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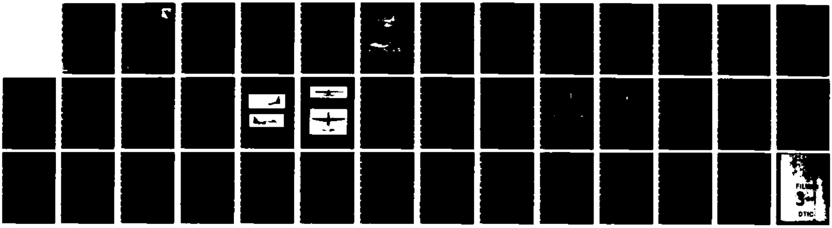

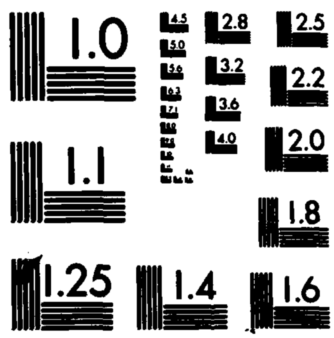

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ELECTROLUMINESCENT FORMATION LIGHTS FOR HC-130 P/N SPECIAL OPERATIONS: I. FLIGHT TEST CANDIDATES

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JULY 1983

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NOTICES

TECHNICAL REVIEW AND APPROVAL

AFAMRL-83-069

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

CHARLES BATES, JR.
Director, Human Engineering Division
Air Force Aerospace Medical Research Laboratory

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report proposes two electroluminescent lighting candidates for HC-130 P/N special night formation operations. Following interviews with selected Air Force Air Rescue pilots on how they conduct low-level daylight operations, an analysis of critical mission factors and aircraft positions was completed. Based on their comments and a previous A-10 configuration flown by AFFWC, simulated EL lights made of paper were added to a C-130 as possible T&E candidates. Interviews were then conducted with HC-130 and HH-53 pilots as Cont'd

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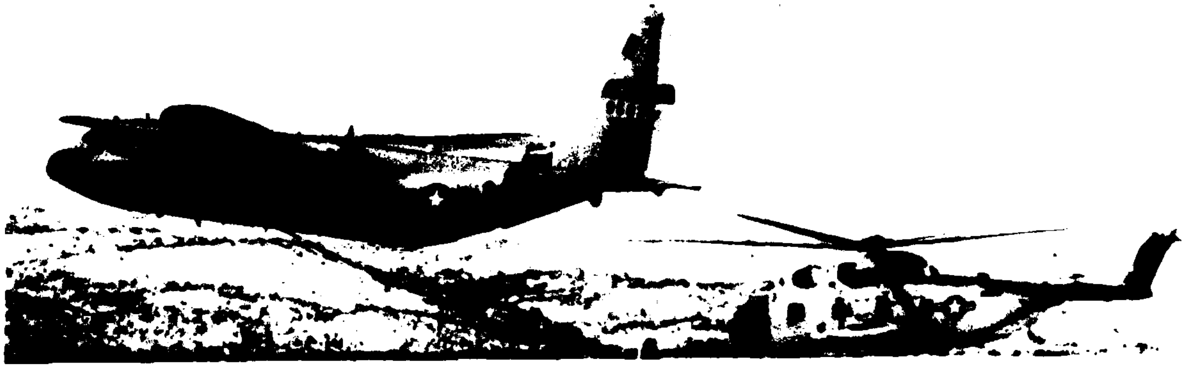
they observed the "papered" aircraft from several positions on the flight ramp. A final selection of two candidate EL configurations was based on ramp interviews and interviews of pilots observing a scaled aircraft and a model of the HC-130 in a darkened room.

A forced-choice methodology based on switching between candidates at various formation positions was proposed for the flight test.

These figures show the HC-130 and HH-53 "in contact" during refueling. The positions of the aircraft, stripe coding on the hoses, and deployment of the drogues are prominent features.

HC-130P refuels HH-53E off the Vietnamese coast, 1969. This team played the major role in rescue of downed airmen in SEA war.



HC-130N-165-LM of the 71st ARRS refueling an HH-53 helicopter over Alaska, February 1978.

(Pictures from Squadron/Signal Publications, Carrollton, Texas)

PREFACE

This report describes the derivation and evaluation of potential electroluminescent (EL) lighting configurations proposed for HC-130 P/N special night operations and recommends two candidates for flight testing. The results are believed to be generalizable to a variety of aircraft and missions. The report was prepared in part by Systems Research Laboratories, Inc. (SRL), 2800 Indian Ripple Road, Dayton, Ohio 45440, under Contract F33615-82-C-0511. The work was performed in support of AFSC Project 7184, Man-Machine Integration Technology for the Air Force, for the Air Force Aerospace Medical Research Laboratory (AFAMRL), Human Engineering Division (HE), Wright-Patterson Air Force Base, Ohio 45433.

The authors gratefully acknowledge the assistance of Captain Gilbride and Major Jeffreys, 55 ARRS/ADO, Eglin Air Force Base, for their organization of the data collection efforts and expertise in special night operations. Acknowledgement is made to Dr. Michael Nelson, SRL, for his analysis of size requirements for the signaling light and Dr. Stuart Fickler, SRL, for his statement on eye/night vision goggle response. Acknowledgement is also made to Mr. James Hawley, SRL, for his adaptation of a C-130 model, and to Squadron/Signal Publications for the refueling pictures obtained from their publication titled "C-130 Hercules in Action, Aircraft No. 47."

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Section 1

INTRODUCTION

CONCEPTUAL BACKGROUND

External electroluminescent (EL) lighting offers an alternative or supplement to the traditional incandescent lighting schemes for aircraft engaged in formation flying. EL lights are applied as area lights and offer a dispersed source of light as opposed to an incandescent point source of light. To the pilot of another aircraft in formation, the softer glow of EL lighting may be less visibly fatiguing while offering more definitive cueing of target aircraft attitude. As noted by Task and Griffin (1980), EL light emits almost all of its energy in the visible region and essentially none in the infrared. This "cold light" effect makes the EL light more compatible with the use of night vision goggles (NVGs) than unfiltered incandescent lighting. With the addition of micro-louvers over the EL lights, luminance direction can be vectored and controlled as required.

Figure 1 illustrates the essential problems associated with the use of NVGs. The human eye has a visual response to wavelengths in the region of about 400 to 700 microns with a peak response at about 555 microns. Since the purpose of NVGs is to receive infrared (IR) energy only, the ideal NVG response would be in the region of about 700 microns and above. This is almost achieved by Generation III NVGs which have a proposed cut-off of about 650 microns and peaks in the neighborhood of 800 microns. If the interior lighting emitted no radiation above 650 microns, then there would be no competition between the visible radiation and the IR response of the NVGs. However, the problems arise due to the fact that traditional incandescent light sources emit considerable IR energy. Because NVGs are designed to be very sensitive to low IR, the goggles will shut down at excessive levels of radiation. The problem is further exacerbated in the case of the Generation II NVGs due to the fact that these goggles are also sensitive to visible radiation. These problems are resolved through the proper application of electroluminescent lighting and filtered incandescent lighting which reduces or eliminates the competition between the visible and IR operating domains of the eye and NVGs, and significantly reduces windscreen glare and reflection. In the case of the Generation III ANVIS NVG system, where there is direct visual access available for reading instruments, one design criteria being considered is to make the visible wavelengths totally invisible to the goggles, thereby eliminating all competition between the two operating domains.

PURPOSE AND APPROACH

The intent of the study was to derive and evaluate potential EL formation light configurations and to recommend two candidates for flight testing. The approach used was: (1) interview HC-130 and HH-53 pilots to determine their current special night operations requirements, (2) interview pilots who flew in the Operational Test and Evaluation (OT&E) of EL formation lights o the A-1[illegible], (3) conduct flight line interviews with HC-130 and HH-53 pi[illegible] d[illegible]ng a walk around of the aircraft to discuss and evaluate

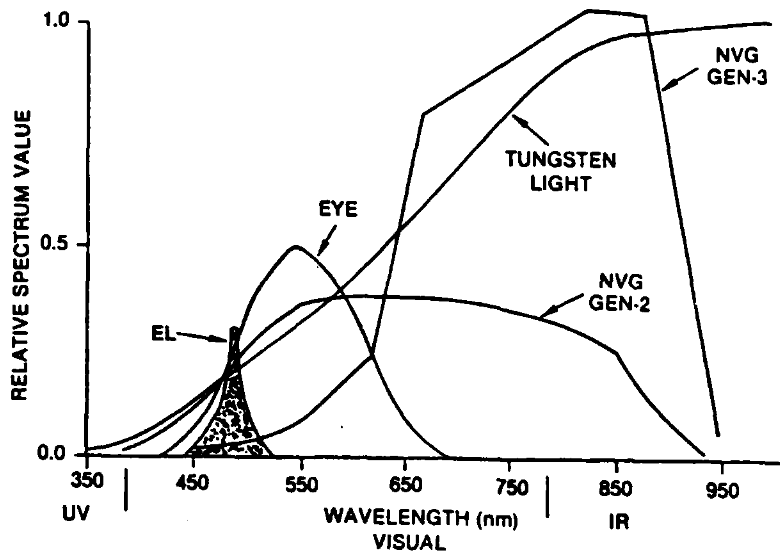


Figure 1. Eye NVG/EL Response to Light

different potential EL formation light design configurations, and (4) perform a final evaluation of the two recommended candidates. This was accomplished in a dark room using a black-light illuminated HC-130 model aircraft configured with reflective tape (simulating EL formation lights). Pilots walked around the model, which was on a tripod in the middle of the room, so they could not only view the aircraft from key formation positions but also see the transition from one position to the next.

