*
12	*0.02*
14	*0.04*
16	*0.06*
19	*0.08*
20	*0.10*
22	*0.12*
24	*0.14*

<u>Potential Outcomes Caused by Fatigue</u>

Attention Problems

- Attention Span Narrows: Inattention to minor, but potentially important details.
- Increased Lapses of Attention: Greater time lapses occur as fatigue increases
- Memory Problems: The ability to integrate, store, and retrieve information declines.
- Reaction Time: Slow and irregular reaction times - We miss relevant cues.
- Cross Checking Declines: Take too much mental effort.
- Perceptual Changes: Channeling of attention, tunnel vision, tunnel hearing
- Cognitive Processes Slow Down: Automatically slows down to maintain accuracy.
- Alertness Declines: Brain shuts down to conserve energy, micro-sleeps occur, involuntary lapses into sleep increase over time.

Attitude Problems

- Motivation: Decreased motivation and conservation of effort.
- Attitude & Mood Deteriorate: "It's good enough" attitude prevails, psychological depression, poor morale.
- Increased Irritability: Little things bother us more – We become more moody.

Teamwork Problems

- Team Breakdown: Impairments in communication, cooperation, and team coordination.
- Communications Breakdown: Social interactions decline.

Performance Problems

- Accuracy and Timing Degrade: Critical Actions—Crosscheck—Relevant Cues.
- Lowering of Performance: Poor and careless performance, increased errors.
- Lowering of Standards: Lower standards of performance become acceptable – Greater tolerance for error.
- Flawed Decision Making: Decisions made on missed, flawed, or incomplete information.
- Thought Processes Suffer: Ability to logically reason is impaired - Difficulty concentrating & thinking clearly.
- Skills Decline: Everything becomes more difficult to perform, even simple tasks.
- Physical Symptoms Increase: Dizziness, headaches, stomach aches increase.
- Mental Tasks Harder To Perform: Mental arithmetic, programming, entering data, remembering.

Causes of Fatigue

• Vigilant monitoring
• Tedious tasks
• Continuous wakefulness
• Shift Work — shift rotation
• Work load
• High threat environment
• Disturbance of circadian rhythms
• Cumulative sleep loss
• Long hours — Overtime

Summary & Conclusion

Fatigue is a major contributor to accidents, lost productivity, and poor quality of life. As the activity continues, the potential for fatigue-related problems will only increase; however, safety, performance, and general well-being can be preserved by adhering to good task-scheduling practices, implementing proven fatigue countermeasures, providing sleep-conducive environments for off-duty people, and making adequate daily sleep a top priority. Remember, sleep is a physical necessity--not a luxury, and there is NO substitute for SLEEP!

RECOMMENDATIONS TO MITIGATE FATIGUE AND STRESS RISKS ASSOCIATED WITH CLASS B AND CLASS C EXTERNAL LOAD OPERATIONS.

The following recommendations are based on what the author believes to be prudent administrative controls to mitigate risks associated with Class A, B and C external load operations. The administrative limitations set forth in this document do not limit the pilot to other types of flying, if a flight time limit is reached. It should also be understood that some form of formal study should be conducted in order to validate the concepts and recommendations in this document. However, since this would require funding and would take time to accomplish and since the potential for fatal accidents exists now, it is important for owners and managers to take proactive measures immediately.

Class A External Load Operations.

- If the work environment involves 20 turns (40 cycles) or less, no more then 8 hours of flight time should be logged in a 14-hour duty day.

- If the work environment involves 21 turns (42 cycles) to 40 turns (80 cycles) then no more than 6 hours of flight time should be logged in a 14-hour duty day.

- If the work environment involves 41 turns (82 cycles) to 60 turns (120 cycles) or more, then no more than 4 hours of flight time should be logged in a 14-hour duty day.

Class B External Load Operations.

- If the work environment involves 20 turns (40 cycles) or less, no more then 8 hours of flight time should be logged in a 14-hour duty day.

- If the work environment involves 21 turns (42 cycles) to 40 turns (80 cycles) then no more than 6 hours of flight time should be logged in a 14-hour duty day.

- If the work environment involves 41 turns (82 cycles) to 60 turns (120 cycles) or more, then no more than 4 hours of flight time should be logged in a 14-hour duty day.

