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Feasibility of MALSR and Runway Lighting for ILS Approaches for Helicopters

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16. Abstract

The Federal Aviation Administration Office of Aviation Research and Development Airport and Aircraft Safety R&D Division (ATO-P), William J. Hughes Technical Center Flight Program Group (ACB-870), Simulation and Analysis Group (ACB-330), and support contractors performed a human-in-the-loop Copter Instrument Landing System (ILS) study in a Level D Sikorsky 76 simulator at Flight Safety International, West Palm Beach, Florida, March 27-April 1, 2004. The purpose of the Copter ILS study was to evaluate the adequacy of airport lighting to support helicopter approaches with reduced minima. Specifically, the study investigated whether a Medium Intensity Approach Lighting System with Runway Alignment Indicator Lights, runway markings, and runway edge lights, only, would be adequate for helicopter pilots to perform an instrument approach to 100-ft decision height above the ground with visibility averaging to 1/4 mile during three time-of-day conditions (day, night, and dusk) and successfully land the helicopter using a prescribed approach and landing technique.

The majority of participant feedback and performance data, based on a sample of 14 pilots, supported the feasibility of the Copter ILS procedure in terms of lighting and visual cue adequacy and the two-person crew landing technique. Some pilots did point out that the addition of runway centerline lighting would be helpful. They all agreed a two-person crew would be essential to the safety of the procedure. Pilots visually acquired the airport environment, in most cases, before the 100-ft decision height. Approach and landing performance for the most part was in accordance with the recommended parameters. Time of day appeared to have some impact on performance and opinion about the lighting and visual cue adequacy for the simulated Copter ILS approaches. Due to the small sample size in the study, the collection of more data is desirable to augment and validate the results of this simulation.

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LIST OF ACRONYMS

AGL	Above ground level
AIM	Aeronautical Information Manual
CAA	Civil Aviation Authority
CAT	Category
CFR	Code of Federal Regulations
CL	Centerline
CRM	Crew Resource Management
DH	Decision height
EMS	Emergency management services
FAA	Federal Aviation Administration
IFR	Instrument flight rules
ILS	Instrument Landing System
KIAS	Knots indicated airspeed
kts	knots
MALSR	Medium intensity approach light system with runway alignment indicator lights
R&D	Research and development
RAIL	Runway Alignment Indicator Lights
RVR	Runway visual range
TDZ	Touchdown zone lighting
U.S.	United States

EXECUTIVE SUMMARY

The Federal Aviation Administration (FAA) Office of Aviation Research and Development Airport and Aircraft Safety R&D Division (ATO-P), William J. Hughes Technical Center Flight Program Group (ACB-870), Simulation and Analysis Group (ACB-330), and support contractors performed a human-in-the-loop study of Copter Instrument Landing System (ILS) approaches in a Level D Sikorsky S-76 simulator at Flight Safety International, West Palm Beach, Florida, March 27-April 1, 2004. The research team conducted the study under the sponsorship of the FAA Rotorcraft Directorate (ASW-100) and FAA Flight Standards Offices (AFS-400 and AFS-800).

The purpose of the study was to evaluate the adequacy of airport lighting to support helicopter approaches with reduced minima. Specifically, the study investigated whether a medium intensity approach lighting system with runway alignment indicator lights, runway markings, and runway edge lights only would be adequate for helicopter pilots to perform an instrument approach to 100-ft decision height above the ground with visibility averaging to 1/4 mile during three time-of-day conditions (day, night, and dusk) and successfully land the helicopter.

The research team analyzed data from a total of 14 pilots who flew in two-person crews with research team pilots. A key determination of the feasibility of conducting Copter ILS approaches as simulated were the ability of the subject pilots to visually acquire the approach lighting system in sufficient time to make a decision to land or go around, and if landing, land safely.

The majority of the feedback from participating pilots supported the feasibility of the Copter ILS procedure in terms of lighting and visual cue adequacy and the two-person crew landing technique. Some pilots did point out that the addition of runway centerline lighting would be helpful. They all agreed a two-person crew would be essential to the safety of the procedure. The performance data also, for the most part, supported the lighting adequacy for Copter ILS approaches. Pilots visually acquired the airport environment, in most cases, before the 100-ft decision height and decided to land. Approach and landing performance for the most part was in accordance with the recommended parameters. Time of day did seem to have an impact on performance and opinion about the lighting and visual cue adequacy for the Copter ILS approaches. Dusk appeared to be the most difficult condition in which to visually acquire the airport lighting environment.

While the data from this study alone is not enough to approve any procedures due to the small sample size, it can contribute to an overall evaluation of Copter ILS approaches to airports with Category I approach and runway lighting. The Copter ILS study provided insight into the feasibility and acceptability of such procedures from a pilot perspective. The collection of more data is desirable to augment and validate the results of this Phase II simulation. In addition, live flight tests of the procedure with real-world airport lighting conditions would be useful to most accurately capture real-world performance.

1. INTRODUCTION.

Instrument approaches to runways throughout the United States (U.S.) have certain requirements based on weather, maneuvers or procedures, and airport facilities. An instrument approach procedure is a series of predetermined maneuvers for the orderly transfer of an aircraft under instrument flight conditions from the beginning of the initial approach to a landing or to a point from which a landing may be made visually (Aeronautical Information Manual (AIM), 2002). Instrument approach procedures vary from airport to airport, as well as by aircraft type, and are a function of meteorological conditions expressed in terms of visibility, distance from cloud, and ceiling less than the minima specified for meteorological conditions for visual maneuvering (AIM, 2002).

At some point during the instrument approach procedure, the meteorological conditions must allow a pilot to attain visual cues from the airport environment to visually maneuver the aircraft to a safe landing onto the runway. When transitioning from instrument flight to visual flight, a pilot's accurate perception of landing is highly dependent on visual cues throughout the landing maneuver. When these cues appear less than adequate (due to marginal weather visibility, time of day, limited angle of view from the aircraft to the visual cues, and increased reaction time due to rate of closure to the visual cue), the visual detection and decision-making process may absorb more time and potentially be flawed. For some pilots, landing with limited visual cues may hamper their detection and decision-making process due to their individual experience and visual processing capability.

A brief explanation of visual processing can be described by an example of someone attempting to catch a ball. As the ball is passed, it is tracked by one's head and eyes, the arms move accordingly, and the fingers open and then close on the ball (Bruce, Green, and Georgeson, 1996). However, even though this process takes place in all human beings, different actions may result from the same visual information provided. Since many different parts of the brain are used for visual processing (approximately 85-90 percent of all due to usage of tactile, auditory, and visual information fused in the association cortex) (Young, 1991), human decision-making and action-taking are therefore unique for each individual. This explains why different batters may swing with the same type of ball pitch or why some pilots land out of low-visibility approaches while others may choose to go missed approach.

For years, the helicopter industry has requested to have instrument approach procedures with lower weather visibilities due to the unique characteristics of helicopters. For example, most helicopter pilots fly instrument approaches at 90 knots (kts) or less, thereby assuming that the increase in reaction time would aid visual processing to detect the runway environment with limited visibility. As a result, in 1994, an operational concept was developed for helicopters by industry and the Federal Aviation Administration (FAA) concerning instrument approach procedures to runways with meteorological conditions less than currently assigned to a given airport (Adams, Adams, Fontaine, and Wheeler, 1994). Specifically, the concept entailed that these lower-weather visibilities may be granted depending on aircraft performance and equipment, pilot training, and availability of systems to augment visual contact to the transition to the landing phase of an instrument approach procedure (e.g., head-up displays or autolanding capabilities).

An agreement was made that instrument approach procedures to airports may be lowered for helicopters to 100-foot decision height criteria and a 1/4 mile visibility on a case-by-case basis (Adams, Adams, Fontaine, and Wheeler, 1994). The term decision height (DH) with respect to the operation of aircraft means the height above ground level (AGL) at which a decision must be made during an instrument approach procedure to either continue the approach and land on the specified runway or to execute a missed approach (a maneuver completed by a pilot when the instrument approach procedure cannot be completed to a landing, thereby requiring the pilot to initiate an immediate climb of the aircraft to a designated altitude specified in the instrument approach procedure) (AIM, 2002). Most runways designated as Category I in the U.S. (which are the majority in the U.S.) are intended to be flown to decision heights no lower than 200 feet AGL and meteorological conditions of no less than weather visibilities of 1/2 mile.

Although this lower-weather visibilities concept was granted (flown operationally for over 10 years with no reported incident), it was never formally tested to confirm the visual processing assumption. Specifically, one of the considerations not discussed at the 1994 meeting was the adequacy of Category I airport's runway lighting systems to support these procedures to lower visibilities. The typical lighting installation at Category I facilities is a Medium Intensity Approach Light System with Runway Alignment Indicator Lights (RAIL), better known as MALSR (AIM, 2002).

1.1 MALSR LIGHTING SYSTEM COMPONENTS.

The MALSR consists of seven to five light bars located on the extended runway centerline (prior to the runway). The first bar is located 200 ft from the runway threshold and at each 200-ft interval out to 1400 ft from the threshold (beginning of the runway). Two additional five-light bars are located on each side of the centerline bar, 1000 ft from the runway threshold, forming a crossbar 66 ft long (FAA Handbook, 1993). The spacing between individual lights in all bars is approximately 2.5 ft. The RAIL portion of the system consists of sequenced flashing lights (known as flashers) located on the extended runway centerline, the first being located 1600 ft before the approach end of the runway threshold with successive flashers located at each 200-ft interval out to the end of the system (2400 or 3000 ft). These lights flash in sequence towards the threshold at the rate of twice per second (FAA Handbook, 1993). The MALSR system is normally 2400 ft long and is shown in figure 1.

A typical Category I airport has runway edge lights but may not have centerline or touchdown zone lighting on the runway itself. Compared to higher category approach lighting systems, brightness of the runway edge lights and the flasher intensity are lower (less bright) at facilities with the MALSR (FAA Handbook, 1993).

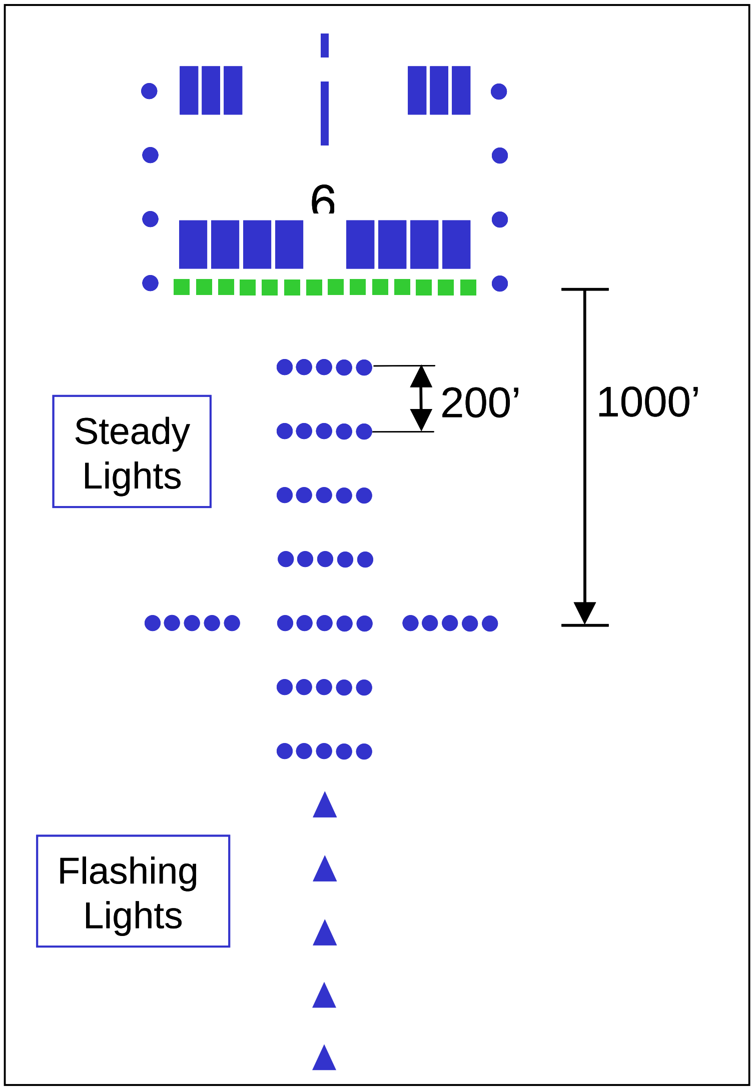

FIGURE 1. MALSR LIGHTING SYSTEM

1.2 PREVIOUS RESEARCH ON INSTRUMENT APPROACH VISUAL GUIDANCE ADEQUACY.

The FAA performed tests in 1966 to determine whether or not MALSR provided adequate visual guidance for airplanes to complete a successful instrument approach. The study concluded that, for DHs of no lower than 150 ft with a weather ceiling of 200 ft and higher and weather visibility of no less than 1/2 mile, the MALSR was adequate for visual guidance for a high approach success rate (Paprocki and Gates, 1966). The speed of the average airplane was 125 kts, which was tested in actual weather conditions at Nantucket Airport in Massachusetts (Paprocki and Gates, 1966). Since 1966, the FAA has conducted many tests to determine whether visual cues can be reduced for MALSRs. A recent report (Gallagher, 2002) summed up the results from a test on reducing the approach lighting system configuration to allow shortening the MALSR to 1600 ft. The test found this reduction unacceptable based on normal Category I minima.

In 1977, the United States Air Force also evaluated the suitability of MALSR for their high-performance, fixed-wing aircraft operations. They found the MALSR inadequate for visual guidance (Kerkering and Armstrong, 1977). This evaluation was performed using a 200-ft DH and no less than 1/2 mile visibility. Subject pilots found the MALSR most difficult to use during the daytime because MALSR has fewer lights and greater spacing between approach lights gave them the illusion of having less vertical visual guidance compared to the other approach lighting systems. This made the pilots uncomfortable during the visual transition from instrument approach procedure to landing onto the runway (Kerkering and Armstrong, 1977). Also, the runway threshold lighting did not adequately define the runway environment in either day or night instrument approaches due to the decrease in visual cues for the pilot to use in defining the end of the runway (Kerkering and Armstrong, 1977). Therefore, the lack of visual cues hampered some of the pilots' decision-making or visual processing. It should be noted that these Air Force evaluations were conducted in 1977, before FAA testing and evaluation (Brown, 1978), and resulted in a change order to the MALSR installation specification. The mandated change added a separate high-intensity threshold lighting component to all MALSR installations, a configuration virtually identical to the threshold pattern provided with the Category II ALSF-2. All MALSR field installations now have this added threshold lighting enhancement.

Previously, it was discussed that usable visual cues or the adequacy of the runway environment is affected by the rate of closure of a given aircraft. During the Air Force Study, the average aircraft flew at speeds greater than 150 kts. In essence, the aircraft was moving forward at 250-ft per second and downward at 10- to 15-ft per second (Kerkering and Armstrong, 1977). This allowed the subject pilot in the study only 1 to 2 seconds to acquire visual cues from the approach lighting and runway environment and make a decision to land onto the runway using these cues (Kerkering and Armstrong, 1977). Therefore, an aircraft that flies much slower, such as a helicopter, may be able to detect the visual cues and the runway environment may be adequate. Most helicopters fly at speeds between 70 and 90 kts, thus moving forward at 125-ft per second and downward at approximately 6-ft per second. Once again, this leads to the assumption that at slower speeds, a pilot's visual processing of runway detection may be enhanced due to increased reaction time.