Section 2

MISSION FACTORS

One of the purposes of the flight line interviews of the ARRS pilots at Eglin Air Force Base (Appendix A) was to establish visual requirements for the observer by deriving the mutual positions of the aircraft in formation. This section describes the major mission planning factors obtained from these interviews that would impact the selection of light candidates; a typical Special Operations Force (SOF) sortie that established basic formation requirements; and the specific HH-53 and HC-130 formation positions required for the full sortie that would define the lighting requirements for the observed aircraft. For the purpose of this report, the HC-130 P/N and HH-53 aircraft will be referred to as tanker and receiver, respectively.

PLANNING FACTORS

Listed in Table 1 are the critical equipment usage and mission factors that would directly bear on candidate designs. The observer's use of NVGs, the minimum inflight visibility, the use of incandescent lights with IR filters, and the use of lights on the receiver to illuminate portions of the tanker were factors that influenced selections of EL light shape and location. To satisfy the general requirement for COVERTNESS, a study goal was established to use the least number of lights and the lowest light intensities that would safely aid the observer to fly all of the required formation positions under all conditions of night illumination (full moon without overcast to black night).

OPERATIONAL PROFILE

To derive the mutual tanker and receiver formation positions, it was necessary to derive a typical SOF profile that included most of the anticipated formation requirements. Figure 2 highlights the altitudes, airspeeds, and formation alignments of the tankers and receivers as well as the tanker/tanker formations. It includes a sampling of the mission planning factors (from Table 1) that highlight this special SOF operation.

After tanker base departure, the major formation positions are tanker/tanker joinup, crossover, echelon, and trail; and tanker/receiver joinup, left echelon, observation, precontact and contact, and crossover. Because of possible equipment failures or combat losses, any tanker may have to serve as LEAD aircraft at any time. Because of the possibility of failure of a refuel pod or saturation of tanker requirements by servicing many receivers, each tanker must be capable of refueling from either side.

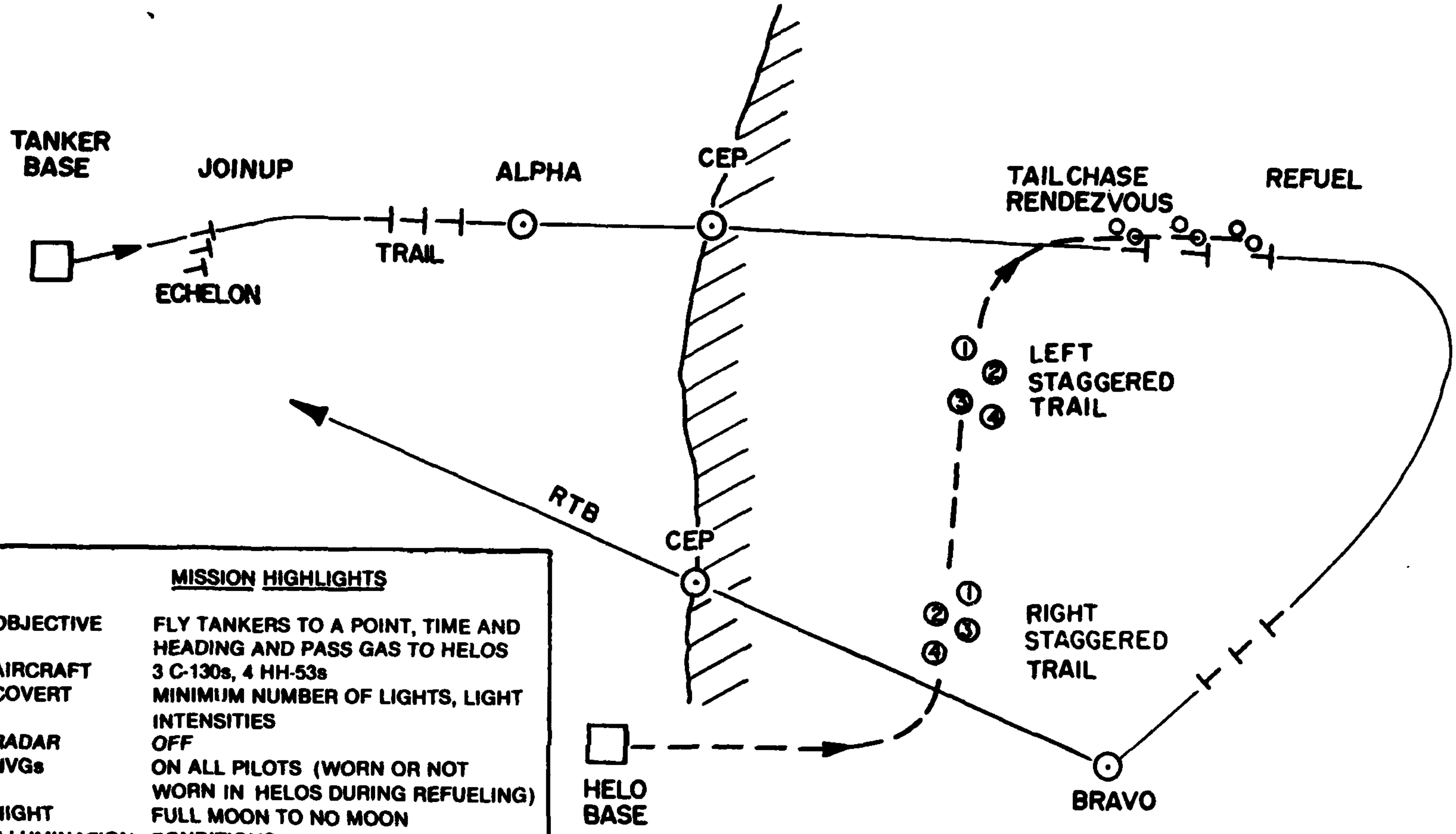
AIRCRAFT POSITIONS

A final selection of tanker/tanker and tanker/receiver positions (Table 2) was based on the pilots' discussions of how they flew daylight training missions or night missions with incandescent lights. Comments about arriving at and maintaining each of the positions are included in Appendix A. A special requirement for tanker/tanker and tanker/receiver covert light signaling was considered a critical need by the ARRS pilots.

TABLE 1. HC-130 P/N MISSION PLANNING FACTORS*

Factors	Comments
C-130	
• Night Vision Goggles (2nd or 3rd Generation)	Worn at Combat Entry point (CEP) by one or both pilots.
• Radar	OFF at CEP, if required.
• Pod Illume Lights	ON for refuel.
• Pod Status Lights	OFF.
• Pylon Fuel Tanks	One on each wing.
• Incandescent Formation Lights	ON until CEP.
• Rotating Beacon (on top of fin)	ON, normally OFF after CEP.
• Navigation Lights	OFF.
• Proposed EL Lights - Formation	ON.
- Refuel	ON only during refueling.
• Beavertail Light	Used for signaling.
H-53	
• Blade Tip Lights	ON (they are dim, not discernible from ground).
• Slime (EL) Lights	ON.
• Night Vision Goggles (2nd or 3rd generation)	Worn by pilots and engineers except during refueling. However, plan capability to wear NVGs during refueling.
• Rotating Beacon	OFF. (ON on last helo during training.) Used for flashing signals.
• Probe Light	ON to illuminate C-130 drogue.
GENERAL	
• Visibility	3 nm minimum for air-to-air mission. Adequate station keeping visibility (with NVGs).
• Neither Aircraft Normally Performs Crossunders	HH-53 pilots prefer not to look up through their rotors; downwash of the C-130 is hazardous; and low altitudes are hazardous for performing crossunders.
• Symmetrical Markings Required	Any aircraft may have to move to left or right echelon or serve as LEAD at any time.
• HC-130 Refueling From a Tanker	No requirement.
• Covertness	No lights be visible with unaided eye from ground or inflight (desired). Use minimum number of lights and intensities in full moon to no moon conditions (practical).

*For combat only. Training flights in the United States require other lights in the lead and trailing aircraft in a formation.