Environmental Factors to Consider: The type of terrain such as mountains or flat land, obstacles such as heavy timber or wire environment, weather such as clear and light winds or reduced visibility or gusty winds, all have an effect that should be considered in reducing or increasing the recommended flight time limitations for this type of operation.

Class C External Load Operations.

- If the work environment involves wire stringing using "fly-blocks" then 7 hours of flight time should be logged in a 14-hour duty day.

- If the work environment involves using a "needle" then no more than 5 hours of flight time should be logged in a 14-hour duty day.

Environmental Factors to Consider: The type of terrain such as mountains or flat land, obstacles such as heavy timber or wire environment, weather such as clear and light winds or reduced visibility or gusty winds, all have an effect that should be considered in reducing or increasing the recommended flight time limitations for this type of operation.

Other considerations and recommendations: Establish mandatory rest breaks or provide a relief pilot that shares the workload when conducting operations in excess of 40 turns (80 cycles). Although this would increase the operator's cost, the personnel costs can be more than offset by the costs associated with an accident. Generally, a fatal accident involving a single fatality and small rotorcraft costs more than 2.8 million dollars.

SUMMARY

In implementing a safety system approach to aerial work, the work should be clearly defined, hazards identified, controls established to mitigate the associated risks, work controls agreed upon, and a process for feedback and improvement established. The basis for preparing this document is meant to stimulate conversation and raise awareness of the potential hazards associated with human factors (stress and fatigue) while conducting external load work. To reevaluate the mindset that just because no empirical evidence exists that fatigue and stress have not been factors in previous aircraft accidents and incidents during external load operations, to recognize that it has been an overlooked factor. In addition, because of the regulatory environment and lack of thorough human factors investigation techniques, over the years, stress fatigue was not recognized as a contributing causal factor in previous external load accidents. What the industry has referred to as pilot “complacency” or “loss of situational awareness” was in fact a failure of the pilot to recognize the onset of fatigue due to work environment induced stress. In addition, the industry as a whole is steeped in a tradition of “getting the job done,” “expectations” of long hours by operators and customers to minimize the costs associated with these operations, and is widely accepted. Change is needed to ensure the safety in these types of operations and the recommendations to implement controls are just one step in reducing accidents in our industry.

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National Transportation Safety Board, Aircraft Accident Report: NTSB Identification: MIA94GA174, 14 CFR Public Use Accident occurred Wednesday, July 06, 1994 in Caryville, FL the pilot's intentional continued flight into instrument meteorological conditions. Contributing to the accident was pilot fatigue.

National Transportation Safety Board, Aircraft Accident Report: NTSB Identification: LAX93LA261, 14 CFR Part 91: General Aviation Accident occurred Saturday, June 19, 1993 in Half Moon Bay, CA, the pilot’s failure to maintain an adequate clearance from the light tower and associated electrical power cables. Factors in the accident were; 1) pilot fatigue due to an excessively long duty day, and 2) glare from the lights, which affected the pilot's ability to clearly see the obstructions.

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CHAPTER VII

Aviation Medicine

Approximately two-thirds of the Army aviation resources supporting operations in Vietnam were assigned to the units, of the 1st Aviation Brigade. The remaining aircraft and men were assigned to those units organic to the divisions; relatively few were assigned to artillery, engineer, aircraft maintenance, signal, or other support units. Although the strength of the 1st Aviation Brigade was not much greater than 25,000 men, its approximately 50 flight surgeons provided primary medical care on an area basis to more than 35,000 troops. In some areas, the dispensaries of the 1st Aviation Brigade were the only source of outpatient care. The medical units of the brigade established liaison and close working relationships with their nearest supporting hospitals, referring patients for consultations, inpatient care, and specialized treatment.