The first and only documented helicopter instrument approach runway lighting test that concerns low-visibility criteria was conducted by the United Kingdom Civil Aviation Authority (CAA) in the early 1980s. The CAA Helicopter Fog Trials test was performed to 200-ft DH, with much lower visibilities than what is being considered for approval by the U.S. helicopter industry (approximately 600 meters) (Talbot and Webber, 1986). In addition, this test was performed first with very rudimentary simulation followed by actual flight trials, but neither simulation nor flight was conducted at night (Talbot and Webber, 1986). The CAA test found that judging height AGL for a helicopter landing was very difficult when using the MALSR and runway edge lights only (no centerline lights). The only feasible means for a successful landing was made when the visual cues from the runway environment were displaced slightly to the side that the pilot would have direct viewing (Talbot and Webber, 1986). Overall, the CAA concluded that further testing would need to be done to analyze the affects at night.

In 1993, Cougar Helicopters[1] (Halifax, Nova Scotia, Canada) received an authorization from Transport Canada allowing them to fly a Category I Instrument Landing System (ILS) approach procedure to runway visual range (RVR) 1200 and DH of 100 ft. This authorization was granted after months of subjective trials in simulators to develop flying and training techniques as well as modify Cougar's helicopter fleet to support this procedure. According to the company's operations manual, Cougar aircraft had to have the following:

- Transport Category A rotorcraft
- Flight Director or single automatic approach coupler augmenting the stabilization system
- Two radio altimeter indicators having an altitude alert function
- Two independent VHF air-ground communications
- Dual ILS localizer and glide slope receivers and associated avionics warning systems

In addition, the specification also contained the following requirements for aircrews:

- A two-pilot procedure with both pilots requiring a minimum of 100 hours in the type of rotorcraft flown

- An approved training program using an approved synthetic training device and initial checkout

- Proficiency check for all crewmembers every 12 months requiring one RVR 1200 and 100-ft DH ILS approach to a missed approach during which a practical emergency (e.g., engine fire) is introduced to assess crew coordination plus a subsequent RVR 1200 and 100-ft DH ILS to a landing.

These procedures were only approved for airports meeting the following criteria:

- Approved/published ILS instrument approach procedure

- ILS system that is serviceable and functioning

- Airport with medium- or high-intensity approach lighting

- Forward scatter visibility sensor or a transmissometer at either the approach end or mid-point of runway.

The Canadians never did a formal research study. However, to insure success, the subjective testing determined that a stable approach began at 80 knots indicated airspeed (KIAS) from the final approach fix as well as a regimented landing technique, which is trained to proficiency to accomplish these procedures. This technique encompassed the following:

- Verbal callouts by the nonflying pilot of airspeed, heading, and radar altimeter height to ensure normal transition to an in-ground effect hover or run-on landing without an

[1] In accordance with Cougar Helicopter's request, any information in this plan pertaining to them should not be released outside the FAA.

abnormally large flare, such that a gain in altitude and/or loss of required visual reference does not occur.

- Deviation from glide path does not exceed one dot, as displayed from the ILS indicator.

- The helicopter is in trim for continuation of a normal approach and landing at DH.

- The helicopter is positioned and tracking to remain on course and within the lateral confines of the runway.

Overall, the subjective approval did not include an evaluation of runway/approach lighting. However, the subjective analysis did determine that a successful landing would require an extra pilot, aircraft equipment, and training to help mitigate the lack of visual cues to accomplish this procedure safely. Within the last 5 years, approximately 223 instrument approaches to 100 ft with 1200 RVR were accomplished safely. There has not been an unsuccessful event to this date.

In 2001, a draft Flight Standards Handbook Bulletin for General Aviation was written concerning the approval of Copter ILS approach minima. Several criteria were considered for developing this approval. The following are samples of the aircraft, training, and experience requirements.

- Flight Director or head-up display approved for approaches to 200 ft or below or autopilot

- One radio altimeter indicator

- One ILS localizer receiver with an associated failure warning system

- Special aircrew member training to include ground training and flight check

- Certificate and ratings requirements

- Recency of experience

This bulletin provided the guidance and requirements for the study.

In addition, in October 2002, a revision of FAA Order 8400.13A allowed for special authorization Category (CAT) II operations to qualifying runways, which do not meet the performance or equipment requirements normally associated with a U.S. Standard or International Civil Aviation Organization-compliant CAT II operation, e.g., touchdown zone lighting (TDZ), centerline lighting (CL), or CAT II approach lighting system with sequenced flashing lights (ALSF-2). This order basically allows for this special authorization to occur to CAT II operations at 1600 RVR and 100-ft DH without the requirement for TDZ/CL lighting systems, provided the operators' aircraft have a Flight Director, autocouple or Head-Up Guidance System, and the glideslope for that airport's ILS system complies with the Class II/D/2 performance. This order revision was established without any formal test research for support.

In summary, even though previous research investigated visual guidance adequacy with various lighting, runway marking, and weather conditions, no formal simulator evaluation of runway/approach lighting was conducted with MALSR to the visibilities requested by the helicopter industry, let alone an evaluation with a actual helicopter.

2. RESEARCH APPROACH.

Under the sponsorship of the FAA Rotorcraft Directorate (ASW-100) and the FAA Headquarters Flight Standards Office (AFS 400 and AFS 800), researchers from the FAA Office of Aviation Research and Development (R&D) Airport and Aircraft Safety R&D Division, the William J. Hughes Technical Center Simulation and Analysis Group (ACB-330) and Flight Program Group (ACB-870)) took the lessons learned from the earlier tests and designed a three-phase research approach to examine the visual processing of a helicopter pilot when flying the helicopter to 100-ft DH at visibilities equivalent to 1/4 mile on airport facilities containing a MALSR and no centerline or touchdown lights on the runway. More specifically, using a Level D Sikorsky S-76 simulator and an actual helicopter, researchers sought to measure where helicopter pilots attain visual cues from the runway environment and when they attain enough cues to decide to land the helicopter during day, night, and dusk conditions while employing flying techniques to aid in visual acquisition.

Phase I was designed to be a simulation pretest for Phase II to develop and refine test techniques and simulator setup using six FAA pilots as subjects. Phase II was designed to be the main simulation test to collect data and identify possible risks for mitigating action using up to 30 industry pilots as subjects. Phase III was designed to be a flight test in actual reduced visibility conditions to validate simulation results in Phase II using FAA R&D test pilots. Further details on each phase are provided below.

2.1 PHASE I—SIMULATION PRETEST AND VALIDATION.

Phase I was successfully completed in August 2001. The six FAA subject pilots completed 25 approaches each, for a total of 150 approaches (42 practice, 108 for data collection). Of the 108 approaches for data collection, 89 landed (touched down on the runway under control), 17 executed a missed approach procedure (11 of these called visual first, then subsequently executed missed approach procedure), and 2 landed off the runway (two separate subject pilots). The subject pilots had on average 10,050 hours total flight time (2,300-17,500-hour range), with an average of 4,533 hours in a helicopter (1000-9000-hour range).

Phase I results, in addition to validating the overall test design and simulation setup, provided the following insights:

- Landing Technique. The subject pilots used either roll-on or flared-to-hover landing techniques. Overall, approaches ending in a roll-on landing had a significantly higher success rate than those ending in a flare/hover in reduced visibility conditions. Consequently, for Phase II, a recommended landing technique was developed to be included as part of the evaluation.

- Time Compression. The subject pilots tended to dip below DH while making the decision to land during reduced visibility conditions. This may, in part, be due to fewer visual cues requiring additional mental processing time before making and annunciating a landing decision.

- Light Fixation. In the low light test conditions (dusk and night), subject pilots tended to drift towards the runway edge lights, typically on their same side (right).

2.2 PHASE II—SIMULATOR APPROACHES.

Phase II, which is the focus of this report, was conducted March 27-April 1, 2004, to collect data from industry pilots flying instrument approaches in a Level D S-76 cockpit simulator. Each pilot flew during one of three possible time-of-day conditions (day, dusk, or night) to provide data on the adequacy of the airport lighting to support helicopter approaches with reduced minima.

2.3 PHASE III—LIVE FLIGHT TESTING.

For Phase III, which has yet to be performed, the FAA R&D test pilots will provide approach data in an actual helicopter under actual reduced visibility weather conditions. The Phase III test design will be predicated on the outcome and lessons learned from the Phase II tests.

3. PHASE II OBJECTIVE.

The objective of the Phase II study was to determine whether a MALSR, runway markings, and runway edge lights, only, would be adequate for helicopter pilots to perform an instrument approach to 100-ft DH AGL with visibility averaging to 1/4 mile (designated as 1600 RVR) during different times of day (day, night, or dusk) and successfully land the helicopter.

This test was strictly concerned with airport lighting adequacy to support helicopter approaches with reduced minima.

The researchers analyzed the helicopter pilot's ability to:

- Visually acquire the approach lighting system
- Decide to land or go around
- Land safely

The results from this test contribute to the overall evaluation and potential approval of Copter ILS approaches to Category I facilities having typical approach and runway lighting.

4. METHODOLOGY.

4.1 PARTICIPANTS.

4.1.1 Pilots.

A total of 15 pilots participated in the study, 5 in each of day, night, and dusk conditions. Data from one pilot participant, however, was excluded from analysis (explained in section 6). Therefore, the total sample size was 14 pilots.

Each subject pilot had the following minimum experience and qualifications:

- A U.S. commercial, instrument rotorcraft rating possessing a minimum of 200 hours (in helicopters) after receiving rating
- Current and qualified in any of the following aircraft: Sikorsky S-76, Bell 412, Agusta 109, or Aerospatiale 365 Dauphin
- Employee of a U.S. company with a U.S. airworthiness certificate
- Not an employee of an original equipment manufacturer of rotorcraft or rotorcraft components including avionics

Prior to participating, volunteer pilots completed a background questionnaire (see appendix A) to provide the researchers with information about their experience, range of skill, and other attributes. Analysis indicated that pilot participants varied in terms of demographics and experience. Of the 14 participants, 10 were corporate pilots, 3 were emergency management services (EMS) personnel, and 1 flew offshore operations. The participants typically flew in the Northeast (12 participants), Midwest (1 participant), and the Gulf of Mexico (1 participant). Three of the participants flew Title 14 Code of Federal Regulations (CFR) Part 135 operations, while 10 flew 14 CFR Part 91 operations. The remaining pilot flew both 14 CFR Parts 91 and 135 aircraft. Eleven of the pilots flew dual-pilot operations; three flew single-pilot operations. For this study, dual-pilot operations were employed. However, the role of co-pilot (also known as the project pilot) strictly provided standard Crew Resource Management (CRM) callouts (500 ft, 100 ft, and minimums) throughout the approach portion and provided unique callouts, consisting of airspeed, pitch, and radar altitude) during the landing.

Pilot experience also varied in terms of total and recent experience. Background information confirmed that the participants were adequately familiar with the equipment and procedures necessary to perform in the study. Table 1 details several aspects of the participants' helicopter experience.

TABLE 1. PILOT EXPERIENCE

Flight Experience	No.	Mean (hours)	Range (hours)
Helicopter total	12	8685	4,000-14,100
Helicopter last 6 months	13	12	30-200
Helicopter IMC total	14	393	150-1,000
Helicopter IMC last 6 months	14	8	0-30
Helicopter simulator total	14	333	25-800
Helicopter simulator last 6 months	13	7	0-30
Helicopter instrument approaches flown in the last year with autopilot	14	23	6-100
Helicopter instrument approaches flown in the last year without autopilot	14	14	1-100

IMC = Instrument Meteorological Conditions

The majority of the participants (12 of the 14) flew some version of the S-76 helicopter used in the study. The remaining two pilots reported that they typically flew an SA 365 and an A5365N2. All 14 participants flew an aircraft that was equipped with three-cue autopilot equipment, although one pilot flew a two-cue aircraft as well. In addition to the autopilot equipment, a radar altimeter was stationed in all the participants' normal operating aircraft. Ten of the eleven responding participants typically used the radar altimeter for instrument approaches.

Twelve of the fourteen participants flew Copter ILS approaches prior to the simulation, two had not. Seven of the experienced participants flew Copter ILS approaches in actual conditions within the past year and a half. Five of them had flown it in simulated conditions.

Twelve of the participants had never flown Category II approaches, either real or simulated. Of the two who had, one flew it in real conditions; the other experienced it in simulated condition the year prior.

4.1.2 Research Personnel.

Research personnel included an FAA project pilot, who delivered the introductory briefing, participated as co-pilot during simulator approaches, performed postsession interviews, and debriefed subject pilots at the end of their participation. Other support personnel consisted of FAA employees and contractors who performed the duties of safety pilot, simulator operator, and data/event collector and observer during each simulator approach.

4.2 FACILITIES AND EQUIPMENT.

4.2.1 Level D Cockpit Simulator.

Testing was conducted at Flight Safety International's West Palm Beach Learning Center using a Sikorsky S-76C+ Level D simulator. The simulator visual system was configured to represent a Category I approach and runway lighting system. For standardization purposes, the simulator was configured to represent any helicopter that could achieve an approval for this procedure. Therefore, the autopilot configuration was set up to be coupled in the two-cue mode only (the subject pilot manually controlled the collective during the run). Coupling the aircraft was the responsibility of the FAA project pilot. The landing gear remained in the locked and down (three-green) position throughout every run. Both digital and analog flight and system gauges were available throughout the simulation (including analog and digital radio altimeter with alerter). All external helicopter lighting (strobe, position, anticollision, landing, and search lights, etc.) remained off throughout the procedure since the simulator could not represent a realistic visual representation and could create unnecessary illusions during the simulation. The subject pilots had their style choice for flight director and heading presentation on the electronic displays (e.g., v-bar versus cross-hairs, compass rose versus arc, etc.).

4.2.2 Flight Viz Data Collection Software.

The simulator's data software package, Flight Viz, was used to collect over 20 aircraft performance parameters during the study. These quantitative parameters were analyzed in conjunction with data on verbal callouts and subjective feedback from questionnaires and debriefings. Flight Viz was also used as a means of playing back audio, video, and flight profiles of each approach to the subject pilots during debriefings. This could be performed on a remote computer terminal in an office outside the actual simulator.

4.3 EXPERIMENTAL DESIGN.

Three time-of-day conditions were simulated: day, night, and dusk. Because adequacy of lighting and other visual cues, as well as lessons learned from Phase I, was the focus of this Copter ILS test, the researchers felt it was important that the participants be acclimated to a particular time of day and not switch between conditions during the test. Because of the limited amount of simulator time per participant, switching between time-of-day conditions could have introduced confounding effects in the data due to insufficient visual accommodation to each new lighting condition (e.g., switching from day to night in a short period of time).

As such, researchers implemented an independent sample design wherein participants experienced only one time-of-day condition during test runs. (Each pilot actually flew three approaches in one time-of-day condition; however, only data from the first test run could legitimately be included in the analysis based on the statistical rule of independent sampling.)

4.4 PROCEDURE.

4.4.1 Introductory Briefing.

The subject pilots were briefed on the Copter ILS simulation by the FAA project pilots prior to participating in the simulator test. The briefing covered the test purpose, overview of test scenarios, and simulator operations, Appendix B. The subject pilot also completed the background questionnaire (appendix A) and a Consent Form (shown in appendix C) during the prebrief.