MISSION HIGHLIGHTS

OBJECTIVE	FLY TANKERS TO A POINT, TIME AND HEADING AND PASS GAS TO HELOS
AIRCRAFT	3 C-130s, 4 HH-53s
COVERT	MINIMUM NUMBER OF LIGHTS, LIGHT INTENSITIES
RADAR	OFF
NVGs	ON ALL PILOTS (WORN OR NOT WORN IN HELOS DURING REFUELING)
NIGHT ILLUMINATION	FULL MOON TO NO MOON CONDITIONS

	JOINUP	ALPHA	INBOUND CEP	TAILCHASE RENDEZVOUS	REFUEL	OUTBOUND CEP	RTB
ALT	3 - 5000'	3 - 5000'	<1000'	<1000'	<1000'	<1000'	3 - 5000'
GROUND SPEED	210-220	210-220	210-220,	220-110	110-120	210-220	210-220

Figure 2. Tanker/Receiver Night Refueling Mission

TABLE 2. AIRCRAFT POSITIONS AND SIGNALING REQUIREMENTS

Formation

Tanker/Tanker Positions

- Joinup
- Echelon
- Trail
- Crossover

Tanker/Receiver Positions

- Joinup
- Echelon
- Observation
- Precontact/Contact
- Crossover

Signaling

Tanker/Tanker and Tanker/Receiver

- Alphanumeric Display

Section 3

PROPOSED EL CANDIDATES

This section presents two candidates for the formation and refuel lights and a segmented light for interaircraft signaling. The candidates would have varied lengths of lights to offer a choice of lamp sizes for the T&E. A basic test concept was to present two options to the test pilot or each option to different pilots and anticipate a hybrid configuration from the T&E based on portions of both candidates.

The two EL candidates are pictured in Figure 3 which was photographed from a table model of the C-130 used in the dark room study.

The individual lights are discussed for each of the formation positions listed in Table 1 and include recommendations for size and shape of each light. Several of the lights would serve as reference markings for several positions.

FORMATION LIGHTS

JOINUP Position (Reference Figure 4)

For long range acquisition, an IR filtered rotating beacon is recommended with the filter installed between the bulb and the mirror. Acquisition range without NVGs should be at least 5 nm. Both candidates would have the same light.

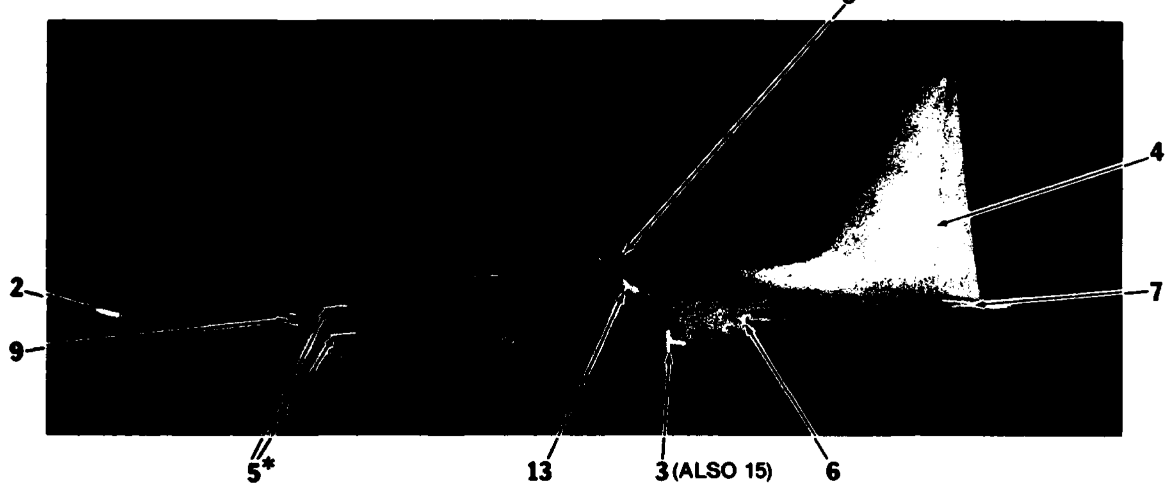
For shorter range, lead cut-off, and abeam approaches, a FORWARD and AFT FUSELAGE light, FIN light, and WINGTIP light are recommended to provide adequate target direction, pitch, and roll cues. The AFT FUSELAGE light would also serve the OBSERVATION position and as a portion of the SIGNAL light. The shorter FORWARD FUSELAGE light would be observed with the AFT FUSELAGE light and serve to fix the tanker's pitch axis. It must be low enough to be seen below the engines from a cut-off position and must be located as low as the PITOT PORTS to be seen below the pylon tank. These lights should also provide adequate cueing for flying other than the low-level refueling mission. Both candidates would have the same lights except for the length of the AFT FUSELAGE light, the FIN light, and the shape of the WINGTIP light.

ECHELON Position

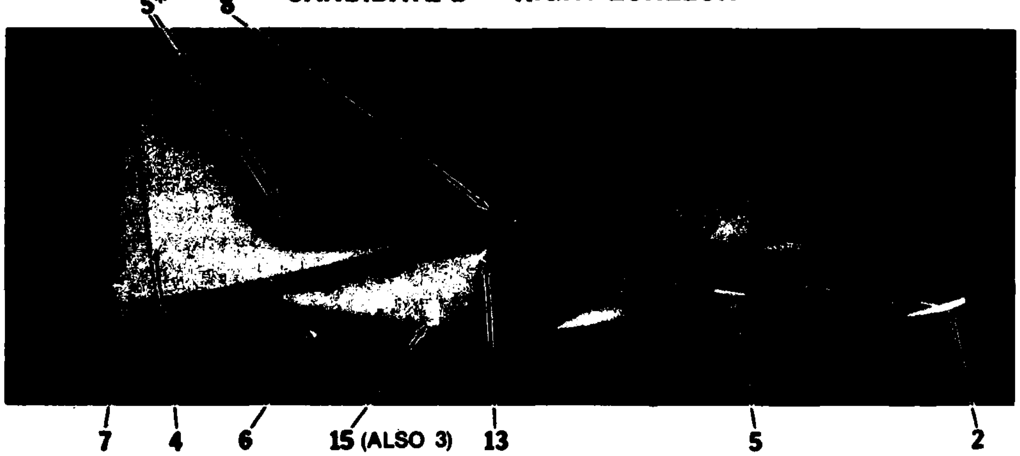
This position would also use the lights proposed for the JOINUP and OBSERVATION positions. At long range, the FUSELAGE, WINGTIP, and FIN lights would serve to describe tanker pitch, roll, and direction of flight. At longer ranges, the rotating beacon would aid acquisition and help define the tail position at closer ranges. The flap lights depicted for the PRECONTACT, CONTACT, and TRAIL positions would aid in defining target roll and yaw. No candidate differences are proposed for this position.

FORMATION LIGHTS	CANDIDATES**	
	A	B
1 FORWARD FUSELAGE	X	X
2 WING TIP LIGHT	STRAIGHT	L
3 AFT FUSELAGE	SHORT	LONG
4 FIN	SHORT	LONG
5 FLAPS*	SHORT	LONG
6 ELEVATOR	X	X
7 STABILIZER	X	X
8 CHEVRON	SHORT	LONG

CANDIDATE A — LEFT ECHELON



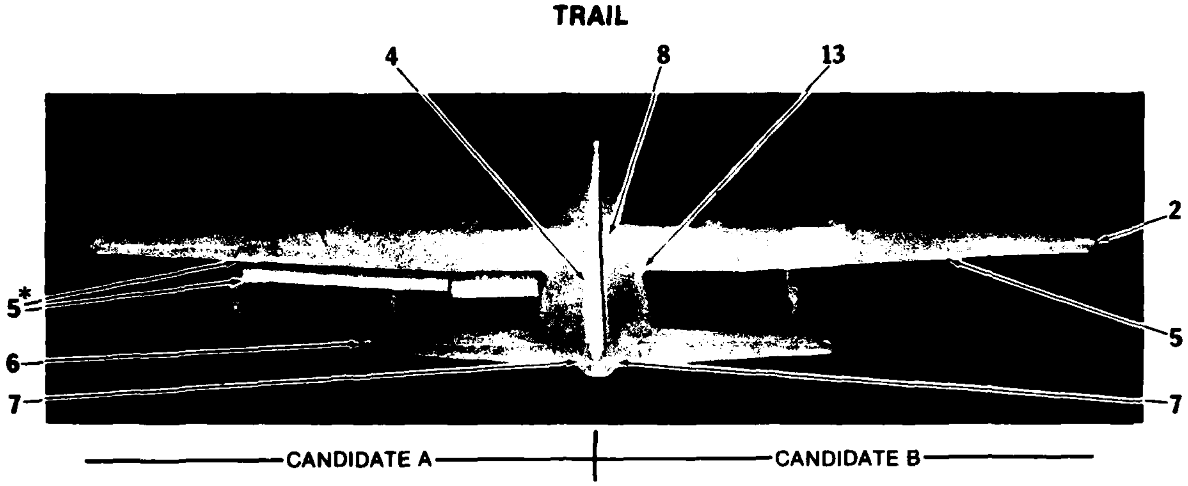
CANDIDATE B — RIGHT ECHELON



REFUEL LIGHTS	CANDIDATES	
	A	B
9 POD STRUT	2	3
10 HOSE ILLUME	X	X
11 TUBE (NOT SHOWN)	X	X
12 HOSE MARKINGS (NOT SHOWN)	SPIRAL	BANDS
13 WING ROOT	X	X
14 DROGUE MARKING (NOT SHOWN)	X	X
SIGNAL LIGHTS		
15 AFT FUSELAGE (ALTERNATES WITH 3)	X	X

