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VFR Heliport Obstacle- Rich Environments: Test and Evaluation

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Letter Report

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1.0 INTRODUCTION

This is the first in a series of two letter reports detailing the specific test and evaluation requirements, scenarios, data processing techniques, and government/industry comments concerning pilot performance in an obstacle-rich environment. The second report will develop and recommend the requirements for a piloted helicopter visual simulator to support data collection in this effort.

This report details the issues and the development of test and evaluation criteria necessary to evaluate the psychological effects of an increasingly obstacle-rich VFR heliport environment on the ability of a pilot to operate. In addition, it addresses a conceptual application of "target level of safety," to assist the FAA and individuals concerned with heliport planning with regard to the proximity of obstacles to a VFR heliport.

The effect of an increasingly obstacle-rich heliport environment on pilot performance will be tested by collecting definitive performance data through the use of a piloted, visual helicopter simulator. Results will be verified with actual flight testing.

This study is divided into two phases. Phase 1 is further divided into four tasks:

1. test and evaluation requirements,
2. simulation requirements and facilities,
3. simulation test plan, and
4. pilot briefing materials.

The product of task 3 is the completed test plan. The product of task 4 is pilot briefing material that explains their role in the test and participation requirements.

1.1 PURPOSE

The intent of this report is to identify the issues and test parameters that must be evaluated through visual simulation to analyze the psychological effects of an obstacle-rich VFR heliport environment on pilot performance. It is anticipated that careful study of the test results can offer a direct contribution to safety. By providing a clear and concise breakdown of the effect obstacles have on performance, specific conclusions can be drawn. Application of these conclusions presents an opportunity to develop specific target levels of safety for the environment in question.

The report additionally presents the results of the literature search and interviews with pertinent individuals in the Federal Aviation Administration (FAA) and the helicopter industry. It discusses the diverse opinions gathered and offers recommendations regarding various criteria and methodologies associated with test parameters. The main focus for developing the testing parameters is FAA and industry concerns that are used to define the dimensions of this project. Industry involvement is critical in parameter development, since active participation by helicopter operators and users is essential to keep the potential of high technology simulation test scenarios in line with real-world situations and practices. A close working relationship is being maintained with the FAA and industry to insure

that the final products of this research are acceptable and meaningful.

1.2 BACKGROUND

Obstacles located in the proximity of VFR heliports have always been of concern to the FAA. However, testing the effects of these obstacles has been limited to airspace concerns. No study has been performed on the psychological effect that these objects may have on the pilot of the aircraft. In other words, at what point does the placement, type, and number of obstacles within the allocated VFR airspace deter a pilot from the ability, or desire, to use a heliport? This study is designed to address that issue.

A recent example of a relevant scenario is the New Orleans Downtown Heliport. Although built to FAA minimum VFR airspace requirements (reference 1), the numerous obstacles surrounding the heliport cause it to be perceived as unsafe by some individuals. Some pilots refuse to fly into this heliport in a single-engine helicopter; others will not use it at all. Some pilots maintain that the real problem with the New Orleans heliport is not the obstacles themselves but the fact that there is no alternate emergency landing area available due to the number of objects surrounding the heliport. Others say that when they are on the landing pad, everything surrounding the heliport looks higher than the heliport itself, giving them the feeling they are in a "hole." This perception indicates that the numerous obstacles do play a psychological role in the desire or ability to use that heliport.

Other public-use heliports may have similar problems. The Pan Am Metroport Heliport in downtown Manhattan is built on the edge of the river with a wall very near the edge of the landing pad. When first-time pilots fly into this heliport, they are very cautious. Continued use builds their sense of confidence as they become accustomed to the approach, but it is impossible to tell how many pilots never use this heliport due to its close-in obstacles. Although this heliport was not Federally funded, it is a public-use facility. However, can any level of government afford to build heliports that will only be used by a small segment of the pilot population?

Private heliports do not even have to meet minimum FAA VFR airspace standards. There is no way to tell how many private heliports, including hospital heliports, are located in areas where obstacle-rich environments cause some negative psychological effect and therefore are potential safety problems.

This issue will become more critical as the demand for heliports in urban areas and city-centers grows. Urban heliports, whether located in the city-center or within the metropolitan area, must frequently be placed in obstacle-rich locations. Often, the only location for an urban public-use heliport may be where high-rise buildings, utility towers, light poles, walls, etc., abound. The expense of constructing these facilities would be unwarranted if only a few pilots are able or willing to use them. Unusable or semi-usable heliports do not support the increased use of rotorcraft within the transportation infrastructure as outlined in the Rotorcraft Master Plan.

2.0 ISSUES

2.1 PSYCHOLOGICAL EFFECT ON PILOT RESPONSE AND PERFORMANCE

This study will attempt to answer some basic pilot performance questions with regard to the number, type, and placement of obstacles found below the VFR heliport imaginary surfaces. Does obstacle intensity create a psychological consequence that outweighs the desirability of a heliport location?

More specifically, what happens when a pilot is placed in unfamiliar surroundings when flying to a heliport which has a jungle of obstacles below the VFR imaginary surfaces? Does this create a measurable perception that this is a dangerous place to land? Is there a predictable point at which the psychological perception affects the ability of the pilot to perform routine flight duty tasks? Does this environment affect the ability to perform emergency procedures? How does the availability of close-by alternate landing sites affect pilot perception and performance in this environment? At what point does the desire to use the heliport cease? What effect does experience and/or proficiency have on the ability to use the heliport? By using an applicable analytical process, similar to the Cooper-Harper Rating Scale (reference 20), these questions will provide the nucleus for establishing a psychological evaluation of the effects of an increasingly obstacle-rich environment on pilots.