4.4.2 Simulator Familiarization.

Prior to the flying data collection test runs, each pilot performed six practice runs in the simulator to gain hands-on experience with the landing procedure (explained in section 4.4.3). Practice approaches were flown to Morristown Airport. Appendix D contains the practice session checklist the research personnel used to configure the simulator to meet the parameters for the practice runs.

The familiarization gave all the subject pilots ample time to become comfortable in the cockpit setting and make any adjustments they found necessary to represent their aircraft. The subject pilots flew practice approaches to get familiar with the following:

- Simulator visual displays and helicopter controls
- Instrument approach and landing technique
- Verbal callouts

During the familiarization, the subject pilots ensured that the seat height and panel settings and lighting were adjusted to best reflect normal practices. Each subject pilot had the Copter ILS approach chart (including airport diagram with appropriate light schematics) to look over prior to practice and test scenarios as well as during any of the flying portions.

Table 2 lists the practice and test parameters.

TABLE 2. TEST PARAMETERS

Parameter	Day	Dusk	Night
RVR (ground)	1600	1600	1600
RVR (100 ft)	900*	900*	900*
Runway edge lights	3	4	4
Runway markings	3	3	5
Runway pavement	3	4	5
Taxiway lights	0	0	0
Ambient/cultural Lighting	Medium	Medium	Medium
Lower ceiling bottom	120	120	120
Lower ceiling top	800	800	800
Fog top	120	120	120

* Equivalent to 1/4-nm slant range visibility and 1600 RVR.

The subject pilots practiced making verbal callouts in preparation for the test scenarios as follows:

- “Visual”—First contact with approach lighting system.
- “Landing”—The pilot has enough visual cues that he/she is able to transition from instrument flying to visually flying the helicopter, thereby making a decision to land.
- “Missed approach (going around)”—Executing missed approach procedure (can execute at any time, including after making the landing call).

The familiarization not only pertained to the participating pilot, it also allowed the FAA project pilot to better understand the subject pilot’s flying techniques and characteristics (e.g., avionics, aircraft, and airport knowledge). This allowed the project pilot to aid the subject pilot as necessary to avoid confounds during the test execution. The FAA project pilot also provided standard crew coordination commands to the subject pilot. During the prebrief with the subject pilot, the project pilot informed the subject pilot that verbal commands concerning altitude, airspeed, and rates of descent calls would be given throughout the instrument approach portion of the run. The project pilot also provided radio altitude, airspeed, and pitch attitude calls throughout each landing portion of the run. These verbal commands were not provided if the subject pilot normally flew single pilot for his/her company. The project pilot based all verbal altitude commands below 200 ft from the radio altimeter. Each subject pilot was briefed that decision height altitude (100 ft) was to be determined from the radio altimeter. The subject pilots were not asked to make radio calls, change frequencies, or identify navigational aids throughout any of the practice or test runs.

4.4.3 Simulator Test Approaches.

Following familiarization, each subject pilot flew three approaches, the first of which was used as the test run for statistical data analysis. Appendix E contains the outcomes of all three approaches per pilot. The test approaches were flown to Teterboro Airport. The runway pavement, lights, and markings were also configured in accordance with Teterboro’s configuration (the test parameters were the same as those applied for the practice session at Morristown). Appendix F contains the test session checklist used by the research personnel to ensure the proper simulator configuration. Settings varied slightly to represent the different times of day. Appendix G contains the simulator session checklist, which was used by research personnel to ensure the appropriate sequence of time of day settings for each participant.

Each test approach was initiated on the final approach path such that it was stabilized at approximately three miles out. Each approach was coupled (two-cue only) and was flown at 80 ±10 KIAS. The subject pilot flew coupled to either the decision height (100 ft), the decision to land (by verbal callout), or the decision to go missed approach. The subject pilot had the ultimate decision as to when he or she chose to uncouple.

For data purposes, the approach was considered complete when the subject pilot either landed on the runway using the prescribed landing technique or initiated a missed approach. When the subject pilot decided to land, he or she was briefed to land the helicopter on the runway with forward touchdown speed not to exceed the following parameters:

- No greater than 30 kts (20 kts was recommended to the subject pilot during briefing)
- Pitch attitude not to exceed 10 degrees
- Yaw correction no more than 10 degrees

4.4.4 Verbal Debriefing.

Following completion of each practice and test approach, the FAA project pilot verbally prompted the subject pilot for comments on that approach. The questions covered what visual cues the pilot used for decision making and verified the correct interpretation of the pilot's verbal callouts.

4.4.5 Postsimulation Questionnaire.

Following completion of all test approaches, each subject pilot completed a postsimulation questionnaire, answering questions as they applied to all the approaches flown. The questions covered safety and adequacy of lighting to support the ILS approaches to a runway for helicopters. The subject pilots also had the opportunity to view simulator session computer/video representations and had project pilot-written logs available to supplement their comments. Appendix H contains the posttest questionnaire.

4.5 DATA COLLECTION.

Both subjective and objective data were collected during the Copter ILS test to gain an understanding of the lighting adequacy of the airport environment and the ability to safely land the helicopter in poor weather conditions with Category I lighting equipment and the associated visual cues. During the test runs, the subject pilots were instructed to verbally indicate at what point they visually acquired the airport environment and at what point they had enough visual information to make a decision to land or felt it necessary to go around. Also during test runs, the data/event observer recorded information on data/event logs to supplement other simulation data for analysis. Appendix I provides a data/event log form. At the conclusion of their participation, the subject pilots provided feedback on the proposed procedure based on the conditions they experienced.

To complement the subjective data, the researchers also collected a range of flight data parameters from the S-76's Flight Viz data recording system. The simulator data provided information on the helicopter's position on the approach at the time of each subject pilot's visual acquisition of the airport and subsequent decision to land or go around. The data also established whether or not the subject pilots landed the S-76 adequately, based on a set of predetermined performance criteria. Visual and audio recordings of the over the shoulder view in the cockpit were collected to assist in data analysis. Plots of the instrument approach flight path were also recorded. (The subject pilots signed a release form regarding the visual and audio recordings prior to participating in the test.) They were assured the recordings were to be used for debriefing and data analysis purposes only and that no recording would be distributed beyond the testing organizations.

5. SIMULATION CONSTRAINTS AND ASSUMPTIONS.

Though this particular study emulated the helicopter operational environment at high-fidelity levels, all simulation studies presume some constraints and assumptions. Therefore, the results from this simulation need to be interpreted with an understanding of such constraints and assumptions, which were as follows:

a. The simulator lacked the ability to produce accurate slant range visibility. Since this simulator was used primarily for training and not research, there was no need to produce such levels of accuracy. To accommodate for the lack of slant range representation, research personnel manipulated the RVR settings dynamically during each approach to emulate actual visible conditions experienced by a pilot flying on a descent profile and transitioning from instrument to visual conditions. They did this in a step fashion; RVR was changed dynamically from a slant range depiction to a horizontal RVR runway depiction during the approach. This manipulation of the RVR settings produced an accurate slant range visibility at 100 ft. After several trial runs with two FAA project pilots and highly experienced FAA airport lighting experts, this technique captured the essence of slant range variation and was negligible to the human eye during simulator testing.

b. The simulator had reduced fidelity when replicating the flight control laws a helicopter would fly under low speed and low altitude flight conditions (i.e., hovering flight or taxi). Therefore, those aspects of flight (such as taxiing or hovering from the runway to parking) were not considered during the simulation. In addition, the landing technique to be used will need validation during actual flight tests.

c. The simulator had difficulty replicating seat-of-the-pants flying or residual sensory inputs translated from the human inertial system combined with one's visual system. Some theorize that a trained experienced Instrument Flight Rules (IFR) pilot does not ever fly any one system (visually or instrument) 100 percent. Instead, he/she combines visual with instruments and inertial/sensory inputs. For example, when a helicopter pilot translates from forward to hovering flight, most of the time he/she knows the need for some collective increase and the translating right tendency, and may naturally perceive this by inputting left roll prior to visually establishing this fact. With this in mind, the simulator is slow to establish these inputs as well as provide cues for this correction. In this case, the pilot may make a predetermined input from experience or training, then the simulation may lag, and the pilot may make an input that would exaggerate his/her normal correction (maybe a right drift away from centerline of the runway). Therefore, the results of lateral displacement from centerline in the simulation could be a simulator phenomena, which should be tested and compared in the actual flight tests of Phase III.

d. No wind component was evaluated since the simulator had reduced fidelity in replicating actual flight conditions (displacement from glideslope and localizer).

e. The test was designed for pilots experienced in two-pilot crew operations. However, if a pilot that normally flew single-pilot operations participated in the study, his/her data was collected (considering the project pilot served as co-pilot in a two-person crew, providing standard CRM callouts (500 ft, 100 ft, and minimums) throughout the approach portion and unique callouts during the landing). Data collected from single-pilot participants, however, was analyzed with the entire data set and also separately to highlight any differences in performances that may have occurred as a result of type of crew experience.

f. The simulator used in this study had the highest level of fidelity (i.e., Level D); even so, it could not precisely simulate airfield lighting compared to the real-world environment. However, the test team was able to reconfigure the simulator to replicate airfield lighting to a degree that the test results would not be compromised. The airfield lighting configuration needs to be validated with actual flight tests.

g. The goal of the study was to acquire 30 subject pilots. Since the subject pilots were recruited on a voluntary basis while they were attending their semi-annual training and recurrency at Flight Safety, the researchers recognized the possibility that the sample would end up smaller. Furthermore, they recognized a smaller sample would limit the power of the resulting statistics.

6. DATA ANALYSIS.

Although 15 subject pilots flew the Copter ILS approach in the study, data from only 14 were analyzed. One of the requirements of the test was that each subject pilot had to be employed with a U.S. company. One pilot did not meet this criterion, but elected to participate in the interest of trying the approach. Coincidentally, a computer software glitch occurred during this pilot's participation, resulting in unusable data, and ultimately his exclusion from the analysis. The data, therefore, included, overall, five day runs, four dusk runs, and five night runs.

The Copter ILS test was designed for two-pilot crews. However, the researchers did not discourage participation from pilots accustomed to flying alone. Three pilots in the study were experienced in single-crew operations (i.e., EMS pilots). For the study, they flew with a co-pilot and, therefore, technically flew two-pilot approaches. As such, their data was included in the analysis with all of the participants. The researchers performed a separate analysis, however, to compare the performance of the pilots used to flying alone versus those familiar with two-pilot crew operations, which is contained in appendix J.

The main indicators of the feasibility of conducting Copter ILS approaches were the ability of the subject pilots to visually acquire the approach lighting system in sufficient time to make a decision to land or go around, and if landing, land safely. As such, researchers analyzed data on:

- Visual acquisition of the airport environment and decision to land or go around—based on pilot verbal callouts during the test approaches

- Approach performance—based on the prescribed technique

- Landing performance

- Subjective feedback from participating pilots

Due to the design of the test and the small number of subject pilots who participated in each condition, researchers computed only descriptive statistics for the analysis; the results of which are discussed in the following sections.

6.1 VISUAL ACQUISITION OF AIRPORT ENVIRONMENT AND DECISION TO LAND OR GO AROUND.

During test approaches, the subject pilots sought to attain visual cues from the airport environment to enable them to visually maneuver the aircraft to a safe landing onto the runway. The subject pilots did have the option to perform a go around, or missed approach, as necessary, if the visual cues were not adequate. Sections 6.1.1 through 6.1.4 present statistics on the number of landings and missed approaches resulting in each time-of-day condition and on other data parameters corresponding to the times of the verbal callouts, including response times, radar altitude, and indicated airspeed data.

6.1.1 Frequency of Landings and Missed Approaches.

Of the 14 approaches flown, 11 resulted in successful landings (78.6%), 2 resulted in missed approaches (14.3%), and 1 resulted in an unsuccessful landing (7.1%). One missed approach occurred in the day condition, and the other occurred in the night condition. The unsuccessful landing may have been a result of a simulator malfunction, as there was documentation of simulator control problems.

6.1.2 Response Times.

For each time-of-day condition, subject pilot response times were computed for the verbal callouts relative to the 100-ft DH. In addition, pilot response times were computed between visual acquisition of the airport and the decision to either land or go around. One should note that the fog top during the simulation was 120 ft AGL to provide a realistic condition for a 100-ft DH scenario. In addition, by creating the 120-ft fog top, the subject pilots could not visually acquire the MALSR system prior to that altitude, ensuring their position on breakout would be inside the 1000-ft barrette on the MALSR system.

6.1.2.1 Visual Acquisition Relative to 100-ft DH.

The response times for visual acquisition of the airport environment relative to the 100-ft DH for all approaches are shown in table 3. The response times presented in the table were calculated from the DH; in other words, DH = time 0. In both the day and night conditions, the subject pilots reported seeing the airport environment, on average, prior to reaching the DH. In the dusk condition, however, the subject pilots visually acquired the airport environment, on average, 1.1 seconds after passing DH. The widest range in response times again occurred in the dusk condition, and the tightest range occurred in the night condition.

TABLE 3. RESPONSE TIMES FOR VISUAL ACQUISITION RELATIVE TO 100-ft DH

Time of Day	No.	Minimum (sec)	Maximum (sec)	Mean (sec)	Standard Deviation (sec)
Day	5	1.3	-1.5	0.5	1.47
Dusk	4	2.7	-3.3	-1.1	2.80
Night	5	2.0	1.5	1.8	0.21

* Decision Height = Time 0

** Positive values indicate visual acquisition x seconds prior to reaching DH; negative values indicate visual acquisition x seconds after passing DH

6.1.2.2 Visual Acquisition to Decision to Land.

Figure 2 depicts the mean elapsed times from visual acquisition of the airport to the decision to land for those approaches that resulted in decisions to land. In figure 2, time 0 represents the 100-ft DH.

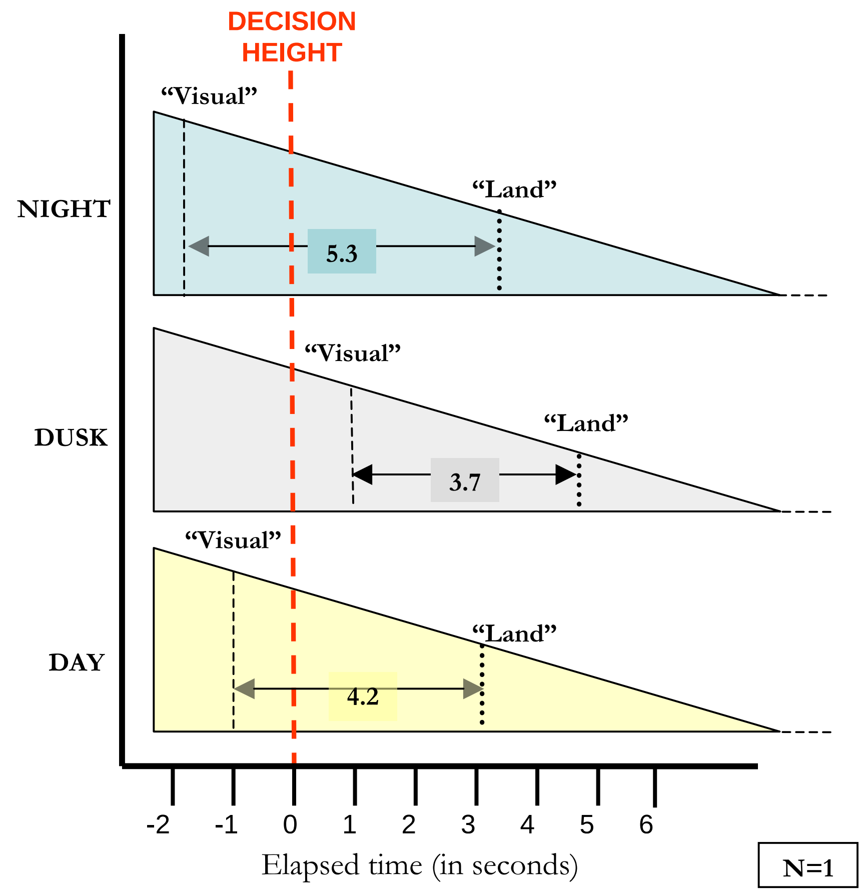

FIGURE 2. VERBAL CALLOUT RESPONSE TIME DATA FOR APPROACHES RESULTING IN DECISIONS TO LAND

The longest mean response time occurred in the night condition (5.3 sec). The shortest response time occurred in the dusk condition (3.7 sec). Figure 2 shows that although the subject pilots reported seeing the airport environment more quickly in the night condition, they took, on average, the longest time to make a decision to land. The total times from visual acquisition to decision to land for day and dusk conditions were fairly close; however, reporting the airport in sight occurred earlier, prior to reaching DH, in the day condition.