*LEFT FLAP LIGHTS ARE SHOWN IN TWO POSITIONS
**X INDICATES IDENTICAL LIGHTS

Figure 3. Proposed Light Candidates



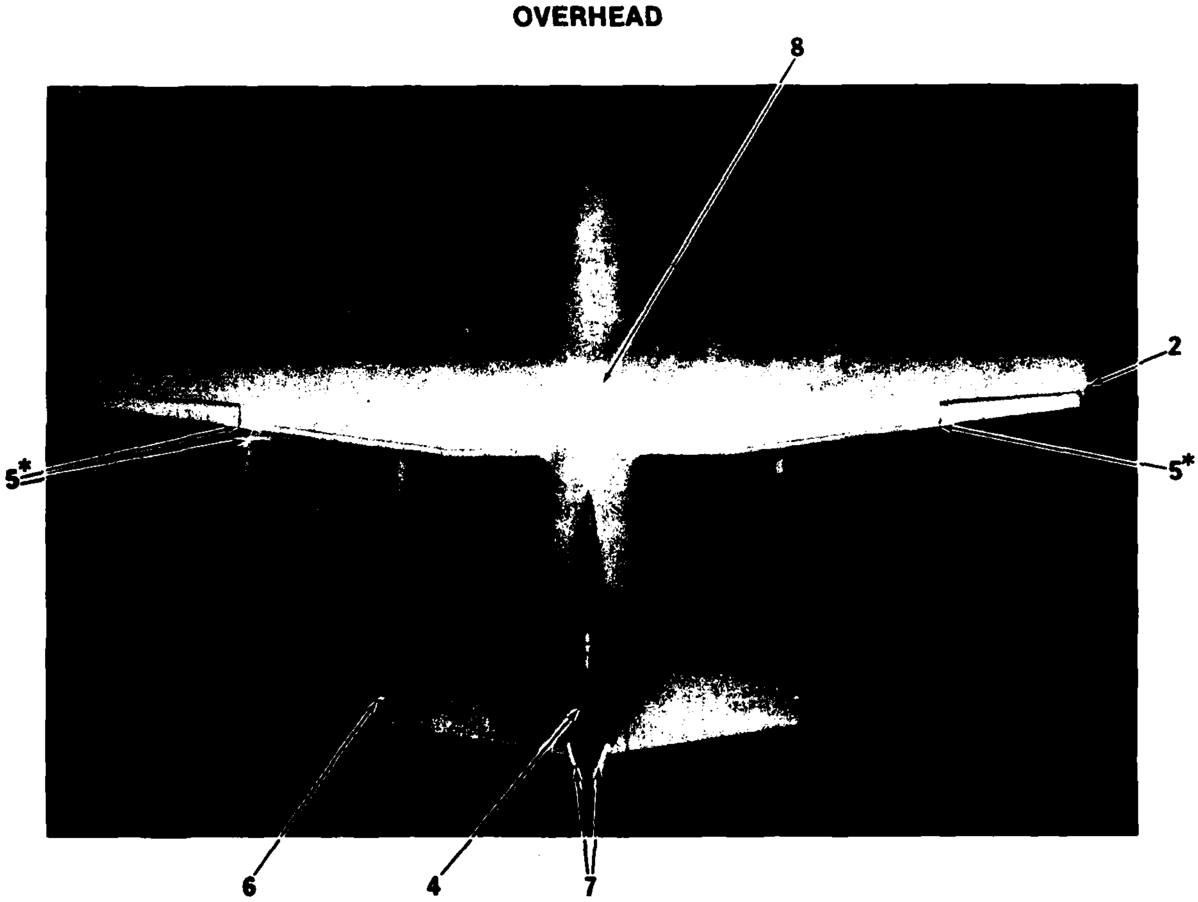


Figure 3. Proposed Light Candidates (continued)

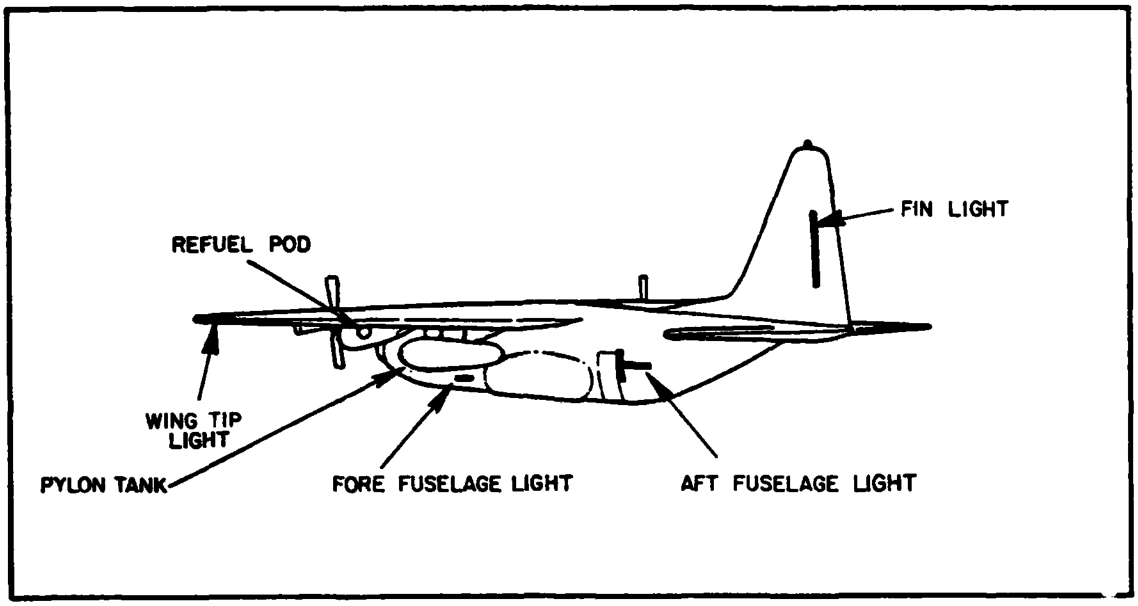


Figure 4. JOINUP Position

TRAIL Position (Reference Figure 5)

The FLAP and CHEVRON lights, engine exhaust, and STAB light relationships should fix the tanker pitch axis. LEAD roll would first be detected by movement of the FLAP lights. The apparent distance between the CHEVRON and STAB lights should assist in maintaining a 200-foot to 500-foot range and could be used to judge relative rates of closure for slowdown/speedup. FLAP light lengths (3 feet versus 4 feet) and STAB light length (3 feet versus 4 feet) would be the difference between Candidates A and B. WINGTIP lights would be varied (straight versus L) to evaluate their adequacy for cueing roll. An azimuth of zero error will present both FIN lights on each side of the rudder. It would be advantageous to add the FIN light as far aft as possible (at the rudder break) to maximize exposure of the light to the trailing observer. The WING ROOT lights would assist in defining pitch and roll cues; however, they are not intended to be ON except during refueling.

CROSSOVER Position

No additional light requirements are proposed for this position. The TRAIL and ECHELON lights are considered adequate to transit from either side to the other. The fin will partially mask fuselage and elevator lights; however, the number of lights on each side of centerline should be adequate for stabilizing target pitch and roll cues.

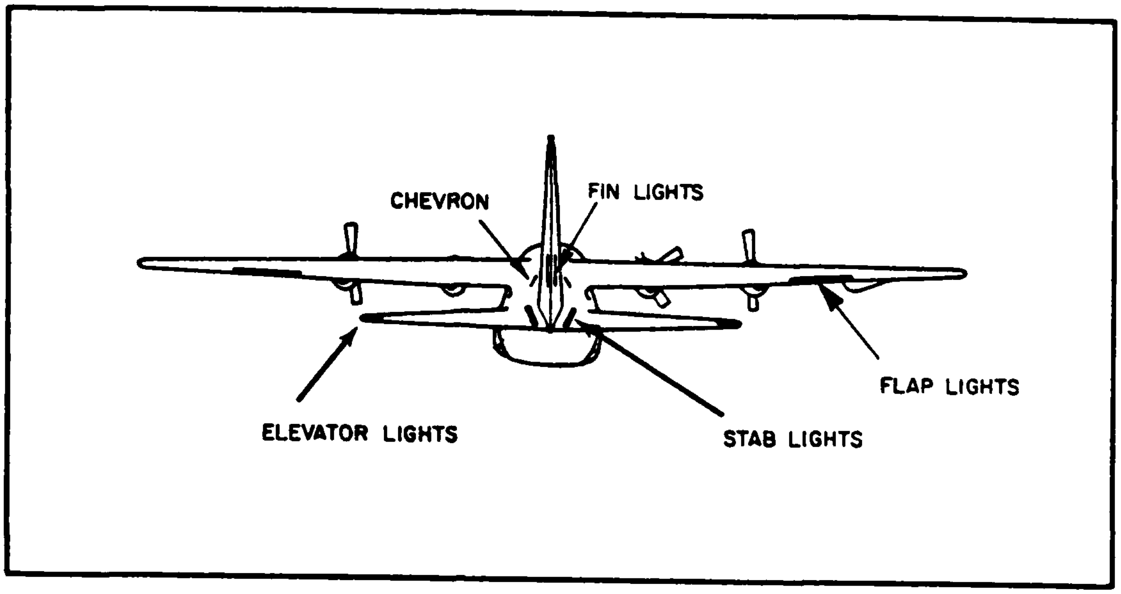


Figure 5. TRAIL Position

REFUEL LIGHTS

OBSERVATION Position (Reference Figure 6)

The vertical portion of the AFT FUSELAGE light, an ELEV wedge (wraparound) light added to the stabilizer, and a WINGROOT wedge light would serve to establish and maintain a proper offset and distance from the tanker. The WINGTIP light would serve to fix the tanker's roll position.