2.1.1 Risk-Assessment for Pilot Decisions

Flight in the vicinity of heliports presents a certain level of risk with regard to striking obstacles. Each pilot assigns a mental assessment with regard to this risk perception prior to making a decision. If it were possible to assign numerical values to this risk, modification of the design or planning of heliports could greatly enhance operability. Can a risk-assessment factor be assigned to a pilot's decision that would yield a numerical weighted value for analysis? Separate discussions with candidate subject pilots could provide insight into the discriminatory process connected with a mental judgment of obstacles. By developing a pilot rating scale to objectively investigate and evaluate the perception of obstacle threat, a potential risk-assessment factor could be formulated.

2.1.2 Obstacle Perception Factor

As helicopter pilots fly to and from various landing sites, approach and departure task complexity apparently can vary dramatically based on the obstacle scenery. Each pilot mentally allocates a level of intimidation to the potential hazard each obstacle may present. Some obstacles are perceived as more dangerous than others, regardless of the true damage a collision may cause. As an example, a tree may be considered by pilots as a soft obstacle and not extremely dangerous, while a building that has the same detrimental effect on a helicopter in an accident is considered a hard and damaging obstacle. Consequently, there is a supplemental factor that must be considered when rating obstacles of different texture and/or consistency and their potential effect on a pilot's perception. By carefully constructing questions that are based largely on the pilot's ability

to draw on his/her knowledge and experience regarding the potential threat of each obstacle, obstacles can be categorized using an assessment factor based on the psychological effect. Collectively, these assessments add to the ability to evaluate obstacles that may be found in a heliport environment.

2.2 TARGET LEVEL OF SAFETY

Safety is of paramount importance to the rotorcraft industry. Rotorcraft accident rates compare favorably with those of fixed-wing aircraft. Still, a significant portion of the public perceives rotorcraft as unsafe. If rotorcraft are to be better accepted by the public, operators need to improve their safety record on a continuing basis. This introduces the need for analytical quantification of obstacles affecting pilot performance in order to generate a fundamental "target level of safety (TLOS)." A TLOS provides an objective way to measure and manage safety. Defining minimum airspace design requirements associated with VFR heliport approach and departure corridors is considered one major element of the TLOS concept.

In general terms, certain generic information, as listed below, forms the basis for any safety assessment of the operational aspects of a heliport environment:

- o size of the target factor required,
- o air traffic mix in the VFR environment,
- o geographical region involved,
- o aviation accident rates for approach and departure,
- o historical data associated with a specific heliport,
- o weather criteria, and
- o time (i.e., time of day and of year).

Historically, two different approaches have been used for deriving a specific TLOS. The first is a comparison of aviation risk with the risk levels associated with non-aviation activity. The second is to determine target levels based on past performance in aviation safety.

In contrast to these previous approaches, this study proposes to use the TLOS concept to develop a "mathematical or statistical strategy" for use in heliport planning when questions of safety in obstacle-rich environments are involved. As one of its major issues, this report explores the possibility of formulating a TLOS for VFR heliports. A level of safety needs to be established with regard to the number and proximity of obstacles near a VFR heliport so that potential psychological effects on pilot performance can be minimized. Obviously, many factors must be considered in devising a technique that can address these issues. Performance results must be cautiously investigated and appropriately analyzed to establish a relevant correlation. To provide a sufficient baseline for assessing this TLOS

concept, two generalized areas must be explored: 1) perceptual factor for obstacles, and 2) close-in obstacle depth perception.

2.2.1 Perceptual Factor for Obstacles

In general terms, the airspace in the vicinity of heliports is considered safe if collision risk factors are less than a predetermined level. The current FAA VFR imaginary surfaces grant obstacle protection for safe ingress and egress operations. However, no specific evaluation process has been designed to test obstacle intensity under the VFR imaginary surfaces from a perceptual basis. Can the perception of the potential risk of individual obstacles be measured by type, location, height, and intensity to yield a result to which a numerical value can be assigned? Our aim is to determine if the same methodology that is applied in determining target levels of safety for other controlled airspace, such as en route and terminal airspace, can be applied to sectorized portions of the approach and departure corridors for VFR heliports. The essence of this investigation will be to offer a rational strategy that heliport authorities can use when working with industry and the community to keep a heliport open and unencumbered by obstacle encroachment.

2.2.2 Close-In Obstacle Depth Perception

The obstacles in the immediate landing and takeoff area environment are believed to be the most critical in this evaluation. Many individuals in the helicopter industry believe that these obstacles play an even more important role in the assessment of the operability and usefulness of a heliport than previously imagined. The appearance of close-in obstacles, as determined by their relative distance and position in the immediate landing and takeoff area, provides a true perspective of the overall obstacle scene. Limitations of visual cues within the surrounding field-of-view may adversely affect an individual pilot's ability to assess an appropriate level of avoidance. The placement of obstacles within a close-in arena may inequitably increase their psychological importance, or they may be more important due to the higher risk of main or tail rotor strikes and collisions. In conjunction with assigning a numerical value to obstacle perception, special consideration must be given to the effect of close-in obstacles. The design and development of the various simulated scenarios for the test must represent the potential significance of close-in obstacles.

3.0 INVESTIGATIVE PROCESS

The development of this report has been accomplished through an investigative process encompassing both a literature search and interviews with knowledgeable representatives from the FAA and the helicopter industry. Through the investigative process, relevant issues were defined and a test methodology was evaluated.

3.1 DOCUMENTATION

In order to identify the requirements of this task, an in-depth review of the documents in the list of references was made with regard to heliport design, airspace, and safety issues.