6.1.2.3 Visual Acquisition to Decision to Go Around.

Figure 3 depicts actual elapsed times from visual acquisition of the airport to the decision to go around for those approaches that resulted in decisions to go around. Because only one go around occurred in daytime conditions and one at night, the values are actual response times, not means. As with figure 2, time 0 represents the 100-ft DH.

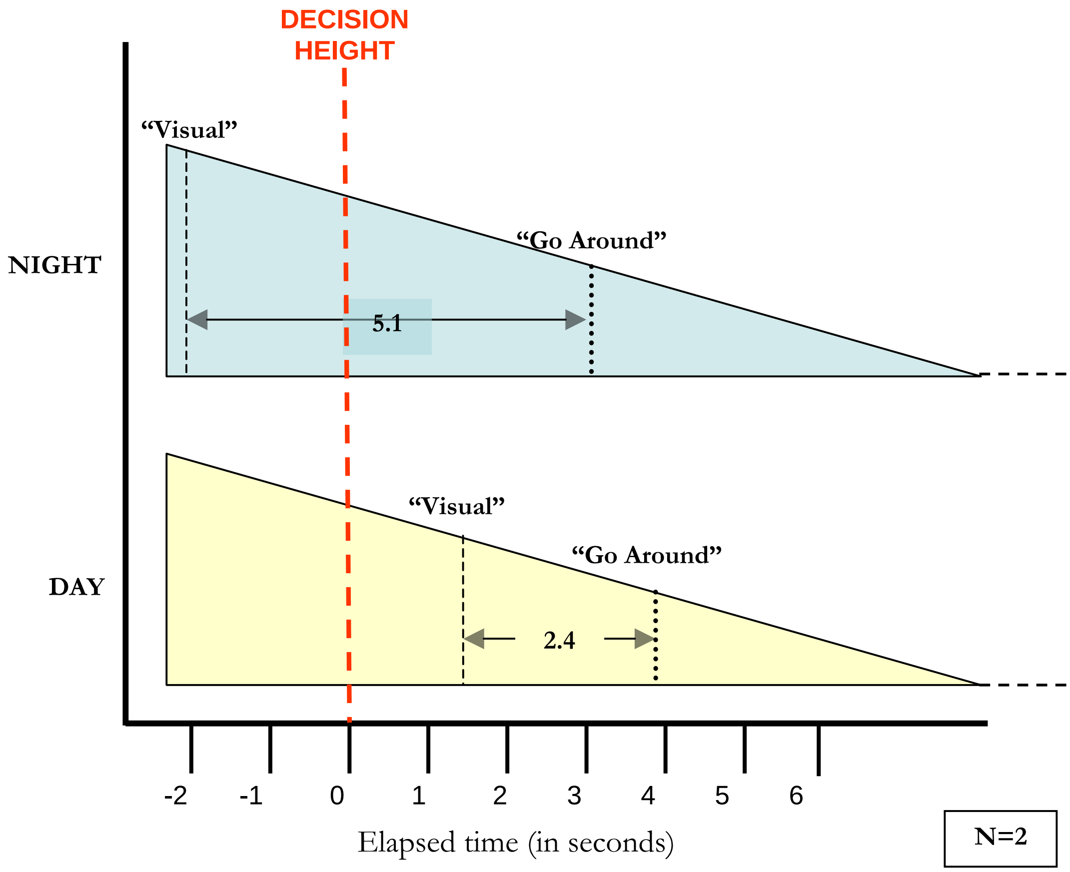

FIGURE 3. VERBAL CALLOUT RESPONSE TIME DATA FOR APPROACHES RESULTING IN DECISIONS TO GO AROUND

As with the approaches where the subject pilots decided to land, response times for visual acquisition of the airport environment relative to DH occurred the earliest in the night condition, but the pilot took a longer time to decide to go around in the night condition.

6.1.3 Radar Altitude.

As another indicator of where the subject pilots visually acquired the airport environment and made a decision to land or go around, the researchers determined the exact radar altitude at the time of the verbal callouts. Table 4 shows the altitude means and standard deviations for each time-of-day condition.

TABLE 4. RADAR ALTITUDE (in feet)

	Day		Dusk		Night	
	Mean	SD	Mean	SD	Mean	SD
Visual acquisition (includes all approaches irrespective of outcome)	100.95	11.60	90.66	18.50	109.14	6.30
Decision to land	71.72	19.78	69.39	14.19	76.84	11.72
Decision to go around	72.41	N/A	N/A	N/A	78.03	N/A

*SD = standard deviation

In both day and night conditions, the subject pilots reported visually acquiring the airport environment overall, on average, at or before the DH of 100 ft AGL (day = 100.95 ft, night = 109.14 ft). The decisions to either land or go around occurred generally around the same radar altitude in each time-of-day condition.

6.1.3.1 Altitude for Approaches Resulting in Landings.

Figure 4 shows the mean radar altitude at the time of visual acquisition for approaches resulting in decisions to land. It also shows the mean radar altitude at the times of decision to land. On average, the subject pilots visually acquired the airport environment before DH in both night and day conditions. They saw the airport earliest in night conditions (108.38 ft), followed by day (104.20 ft). The subject pilots took the most time visually acquiring the airport environment in dusk conditions with an average report at 90.66 ft.

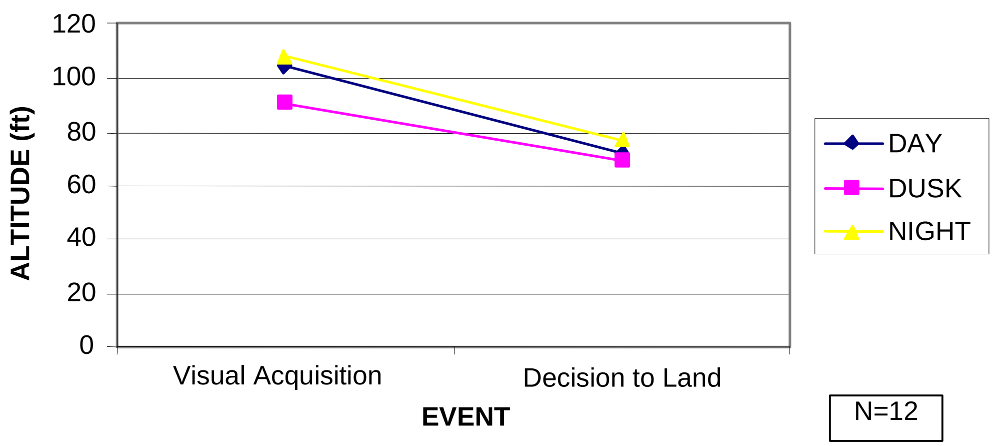

FIGURE 4. MEAN RADAR ALTITUDES FOR APPROACHES RESULTING IN DECISIONS TO LAND

6.1.3.2 Altitude for Approaches Resulting in Go Arounds.

For a closer inspection of the two approaches that resulted in missed approaches (one in day condition, one in night condition), the radar altitudes at the time of visual acquisition and the decision to go around were determined separately than those in which the subject pilots decided to land, as shown in figure 5. The data show the actual altitude values, not means, since only two instances occurred. Visual acquisition of the airport environment occurred before DH in the night condition only (112.16 ft). In the day condition, the subject pilot reported seeing the airport at 87.92 ft.

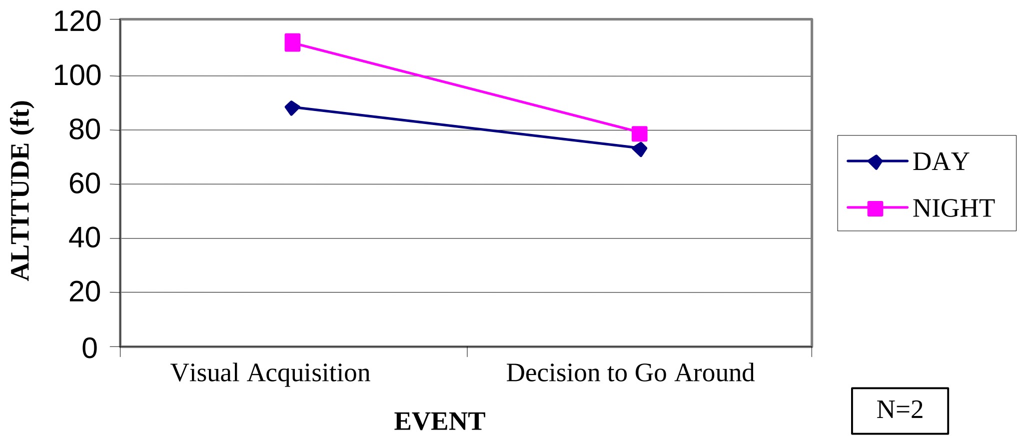

FIGURE 5. RADAR ALTITUDES FOR APPROACHES RESULTING IN DECISIONS TO GO AROUND

6.1.4 Indicated Airspeed.

Researchers determined the indicated airspeed of the aircraft when the pilot visually acquired the airport environment and made a decision to land or go around. Table 5 shows the airspeed means and standard deviations for each time-of-day condition. All mean airspeeds were within 80 ±10 kts at each event marker and in every time-of-day condition. Airspeed parameters are discussed in more detail in section 4.1.1.

TABLE 5. INDICATED AIRSPEED (in kts)

	Day		Dusk		Night	
	Mean	SD	Mean	SD	Mean	SD
Visual acquisition (includes all approaches irrespective of outcome)	83.85	1.62	78.39	7.20	80.20	3.85
Decision to land	81.60	3.70	75.64	8.36	80.44	1.60
Decision to go around	83.59	N/A	N/A	N/A	73.57	N/A

SD = standard deviation

6.1.4.1 Airspeed for Approaches Resulting in Landings.

Figure 6 shows the mean indicated airspeed data for those approaches resulting in decisions to land. The day approaches had the highest mean airspeeds at visual acquisition and decision to land, which were 83.42 and 81.60 kts, respectively. The night approaches had mean airspeeds of 81.55 kts at visual acquisition and 80.44 kts at the time of the decision to land. The dusk approaches had the lowest mean airspeeds at visual acquisition and decision to land, which were 78.39 and 75.64 kts, respectively.

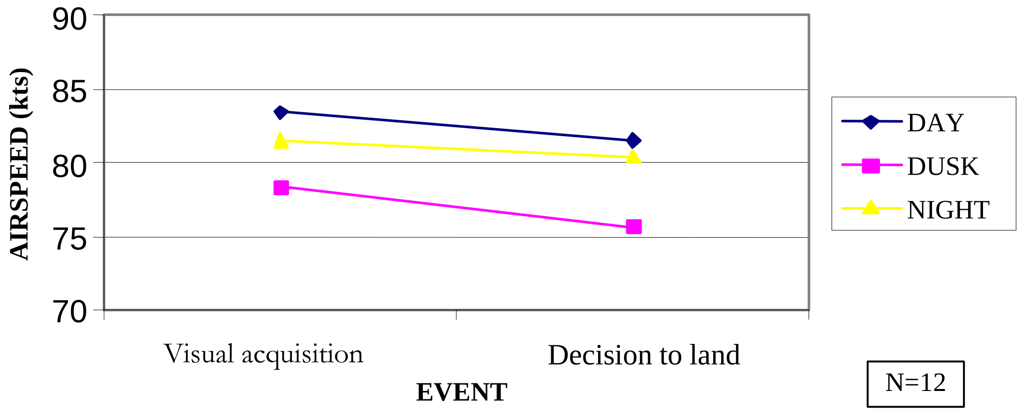

FIGURE 6. MEAN INDICATED AIRSPEED FOR APPROACHES RESULTING IN DECISIONS TO LAND

6.1.4.2 Airspeed for Approaches Resulting in Go Arounds.

Figure 7 provides a closer inspection of the indicated airspeeds for the two approaches that resulted in decisions to go around. The data show the actual airspeed values, not means. For the day approach, the airspeed at visual acquisition was 85.57 and 83.59 kts at the time of the decision to go around. For the night approach, the airspeed at visual acquisition was 74.82 and 73.57 kts at the time of the decision to go around.

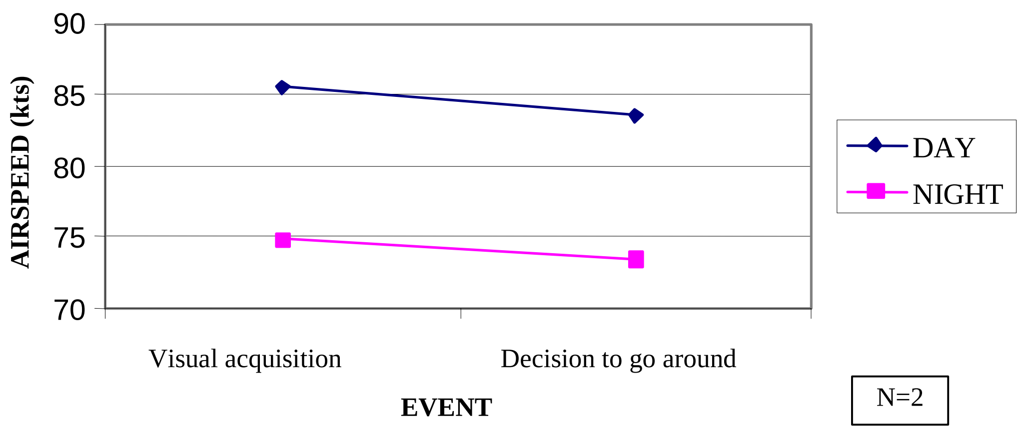

FIGURE 7. INDICATED AIRSPEED FOR APPROACHES RESULTING IN DECISIONS TO GO AROUND

6.2 APPROACH PERFORMANCE.

6.2.1 Prescribed Technique.

Researchers briefed the participating pilots on the landing technique to be employed during the Copter ILS test approaches, which included guidance on preferred speeds and autopilot status. The resulting performance data are described in detail in sections 4.1.1 and 4.1.2.

6.2.1.1 Airspeed.

The subject pilots were instructed to maintain an indicated airspeed of 80 ±10 kts during the approach. Figure 8 depicts the airspeed data for each participant, color coded by time-of-day condition. The T-bars indicate the maximum speed during the approach, and the filled bars show the airspeed at the missed approach point, which was approximately 0.2 nm from the runway threshold.