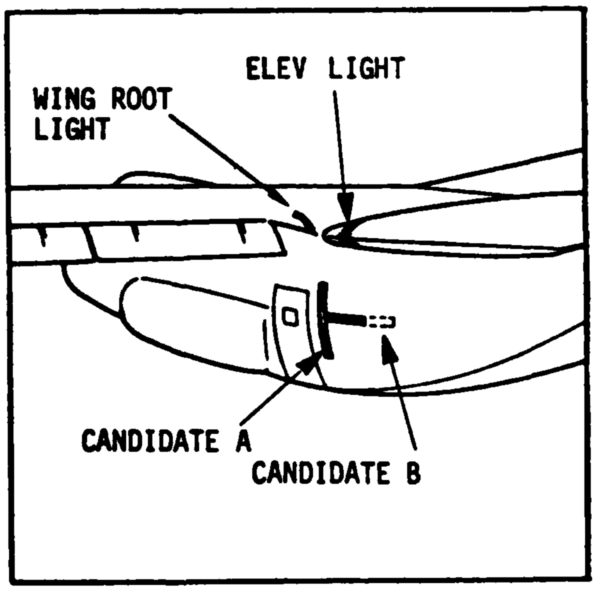


Figure 6. OBSERVATION Position

PRECONTACT and CONTACT Position (Reference Figure 7)

For Candidate A, a 3-foot horizontal FLAP light (introduced as a cue for the TRAIL position) is proposed. Two horizontal lights on the pylon strut would be used in combination with the FLAP light (the flaps are now extended 70 degrees) to line up a correct azimuth, elevation position. For Candidate B, a 4-foot horizontal flap light is proposed and the center STRUT light is turned off. A highly reflective white material is proposed for the drogue that will outline its perimeter to on-course and off-center observers.

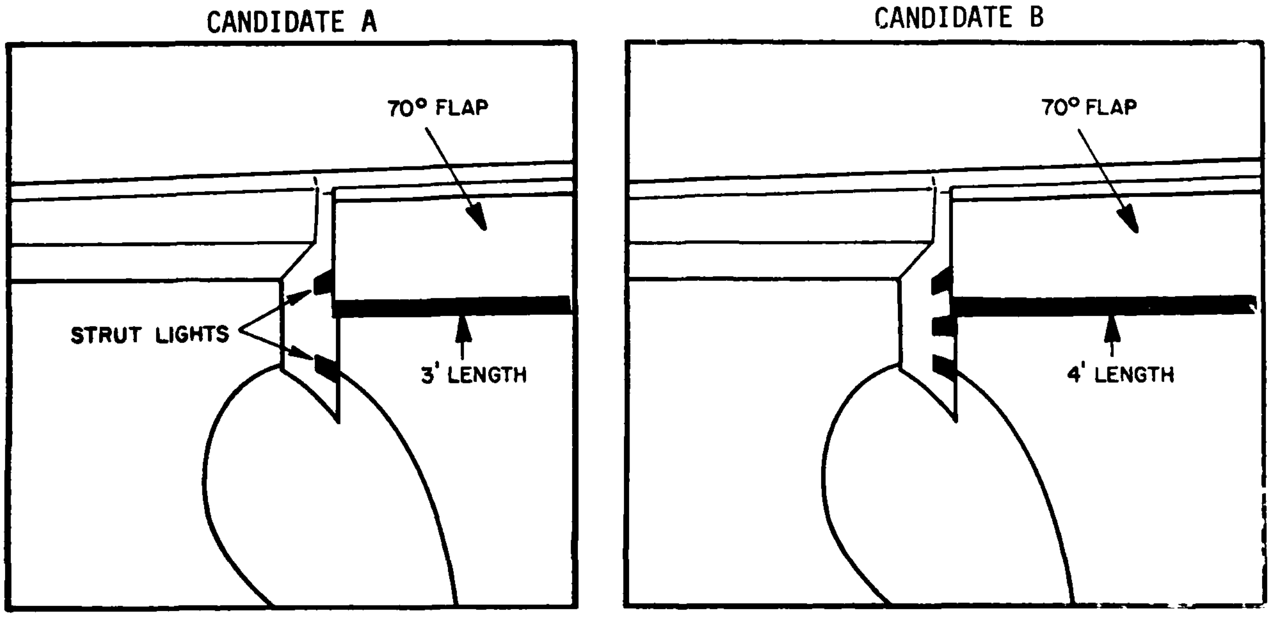


Figure 7. PRECONTACT and CONTACT Position

Hose Illumination and Tape (Reference Figures 8 and 9)

A hose illume light (Figure 8) and an IR filter over the HH-53 probe light are proposed to illuminate the hose. Use the Israeli spiral marking concept (Figure 9) and add a midrange circular mark to enhance judgments of hose length. The tape must reflect light from the EL source and be easy to clean.

As shown in Figure 10, a single TUBE light is proposed beneath the wing in line with the dump tube. A single light length is proposed for the two candidates and a maximum length of light used for nulling azimuth error. The WINGTIP light would be used as a reference when the receiver is positioned above the tanker's wing. This light might be eliminated if the T&E results showed that the WINGTIP and FLAP lights were adequate for maintaining the CONTACT position.

POD STATUS Lights (Reference Figure 11)

Recommend flashing segments of the FLAP light (Figure 11) following the code presented in Table 3.