3.2 INTERVIEWS

Interviews were conducted with the FAA National Simulator Program Staff, (ASO-205) in Atlanta, Georgia; the FAA Technical Center (ACD-330) in Atlantic City, New Jersey; the FAA Rotorcraft Directorate, Policy and Procedures Branch (ASW-112) in Fort Worth, Texas (contacted at the American Helicopter Society (AHS) Annual Forum held in Phoenix, Arizona); and the FAA Field Office, NASA Ames Research Center, Moffett Field, California (contacted at the NASA/FAA Helicopter Simulation Workshop held in Santa Clara, California). Helicopter manufacturers who run helicopter simulators capable of handling this project were also contacted. Insights into testing requirements were obtained and the potential of simulator testing determined.

3.3 INDUSTRY/FAA BRIEFING

To further refine the test and evaluation parameters, a meeting was held with both helicopter industry and FAA representatives. On May 23, 1991, the FAA Vertical Flight Program Office (ARD-30) through their support contractor Systems Control Technology conducted a meeting to brief members of the helicopter industry and the FAA about the purpose and scope of this study and to garner their views on the applicability and potential results of this project. Emphasis was centered around obtaining their insights and comments regarding the issues being addressed. Appendix A contains a copy of the proceedings of that meeting, and appendix B contains a summary of the comments received.

4.0 TEST METHODOLOGY

The purpose of this study is to develop a reasonable test methodology based on the issues described, and to decide what variables need to be included and evaluated in order to produce valid results. Programmatically, the test methodology is subdivided into two specific fields: 1) simulation, and 2) human factors engineering. Preliminary categorization of these fields will provide initial definition and direction for testing. It is essential that all elements within each field be accurately depicted. The potential number of variables and characteristics in these categories could generate a test scheme that would be too complicated to produce reliable conclusions, not to mention too expensive to conduct. As a pure research and development (R&D) task, it was decided to restrict the number of variable conditions in order to keep the overall simulation effort uncomplicated, yet progressive enough to provide viable test parameters. It should be understood at this point that each category, variable, or condition as it applies to scenario development or simulation testing requires validation. Preliminary program evaluations of software and scenario runs will be required to ensure that all test prerequisites are satisfied prior to the actual simulation exercise. Specific simulation variables under consideration are:

- o rotorcraft type and weight configuration;
- o various meteorological conditions;
- o different flight regimes such as takeoff, climbout, approach, and landing;

- o number and types of obstacles;
- o geometric relationships of the obstacles with respect to the heliport airspace imaginary surfaces;
- o heliport lighting;
- o ambient light;
- o day and night conditions;
- o visual aids;
- o engine failures and other emergency procedures;
- o pilot experience; and
- o pilot proficiency.

Human factors in general cover a wide category of topics. The prime characteristics to be analyzed include a variety of induced stress and risk conditions. We anticipate this study will demonstrate that as obstacle intensity increases, significant adverse effects will ensue with regard to pilot perception and performance. Test evaluations will include, but not necessarily be limited to, conditions of:

- o stress in relation to the
 - heliport environment
 - helicopter (vehicle)
 - emergency operation situations, and
- o risk and uncertainty involving
 - safe/unsafe operations
 - a combination of all factors.

The following paragraphs incorporate the final decisions on these variables and characteristics as determined by research and the industry meeting.

4.1 TEST PARAMETER DEFINITION

Specific test parameter definition must be forged to maximize test results when using a piloted visual simulator to collect data for this study. Parameter definition must be duplicated by visual scenarios and optimal simulator requirements to satisfy all requirements. The prime function is to devise a test that will answer task initiatives and provide a feasible solution with regard to psychological effects and target levels of safety within acceptable industry standards.

4.2 SIMULATION VARIABLES

4.2.1 Helicopter Model

Initially, plans called for an appropriate sampling of both single- and twin-engine helicopter types to be tested to see if the presence of a second engine made a difference in pilot performance. However, this representation exceeded the intent of the evaluation. The single-engine helicopter was chosen to insure the test retained a research result and to reflect the lowest common denominator since public-use heliports need to accommodate even the least experienced pilot. It also afforded the highest risk factor in performance analysis, and a varying degree of difficulty with regard to maneuvering and overall capability under adverse conditions.

Second, gross weight had to be considered because it could adversely affect vehicle operation, pilot attitude, and performance in the heliport environment. The significance of various combinations of weight from light to heavy were evaluated. As with engine configuration, unlimited variables were possible, but would unnecessarily complicate the test variables and reduce the plausibility of the results. It was decided that a moderately loaded helicopter, one where the actual weight configuration remained within the light category, would be used. This particular vehicle model is more widely in use with regard to actual operations at public-use heliports. The following specifications were chosen for modeling:

- o empty weight - 1,500 to 2,000 lbs.;
- o useful load - 1,600 to 2,100 lbs.; and
- o gross weight - 3,100 to 4,100 lbs.

4.2.2 Meteorological Conditions

Only a limited range of visual meteorological conditions (VMC) can be displayed. A blend of circumstances that represent a limited range of flight conditions, preferably less than ideal, will be formulated in the test plan. Interviews with helicopter operators and pilots patterned the envelope tolerances listed below. The rationale was to offer scenarios that all representative pilots could effectively perform, yet provide a range to challenge individual abilities. The following meteorological parameters were established as minimum scenario specifications:

- o temperature - standard day - 59°F and hot day 95°F;
- o pressure altitude - mean sea level (MSL) and 4,000 feet;
- o wind direction and velocity - calm (at high temp/alt) 15 knots with gust to 25 knots;
- o visibility - average 1 statute mile with .5/.25 reductions;
- o ceiling - 3,000 feet with 500 feet reductions; and
- o precipitation - rain.

