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Forward-Looking Infrared: Capabilities for Search and Rescue

By

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Joint doctrine for search and rescue stress capability and flexibility to respond to various mission scenarios. Expanded mission requirements will necessitate enhanced visual capabilities for navigation and rescue in hostile environments. Forward-looking infrared (FLAIR) is to be used for search, rescue, and navigation on the U.S. Army MEDEVAC (UH-60Q) helicopter currently under development. The purpose of this study was to determine FLIR capabilities needed for search and rescue operations with the UH-60Q (concept) helicopter. Five aviators were assessed in flight with two FLIR systems having different magnification and look-down capabilities. Detection and recognition of a human target and aircraft positioning for rescue were evaluated using FLIR. There was no difference between FLIR systems in the distance for detection of the human target ($p>0.50$), but recognition occurred at a 4x greater range with sensor magnification ($p<0.01$). In addition, the accuracy of aircraft positioning for rescue was 2x greater with unrestricted look-down capability in the FLIR system ($p<0.03$). These results indicate the value of multiple FLIR magnification and complete look-down capability for search and rescue operations.

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Introduction

U.S. Army doctrine for air-to-ground search and rescue emphasizes flexibility and capability to adapt to various environments and conditions. Operational requirements for search and rescue range from single ship missions to larger task forces of attack, medical evacuation (MEDEVAC), and support aircraft (Joint Publication 3-50.21). In hostile environments, MEDEVAC aircraft should be capable of rapid penetration for effective rescue. This augments the tactical nature of the MEDEVAC mission, and will require enhanced visual capabilities to match those of modern attack aircraft.

The U.S. Army MEDEVAC (UH-60Q) helicopter currently under development will have a panel displayed Forward Looking Infrared (FLIR) system for all-weather, day/night search and rescue and navigational purposes. Night pilotage will be conducted with the Aviator's Night Vision Imaging System (ANVIS; Lindberg, 1993). Selection of an appropriate FLIR system will depend on mission requirements such as detection, recognition and recovery of survivors, and situational awareness and obstacle avoidance.

The purpose of this study was to determine FLIR capabilities needed for effective search and rescue operations with rotary wing aircraft. Two FLIR systems which had different magnification and look-down capabilities were assessed in-flight on the UH-60Q concept helicopter.

Method

Subjects

Five UH-60 rated aviators served as subjects (ages 27 to 48, mean = 36 ± 8 years). All subjects had normal vision with no evidence of ocular disease or anomalous binocular function. Prior to testing, each subject was familiarized with the operations of the FLIR systems and allowed to fly over the detection area to view the target through FLIR. Each subject served as the copilot and sat on the right forward seat, while the pilot-in-control sat on the left.

Aircraft, test site, and material

The UH-60Q concept aircraft was use for the in-flight evaluation (Figure 1). The aircraft was equipped with one of two FLIR systems with the FLIR sensor located on the nose of the aircraft. Due to the time required for sensor changeover (8 hours), each system was tested in separate sessions on successive days at Madison Airport in Richmond, Kentucky. In-flight assessment was conducted between 0930-1430 under overcast conditions, average temperature 47°. Since there was little variation in temperature and weather during the 2 periods of testing, the stimulus to FLIR remained relatively constant. Therefore, differences in performance was not attributable to variation in stimulus conditions during the period of testing.

Figure 1. UH-60Q concept helicopter.

Two FLIR systems available for testing were: (1) Pilot Night Vision System (PNVS), manufactured by Martin Marietta, and (2) Safire, manufactured by FLIR Systems, Inc. Table 1 shows relevant characteristics of each system. The two systems had comparable resolution (20/64 and 20/57) at low magnification which was estimated to be approximately unity for each system in the field environment. For the purpose of visually-guided search and rescue, the most prominent differences between the two systems were the presence of image magnification and unlimited look-down capability with Safire. With this system, the FLIR image could be magnified (5x), and the field-of-regard along the vertical meridian (elevation of +30 to -120 deg) allowed the user to look down directly below the aircraft. In view of these capabilities, and the possibility that training may lead to a slight improvement of performance during the course of assessment, the first day was conducted with Safire, while the second day was conducted with PNVS.