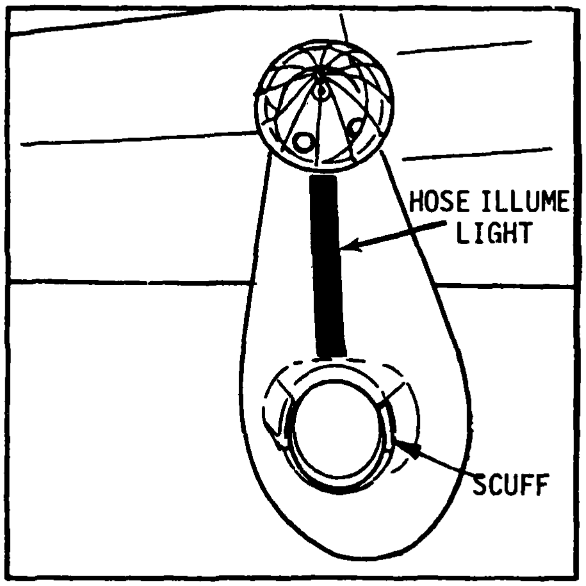


Figure 8. HOSE ILLUME Light

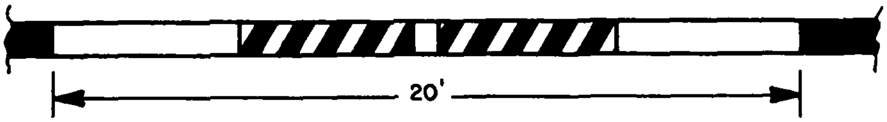


Figure 9. Proposed Hose Markings

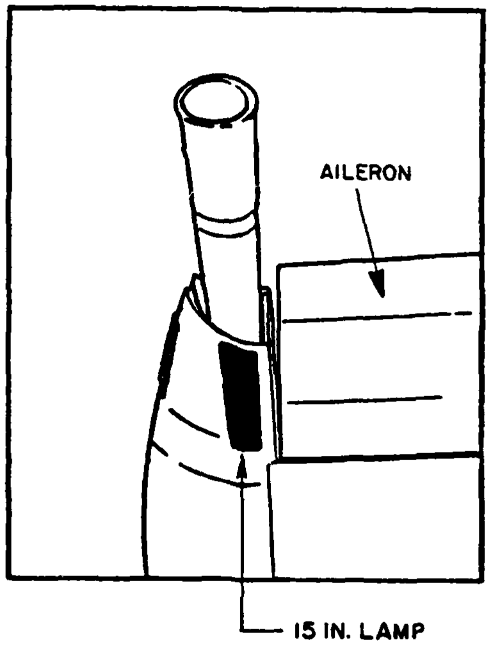


Figure 10. TUBE Light

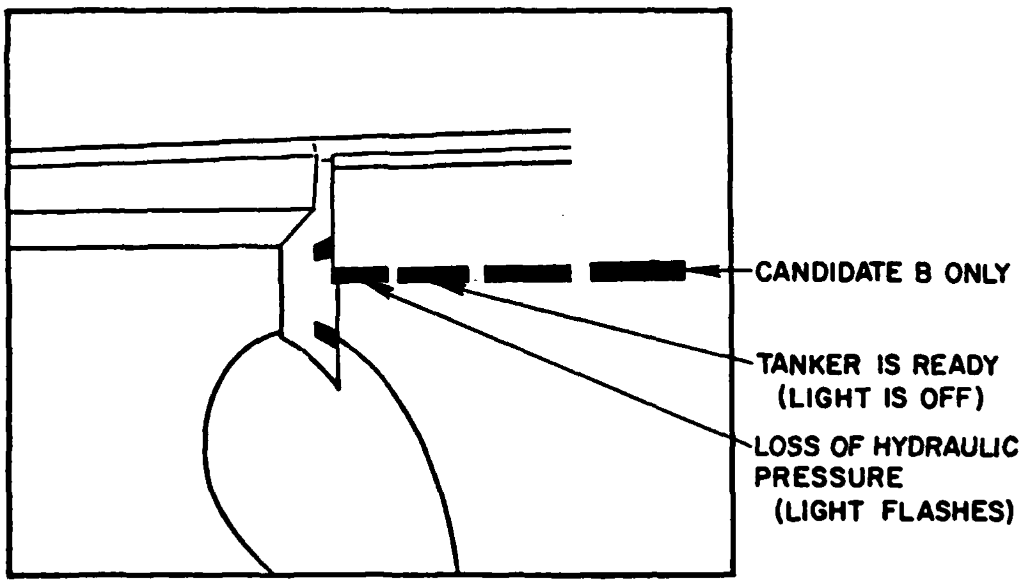


Figure 11. POD STATUS Segments on FLAP Light

TABLE 3. CODE FOR SIGNALING POD STATUS WITH FLAP LIGHTS

Code	Meaning	Color*
Outboard Segment Flashes	Loss of Hydraulic Pressure	Red
Middle Segment Off	Tanker is Ready	Yellow
All Segments On	Fuel is Flowing	Green

*Color of present POD lights viewed without NVGs.

The modification could automatically turn off or flash one of the segments of the FLAP light. The "Loss of Hydraulic Pressure Light" condition being most critical, its signal is located adajcent to the pod.

SIGNAL LIGHTS (Reference Figures 12 through 15)

A segmented EL light is proposed for signaling from the echelon position. It would alternately flash with the AFT FUSELAGE light. The STAB and FIN lights would be used for trail position signaling. The STAB, FIN, and FUSELAGE lights would be independently selected; however, the flash control would operate from one rheostat.

Alphanumeric Signal (9) Flashed
Alternately with AFT FUSELAGE Light

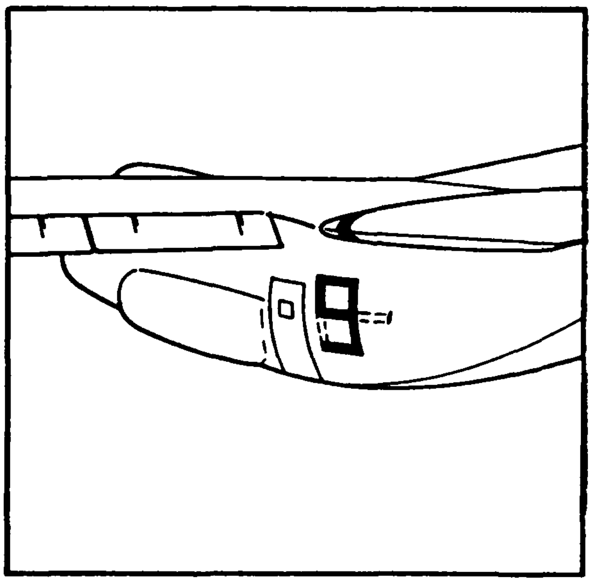


Figure 12. SIGNAL Light

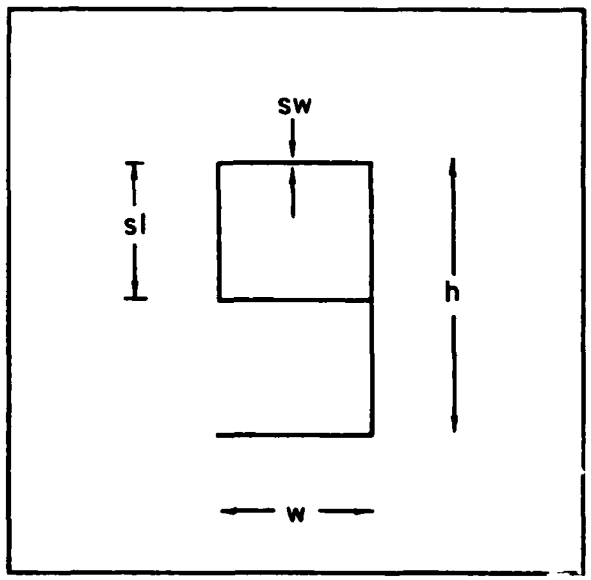


Figure 13. SIGNAL Light Description

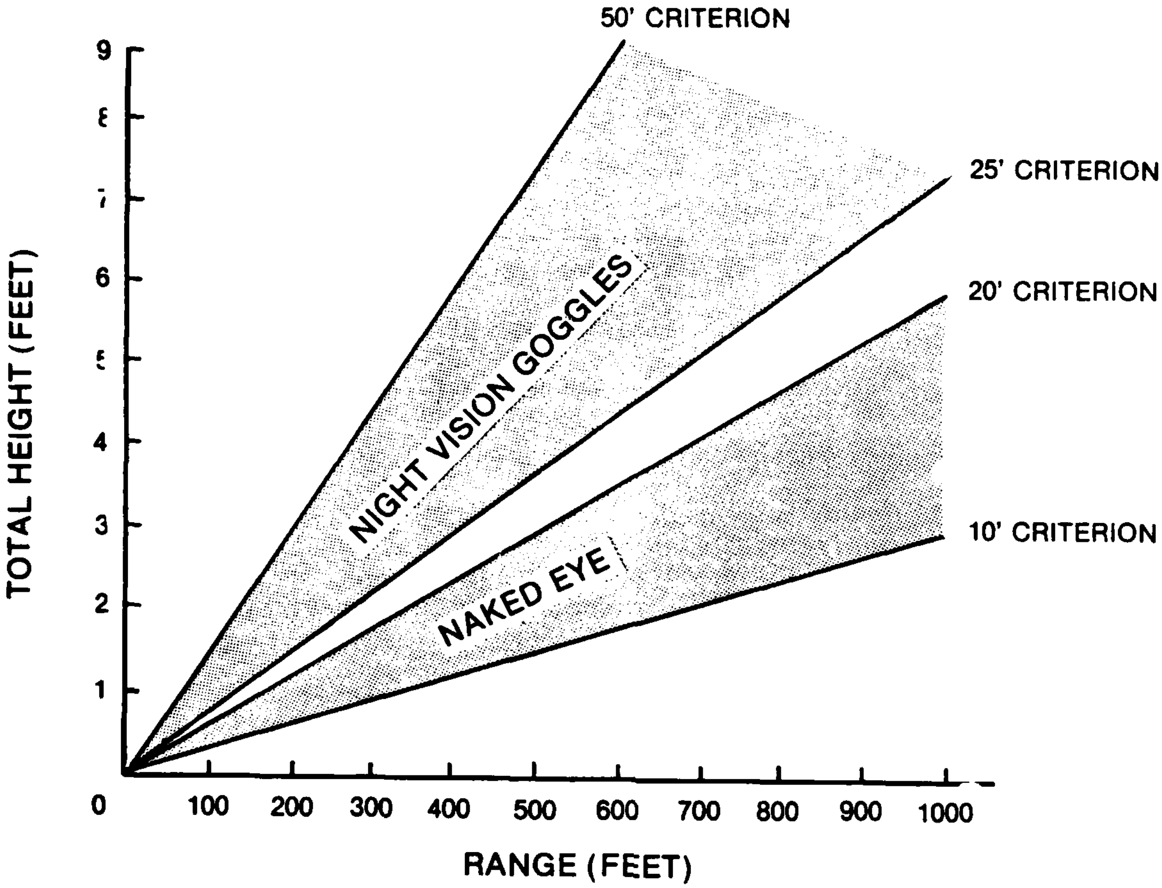


Figure 14. Signal Light Size Requirements for Viewing Ranges

SIGNAL Light Size

The pertinent physical factors for determining light size are total character height (h), ratio of segment width to segment length (sw:sl), width (w) as a proportion of height, luminous output, and background luminance.