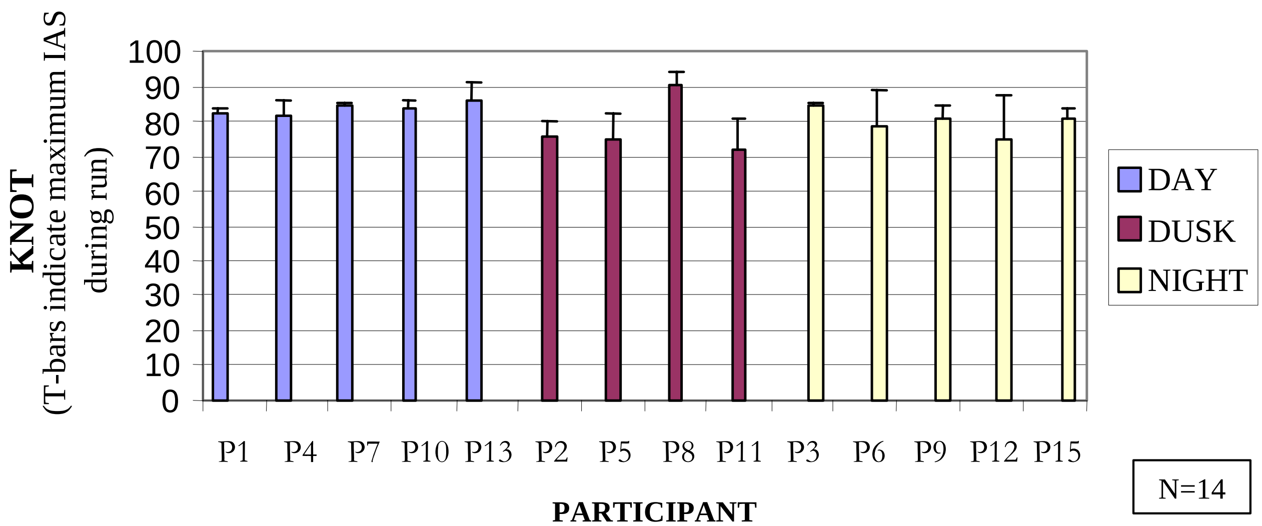

FIGURE 8. INDICATED AIRSPEED DURING APPROACH AND AT MISSED APPROACH POINT

All but two participants maintained the preferred airspeed during the approach. Of the two who did not, one reached a maximum airspeed of 94.29 kts and the other reached 91.34 kts.

6.2.1.2 Autopilot Status.

The subject pilots were instructed to fly the Copter ILS approach initially in a two-cue, autocouple mode. The co-pilots/researchers ensured this autopilot configuration was set at the start of each run. In addition to getting a confirmation of the initial autopilot status, the simulator software was supposed to capture if and when the pilots disconnected the autopilot during the approach, since they could do so at their discretion. The software, however, failed to do so, and this data was not collected.

6.3 LANDING PERFORMANCE.

In addition to verbally stating a decision to land, each subject pilot was instructed to land the aircraft within certain parameters. The researchers analyzed pilot landing performance based on a predetermined set of performance criteria. For each approach, the degree of deviation off the localizer was determined along with several touchdown parameters, including ground speed, pitch attitude, yaw correction, and the length of runway used before coming to a stop.

6.3.1 Localizer Deviation.

The researchers requested to capture runway centerline deviation data; however, this requirement was not fulfilled. Instead, as second choice, they obtained localizer deviation data from simulator software approach profile hardcopy printouts. From those, they could determine the aircraft's lateral deviation from the localizer at or near the point at which the localizer ended (this point depended on when the profile and corresponding printout was generated at the end of the run). One hardcopy printout was not collected (P1), therefore N=13 in this analysis.

Figure 9 shows the localizer deviation per subject pilot by time-of-day condition. The letters L or R just above each bar in the chart refers to either a left deviation or a right deviation, respectively, off the localizer. The line connecting the bars represents the exact distance (nm) to the end of the localizer that the measurement was taken. The distance to the end of the localizer was variable due to the varying times the printouts were generated. The data do, however, give an indication of the position of the helicopter relative to the localizer just prior to landing.

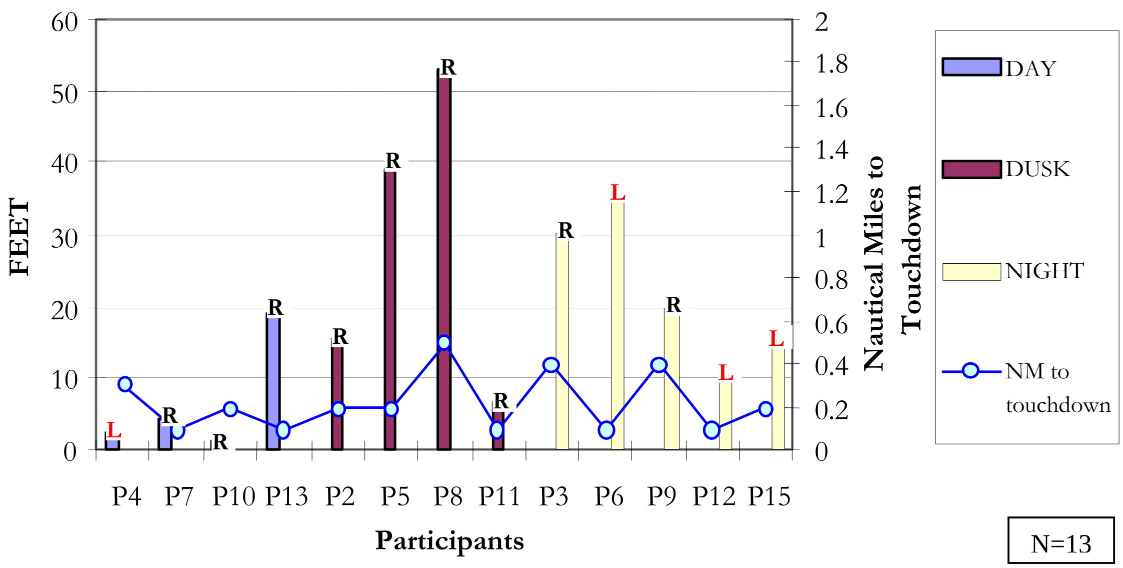

FIGURE 9. LOCALIZER DEVIATION APPROACHING RUNWAY THRESHOLD

The deviations worth noting are two that occurred in the dusk condition and two that occurred at night. In the dusk conditions, one aircraft was 52.7 ft from the localizer at approximately 0.5 nm from the end of the localizer, and the other aircraft was 39.2 ft from the localizer at approximately 0.2 nm to the threshold (this approach resulted in an unsuccessful landing). In the night conditions, one aircraft was 35.4 ft from the localizer at approximately 0.1 nm from the end of the localizer, and the other aircraft was 30.4 ft from the localizer at approximately 0.4 nm to the threshold. All other aircraft seemed to maintain their flight paths within 20 ft of the localizer as they approached the runway threshold. Of the 14 approaches, 10 resulted in deviations to the right of the localizer course. Of the four that resulted in deviations to the left, three occurred in the night condition. The simulation of Teterboro Airport portrayed its width accurately as 150 ft, thereby ensuring excessive localizer deviation did not displace the aircraft off the runway.

6.3.2 Touchdown Parameters.

The researchers instructed the participating pilots to land the helicopter within certain parameters, which included the following:

- Forward touchdown speed no greater than 30 kts
- Pitch attitude no greater than 10 degrees
- Yaw correction no greater than 10 degrees

Table 6 shows the overall results of touchdown performance. The subject pilots who executed missed approaches (P12 and P13) were not included in the analysis because they did not touchdown and land the aircraft. The approach that resulted in an unsuccessful landing (P5) was included since these parameters were captured up until the time of impact. Therefore, the researchers determined touchdown parameters for a total of 12 participants.

TABLE 6. TOUCHDOWN MEASURES

	Day		Dusk		Night	
	Mean	SD	Mean	SD	Mean	SD
Ground speed (kts) Not to exceed 30 kts; 20 kts recommended	26.71	4.57	24.84	8.90	21.50	6.70
Pitch attitude (deg) Not to exceed 10 degrees	7.99	3.39	6.71	3.51	8.48	2.11
Yaw correction (deg) Not to exceed 10 degrees	2.72	1.11	4.65	1.54	5.00	2.13

*SD = standard deviation

On average, the subject pilots successfully met all of the touchdown criteria. The mean forward touchdown speeds were under 30 kts in all time-of-day conditions. The mean pitch attitude was less than 10 degrees in all time-of-day conditions. The mean yaw correction was less than 10 degrees in all time-of-day conditions.

Sections 5.2.1 through 5.2.3 present individual performance data related to ground speed, pitch attitude, and yaw correction.

6.3.2.1 Ground Speed.

Figure 10 depicts individual pilot performance data on ground speed. The data showed that 2 of the 12 subject pilots that landed the helicopter exceeded the maximum forward touchdown speed of 30 kts. One subject pilot had a maximum ground speed of 37.18 kts, and the other pilot had a maximum ground speed of 31.92 kts.

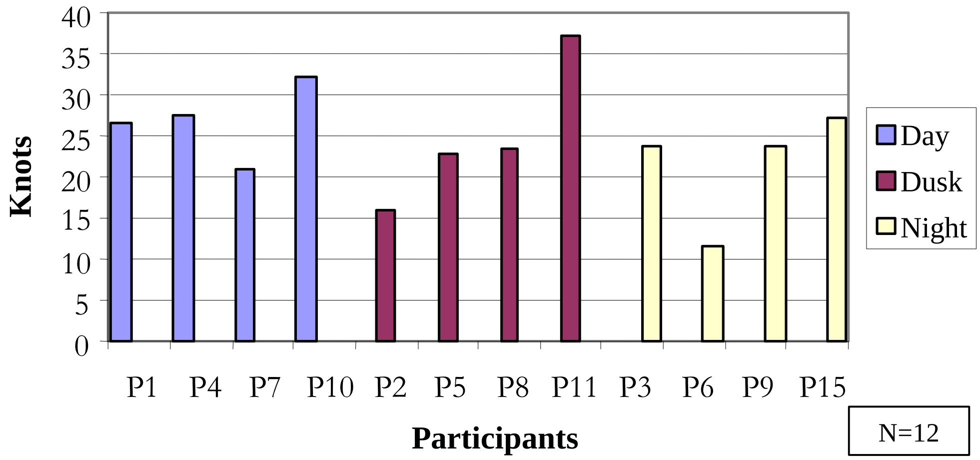

FIGURE 10. MAXIMUM GROUND SPEED BY INDIVIDUAL PILOT

6.3.2.2 Pitch Attitude.

Figure 11 shows individual subject pilot performance data on pitch attitude. Four of the twelve subject pilots exceeded the maximum pitch attitude of 10 degrees upon touchdown. Three of those violations, however, were marginally over the preferred maximum. One subject pilot had a maximum pitch attitude of 12.90 degrees. The other three subject pilots reached maximum pitch attitudes of 10.53, 10.17, and 10.04 degrees.

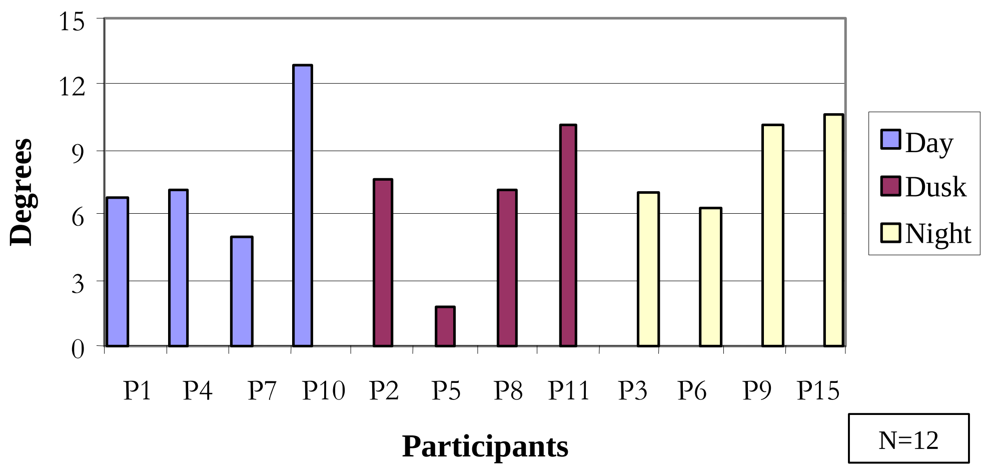

FIGURE 11. MAXIMUM PITCH ATTITUDE BY INDIVIDUAL PILOT

6.3.2.3 Yaw Correction.

Figure 12 shows individual subject pilot performance data on yaw correction. No subject pilot violated the yaw correction criteria.

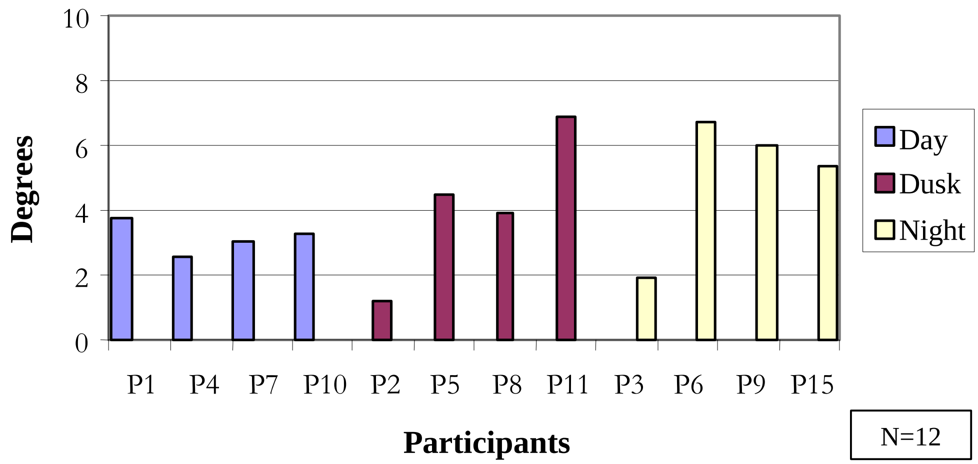

FIGURE 12. MAXIMUM YAW CORRECTION BY INDIVIDUAL PILOT

6.3.3 Runway Length Usage.

Researchers determined the length of runway used overall and on an individual basis, which was calculated from the point the aircraft crossed the runway threshold to the point at which the aircraft stopped. The total runway length at Teterboro's runway 6 was 6015 ft. Table 7 shows the runway length usage along with standard deviations in each time-of-day condition. One subject pilot (P5) was not included in this analysis because he had an unsuccessful landing. Therefore, N = 11 for this section.

TABLE 7. RUNWAY LENGTH USAGE

	Day		Dusk		Night	
	Mean	SD	Mean	SD	Mean	SD
Runway length used (ft)	2463.11	673.09	2411.24	1895.90	2585.33	898.30

*SD = standard deviation

The mean runway distance used was fairly similar for all time-of-day conditions. The subject pilots used the shortest distance of runway in the dusk condition (2411.24 ft) and the longest in the night condition (2585.33 ft). The most consistent runway distance used occurred in the day condition as indicated by the lowest standard deviation value of the three time-of-day conditions. Figure 13 shows the runway length used by an individual subject pilot. The range of distances is better seen in this graph. This data is for informational purposes only, as no parameter was set or recommendation made to the subject pilots prior to the test about optimal runway distance.