Table 1

Characteristics of FLIR systems.

Characteristic	Safire	PNVS
Spectral sensitivity	8-12 microns	8-12 microns
Resolution	0.93 milliradians (20/64)	0.83 milliradians (20/57)
System magnification*	1.86X & 10.5X (with 2:1 zoom)	1X
Field-of-view	wide: 16.8x28 deg narrow: 3x5 deg	30x40 deg
Field-of-regard	azimuth: 360 deg elevation: +30 to -120 deg	azimuth: ±90 deg elevation: +45 to -20 deg

*Nominally 1x and 5x magnification

Experimental design and procedures

Detection, recognition, and recovery of a simulated casualty using FLIR were evaluated. The target for detection and recognition was a member of the experimental team dressed in the U.S. Army flight suit. The target was positioned randomly in one of three locations forward of the aircraft (left, right, or center). These three positions were located on an airstrip perpendicular to the direction of the aircraft's approach. Prior to testing, the center position was stored as a waypoint in the aircraft's Enhanced Navigation System and updated periodically by flyover. The distance to the airstrip could be read to the nearest 0.1 km from the multifunction display (MFD) on board. At the conservative speed of approach (60 knots) employed, the digits on the display changed slowly enough to be recorded by the experimenter, without error, when visual detection and recognition occurred (see below). Radio contact was maintained between the aircraft and the experimental team on the airstrip.

On each trial, the aircraft began its approach to the airstrip from a distance of 2.5 km. The direction of approach was always toward the center position at a constant ground speed of 60 knots and at an altitude of 300 feet. The test subject, seated in the right pilot seat, used the panel-mounted FLIR to search for the human target. The test subject was free to use the pendant to move the sensor left or right to scan for the target, but was allowed to use only the lowest magnification during the search procedure. Upon detecting the target, the test subject had to report the correct target location (left, right, or center). The experimenter, located behind the pilot, recorded the distance of target detection from the MFD. The aircraft then proceeded further toward the center position while the test subject continued viewing the target with FLIR and magnification available on the Safire system. The test subject reported when the target was recognized definitely as a human survivor (from the body shape, appendages, and head), and the experimenter recorded the distance of target recognition. This completed one detection/recognition trial. The aircraft then returned to the approach point to begin the next trial. A vehicle on the airstrip was used to (randomly) vary the position of the human target between trials. Three detection/recognition trials were conducted on each subject with each FLIR system, and the mean for each subject was used as a single datum point. If, on any trial, the subject failed to detect the correct target location, that trial was aborted, the human target was repositioned, and a new trial was initiated from the 2.5 km start point.

The aircraft control and positioning for rescue also were evaluated. Each trial began with the aircraft hovering at an altitude of 70 feet, approximately 100 feet (ground distance) from the human target. The test subject used FLIR imagery to provide verbal navigational cues to the pilot to position the aircraft directly over the human target below. The trial ended when the test subject reported that the aircraft was directly over the target below. A member of the experimental team below used a rope marked in feet to measure the distance between the final aircraft position and the actual position of the human target. This distance was used as a measure of the accuracy of aircraft positioning for rescue. Three trials were conducted on each subject with each sensor, and the mean for each subject was used as a single datum point.

A postflight debriefing questionnaire (Appendix A) was administered to each subject immediately following each flight session.

Results

Detection

Figure 2 shows the mean (± 1 SE) distance for detection of the human target plotted for each FLIR system. It is clear that detection occurred at about the same distance for each system. A paired comparison test revealed no significant difference between systems in the distance for detection of the human target (paired $t=0.61$, $p>0.50$).