The relationship between range and adequate legibility as a function of the appropriate combination of the above physical factors must be determined. It was assumed that viewing would occur on a dark, moonless, clear night; that the segments were mounted on a dark background; that output would be on the order of 20 ft-L; that discrimination would be done with foveal vision; that there was no internal cockpit lighting or windscreen glare; and that the relative movement of the target is very slow.

Since communications during missions is often critical, the error rate in discrimination must be kept low and, ideally, at zero. Therefore, values derived from optometric threshold studies based on Snellen charts, and the like, must not be used without modification since they represent threshold values (e.g., probably less than 75 percent accuracy). Shurtleff (1980)

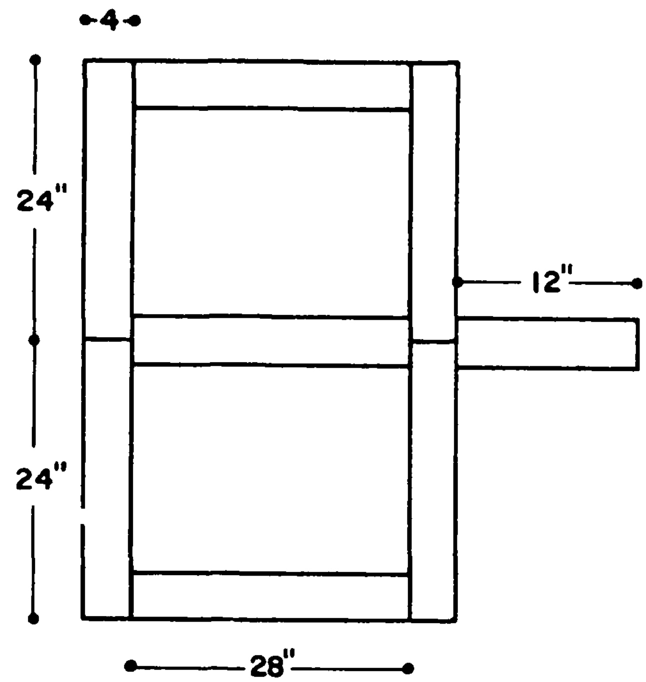


Figure 15. Proposed SIGNAL Light

has surveyed the results of a large number of legibility studies, and has recommended for high accuracy and quick recognition that characters extend about 10 to 37 minutes of visual angle, compared to the threshold of clinical visual acuity of 1 minute of arc. Shurtleff recommends that the character width be about 75 percent of height, the segment width to length ratio be about 1:5, and the contrast ratio (symbol luminance/background luminance) be between 2:1 and 18:1, with symbol luminance itself from 10 to 50 ft-L. Based on these criteria, a graph showing the relationship between character height and range at which desired legibility is still maintained was developed, as shown in Figure 14. The data are plotted as upper and lower bounds representing the range from about 95 percent performance to about 65 percent performance.

An additional factor was the effect on the ranges shown in Figure 14 when viewing through night vision goggles. AFAMRL (Task, 1983) has found that these goggles result in a degradation of possible visual acuity to 20/50, or a 2.5X reduction. A second set of curves on the graph shows the ranges of useful legibility to be expected with vision through these goggles.

It is recommended that these values be considered tentative; and it would be desirable to conduct a study to verify the level of obtained performance, both with the naked eye and with night vision goggles. A 48-inch x 36-inch configuration is proposed for the tanker (Figure 15) which should insure recognition of the number at a range of 500 feet while wearing NVGs.

Presented in Table 4 are the flash rates proposed for the signal and pod status lights.

TABLE 4. PROPOSED FLASH RATES*

Light	Flash Rate (Hz)	ON-OFF Cycle	Function
SIGNAL Lights			
Alphanumeric			
AFT Fuselage	2	250-250 ms	Alert and recognize
TAIL Lights	1	125-875 ms	Alert and count
FLAP Light			
(Outboard Segment)	4	125-125 ms	Warn

*Personal communication, Dr. M. N. Nelson, 1983.

Section 4

PROPOSED EL LIGHTING CONTROLS

This section proposes four controls for switching the navigation, refuel, and signalling lights from the flight deck. The panel is based on the pilots comments (see Appendix A) and the authors experience with a recent A-10 EL formation lights modification (A-10 EL, 1982).

The present HC-130 P/N incandescent light controls are shown in Figure 16 and control 13 incandescent red, green, yellow, and lunar (white) lights on the wing, wing tips, and fuselage.

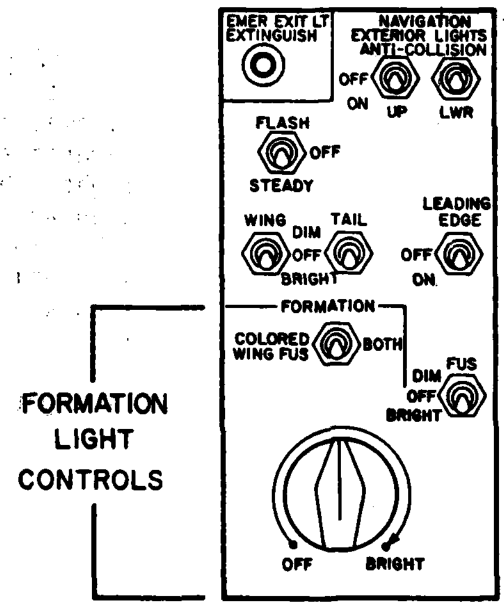


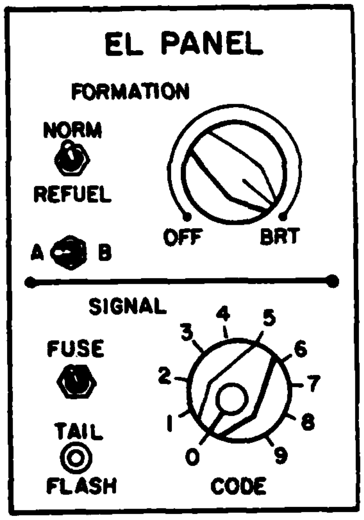
Figure 16. Current HC-130 Formation Light Controls

These controls are exclusively dedicated to normal operations and were not available for EL control.

The switches and switch functions proposed for EL formation light control are shown in Figure 17. The A, B test switch is proposed for the test and evaluation (T&E) of the two candidates and would not be included in the operational panel.

The NORM/REFUEL toggle switch selects the normal (NORMAL) (without refuel) lights or the normal and refuel (REFUEL) lights. The switch arms the rheostat (INTENSITY) which actually turns on the lights and adjusts light intensities. Circuit breakers could be used for turning off some lights for special missions.

The FUSE/TAIL and CODE controls would automatically flash either the AFT FUSELAGE EL signal light or the TAIL (FIN lights on Candidate A, FIN and STAB lights on Candidate B) lights. Flashing would only begin after the



Legends	Functions
NORMAL/REFUEL	Toggle switch selects all EL lights (REFUEL) or only formation lights (NORMAL). It also arms rheostat control of intensity.
OFF-BRT (INTENSITY)	Rheostat turns EL lights on or off and changes intensity.
FUSE/B-TAIL	Switch selects beavertail or aft fuselage signal light (may be deleted after flight test).
CODE	In FUSE position, detented, push-to-activate rheostat automatically alternates numeric and aft fuselage lights when turned for selection and depressed for ON and OFF. In TAIL position, it automatically flashes TAIL lights (FIN and/or STAB lights).
FLASH	Pinlight flashes whenever signal light flashes.
A,B (Test Only)	Two position toggle switch selects Candidate A or B.

Figure 17. Proposed EL Control Panel

code were selected and the center post pressed. If the CODE rheostat were turned, the center post would spring out, turning off the flashes.

Recommend the panel be located adjacent to the antiskid control panel.

Section 5

INSTALLATION FACTORS

This section summarizes the light requirements for both EL and IR filtered incandescent lights for the SOF mission after passing the Combat Entry Point (see Figure 2). A list of general installation factors is also included.

Table 5 contains a listing of the EL lights and light sizes and IR filtered incandescent lights proposed for the flight test. The sizes are given for LONG lengths; for SHORT lengths, one 2-inch x 11 1/2-inch light would be subtracted.

The installation factors shown in Table 6 are proposed for consideration when designing the light fixtures for the HC-130 P/N.