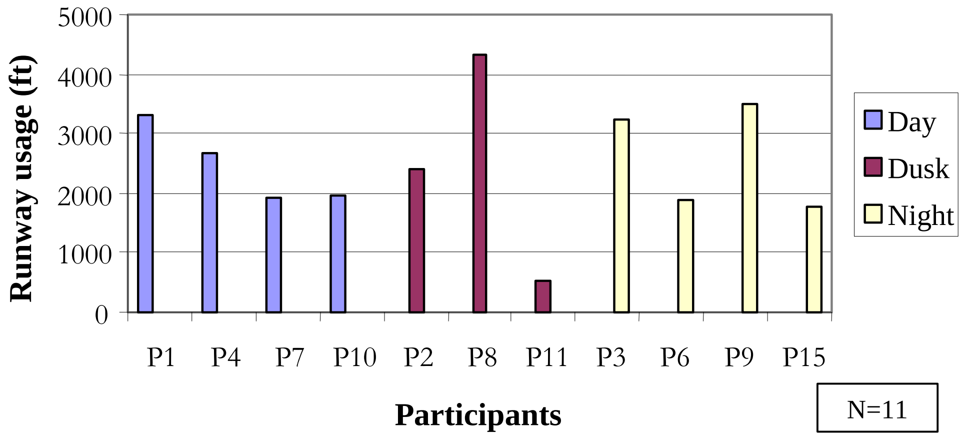

FIGURE 13. RUNWAY LENGTH USAGE BY INDIVIDUAL PILOT

6.3.4 Ground Rollout Distance.

Researchers determined the length of the rollout distance overall and on an individual basis, which was calculated from the point the wheels touched down to the point at which the aircraft stopped. Table 8 shows the mean rollout distance along with standard deviations in each time-of-day condition. One subject pilot (P5) was not included in this analysis because he had an unsuccessful landing. Therefore, N=11 for this section.

TABLE 8. GROUND ROLLOUT DISTANCE

	Day		Dusk		Night	
	Mean	SD	Mean	SD	Mean	SD
Ground rollout distance (ft)	254.78	83.77	155.85	112.14	265.07	120.81

*SD = standard deviation

The subject pilots had the shortest rollout distance in the dusk condition (155.85 ft) and the longest in the night condition (265.07 ft). There was a considerable range of rollout distance in each condition, as indicated by the standard deviations. Figure 14 shows the ground rollout distance used by the individual subject pilot. The range of distances is better seen in this graph. This data is for informational purposes only, as no parameter was set or recommendation made to the pilots prior to the test about optimal rollout distance.

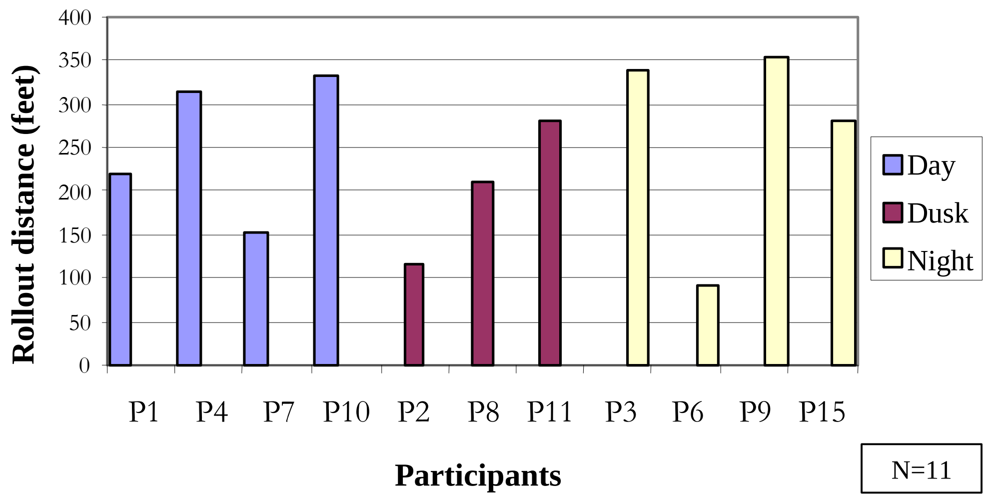

FIGURE 14. GROUND ROLLOUT DISTANCE BY INDIVIDUAL PILOT

6.4 SUBJECTIVE FEEDBACK.

The subject pilots provided feedback on a number of issues related to the test, both verbally and in writing on questionnaires at the end of their participation. Feedback included information on the specific visual cues that allowed them to visually acquire the airport environment and make a decision to land or go around, lighting and visual adequacy overall, effect of transitioning from instrument to visual flight, prescribed landing technique, runway environment fidelity, flight profile fidelity, and simulator training. Sections 6.4.1 to 6.4.7 present the subjective responses to each of these issues.

6.4.1 Specific Visual Cues.

Following each test run, researchers first asked the subject pilots to indicate, on MALSR and runway threshold marking diagrams, the specific visual cues they first acquired in the airport environment and the cues that enabled them to make the decision to land. As mentioned in section 6.1.2, subject pilots broke out of the fog during each approach inside the 1000-ft barrette. Appendix K contains each subject pilot's responses to these questions. The circled areas on the diagrams refer to where on the approach the pilot visually acquired the airport environment. The boxed-in areas refer to where on the approach the subject pilot decided to either land or go around.

After marking the diagrams, the participants discussed their visual cue responses in a short verbal debrief session. The subject pilots in the day condition reported that their initial visual of the airport generally consisted of the 800- to 600-ft barrettes on the MALSR. Landing cues for the majority of the day participants were the threshold, pavement, and pavement markings. Two of the five participants in the day condition were able to see edge lights at the time of the landing decision. A missed approach was executed by one participant. The subject pilot did recall that after he made the call to go around, he obtained a visual that extended from the 400-ft barrette to the threshold.

The dusk condition participants reported a fairly wide range of initial visual cues. Reports indicated that their initial visual ranged from the flashing lights of the rails to the 800-ft barrette. The participants' predominant visual for landing was the threshold, along with one or two edge lights. Two participants reported using pavement and/or pavement markings.

The initial visual for the night participants typically extended from the 800- to 600-ft markers on the MALSR (or the last three to four barrettes). The landing visual generally consisted of threshold and edge lights. One missed approach was executed under this condition. The go around participant reported that he was counting lights during his approach and did obtain a visual of the MALSR. He decided to go around, though, because he did not have enough cues to land.

6.4.2 Lighting and Visual Cue Adequacy.

Four of five daytime participants felt the approach lighting was adequate. One participant believed that due to lighting intensity and approach speed, the lighting was dim for visual minimum. All daytime participants (five of five) believed the runway lighting was adequate. The majority (four of five) of the participants used cues other than runway lighting. Threshold and runway centerline markings (not the lights) were most commonly relied upon by the day condition participants. However, other cues used included distance markers, taxiway and runway signs, and ground and runway contrast. None of the daytime participants doubted the outcome of the landings.

All the dusk participants felt the approach lighting and runway lighting environments were adequate (four of four). Three of the four participants used cues other than runway lighting. These subject pilots reportedly used ground points and runway contrast, in addition to runway lighting. One participant reported that the striping was very visible, and the centerline was very helpful when landing. One of the four participants doubted the outcome of the approach at some point.

Four of the five participants in the night condition believed that the approach lighting was adequate. One participant reported that the 1000-ft barrette was inadequate and needed to be more visible and different. All the participants believed that the runway lighting environment was adequate as well. However, one participant commented that runway centerline lighting was necessary. The majority (four of five) of the subject pilots did not use cues other than runway lighting on approach, but one subject pilot reported using runway distance markers as a cue. Two of the five participants doubted the outcome of the approach, one of which reported missing the approach.

6.4.3 Effect of Transitioning to Visual Flight.

The subject pilots responding to this question (N=11) reported that the effect of transitioning from instrument to visual flight on short final was minimal. However, mention was made by several subject pilots that dual- and single-pilot operations would present a different level of complexity because the crew cannot share the workload as they can in a dual-pilot setting. Dual-pilot operations could contribute to a safer and more efficient operation.

6.4.4 Landing Technique.

The majority of the respondents in the day and dusk conditions reported that the landing technique was adequate, although one participant in the day condition believed that a longer runway was needed to stop. The night condition participants (N=3) reported other difficulties. Two participants reported that more runway marking visuals, such as landing lights, were necessary for a safer landing. The remaining participant commented that the 100-ft envelope was too short to reduce airspeed for landing.

6.4.5 Runway Environment Fidelity.

On the whole, both day and dusk participants believed that the fidelity of the runway environment was good. Three responses were recorded out of the expected five in the night condition. One night condition participant commented that the fidelity was adequate to align and land. The remaining two respondents reported problems. One reported insufficient visual cues from the runway surface; the other reported that although lights were depicted well, they did not provide flood lighting to nearby areas.

6.4.6 Flight Profile Fidelity.

Nearly all the participants reported that the simulator fidelity ranged from good to excellent. The few less positive answers pertained to the simulator responding less realistically during lower speeds and that control rates were somewhat excessive compared to real operations.

6.4.7 Simulator Training.

Of the 14 respondents, all but one felt the simulator was adequate preparation for flying approach in an operational environment. The remaining participant commented that he believed that the simulator was "very different from a real aircraft."

7. SUMMARY.

The majority of the subjective feedback from the participating pilots in the study supports the feasibility of the Copter ILS procedure in terms of lighting and visual cue adequacy and the two-person crew landing technique. Twelve of the fourteen subject pilots thought the approach lighting was adequate. Some subject pilots did point out that the addition of runway centerline lighting would be helpful. They all agreed a two-person crew would be essential to the safety of the procedure.

The objective performance data also support the lighting adequacy for Copter ILS approaches. The subject pilots visually acquired the airport environment, in most cases, before the 100-ft DH. Twelve of the fourteen approaches resulted in decisions to land. One of those approaches was unsuccessful; however, this may have been attributed to simulator control malfunctions. Approach and landing performance for the most part was in accordance with the recommended parameters. Two of the subject pilots exceeded recommended speeds or pitch attitudes at some point, but nevertheless, brought the S-76 helicopter to a safe stop. Some of the performance deviations may have been attributed to unfamiliarity with the Level D type of simulator performance.

Time of day did seem to have an impact on performance and opinion about the lighting and visual cue adequacy for the Copter ILS approaches. Dusk appeared to be the most difficult condition in which to visually acquire the airport lighting environment. Pilot response times were the longest from DH to visual acquisition, and one go around occurred in dusk conditions.

Night conditions also demonstrated an interesting effect. While pilots visually acquired the airport environment, on average, the earliest in the nighttime environment, they took the longest amount of time thereafter to make a decision to either land or go around. The lack of centerline lighting may have contributed to this effect. In addition, perhaps they could not detect other visual cues, such as threshold, pavement, and pavement markings as quickly as other subjects flying in daytime conditions. One go around occurred in night conditions.

Several issues are important to note when interpreting the data in this report. First, because the focus of the test was on lighting adequacy (as measured by pilot acknowledgements of visually acquiring the airport environment and having enough visual cues to land), and the simulated airport lighting lacked some of the intensity of real-world lighting, the results should be more conservative than they would be had these approaches been flown in a real-world environment. In other words, had pilots been exposed to a more realistic presentation of airport lighting, they may actually had visually acquired the airport environment sooner than they did in the simulator. This would have, in turn, given them a greater amount of time to make a decision to land or go around, and more time to actually execute the chosen maneuver.

Second, it is important to keep in mind that the study included a relatively small number of participants. To be able to draw inferences about the population of helicopter pilots and the feasibility of the Copter ILS approaches as simulated, more data would need to be collected and analyzed. Conclusions from this report should therefore be kept in perspective, as they are based solely on descriptive statistics.

The majority of the participating pilots supported procedures for instrument approaches to 100-ft decision height AGL with visibility averaging 1/4 mile at airports with Category I approach and runway lighting during varying time-of-day conditions. The corresponding flight simulator data showed promising results in terms of flying performance based on the prescribed approach and landing technique. Different times of day may have affected performance, however, with dusk conditions being most questionable.

This human-in-the-loop flight deck simulation provided data to contribute to an overall evaluation of Copter ILS approaches to airports with Category I approach and runway lighting. The data set acquired, however, was not enough to approve any procedures. It did, however, provide insight into the feasibility and acceptability of such procedures from a pilot perspective. The collection of more data is desirable to augment and validate the results of this Copter ILS simulation. In addition, live flight tests of the procedure with real-world airport lighting conditions are proposed to most accurately capture real-world performance.

Upon completion of the study, researchers noted several areas in need of correction, or lessons learned, with regard to different aspects of conducting the Copter ILS simulation. In the event a follow-up study could be performed, the researchers should incorporate the following changes.

With regard to test design, a repeated-measures approach should be considered where each participant would experience all three time-of-day conditions, thereby increasing the data sample size and reducing the variability in performance. This was not incorporated into this initial study because of concerns of the carryover effect on the visual system of changes between time-of-day conditions in such a short period of time. Since pilot participants were volunteers, the researchers wanted to maintain a minimum time required for each pilot to complete his/her participation. As such, times between each approach were as short as possible. A repeated measures design would require more time to allow a pilot to visually accommodate to the new time-of-day condition between each simulator session or approach. One way to allow for more time would be to pay pilots for their participation, rather than solicit their help on a volunteer basis. As paid participants, they would commit their time to the study and the researchers would not feel the pressure of having to speed them through the process.

With regard to test procedures, to maximize the time in the simulator, the researchers should request that macros be developed in the simulator software to allow for quick reconfigurations of the test profiles in between each run. The manual steps employed to reconfigure the simulator between runs in this study were tedious and rather time-consuming. The researchers learned that a macro capability could be developed with advanced notice, where the researcher could push one button to reset the simulator, rather than sequencing through a series of buttons, making the study run more efficiently.

With regard to data collection, several variables of interest did not get recorded in the simulator. For a future study, it will be imperative to collect autopilot status (which would capture when and where on the approach a pilot disconnected the autopilot) and runway horizontal deviation (only approach deviation data was retrievable in this study). Incorporating these data requirements into the study would involve more front-end coordination with simulator technicians and validation of their existence in the data recordings.

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APPENDIX A—BACKGROUND QUESTIONNAIRE

The purpose of this questionnaire is to collect information concerning your aeronautical experience. This information will be used for test purposes, only.

1. Subject Pilot # ____ Consent Letter completed ____________

2. Operations:

   a. Type of flight operation (Corporate, EMS, etc) ____________________________

   b. Do you fly under Part 91 or 135? Please circle.

   c. Do you fly single or dual pilot? Please circle.

   d. Area of the country you fly in? (i.e., North East, Gulf of Mexico, etc) ____________

3. Flight experience:

		Helicopter		Airplane	
		Hours	Instrument Approaches	Hours	Instrument Approaches
Total	Total				
	Last 6 months				
Actual IMC	Total				
	Last 6 months				
Sim. IMC	Total				
	Last 6 months				

4. Date approaches last flown in IMC (month/year):
   a. Helicopter Precision _______ Nonprecision _______
   b. Airplane Precision _______ Nonprecision _______

5. What aircraft do you most often fly instrument approaches in (be as specific as possible, i.e., SK76C++): ____

6. Do you have an autopilot? YES/NOIf so, is it two or three-cue (Does the collective couple)? 2 / 3

7. Do you have a radar altimeter? YES/NO If so, do you use it for instrument approaches? YES/NO

8. How many instrument approaches have you flown in the last year:
   a. Helicopter With Autopilot ____ Without Autopilot ____
   b. Airplane With Autopilot ____ Without Autopilot ____

9. Have you flown a COPTER ILS before? Yes / No
   If yes, date last flown COPTER ILS _______ actual / ______ simulator

10. Have you ever flown a CAT II IFR approach before? YES/NO
    If yes, date last flown CAT II IFR approach,
    a. Helicopter Actual ____ Simulator ____
    b. Airplane Actual ____ Simulator ____

APPENDIX B—SUBJECT PILOT PREBRIEF

Briefing

This handout provides the subject pilot pre-brief on test purpose, test scenarios, and simulator operations. The subject pilot should also complete the background questionnaire.