4.2.3 Flight Regimes

In order to develop realistic scenarios of operations at a heliport, appropriate flight scenarios need to be developed. The types of flight regimes encountered at a heliport are takeoff, climbout, approach, and landing. The unique capabilities of helicopter flight means that these regimes are not always straight-in simple procedures. Curved approaches and departures must be incorporated into the test scenarios. Obstacles need to be incorporated into the curved approaches, for example, a curved approach/departure with a building on the inside of the curve that restricts the pilot's visibility.

4.2.4 Number and Types of Obstacles

Specific VFR approach and departure corridors will be designed to follow developed flight regimes, as stated above, for the modeled heliport. Each corridor, or trapezoid, will be apportioned a varying intensity and variety of obstacles. Specific definition will be assigned using preliminary testing results. Preliminary scenario evaluation will be based on a random selection of obstacles generated

by software parameters based on various programmed flight factors, such as pilot experience, meteorological conditions, and simulation facility capabilities. Prior to final scenario selection, parameters will be reviewed and modified as necessary to satisfy test requirements.

4.2.5 Placement of Obstacles

Obstacle placement will be predicated on and modeled according to the VFR imaginary surfaces underlying the various flight paths to and from the heliport. The objective is to provide a less than ideal flight situation, while inducing an ever increasing pilot workload created by increasing the obstacle intensity. The goal of obstacle positioning is to add more dimensional flying challenges beyond a clear path to the landing objective. It is important to ensure that obstacle placement does not conform to and thus define the VFR imaginary 8:1 surface.

4.2.6 Heliport Lighting

Current minimum VFR heliport lighting requirements will be used to pattern standard configurations in use at most public-use heliports. The primary objective is to produce conditions that are less than ideal for any period of time during a day. A minimal lighting configuration was selected to again limit the number of parameters, yet provide an additional challenge that would increase workload requirements and offer the most promising conclusions and results.

4.2.7 Day and Night Conditions

Three separate day and night conditions are envisioned for each set of scenarios developed.

- o Full daylight - This would be a highly developed visual scene with sufficient levels of visual fidelity to provide clear and undistorted recognition.
- o Full night - The controlling concern during this scene would be to remove the tincture that natural illumination provides, thus reducing optical perspective recognition. The main intent is to pattern the visual scene to closely resemble nighttime helicopter operations in and out of heliports.
- o Dusk - This visual scene would be an attempt to produce the dimming of natural light sources to emulate a gloomy or shadowy quality. The continued reduction of illumination within this textural scene would provide the most work intensive condition for the subject pilots. The creation of a visual scene with diminished light, applied to the various flight regimes, should yield the best psychological evaluation.

4.2.8 Ambient Lighting

The artificial light source provided by a man-made environment is critical to any flight in VFR conditions. Scenario modeling must keep these ambient lighting conditions realistic so as not to detract from

the psychological issue being tested. Initial testing will be designed to parallel normal lighting situations associated with day and night conditions, as indicated above. Refinement of this test parameter may be necessary once initial scenario qualification evaluations are completed.

4.2.9 Visual Aids

Discussions with the FAA and industry established the need for visual aids as a test parameter. Participants were adamant that this be included because of the relatively high importance associated with visual aids for recognition of the VFR heliport environment. It must be stated at this point that the intent is not to deliberately flaw the test results by overemphasizing the heliport with visual aids, but to use them within the normal range of visual recognition as required. Only required VFR heliport visual aids, as listed below, will be included in the model:

- o wind direction indicator,
- o landing direction lights,
- o visual glidepath indicator,
- o heliport identification beacons, and
- o obstruction marking and lighting.

4.2.10 Emergency Situations

The significance of emergency procedures with regard to safety and the utilization of current heliports can not be underplayed. This factor will be introduced into the scenario design to actively evaluate pilot response to emergencies within an obstacle-rich environment. Emergency conditions, such as engine failure, will be interjected into the scenario to demonstrate pilot reaction and decisionmaking such as the selection of an alternate landing site. This issue was mentioned with regard to current heliports where the lack or perceived lack of an emergency landing site may contribute to limited serviceability.

4.2.11 Subject Pilot Selection

The prime objective in selecting pilot candidates is to provide a sampling that actually fly single-engine helicopters in and out of public-use heliports. Nominees should include professional research pilots selected from the FAA and NASA, and professional commercial and private helicopter pilots with emphasis on those who currently operate in an urban city-center environment. The participation of current research pilots, besides serving as an additional data source, will help in interpreting the performance of other subject pilots, assist with real-time evaluation of test parameters, assist in making recommendations for program updates, and assist with any other required/desired program changes as data processing/analysis takes place.

4.3 HUMAN FACTORS ENGINEERING

The study of human factors views human abilities and limitations from the perspective of systems design, focusing on those dimensions of human behavior that are most relevant to the problems imposed by the

specific task. With the explosion in complexity that technology has fostered, creativity in problemsolving, decisionmaking, and pattern recognition abilities will be the human resources that are most valued. Understanding these areas and their relationship to performance will offer better definition to the task at hand.

Human factors engineering plays an important role in this study, but where should our focus be directed? Although there is no clear-cut accepted definition for human (pilot) mental workload, it may be conceptualized as the interaction of many different factors, including the structure of systems and tasks, capabilities, motivation, and the psychological state of pilot or crew. These factors can induce conditions of stress, risk, and uncertainty that collectively produce psychological effects that impair a pilot's ability to perform. The responsibility of navigating through an obstacle-rich environment could ultimately be beyond the psychological limits of any specific individual. The ability of the pilot to perform various workloads will be evaluated. In pursuit of that evaluation, initial direction will focus on defining:

- o pilot workload,
- o risk assessment techniques,
- o task and performance measures,
- o subjective measures, and
- o physiological measures.