TABLE 5. EL LIGHT DIMENSIONS

Lights	Number of Lights (both sides)	Visible Light Lengths*	Comments
FORMATION LIGHTS			
Fore Fuselage	2	36" long	Condition A has two wingtip lights.
Wing Tip	4	36" horz 12" lat	12" L-bar added for Candidate B has two horizontal lights and two 12" L-bars.
Aft Fuselage	8	48" high 48" wide	
Fin	4	48" high	Two 36" lights, two 12" lights.
Flap	8	48" wide	Four 12" lights. Three segments to flash for pod status.
Elevator	2	28" long	Wedge light with equal "above" and "below" dimensions.
Stabilizer	2	36" long	
Chevrons	4	48" long	Two 36" lights, two 12" lights. Mounted along wing fillet for maximum trail exposure.
REFUEL LIGHTS			
Pod Strut	5	18" long	Candidate A has two lights; Candidate B has three lights.
Hose Illume	2	28" long	May be deleted after OT&E if HH-53 probe light is adequate illuminator.
Tube	2	15" long	May be deleted after OT&E if WINGTIP light is adequate reference.
Wing Root	4	28"	Lights with equal "above" and "below" dimensions.
Hose Marking	N/A	N/A	Reflective tape wrapped around hose. Spiral on left hose, no spiral on right hose for OT&E.
Drogue Marking	N/A	N/A	Reflective material added to perimeter of drogue.
SIGNAL LIGHTS	8	48" high 36" wide	Includes use of eight AFT FUSELAGE lights.
TOTAL	55		

*All lights are 2" wide except for the 4-inch WINGTIP, SIGNAL, and HOSE ILLUME lights. The light lengths are nominal and can be varied slightly to accommodate off-the-shelf hardware and fixture requirements. Light fixtures would have the flexibility to add filters and/or microlouvers.

TABLE 6. LIGHT INSTALLATION FACTORS

Factors	Comments
Light Location	• Ease of undersurface access for mounting and wiring. • Lack of surface irregularities. • Flap lamp may be unfeasible because of cabling, airstream deflection problems.
Light Length	• Fabricate variable-length lights as a single unit with selectable segments. This reduces the number of discrete mountings. • Use standard light sizes available from the suppliers.
Light Type	• A special mounting that can easily accept microlouver inserts can be used for the hose illume light.
Control Types	• The signaling unit will require a logic box.
Control Location	• EL light controls may be handled by flight engineer on the flight deck.
Hose Markings	• The selection of reflective tape should consider wearability and cleaning problems.

Section 6

PROPOSED T&E OBJECTIVES AND MEASURES

A flight test and evaluation could be flown with one candidate followed by a debrief on what changes the pilots thought prudent for safety or better positioning cues. The previous A-10 evaluation (A-10 EL, 1982) included two candidates in a limited effort to examine both size and shape preferences for selected lights. Costs of installation and installation access will also limit a C-130 EL T&E; however, the authors propose using a methodology similar to the A-10 effort--present two candidates; switch between the candidates at echelon, trail, crossover, and refuel positions; and anticipate the result of a hybrid configuration that borrows from both candidates. The test agency would have the option of having all of the pilots see both candidates or half of the pilots seeing one candidate; however, statistical confidence may be optimized by having all of the pilots see both candidates in alternating order of first presentation (see Table 7) so that pilot group 1 flew to a position with Candidate B illuminated and then the tanker would switch to Candidate A. To reduce the memory factor, inflight recordings of verbal responses are recommended followed by a post flight questionnaire that is oriented to reporting the adequacy of each light for cueing each aircraft position.

TABLE 7. ALTERNATING ORDER OF FIRST PRESENTATION

Pilot Groups	Candidates A	Candidates B	With NVGs	Without NVGs
1	First	Second	First	First
2	Second	First	Second	Second

In addition to these recommendations, Table 8 lists additional questions suggested for conducting the flight test.

TABLE 8. FLIGHT TEST ITEMS AND OBJECTIVES

- Is Candidate A or B preferred?
- How would you change (or not change) each light for the preferred candidate?
- What is the maximum range for which you would use this system?
- Is the HH-53 PROBE light (high intensity, black night) adequate for illuminating the basket?
- What is the adequacy of each light, with and without NVG viewing?
- Is the TUBE light required if the WINGTIP light is wrapped around the wingtip?
- If the FLAP light proves unfeasible, are the WINGROOT, CHEVRON, and ELEV lights adequate for flying the CONTACT position?

Appendix A

PILOT COMMENTS ON AIRCRAFT POSITIONS
AND PROPOSED LIGHTS AND CONTROLS

This appendix includes tables of comments from the ARRS HC-130 and HH-53 pilots concerning their formation positions and the proposed lights and controls. Tables 9 and 10 include comments that have been minimally edited for continuity. Comments from individual pilots are indicated by bullets (•).

TABLE 9. PILOT COMMENTS ON AIRCRAFT POSITIONS AND PROPOSED LIGHTS

TANKER/TANKER TRAIL POSITION

- This position is fixed by flying directly behind LEAD's fin and seeing the engine nacelles cut in half by the trailing edge of the wing. The nacelles are seen between the wing and the stabilizer as the aircraft trails by 200 to 500 feet behind the fin.
- Roll cueing is especially critical.

TANKER/RECEIVER OBSERVATION POSITION

- The HH-53 pilot moves into the tanker along an echelon line extending from the forward edge of the stabilizer tip to the amber light adjacent to the paratroop door.
- The trailing edge of the opposite wing is very helpful in holding angle of approach.
- Need long vertical cue because stab will block out portions of the horizontal light.
- Need a "cleared L" space for a fluid position that is defined by wingtip, wing root, and horizontal stabilizer positions.
- Ideal place to add signal light because pilots track in on the star during daylight.
- NVGs are removed just before achieving observation position.

TANKER/RECEIVER PRECONTACT/CONTACT POSITION

<u>Aircraft Markings</u>

- The horizontal position is achieved by aligning the outboard edge of the 70 degree extended flap with the aft vertical of the pod strut. The vertical position of the helo is achieved by placing the corner of the flap about 1/3 or 1/2 down the strut, depending on situational variables.
- The lower edge of the flap should cut the engine exhaust in half.
- Pod signal lights should be dimmed but not turned off.
- Trainees are instructed not to look at the basket; however, some pilots do line up on it at PRECONTACT.
- The pod signal lights are red (hydraulic pressure below 1700 psi), yellow (system is ready), and green (receiver is in proper position and fuel is being passed).

TABLE 9. PILOT COMMENTS ON AIRCRAFT POSITIONS AND PROPOSED LIGHTS (continued)

- The underside of the wing is seen from this position.
- A 1-foot horizontal light on the flap is sufficient for refuel.
- Add a wraparound wedge.
- Need a "cleared L" space for a fluid position that is defined by wingtip, wing root, and horizontal stabilizer positions.

Hose Markings

- The proper fore/aft position of the helo is monitored by maintaining a hose length between 56 and 76 feet. The precise position is determined by noting which portion of the hose is entering the scuff plate at the pod hose entrance. As fuel is transferred, collective is added which moves the nose down and the basket appears to ride higher.
- The Israelis added a spiral reflective tape between the refueling range limit marks which makes the hose appear to screw in and out with retraction and extension.
- Small EL lamps at 2, 6, and 10 o'clock positions on the aft end of the pod might be used to replace pod signal lights if refueling is to be flown with NVGs.
- Hose movement is very difficult to monitor because the pilot cannot look to the side for tanker cues.
- Hose markings tend to get dirty and difficult to see at night.
- Cuff exit is poorly illuminated. Hose extension is especially difficult to perceive.
- "I have my engineer watch the hose from the rear window and alert me to aft motion." "By the time the amber light comes on, it may be too late to kill error and stop disconnect." (Disconnect is achieved by moving aft and pulling 450 pounds of force on the hose.)
- Forward thrust is lost as fuel is transferred.
- Cuff light has to be above hose.
- Might use microlouvers to better direct light onto hose.
- Pod illume lights are too bright, often do not adequately illuminate hose or basket.
- Immediately after contact, the helo is moved laterally outboard to a position where the pilot is looking straight down the dump tube at the wingtip. This is done to move the rotor to a greater distance from the C-130.
- At night, this position is usually flown slightly lower so that copilot can see the hose markings.
- A portion of the top of the wing can be seen during refueling.
- Must be able to see hose markings and tube position simultaneously.
- Might be better not to have lights above and below tube because tube will mask one light and where are you?
- Tube light should be long enough to indicate outboard or inboard lateral drift.

TABLE 9. PILOT COMMENTS ON AIRCRAFT POSITIONS AND PROPOSED LIGHTS (continued)

TANKER/TANKER AND TANKER/RECEIVER SIGNALING
• Need separate control of beavertail light.
• Need a 0 through 9 code for numeric signal.
• A portable signal device that could be hung in HH-53 or C-130 windows would be ideal.
• Because any aircraft might have to assume lead, all aircraft need signal devices.
• A window device should not block out ability to see through the device for scanning other aircraft.
• Any signaling light must be independently controlled.

TABLE 10. PILOT COMMENTS ON PROPOSED EL CONTROLS

• HH-53 rheostats have detents that can be set without looking ("full over and back two").
• If there is more than one mode, a dimmer would be required for each mode.
• Toggle switches are OK for EL mode selection.
• "EL NORMAL" (without refuel lights) and "EL REFUEL" (both normal and refuel lights) switch positions would reduce aircraft exposure during nonrefuel mission segments.
• Recommend separate rheostat control of incandescent and EL light intensities. [All seven pilots interviewed preferred rheostat (continuous) rather than discrete control of intensity.]
• Place the EL control panel adjacent to the antiskid control panel.
• The proposed B-TAIL and CODE switches require the sender and receiver to know different sets of signals; therefore, a single set of CODE signals should be used with a function switch added for B-TAIL or FUSE (fuselage) selection.

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