The purpose of this test is to provide data on approach and runway lighting adequacy for helicopter ILS approach and landing operations at Category 1 (CAT 1) runways.

A ‘COPTER ILS” differs from a normal ILS in three ways:

(1) Decision Height as low as 100 feet.

(2) Minimum Weather as low as 1600 RVR

(3) FAF to MAP distance is usually one-half the normal ILS distance.

In order to test the adequacy of this type of lighting system, it is important that the subjects fly the approach and landing which he/she deems to be comfortable and safe.

Simulator Familiarization

Subject pilots will fly practice approaches to provide familiarity with the simulator visual displays and helicopter controls; COPTER ILS approach chart; landing technique and verbal callouts.

During the familiarization, the subject pilot will ensure seat height and panel settings/lighting are adjusted to best reflect normal practices.

Subjects will also practice test callouts. Following each approach, the subject will be asked for what visual cues were used to make the “visual” call. Callouts are as follows:

> “*Visual*” – First contact with the approach lighting system and continuing on approach with expectation to land. (refer to the following attachment on FAR 91.175 section on runway environment).
>
> “*Landing*” – The subject pilot perceives he/she has enough visual cues that they are able to transition from instrument flying to visually flying the helicopter, thereby making a decision to land.
>
> “M*issed approach (or going around)*” – Executing missed approach procedure. (Can execute at any time, to include after making “**Landing**” call).

In addition, the FAA Project Pilot will also provide necessary crew coordination commands of altitude, airspeed (deviation of +/- 10KIAS), and rates of descent in excess of 500 fpm throughout each instrument approach portion of a run. The project pilot will also provide radio altitude, airspeed and pitch attitude commands throughout each landing portion of the run. Project pilots will base all altitude commands below 200 feet from the radio altimeter. Project pilots will not offer crew coordination commands pertaining to visual acquisition of the approach or runway lighting system or the decision to land from the instrument approach portion. These calls will not be provided if the subject normally flies “single pilot” for his/her company.

Even though this simulator is rated at Level D (highest fidelity rating for a simulator), experience has shown that the simulator still does not perfectly replicate the real aircraft. For example, during your practice session, you may notice if the airspeed falls below 60 knots that aircraft recovery is much more difficult than the real aircraft.

After completion of practice session, subject may review digital data during a short debrief as well as discuss any questions.

Test Execution

Following the familiarization session, each subject pilot will fly at least three test approaches. Subject pilot will have available COPTER ILS approach chart prior to commencing each approach.

Each test approach will be initiated on final approach path such that the approach is stabilized at approximately three miles out on final approach. Weather for each approach will be at published minimums. Landing lights will not be used.

The approach will initially be flown in a two-cue, auto-couple mode (the pilot will have to manually work the collective) and flown at 80 KIAS. The approach will be completed when the subject has either landed on the runway using the pre-briefed landing technique, initiated a missed approach, or when directed by the FAA Project pilot. When the subject decides to land, s/he must land the helicopter on the runway with forward touchdown speed within the following parameters:

- No greater than 30 knots (20 knots recommended)
- Pitch attitude not to exceed 10 degrees, and
- Yaw correction no more than 10 degrees.

The subject can determine at his/her discretion when to decouple the aircraft.

Subject's verbal comments, in addition to the defined callouts, are encouraged throughout the session. Following each approach, test director will record pilot verbal comments on cues (or lack of cues) used to make the "visual", "landing", and/or "missed approach" call (refer to following MALSR discussion on approach and runway lighting configuration).

Post Test Debriefing

Following completion of the test, the subject pilot will complete the post-test questionnaire. Subject pilots will have simulator session digital data and data logs available to supplement his/her comments.

SIMULATOR SESSION TIMELINE

T-1:00	Pre-Brief/Questionnaire (30-60 min)
T-0:00	Practice Approaches & Set-Up (30 min)
T+0:30	Debrief Practice (either remain in sim -15 min or review video 30 min)
T+1:00	Test Approaches (30 min)
T+1:30	Session Completed

Runway Environment Definition

Runway environment is defined according to 91.175 as follows:

Except for a Category II or Category III approach where the Administrator specifies any necessary visual reference requirements, at least one of the following visual references for the intended runway is distinctly visible and identifiable to the pilot:

(i) The approach light system, except that the pilot may not descend below 100 feet above the touchdown zone elevation using the approach lights as a reference unless the red terminating bars or the red side row bars are also distinctly visible and identifiable.

(ii) The threshold.

(iii) The threshold markings.

(iv) The threshold lights.

(v) The runway end identifier lights.

(vi) The visual approach slope indicator.

(vii) The touchdown zone or touchdown zone markings.

(viii) The touchdown zone lights.

(ix) The runway or runway markings.

(x) The runway lights.

MALSR

The MALSR consists of seven-five light bars located on the extended runway centerline (prior to the runway). The first bar is located 200 feet from the runway threshold and at each 200-ft interval out to 1400 feet from the threshold (beginning of the runway). Two additional five-light bars are located, one to each side of the centerline bar 1000 feet from the runway threshold forming a crossbar 66 feet long (FAA Handbook, 1993). The spacing between individual lights in all bars is approximately 2.5 feet. The RAIL portion of the facility consists of sequenced flashing lights (known as flashers) located on extended runway centerline, the first being located 1600 feet before the approach end of the runway threshold with successive flashers located at each 200-ft interval out to the end of the system (2400 or 3000 feet). These lights flash in sequence towards the threshold at the rate of twice per second (FAA Handbook, 1993). The MALSR system is normally 2400 feet long and is depicted in Figure 1 below.

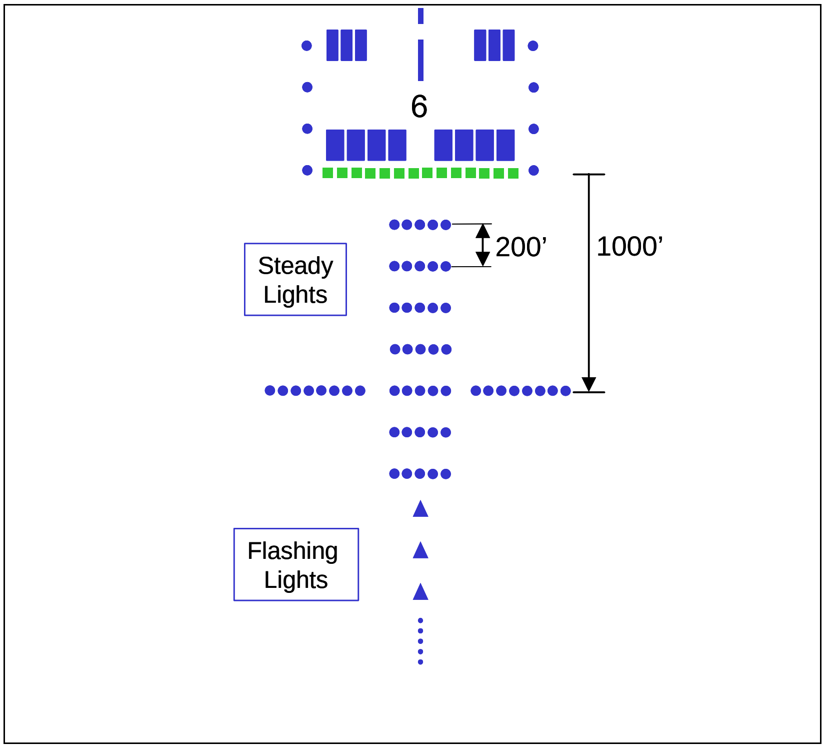


Figure 1. MALSR

A typical Category 1 airport has runway edge lights but may not have centerline or touchdown zone lighting on the runway itself. As compared to higher Category approach lighting systems, brightness of the runway edge lights and the flasher intensity are lower (less bright) at facilities with the MALSR (FAA Handbook, 1993).

APPENDIX C—DATA COLLECTION CONSENT FORM

Your participation is this study is completely voluntary. You are free to withdraw at any time without penalty. You may cancel, postpone, modify, or prematurely terminate a simulator session at any time for any reason, including if, in your sole judgment, adequate safety is in any way compromised.

You participation is strictly confidential, and no individual names or identities will be recorded or released in any reports, and only arbitrary numbers are used to identify pilots who provide data. Digital recordings made during this study will only be viewed by researchers directly connected with this study, and they will be destroyed five years after completion of this study.

You do not give up any legal rights or release any individual or institution from liability by participating in this study.

If you have any questions, ask the FAA project pilot or test director. Contact information is as follows:

Project Pilots: Lorry Faber, (609) 485-5461

Larry Vanhoy, (609) 485-4552

Signature

I, _____________________, have read this consent document. I understand its contents, and questions I have at this time have been answered to my satisfaction by the researcher. I freely consent to participate in this study under the conditions described. I understand that I am free to withdraw from the study at any time. I release to the researcher all data collected including digital recordings to be used in the manner described in this document. I have received a copy of this consent form.

APPENDIX D—PRACTICE SESSION CHECKLIST

(Pilot#:_____ Date: _______ TOD: ______)

SIMULATOR TECHNICIAN

Prior to first approach - Configure Simulator

1. Record 'session header' on Verify FlightViz – "Pilot #, date, TOD"
2. Configure simulator cab – lighting level, intercom panel, motion (required)
3. Deselect/turn down – GPWS, Middle Marker, landing light, fuel freeze
4. Select runway – **MMU**
5. Select TOD – DAY, DUSK, NIGHT
6. Configure *visuals* (see table):

Parameter	Day	Dusk	Night
All Brightness	3	4	4
Fixed Displacement Mkr	3	3	3
Runway – Markings	3	3	5
Runway – Pavement	3	4	5
Runway – Centerline	0	0	0
Ambient/Cultural Lighting	3	3	3
Centerline Lights	0	0	0
Touchdown Zone Lights	0	0	0
PAPI	0	0	0

Initialize for each practice approach:

7. Configure *weather* (see table) (*** *no wind* ***)

Approach #:	P1	P2	P3	P4	P5	P6
RVR	No WX	**2400**	**1800**	**600**	**1200**	**100**
Lwr Clg-Btm	No WX	**120**	120	120	120	**60**
Lwr Clg-Top	No WX	**800**	800	800	800	800
Fog Top	No WX	**120**	120	120	120	60

8. Reconfirm *Step 6* settings
9. Allow 20-second trim at 80 KIAS, 1000 feet, 3-mile ILS final
10. Verbally confirm subject pilot is ready
11. Cycle FlightViz recording – OFF, then back ON (starts new file)
12. Release 'Flight Freeze'
13. When test director calls "End Run" -- Back on 'Flight Freeze',
14. Hard copy – Runway Plot, then clear display

SUBJECT PILOT

Prior to first approach - Configure Cockpit

1. Adjust seat height
2. Adjust panel lighting
3. Select – Decision height altitude in radio altimeter; set-up 29.92

For each approach -

4. Allow 20-second trim at 80 KIAS, 1000 feet, 3-mile ILS final
5. Couple two-cue (ILS)
6. When off 'Flight Freeze', fly coupled approach (uncouple at own discretion)
7. Practice verbal calls (visual, landing, going around)
8. Complete approach (landing, MAP)
9. Provide debrief comments in response to test director

TEST DIRECTOR/PROJECT PILOT

1. Coach & monitor approach (maintains 80 kt$\pm$10 kt, explain torque, note when decouples)
2. Make verbal call-outs, per subject pilot direction/request (no call-outs if single pilot)
   a. Approach: Altitude, airspeed, rate of descent
   b. Landing: Altitude, airspeed, pitch
3. Call "End Run" (touchdown, or climbing on MAP)
3. Debrief approach with subject ('visual' vs 'land' calls)

APPENDIX E—FREQUENCY OF LANDINGS AND MISSED APPROACHES FOR ALL APPROACHES

Time of Day	Pilot	Test Approach 1	Test Approach 2	Test Approach 3
DAY	**1**	Land	Land	Land
	4	Land	Land	Land
	7	Land	Land	Land
	10	Land	Land	Land
	13	Go Around	Land	Land
DUSK	**2**	Land	Land	Land
	5	Unsuccessful Landing	Land	Land
	8	Land	Go Around	Unsuccessful Landing
	11	Land	Land	Land
NIGHT	**3**	Land	Land	Land
	6	Land	Land	Land
	9	Land	Land	Land
	12	Go Around	Land	Land
	15	Land	Land	Land

APPENDIX F—TEST SESSION CHECKLIST

(Pilot#:_____ Date: _______ TOD: ______)

SIMULATOR TECHNICIAN

Configure Simulator:

1. Record 'session header' on Verify FlightViz – "Pilot #, date, TOD"
2. Configure simulator cab -- lighting level, intercom panel, motion (required)
3. Deselect/turn down – GPWS, Middle Marker, landing light, fuel freeze
4. Select runway -- **TEB**
5. Select TOD – DAY, DUSK, NIGHT
6. Configure *visuals & weather* (see table): (*** *no wind* ***)

Parameter	Day	Dusk	Night
All Brightness	3	3	3
Fixed Displacement Marker	3	3	3
Runway – Markings	3	3	5
Runway – Pavement	3	4	5
Ambient/Cultural Lighting	3	3	3
Edge Lights	3	4	4
Taxiway Lights	0	0	0
Lower Ceiling – Bottom	120	120	120
Lower Ceiling – Top	800	800	800
Fog Top	120	120	120

Initialize for each test approach:

7. Configure *weather:* 900 RVR, then 1600 RVR @ .2NM on ILS path + 1 second
8. Reconfirm *Step 6* settings
9. Allow 20-second trim at 80 KIAS, 1000 feet, 3-mile ILS final
10. Verbally confirm subject pilot is ready
11. Cycle FlightViz recording – OFF, then back ON (starts new file)
12. Release 'Flight Freeze'
13. When test director calls "End Run" -- Back on 'Flight Freeze'
14. Hard copy – Runway Plot, then clear display

INDUSTRY SUBJECT PILOT

Configure Cockpit

1. Adjust seat height
2. Adjust panel lighting
3. Select – Decision height altitude in radio altimeter; set-up 29.92

Fly approach

4. Couple two-cue (ILS)
5. When off 'Flight Freeze', fly coupled approach (uncouple at own discretion)
6. Make verbal calls (visual, landing, going around)
7. Complete approach (landing, MAP)
8. Provide debrief comments in response to test director

TEST DIRECTOR/PROJECT PILOT

1. Monitor approach (that maintains 80 kt, when decouple)
2. Make verbal call-outs, per subject pilot direction/request (no call-outs if single pilot)
    a. Approach: Altitude, airspeed, rate of descent
    b. Landing: Altitude, airspeed, pitch
3. Call “End Run” (touchdown, or climbing on MAP)
4. Debrief approach with subject (‘visual’ vs ‘land’ calls)

APPENDIX G—SIMULATOR SESSION CHECKLIST

PILOT	TOD	1	2	3	4(if needed)	Completed
1	DAY					
2	DUSK					
3	NIGHT					
4	DAY					
5	DUSK					
6	NIGHT					
7	DAY					
8	DUSK					
9	NIGHT					
10	DAY					
11	DUSK					
12	NIGHT					
13	DAY					
14	DUSK					
15	NIGHT					
16	DAY					
17	DUSK					
18	NIGHT					
19	DAY					
20	DUSK					
21	NIGHT					
22	DAY					
23	DUSK					
24	NIGHT					
25	DAY					
26	DUSK					
27	NIGHT					
28	DAY					
29	DUSK					
30	NIGHT					

Table G-1. Randomized Test Approach Order

APPENDIX H—POST TEST QUESTIONNAIRE

(Pilot#:_____ Date: _______ TOD: ______)

<u>Simulator Session</u>

1. Did you find the **approach** lighting environment adequate for COPTER ILS approaches? YES / NO

2. Did you find the **runway** lighting environment adequate for COPTER ILS approaches? YES / NO

3. Did you use cues other than runway lighting for COPTER ILS approaches? YES/NO (If yes, what?)

4. Was the outcome of the **approach** ever in doubt for COPTER ILS approaches? YES / NO

5. Was the outcome of **transition to flying by visual cues** ever in doubt for COPTER ILS approaches? YES / NO

6. Do you have any other comments?

POST TEST QUESTIONNAIRE (cont’d)

(Pilot#:_____ Date: _______ TOD: ______)

Test Set-Up

1. Comment on simulator fidelity with respect to the flight profiles.

2. Comment on simulator fidelity with respect to the runway environment.

3. Comment on effect, if any, of starting test inside the final approach fix, i.e., at 3 nm?

4. Comment on effect, if any, of transitioning from instrument to visual flight on short final?

5. Comment on the landing technique.

6. Did you find the flying the approach and landing in the simulator adequate preparation for flying in your aircraft with similar, real world weather?