By adding definition to the above parameters, a strategy will be developed to weigh the correlation between obstacle intensity and how it affects performance and safety. Pertinent areas of human factors engineering must be introduced to establish a foundational nucleus with which to measure and evaluate these parameters. At a minimum, three major areas, stress, risk, and uncertainty, must be examined to determine their significance to psychological effects.

4.3.1 Stress

The initial process of understanding aspects of human factors engineering with regard to pilot performance and safety consists of examining the composition of an obstacle-rich environment itself and its relationship to stress. What stressors will the environment present? Previous studies indicate a direct tie between stress and judgement. Could "judgement error" be a substantial role player in assessing the effects of stress, since judgement may constrain and impair perception and performance?

Duration of stress effects is also an important consideration. Short-term effects of stress on perception and performance are often positive. However, this positive effect is likely to diminish as stress reaches higher levels or persists for longer periods. What is the consequence for pilot perception and performance? It will be necessary to further examine particular aspects of stress in this study.

4.3.1.1 Helicopter Environment

How does the degree of familiarization with a heliport affect a pilot? Resistance to change is a common human trait. For the most part, adjustments to change, such as with an unfamiliar environment could have a positive or negative influence on a pilot's capability to effectively execute required performance tasks. As this level of uncertainty increases, where will these stress-producing situations lead? Does the level of stress either increase or decrease based on the environmental conditions at a heliport?

4.3.1.2 Helicopter (Vehicle)

Where do a helicopter's capabilities come into play? The vehicle performance parameters must be well matched to the individual pilot's abilities. More important, what effect does pilot proficiency play with regard to intense obstacle-rich environments and vehicle capability? The vehicle model will not be required to perform beyond its operational envelope, but the conditions will be less than ideal to challenge pilot techniques.

4.3.1.3 Emergency Operations Situations

The relationship between stress and emergency situations is not simple. On a psychological level, the individual pilot experiences tension, anxiety, and perhaps increased alertness. The non-availability of an alternate, emergency landing site obviously has an effect on performance, but to what degree? Is it serious enough to cause a heliport to be considered unsafe?

4.3.2 Risk and Uncertainty

Research has shown that risk and uncertainty are significant variables in decisionmaking. There is evidence that pilots are willing to take more risks in decisions they judge as relatively unimportant. Uncertainty itself affects the degree of risk a pilot will take. As the intensity of obstacles increases, how will risk and uncertainty affect perception and performance? Generally speaking, as uncertainty decreases, risk increases. But what part does an obstacle play with respect to risk or uncertainty? How does this affect a pilot's ability to make decisions?

4.3.2.1 Safe and Unsafe Operations

Risk and uncertainty will understandably fluctuate if the level of safety is questionable. A pilot's assessment of the safety of a heliport operation in an obstacle-rich atmosphere could most likely be a deciding factor on usage. The intense obstacle display underlying the VFR imaginary surface may seem unsafe, even though no obstruction violations exist. What effect does this have on perception and performance?

4.3.2.2 Combination of All Factors

The complexity of a decision has a predictable relationship with time needed to make that decision. Pilots tend to take longer to make

complex decisions than to make simpler ones. Based on an individual pilot's proficiency, workload intense environments can produce high levels of risk or uncertainty. When all of the various stress, and risk and uncertainty factors are combined, what effect will this have on perception and performance?

4.3.3 Human Factors Consultant

The role of human factors in relationship to technology must be placed in proper perspective to evaluate the pilot's performance and not the simulator's. It is important to understand technology with regard to simulation and human factors engineering. However, technology cannot be the driving force for this project. Specific research and parameter task definition will be supplied by human factors engineering consultant. Consultant prerequisites will be established so that an authority can be chosen in the field of human factors psychology who is familiar with flight simulation capabilities and limitations.

5.0 SIMULATION DATA COLLECTION METHODOLOGY

This section addresses the specific data collection methods and procedures which must be applied during the simulation tests. In order to develop a set of simulator runs, the specific variables that are to be included must first be identified. It is not possible at this point to decide the specifics of all individual scenarios and test runs; there are still many tradeoffs that must be made pursuant to the availability and cost of a suitable simulator, the cost of simulator visual database development, and the scope of the evaluation to be undertaken relative to the details of the parameters to be tested. Therefore, at this time an overall set of variables to be evaluated is suggested.

5.1 DATA COLLECTION PROCEDURES

Preparation for the data collection phase of the simulator evaluation involves subject pilot selection, development of pilot briefing materials, and definition of the sequence for performance of the tests.

5.1.1 Sequencing and Performance of Test Scenarios

A plan will be developed for the random sequence of simulator scenarios to be flown by each pilot which will minimize the effect of learning on test results. This will prevent, for example, the pilot from knowing where to expect to find a specific obstacle based simply on a recently completed prior run (except for those runs whose purpose is to analyze the value of familiarity; in those cases, a specific run may be initiated to purposely allow the pilot to become very familiar with the flight simulator capabilities). Since pilot availability is always a significant limiting factor, entire sequences of scenarios must be presented to a given pilot in a relatively short time.