The flight surgeon is a physician who has received formal training in the specialized field of aviation medicine. His mission includes the prevention and treatment of disease, injury, and mental or emotional deterioration among aviation flight, ground crew, and maintenance personnel. He monitors the programs of flyers and is expected to participate in frequent flights. He is confronted by the problems of traumatic injury; of acute and chronic disease, ranging from the common upper respiratory infections to the most uncommon of tropical diseases; of psychiatric disorders, which run the gamut front occupational fatigue through the minor disorders of personality to overt psychoses; and of personal hygiene and environmental sanitation, including dietetics, venereal disease, insect control, and a multitude of bizarre and homely worrisome matters. The flight surgeon treats physical and mental conditions that might endanger pilots or passengers. Whether in the examination room or upon the flight line, he must be able readily to detect incipient major and minor disorders of personality in men who, in their zeal to fly, frequently try to conceal the disorders. He administers and prescribes medications and treatment, and he reviews and studies the case history and the progress of the patient, He also acts as consultant in his specialty to other medical services and provides aeromedical staff advice. In addition, the flight surgeon serves as medical member of aircraft crash investigation teams and, when possible, contributes to aeromedical research and development.

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The number of flight surgeons authorized in Vietnam reached a maximum of 86 in August 1968; by November, 98 were actually assigned there. This maximum contrasted with shortages during such periods as August 1967, when these assignments fell to 40 percent below the authorized strength.

The flight surgeon, assigned to a unit of an aviation brigade, was supported by a medical detachment team which provided dispensary service. These teams were assigned generally on a basis of one detachment per two aviation companies. The unit flight dispensary was usually located next to the airfield, often in a unit billeting area, and the flight surgeon and his staff usually lived with the troops that they served. This arrangement, allowing for optimum rapport and medical services, was especially advantageous when the airfields were, under attack, and it proved vital during the 1968 Tet Offensive, when many airfields, were isolated.

Flyer Fatigue

The aeromedical problems that faced Army aviation, units in Vietnam provided a challenge to their supporting flight surgeons. No problem, however, was more common yet more elusive than that of flyer fatigue. It became more pronounced after 1965 when the buildup of U.S. forces gained momentum and remained a significant limiting factor in the conduct of airmobile operations. By the end of 1966, aviators were flying 100 to 150 hours or more per month, and the need to know how much an aviator could fly before, he was so fatigued that he was no longer effective or safe was evident.

Army aviators were assailed by a multitude of stresses, each to some extent capable of endangering their missions. The stress from hostile fire was aggravated by such factors as heat, dehydration, noise, vibration, blowing dust, hazardous weather, exhaust from engines and weapons, and labyrinthine stimulation. Additional stress was caused by psychic elements, such as fear, insufficient sleep, family separation, and frustration. These stresses, acting on the aviator day after day, combined with the physical exertion of long hours of piloting an aircraft, caused fatigue.

The ever-increasing requirements during the years 1967-68 for aviation support caused the accrual of extremely high aviator flying times in all units. Night operations, with their extra demand upon the critical judgment of the aviator increased. The shortage of crews often forced an individual to undertake both day and night missions without adequate rest.

In response to expressed concern of the unit commanders and of aviation safety officers, flight surgeons at all levels of aerornedical support studied every aspect of the fatigue problem. Because fatigue was the result of many variables, it defied easy definition and precise measurement.

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Emphasis, therefore, was placed on prevention- eliminating or reducing those factors in the aviator's environment that caused stress.

General Neel, Surgeon, USARV, noted in the Command Health Report for August 1968 that approximately 70 percent of aircraft accidents were found to be the result of pilot error and that pilot fatigue had been implicated as a contributing factor in a large proportion of accidents. He indicated that the only way to cope with pilot fatigue was prevention by reducing the aviator's flying hours. His recommendation was "that immediate action be taken to provide additional aviators to USARV insuring at least 100 percent authorized aviator strength to reduce the degree to which pilot fatigue is contributing to the loss of lives and expensive aircraft." This was never done.

The unit flight surgeon's close scrutiny of charts that showed each pilot's flying hours for the previous 30 days, followed by close cooperation among the unit commander, platoon leaders, operations officer, noncommissioned officers, and flight surgeon, proved an invaluable system for collecting data on which the flight surgeon based his final recommendation to the commander. By the end of 1968, this system was utilized by most of the aviation units.