As shown in Figure 2, detection occurred at about 1 km with each system. This distance is consistent with the FLIR resolution, target contrast, and nature of the detection task. The human target subtended a vertical dimension of about 1.6 m which, at 1 km, corresponds to a resolution of 20/110. While this FLIR resolution is less than that achieved with maximum contrast (20/60-20/70), it is likely that the target contrast, while high, was not maximum under the testing conditions, and thus resolution was somewhat reduced. In addition, the dynamic nature of the task and requirement to scan the field probably diminished the detection range relative to the value predicted from system resolution alone. Therefore, the 1 km average detection range was consistent with the nature of the task, the contrast of the stimulus, and resolution of the systems.

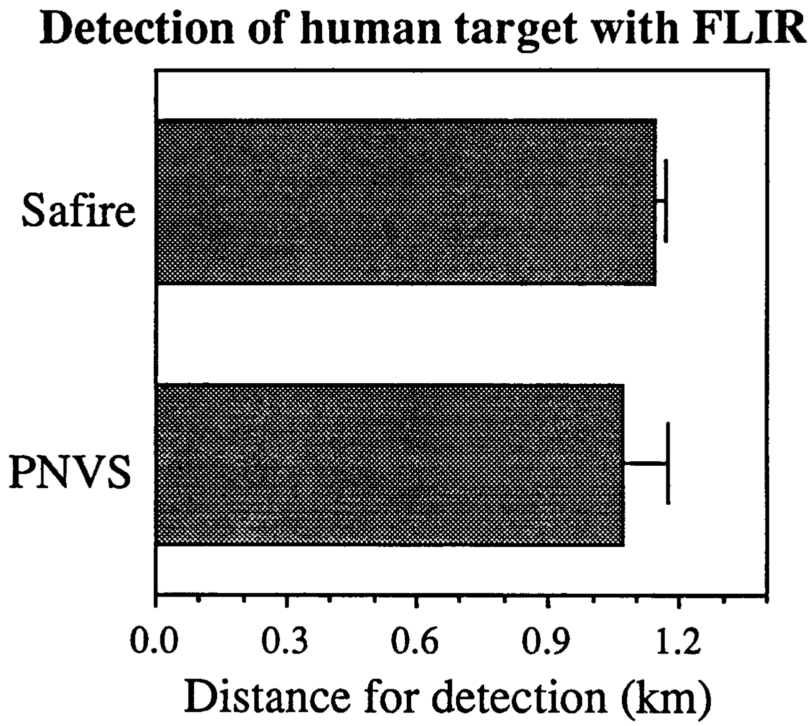

Figure 2. The mean distance (± 1 SE; n=5 subjects) for detection of the human target is plotted for each FLIR system.

Although the nominal resolution was slightly better and the field-of-view larger for PNVS (Table 1), these differences were apparently not significant for the in-flight detection task evaluated in this study. The similar detection ranges obtained with each system under unity magnification suggests that they are equally effective for detection of a human survivor during wide-field search.

Recognition

Figure 3 shows the mean (± 1 SE) distance for recognition of the human target for each FLIR system. There was a significant difference between systems in the distance for recognition of the human target (paired t=4.68, p<0.01). Recognition occurred at about a 4x greater range with Safire, nearly a kilometer away from the target position.