5.1.2 Logs and Parameter Lists

The data collection methods and logs will be developed prior to the test runs and will be verified during the simulator shakedown tests. The recorded parameters will be stored at an appropriate sample rate (twice per second) and converted to distribution media, such as high-density diskettes or magnetic tapes, as required for post-test processing. Four sets of parameters follows, each with a itemized inventory of specific fields of concern.

o Simulator Operator Log

- o Run sequence number
- o Scenario number
- o Flight regime being flown
- o Visibility, obstructions, etc.
- o Helipad, obstruction and landmark lighting
- o Record of off-nominal conditions experienced during the run

o Test Observer Log

- o Run sequence number
- o Subject pilot number, date and time
- o Procedure under test
- o Events and commentary - turn points, deviations, pilot comments, areas of difficulty, etc.

o Pilot Log

- o Helicopter certification/rating
- o Flight experience by type/hours
- o Private
- o Commercial
- o Airline transport
- o Simulator currency
- o Simulator by type/hour
- o Debriefing

o Recorded Parameter List

- o Run sequence number
- o Time mark
- o Environmental conditions (winds, temperatures, etc.)
- o Aircraft position (X,Y,Z)
- o Aircraft velocity (X,Y,Z)
- o Sensor signals (altimeters, etc.)
- o Course deviations (lateral, vertical)
- o Controls & switches
- o Control positions (throttle/engine speedlevers, cyclic, collective, etc.)

5.2 DATA REDUCTION AND ANALYSIS

The intent of the planned task is primarily to collect simulator data and reduce it to a form useful to analysts. Actual use of this data in the development or analysis of psychological effects or target

levels of safety will be accomplished in the latter part of phase II of this project.

Reducing the data to a form useful to analysts will involve conversion to a presentation format showing plan and profile view, overlaying a plot of the particular flight regime involved and its relationship to the obstacles underlying the VFR imaginary surface for each scenario. Additionally, plots of track deviation from the ideal course will be developed in the same format (plan and profile) to highlight their relationship to the actual course flown. All presentations will be annotated with time marks to allow correlation of flight control data with the data contained in the operator and observer logs.

Other data recorded as a part of the simulator tests (including primary flight control inputs, navigation control inputs, and instrument flags and warnings) will be plotted versus time for correlation to the graphical data. Statistical analysis of pilot performance factors with regard to the plan and profile views, as well as identification of maximum deviation or deflection events, will also be performed with results presented in tabular and graphical form.

LIST OF REFERENCES

- 1) "Helicopter Design Advisory Circular," AC 150/5390-2, Federal Aviation Administration, Washington, D.C., January 1988.
- 2) "Code of Federal Regulations, Title 14 Aeronautics and Space," Part 77 - Objects Affecting Navigable Airspace, Office of the Federal Register, National Archives and Records Administration, January 1989.
- 3) "Certification of Normal Category Rotorcraft Advisory Circular," AC 27-1, Federal Aviation Administration, Washington, D.C., August 1985.
- 4) "Certification of Transport Category Rotorcraft Advisory Circular," AC 29-2A, Federal Aviation Administration, Washington, D.C., September 1987.
- 5) "Helicopter VFR Airspace Design Based on Helicopter Performance," Draft, DOT/FAA/RD-90/4, Federal Aviation Administration, Washington, D.C., November 1990.
- 6) "Helicopter Physical and Performance Data," Draft, DOT/FAA/RD-90/3, Federal Aviation Administration, Washington, D.C., November 1990.
- 7) "Operational Survey - VFR Helicopter Approaches and Departures," Draft, DOT/FAA/RD-90/5, Federal Aviation Administration, Washington, D.C., November 1990.
- 8) "Helicopter Rejected Takeoff Airspace Requirements," Draft, DOT/FAA/RD-90/7, Federal Aviation Administration, Washington, D.C., October 1990.
- 9) "Helicopter Visual Approach and Departure Airspace Tests Volume I Summary," DOT/FAA/CT-TN87-40, Federal Aviation Administration, August 1988.
- 10) "Helicopter Visual Approach Surface High Temperature and High Altitude Test Plan," DOT/FAA/CT-TN 88/5, Federal Aviation Administration, June 1988.
- 11) "Analysis of Helicopter Mishaps at Helicopters, Airports, and Unimproved Sites," Draft, DOT/FAA/RD-90/8, Federal Aviation Administration, Washington, D.C., January 1991.
- 12) Helicopter Flight Manuals.
- 13) Simulator Approval Test Guides (manufacturer supplied).
- 14) "Airplane Simulator Qualification Advisory Circular," Draft, AC 120/40B, Federal Aviation Administration, Washington, D.C., October 1990.

- 15) "Helicopter Simulation Qualification Advisory Circular," Draft, AC 120-xx, Federal Aviation Administration, Washington, D.C., October 1990.
- 16) Stanley N. Roscoe and Richard S. Jensen, "Computer-Animated Predictive Displays for Microwave Landing Approaches," IEEE Transactions on Systems, Man, and Cybernetics, Vol. SMC-11, No. 11, November 1981.
- 17) Stanley N. Roscoe, "Flight Display Dynamics Revisited," The Human Factors Society, Inc., June 1981.
- 18) James F. Grenell, Arthur F. Kramer, Erik J. Sireevaag, and Christopher D. Wickens, "Advanced Workload Assessment Techniques for Engineering Flight Simulation," paper presented at the American Helicopter Society (AHS) Annual Forum, held in Phoenix, Arizona, May 1991.
- 19) John M. Flach, "The Human Factor: A Positive Factor for Aviation Safety," Journal of ATC, Vol. 33, No. 2, April-June 1991.
- 20) Cooper, G.E and Harper, R.P, Jr., "The Use of Pilot Rating in the Evaluation of Aircraft Handling Qualities," NASA TN D-5153, National Aeronautics and Space Administration, Washington, D.C., April 1969.

APPENDIX A
MEETING WITH INDUSTRY HANDOUT



Meeting the challenges — today
and tomorrow...