7. Any other comments on test set-up?

APPENDIX I—DATA SHEET

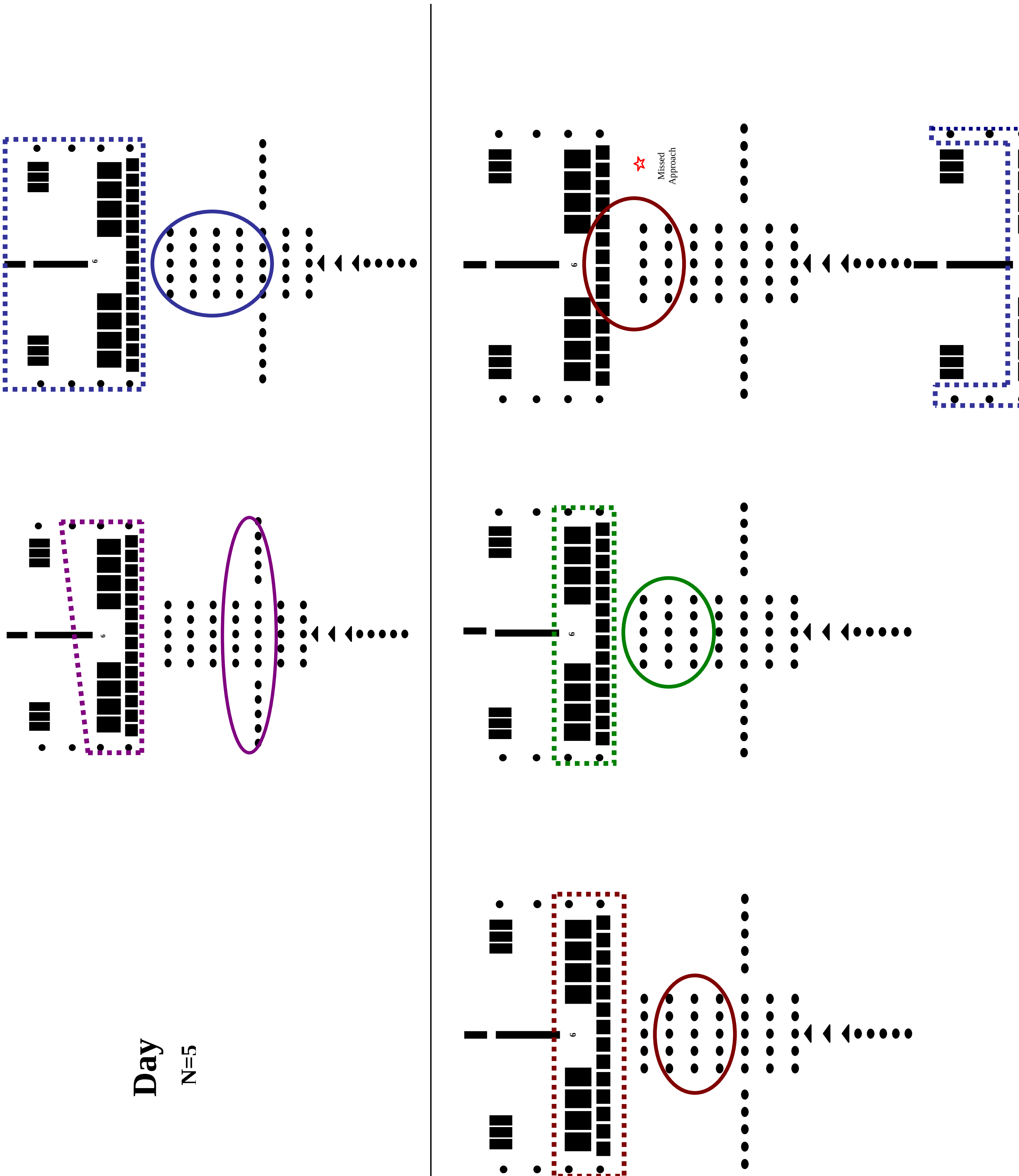
Pilot#:_____ Date: ______ TOD: ______ Project Pilot: _______ Test Director: _______

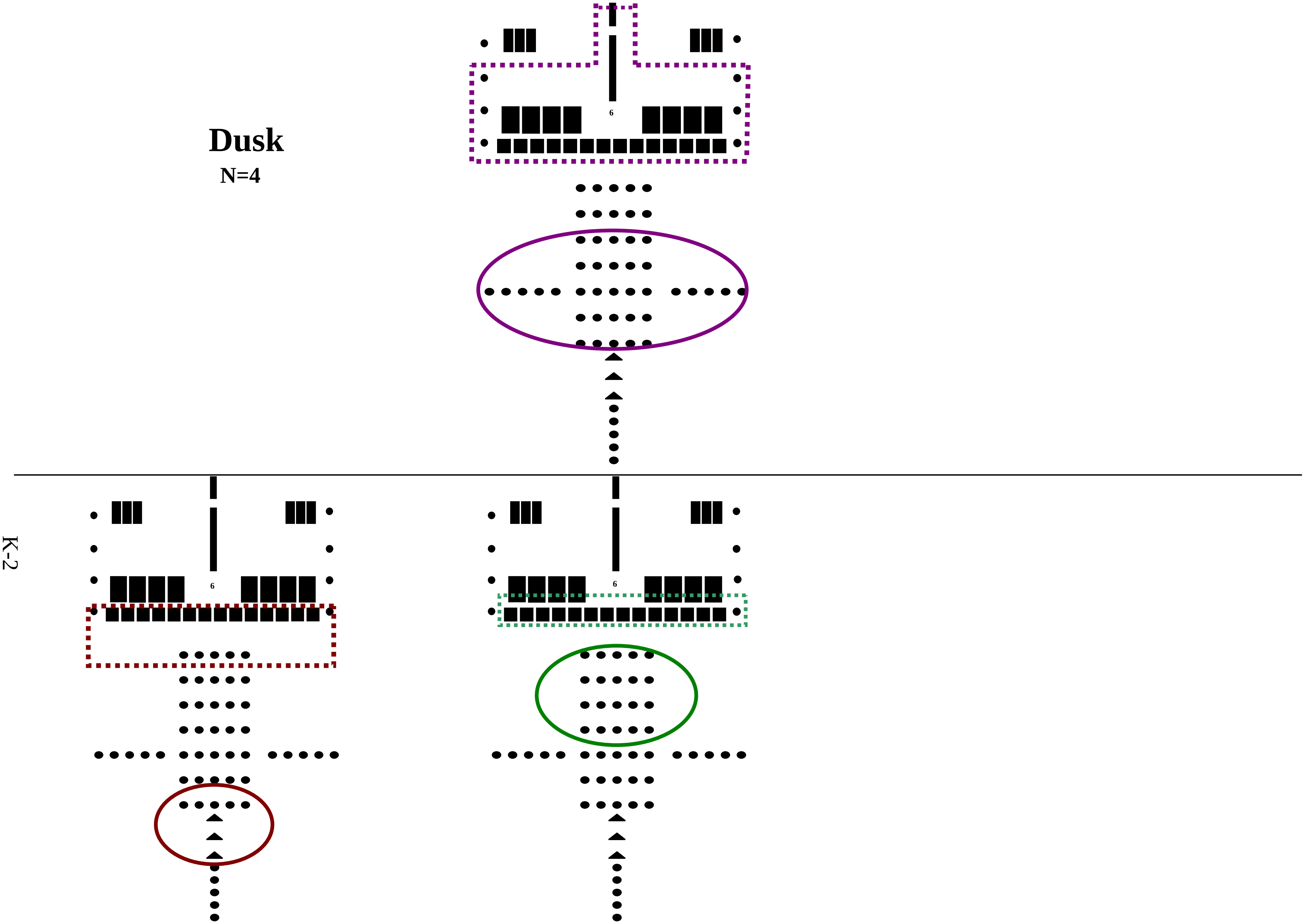
Run	**RVR**	**Start**	**Stop**	**Call**	**Comment (distance, altitude)**

APPENDIX J—DUAL VS. SINGLE PILOT PERFORMANCE

		Pilot Experience	
Performance Parameters	**Time of Day**	**SINGLE**	**DUAL**
RESPONSE TIME *btw 100' and visual*	DUSK	1.60	.43
	NIGHT	-1.80	-1.80
RESPONSE TIME btw *visual and landing*	DUSK	1.10	4.57
	NIGHT	4.85	5.75
ALT at DEC HEIGHT *visual acquisition*	DUSK	74.04	96.20
	NIGHT	112.01	107.22
ALT at DEC HEIGHT *decision to land*	DUSK	62.68	71.6
	NIGHT	78.93	74.74
SLANT RNG DISTANCE *visual acquisition*	DUSK	507.39	966.19
	NIGHT	1165.64	1070.33
SLANT RNG DISTANCE *decision to land*	DUSK	343.56	502.27
	NIGHT	492.01	343.90
INDICATED AIR SPEED *visual acquisition*	DUSK	89.13	74.81
	NIGHT	81.83	79.11
INDICATED AIR SPEED *decision to land*	DUSK	87.87	71.56
	NIGHT	80.65	80.24
YAW CORRECTION	DUSK	1.93	4.91
	NIGHT	5.32	5.67
MAX PITCH ATTITUDE	DUSK	7.05	6.56
	NIGHT	6.73	10.28
MAX GND SPEED	DUSK	23.64	25.32
	NIGHT	17.56	25.33
LENGTH of RWY USED	DUSK	339.02	196.99
	NIGHT	149.75	315.38
** 2 single pilots in the night condition; 1 single in dusk; 0 in day			

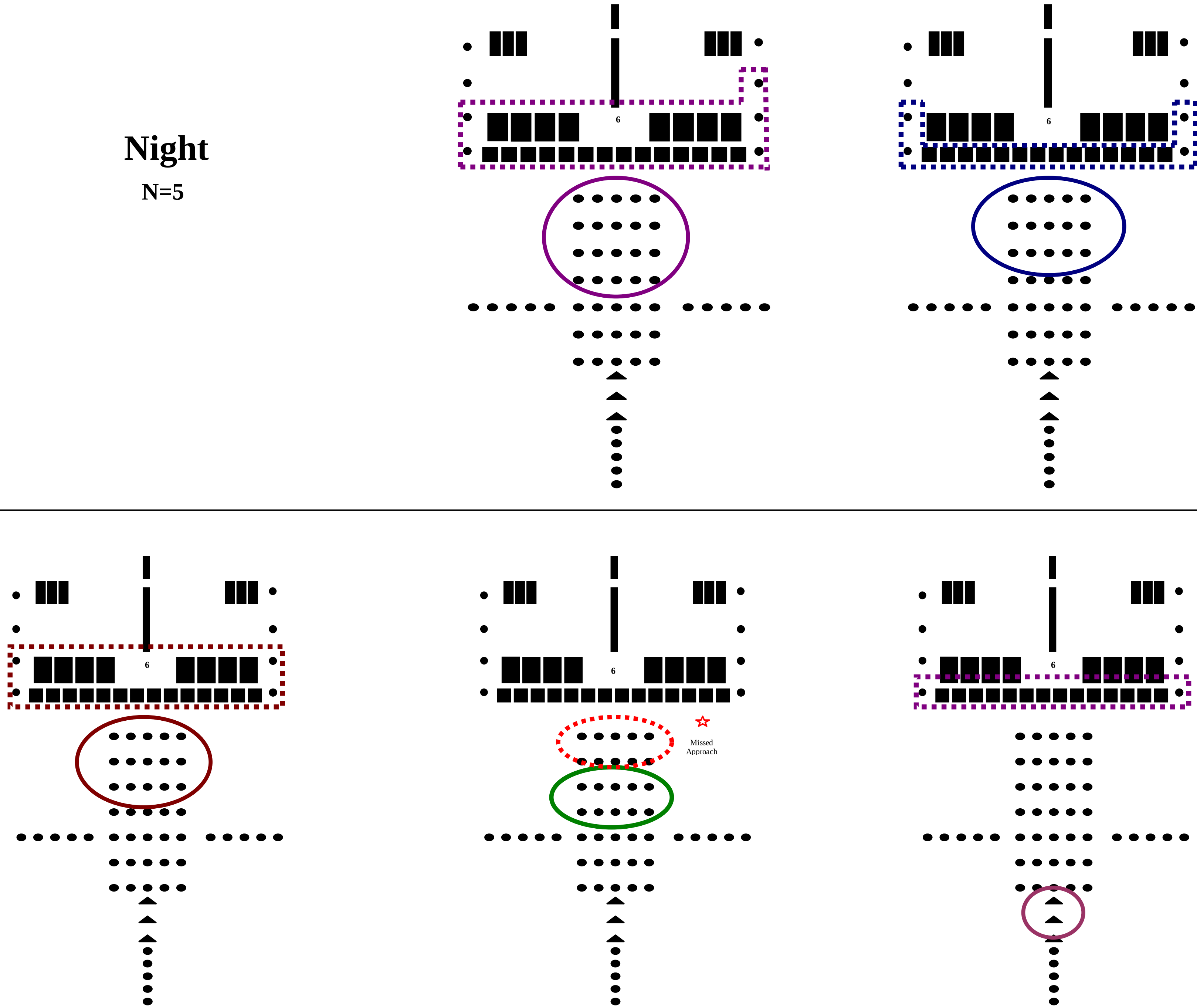
APPENDIX K—MALSR AND RUNWAY THRESHOLD MARKING DIAGRAMS




Dusk
N=4

Night

N=5



K-3/K-4