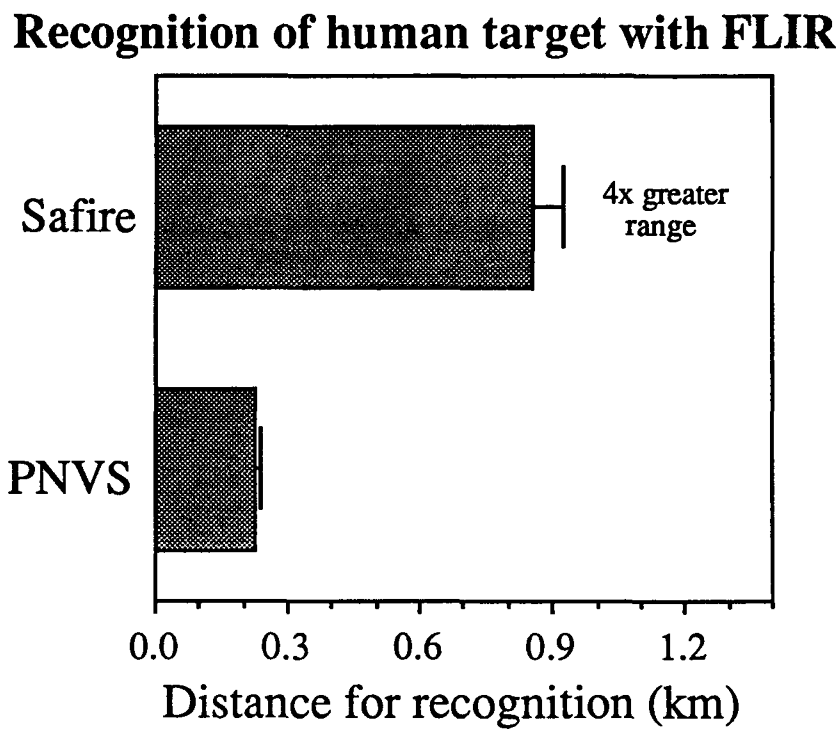

Figure 3. The mean distance (± 1 SE; n=5 subjects) for recognition of the human target is plotted for each FLIR system.

The 4x greater range for recognition with Safire reflects the magnification capability of this system. Once detection occurred, the subjects used the 5x magnification to "zoom in" on the target and recognize relevant detail. The 4x greater range is consistent with magnification of approximately 5x since a small amount of time was required to focus the system and recognize the target. Hence, recognition was expected to occur at a distance somewhat less than that predicted from magnification alone. Suffice it to say that, under the dynamic conditions of this assessment, 5x magnification affords a 4x greater range for recognition of a human target.

There is considerable operational significance to this result. It is crucial that MEDEVAC aircraft identify targets accurately to minimize the time required for mission completion and to avoid hostile activity. The capacity for sensor magnification would seem essential to the search and rescue mission.

It might be argued that, since detection and recognition occurred at nearly the same range with Safire, unity magnification is unnecessary--search can be conducted with 5x magnification. However, magnification dramatically reduces the field-of-view (from about 30° to 5°), which could result in a loss of situational awareness. Wide field, low magnification is effective for detection, while increased magnification is essential for long-range recognition.

Rescue

The value of FLIR for rescue was assessed by having the subject use FLIR imagery to provide navigational cues to position the aircraft over the human target below. It is important to note that, as is currently planned for the UH-60Q, FLIR was not used for pilotage in this assessment, but was used to provide visual information to help navigate the aircraft over the target.

Figure 4 shows the accuracy of aircraft positioning for each system expressed as the average deviation (± 1 SE) between the final aircraft position, and the actual position of the human target below. The deviation was 2x less with Safire, indicating greater accuracy of positioning with this system. This difference was statistically significant (paired $t=3.34$, $p<0.03$).

The greater accuracy of positioning with Safire clearly was related to the unrestricted look-down capability of this system. Subjects were able to view directly below and all around the aircraft, and therefore provide more accurate navigational cues. With limited look-down capability, subjects often lost sight of the human target below.