FAA HELICOPTER DEVELOPMENT CONTRACT

TASK 6I - VFR HELIPORT OBSTACLE-RICH ENVIRONMENTS

MEETING WITH INDUSTRY

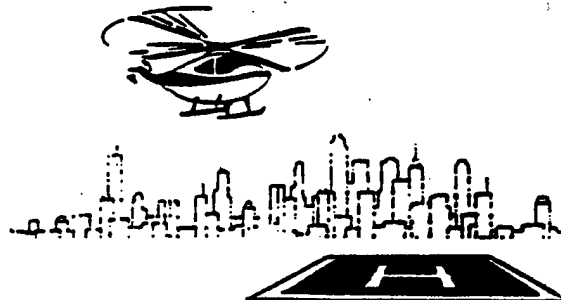
MAY 23, 1991

PREPARED BY:

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PREPARED FOR:

**FAA/ARD-30
VERTICAL FLIGHT SPECIAL PROGRAM OFFICE**





Subject: **ACTION:** Meeting on Performance Data for
Helicopters in "Obstacle-Rich Environments"

Date: April 23, 1991

From: Manager, Vertical Flight Program Office, ARD-30

Reply to
Attn. of:

To: Manager, Design and Operations Criteria Division, AAS-100
Manager, Air Transportation Division, AFS-200
Manager, Technical Programs Division, AFS-400
Manager, General Aviation and Commercial Division, AFS-800

Over the last several years the FAA and the rotorcraft industry have maintained a dialogue regarding minimum airspace requirements at VFR heliports. Several recent FAA efforts have examined aspects of this issue. However, prior testing has only addressed the presence of a very limited number of obstacles in the vicinity of a specific heliport. Limited consideration has been given to the psychological effect on pilot performance of a very large number of obstacles in the vicinity of a heliport.

With heliports in urban areas, we face continued growth in the number and height of nearby obstacles. In the presence of a few obstacles, the Heliport Design Advisory Circular will continue to provide guidance on when a proposed obstacle would be presumed to be an aviation hazard. In the presence of many, many obstacles, however, we are considering whether the Advisory Circular provides sufficient guidance. Our experience with the New Orleans Downtown Heliport leads us to suspect that a heliport could meet all the Advisory Circular recommendations and still be regarded as undesirable or even unsafe by helicopter pilots. In the interest of acquiring and retaining safe urban heliports, we see a need to examine this issue.

The FAA Vertical Flight Program Office (ARD-30) plans to collect performance data for helicopter operations in "obstacle-rich environments." Our intent is to determine the effect of these obstacles on pilot performance. The most effective means for collecting this data is to use a well-instrumented helicopter visual simulator. The ultimate objective is to provide definitive guidance that will better enable heliport proponents to defend against airspace encroachment at urban heliports.

We invite you to attend a meeting that will present the purpose and scope of this project and we solicit your comments regarding the issues being addressed. The meeting will be held Thursday, May 23, 1991 at 8:30 A.M. at 1611 N. Kent Street, Suite 910, Arlington, VA. In an effort to allow you to consolidate travel plans, this meeting is being held the same week as the

FAA/Industry Vertiport - Heliport Working Group on May 21, and the Heliport
Technical Planning Committee on May 22.

Please let us know if you will be able to attend. Direct your response or any
additional coordination and comments to Robert Smith at (202) 267-3783.

Robert D Smith

for James I. McDaniel

AGENDA

- o Background - Mr. Robert Smith (ARD-30)
- o Staffing
- o Overview - VFR Heliport Obstacle-Rich Environment
 - Phase I - Research and Development
 - Phase II - Simulation and Validation
- o Abstract - Task I Test and Evaluation
- o Purpose of Meeting with Industry
 - Test and Evaluation Definition
 - Comments/Suggestions/Recommendations

BACKGROUND - MR. ROBERT SMITH (ARD-30)

- o Obstruction Requirements
 - Target level of safety
- o Previous Test and Studies
 - Number/placement of obstacles
 - Psychological/performance affects
- o Heliport Location
 - Downtown city centers
 - Concern for obstacles

STAFFING

FAA/ARD-30
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TECHNICAL LEAD
BRIAN SAWYER

SYSTEMS ANALYSIS
DEBORAH PEISEN

ENGINEERING SUPPORT
ROBERT ANOLL

OVERVIEW - VFR HELIPORT OBSTACLE-RICH ENVIRONMENTS

PHASE I - RESEARCH AND DEVELOPMENT (4 SUBTASKS)

- o *Test and Evaluation Requirements*
- o *Simulation Requirements and Facilities*
- o *Simulation Test Plan*
- o *Pilot Briefing Material*

PHASE II - SIMULATION AND VALIDATION (4 SUBTASKS)

- o *Simulation Facilities*
- o *Simulation Test Support*
- o *Data Processing/Evaluation and Documentation*
- o *Validation Proposal*

Task I - Test and Evaluation

- o *Investigative Process*
- o *Issue Definition*
- o *Test Methodology*
- o *Data Collection*
- o *Meeting with Industry - May 23, 1991*

o **Investigative Process**

In-depth investigation

Establish a factual core of related knowledge

Informational reference file to provide a balanced cross check between each subtask

Ensure similar areas are addressed at the appropriate level

o **Issue Definition**

Clarify relevant issues,

Identify unresolved questions, and

Highlight concerns from the standpoint of:

Psychological affects, and

Target levels of safety

o **Issue Definition - Psychological Affect (Pilot)**

Pilot Performance - Do pilots dropoff tasks due to psychological effects (pucker factor) of increasing obstacles?

Pilot Perception - Is there a point at which a pilot's perceptions of obstacles affects the desire/ability to use heliports?