Some flight surgeons, notably Captain Philip Snodgrass, MC, of the 269th Aviation Battalion at Cu Chi, believed that: the relationship of days flown to days off and, particularly, the provision of a scheduled "on-off" work cycle were more important than the total number of hours flown. Captain Snodgrass's staff study of a "goal-directed" flying-hour schedule indicated that a series of 5 or 6 days flown, followed by a scheduled day free from flying and from other duties, resulted in a unit that evidenced less fatigue and could fly even greater numbers of hours. This idea was adopted by many units and proved workable and effective.

Fatigue in the enlisted crew members was a less obvious, though very real, threat. These individuals, who accompanied the aircraft on all its missions, returned to their base camps only to work many additional hours in providing required maintenance and preparing for the following day's missions. With the added requirement of aiding in perimeter defense and in the multitudinous other details of combat aviation, they performed under great stress. Efforts by the unit flight surgeons in their behalf centered upon improving their living conditions, eliminating some extra duties, and increasing their numbers.

By 1970, fatigue as an entity was still no better defined nor more capable of measurement than before. Moreover, the attempt at limiting aviator flying hours by regulation had been proved ineffective in the combat environment, and the requirement for continued study of the problem was evidently needed.

ARTICLE ROTOR & WING MAGAZINE

Monday, August 1, 2005, Feedback--TOUGHEN FATIGUE RULES

In Tim McAdams Safety Watch article, "Frustration's Ill Effects" (May 2005, page 62), do I detect an element of chronic fatigue build-up in the pilot?

Whilst his flying hours (14.6 hr. in previous eight days) were certainly not excessive, it would appear that his duty hours and continuous number of days on duty were. Neither the article, nor indeed the NTSB accident report, for some reason, are specific as to the exact total of cumulative duty hours achieved, being between eight and 13 hr. for each of the previous eight days. Does anyone know the accurate figures--if not, why not? What is also omitted is any mention of the question of how much recovery rest/time off was achieved between each consecutive duty period.

Working on the figures as presented would seem to indicate that this pilot, in a worst-case scenario, would have averaged more than 12 hr. duty per day for nine days (i.e., say one duty day of 8 hr. plus seven duty days of up to 13 hr. equals 99 hr. plus the 11 hr., 19 min. on Day nine). In any profession, the human being will undoubtedly build up sleep deprivation and fatigue working such hours. I am surprised that the current rules permit such excesses.
In the United Kingdom, CAP 371, "Avoidance Of Fatigue in Air Crews," (3rd Edition) has governed the flight and duty time limitation rules for the last 15 years. Helicopter pilots are restricted to a maximum of seven consecutive days on duty before being required to take two consecutive days off. The total duty hours must not exceed 60 hr. in any seven consecutive days.

This pilot, if we take 11 hr. as the average between the eight and 13 hr. achieved each day, would have done 77 hr. in seven days.

Minimum rest requirements dictate each rest period to be at least as long as the preceding duty period or 12 hr., whichever is the greater. Finally, a single pilot coming on duty at 1330 local time would be restricted to a maximum flying duty period of 10 hr. compared to the 11 hr., 19 min.-plus for this pilot.

Thus, with all these U.K. safeguards, it is difficult to envisage a pilot reaching such levels of fatigue that I strongly suspect occurred here. Group Capt. Douglas Bader, a Commander of the British Empire and recipient of the Distinguished Service Order and the Distinguished Flying Cross, quotes in his 1973 "Report of the Committee on Flight Time Limitations" (upon which CAP 371 is based), the committee's considered opinion that "flying helicopters can be more fatiguing than flying aeroplanes."

However, it is not just simply a case of the amount of "stick time," that determines pilot fatigue levels. It is the total lifestyle package of each pilot in terms of total flying hours, total duty hours, adequate rest to recover and number of days off achieved. Sympathetic rostering is one of the keys to countering any build-up of fatigue during operations, but in the United States it would appear to me that the rules that allowed this pilot to reach the stage he did are far too relaxed and in need of a complete overhaul and a significant tightening up. Should that not now become the U.S. National Transportation Safety Board's Number One wish list priority, I wonder?

Finally, the sooner both the FAA and European Aviation Safety Agency--under ICAO auspices--get together to determine, with agreed hard numbers, what would become a common, worldwide flight and duty time limitations scheme the better. It is something I have been advocating for the last decade or more and is definitely Number One on my wish list!

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