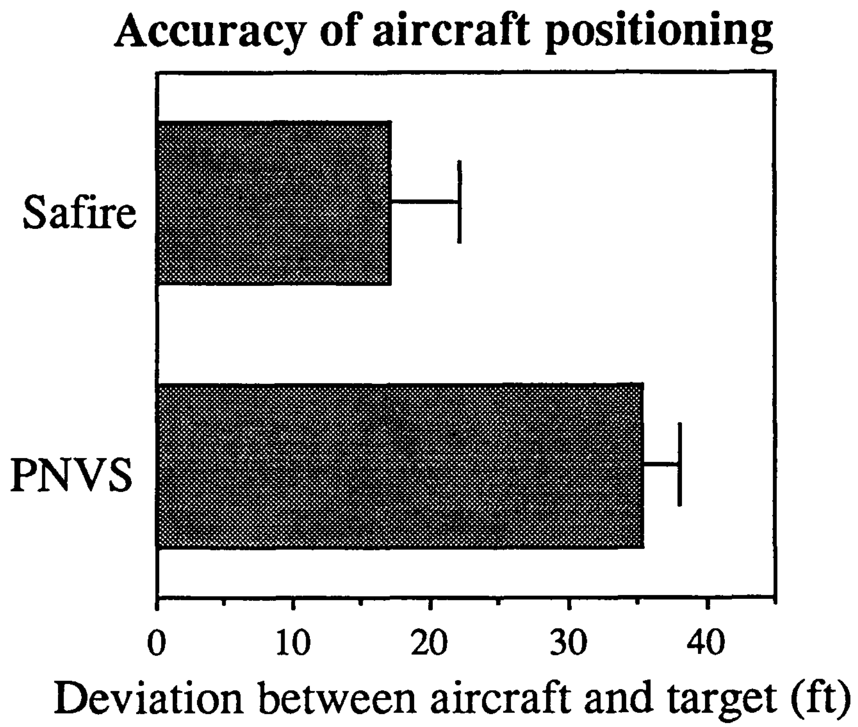

Figure 4. The mean deviation (± 1 SE; n=5 subjects) between the final aircraft position and the position of the human target is plotted for each system.

Postflight questionnaire

A questionnaire (Appendix A) was administered to each subject immediately following each flight. The results are summarized in Figure 5 which shows the average rating (± 1 SE) from five subjects for each category evaluated. Subjective ratings were consistently higher for FLIR with multiple magnification and complete look-down capability, and this difference was significant ($F=133.88$, $p<0.001$).