Pilot Experience - What effect does experience and/or proficiency in "type specific" helicopters play with regard to the performance under test conditions?

o **Issue Definition - Target Level of Safety**

Does an obstacle-rich environment affect safety?

In the ability to accomplish:

Routine procedures,

Emergency procedures,

Unique situations,

Maneuvering to/from landing sites, within

congested environments

o **Simulation Test Methodology Definition of Visual Scenarios**

What type of obstacles will be in a metropolitan area?

What parameters should be introduced (size, height, etc.)?

How many is considered intense?

How should placement/location be defined?

Restricted pilot visibility - curved approach/departure

What types of rotorcraft models should be used?

Weight/load configuration

Single and/or twin engine

Light and/or heavy helicopters

o **Simulation Test Methodology**

What basic meteorological conditions should be simulated?

Density altitude

Weather minima

What minimum aerodynamic configurations should be considered?

Takeoff

Climb-out

Approach

Landing

Minimum heliport visual recognition should include?

Lighting

Takeoff/landing area or more

Varying the intensity of lighting

What type of visual aids will be employed

Wind/landing direction indicator

Heliport identification beacons

Obstruction marking

o **Simulation Test Methodology**

How important is ambient lighting?

Surrounding area or environment

Urban lights/isolated heliport

Of what value are day and night conditions?

Full daylight

Night

Dusk

What type of emergencies situations should be introduced?

Engine failure

Aborted takeoff/landing

o **Data Collection**

What types of Data should be recorded?

Pilot performance parameters

Pilot perception parameters

Flight track/relative position

Flight control activity

What type of media data recording should be considered?

Simulator/operator logs

Scenario sequence number

Scenario number

Number of obstructions per run

o **Data Collection**

Placement of obstruction per run

What information should be entered in an observer log?

Sequence number

Subject pilot number

Date/time

Procedure under test

Events and commentary (Questionnaire)

What types of pilot log information are germane to the test data?

Helicopter certification/rating

Flight experience by type/hours

Private/commercial/ATP/military

Simulator currency by type and flight hour

Recorded parameter list

Run sequence number

Time mark

Aircraft position (x,y,z)

Aircraft velocity (x,y,z)

Controls and switches (nav/landng system, etc.)

Control position (throttle, levers, cyclic, collective)

Frequency of data collection

Appropriate sample rate

o **Data Collection**

Distribution media conversion

Data process requirements

Data presentation formats

Pilot questionnaires/debrief

APPENDIX B
SUMMARY OF INDUSTRY COMMENTS

o **Investigative Process**

- Review current operational requirements and potential changes at active heliports to reinforce background investigation (i.e., Wall Street, New Orleans, Indianapolis, etc.)

o **Issue Definition - Psychological Effects**

- Obstacle perception factor

Is there an associated factor that would highlight a tree as a soft obstacle and a building as a hard obstacle, although each would have the same detrimental effect on the helicopter?

- Risk assessments for pilot decisions

Can a risk-assessment factor be assigned to a pilot's decisions that would yield a numerical weighted value for analysis?

o **Issue Definition - Target Level of Safety**

- Perceptual factor for obstacles

Can a perceptual factor be assigned to individual obstacles that will yield a numerical weighted value for analysis?

- Close-in obstacles

The obstacles in the immediate landing zone environment must be included in the scenario.

o **Test Methodology**

- Scenario development

Only a minimal slice of the overall performance arena can be tested. The test project must be maintained in a "research environment" to provide realistic results. In the future these results may be a prerequisite for a larger scale analysis of the visual approach/departure corridor, but for now definite limits must be placed on the program.

The test conditions should cover the worst environment and the best available vehicle performance.

Test conditions should evaluate how helicopters "do fly", not how they should fly.

- Visual curved/straight approaches/departures

Because of variations in flight configurations (angle of bank, angle of descent, turns, and speed control) and limited field of view, this type of procedure must be introduced and tested.

- Vehicle touchdown

All approaches must be tested to at least a hover and perhaps to touchdown, to test realistic operations. Departures need to start from engine start through exiting the scenario safely.

- Emergency situations

The availability of emergency landing sites must be explored. Industry feels that the lack of an emergency landing site will have a profound effect on the pilots' ability to perform in or out of the scenario heliport.

- Pilot Experience

Within industry, there is a limited availability of pilots with simulator experience. It will be necessary to provide a familiarization training to bring each candidate up to a minimum proficiency level to execute the test program.

Pilot background is very important. The test program should be centered around the "average pilot", not the "master." As an example, EMS pilots continually operate in an unimproved environment. Varying the obstacle intensity for them would not answer questions for the "average pilots" in a city-center heliport scenario. The same holds true for the military pilot in the sense that individual proficiency levels in unusual environments are considered to be higher than the "average pilot."

Pilot confidence levels increase with the number of runs executed, which tends to create a false sense of security. In addition, pilots will be more careful when heliport conditions are bad.

- Vehicle model

The consensus centered around using an engineering type simulation vehicle model, because these simulators can be programmed to provide a wide variety of scenarios. Using a proficiency simulator would not cover the range of situations necessary.

The consensus favored using a single-engine model. This conclusion highlighted the single-engine vehicle as the most common helicopter in use overall by the "average pilot" and the fact that single-engine simulation test facilities are available. Using a single-engine vehicle also provides the highest single risk factor in performance analysis, a higher

pucker factor with varying degrees (both positive and negative) of maneuvering and capability under adverse conditions.

o **Data Collection**

- Margin of error

What will the margin of error be for the simulation test program? What is the acceptable level of error? These conditions must be defined early on in the program.

- Human factors

What specific performance and perception factors will be evaluated? The need exists to contract with a human factors/performance expert to provide this information.