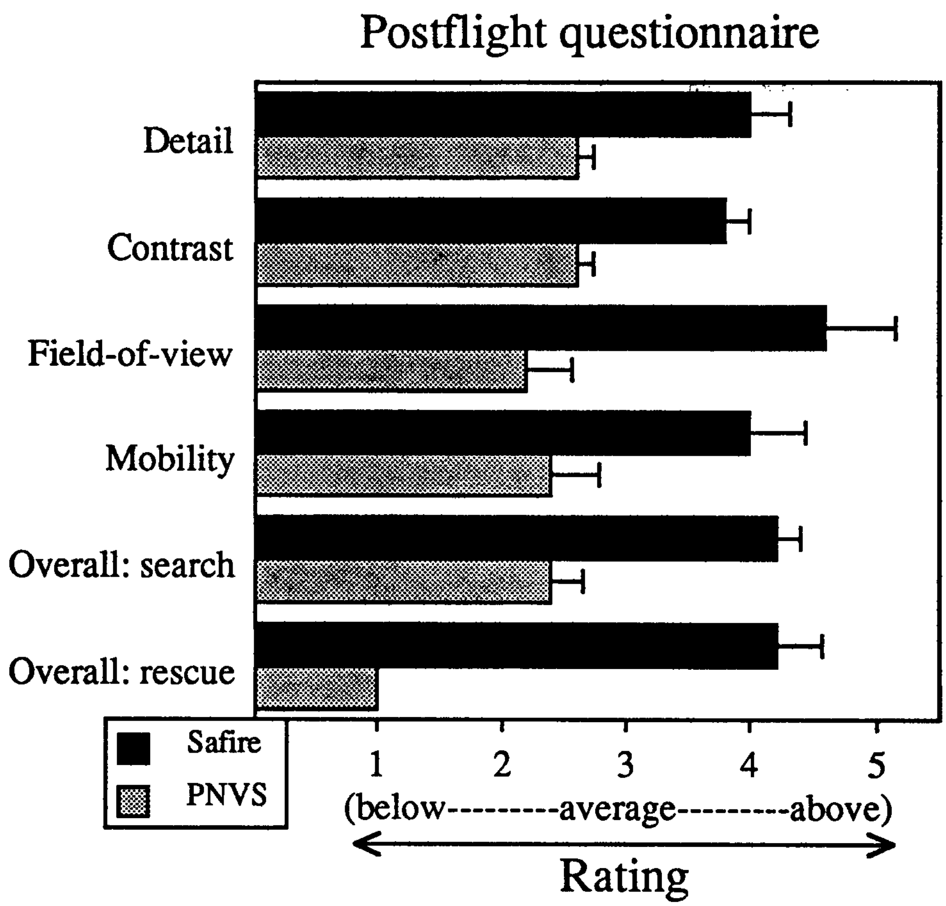

Figure 5. The mean postflight subjective rating (± 1 SE; n=5 subjects) is plotted for each category and each FLIR system.

Discussion

This assessment demonstrates that FLIR with multiple sensor magnification and unrestricted look-down capability will be a useful visual aid for search and rescue operations. Under the conditions of this evaluation, detection of a human target with panel-mounted FLIR occurred at a range of about 1 km. This distance was consistent with the FLIR resolution, target contrast, and task difficulty. The two systems evaluated proved to be equally effective for this detection task, which was performed with a wide field and low magnification. Notwithstanding the equivalence of detection ranges, recognition of the human target occurred at a much greater range (4x) with magnification in the FLIR system. Once detected, the ability to zoom in on the target to recognize relevant detail significantly enhanced the operational range of FLIR. The capacity to look-down directly below the aircraft also proved to be an invaluable feature for FLIR-assisted rescue and navigation. Accuracy of aircraft position for simulated rescue was 2x greater with unlimited look-down capability in FLIR.

With fewer military forces, greater emphasis will be placed on joint operations. MEDEVAC aircraft must be equipped to adapt to a wide spectrum of environmental conditions and mission scenarios. The capacity afforded by FLIR to search, detect, and recognize human targets, obstacles, and terrain at extended ranges will enhance performance, particularly under conditions of limited visibility. The long wavelength infrared sensitivity of FLIR makes it valuable when the amount of visible light is limited or obscured such as in dense fog, smoke, or at night (Green, 1987; Rash, Verona, and Crowley, 1990; Pfeiffer, 1993). Whereas night pilotage of the UH-60Q will be conducted with ANVIS, sensitive to short wavelength infrared light, FLIR, by virtue of long wavelength sensitivity, offers another perspective at night which can be useful when the stimulus to ANVIS is reduced, such as in overcast starlight (Kotulak and Rash, 1992; Rabin, 1993). Human survivors or obstacles not readily visualized through ANVIS may be better detected with FLIR. Moreover, the magnification capability of FLIR, unavailable with ANVIS, should allow recognition of survivors at night at a far greater range.

Since FLIR will not be used as a pilotage device on the UH-60Q, it is essential that training be implemented to optimize its use for search, rescue, and navigation. Periodic training also will help maintain safety of flight.

Conclusions

1. Detection of a human target with FLIR is dependent on the resolution of the system, while target recognition is significantly enhanced with sensor magnification.

2. Unrestricted sensor look-down capability increases the accuracy of aircraft positioning for hoist operations.

3. FLIR with magnification and complete look-down capability is a useful visual aid for search and rescue operations on MEDEVAC aircraft.

4. Structured training is recommended to ensure optimal use of FLIR and to maintain safety of flight.

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Appendix A

Test subject questionnaire

In performing the search and rescue mission, please rate the night vision system along the following dimensions:

1. Amount of detail seen in the sensor image (circle one).

1 2 3 4 5

<----below average-----average-----above average---->

2. Contrast of the sensor image (circle one).

1 2 3 4 5

<----below average-----average-----above average---->

3. Field of view (circle one).

1 2 3 4 5

<----below average-----average-----above average---->

4. Mobility of sensor in response to joystick (circle one).

1 2 3 4 5

<----below average-----average-----above average---->

5. Overall performance for search (circle one).

1 2 3 4 5

<----below average-----average-----above average---->

6. Overall performance for rescue (circle one).

1 2 3 4 5

<----below average-----average-----above average---->