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ELECTRO-OPTICS ENGINEERING SUPPORT FOR THE INTEGRATED LAUNCH AND RECOVERY TELEVISION SURVEILLANCE SYSTEM

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The Integrated Launch and Recovery Television Surveillance (ILARTS) System is used aboard U.S. aircraft carriers to provide aircraft landing information. The images are used to supplement the LSO's view during landing operations. In addition, recorded imagery is used during pilot de-briefings and accident investigations. Operational requirements of the system are analyzed. The results of a vendor camera survey are summarized. Recommendations are made for modifying the system specification without loss of performance. The possibility of replacing visible light cameras with ~~FLIRs~~ forward look infrared is examined. Methods for quantifying and reducing blooming are discussed.

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PREFACE

The work reported here was performed in the Optical Science Laboratory of the Advanced Concepts Division of the Environmental Research Institute of Michigan under the supervision of ERIM's Technical Information Analysis Center.

This report covers work performed between October 1, 1989 and April 30, 1990. The program manager was Dr. Joseph Accetta. The principal investigator was Kenneth K. Ellis. Additional work was performed by Brad Neagle and Russell Watts.

DISCLAIMER

Corporate and product names are included in this report for information purposes only. The use of corporate and product names does not constitute endorsement by the authors, the Environmental Research Institute of Michigan, the Naval Air Engineering Center, or any agency of the government of the United States.

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1 INTRODUCTION

The Integrated Launch and Recovery Television Surveillance (ILARTS) System is used aboard U.S. aircraft carriers to provide aircraft landing information. The images are used to supplement the LSO's view during landing operations. In addition, recorded imagery is used during pilot de-briefings and accident investigations. The Naval Air Engineering Center (NAEC) started a program to replace the ILARTS camera in 1987. These efforts resulted in a solicitation for cameras in April 1989. The solicitation only produced one proposal, which was determined to be unacceptable, resulting in cancellation of the solicitation in September of 1989.

The effort to replace the ILARTS camera system started as a cost savings program. Due to the age of the system, however, major system components are becoming unavailable and the system can no longer be supported. Therefore, it is imperative that other options be investigated to maintain the ILARTS system.

This program has examined several approaches to solving this problem. To begin with, a survey of camera vendors has been completed in order to determine if any current products could meet the requirements of the solicitation. While no such cameras were found, the specifications that they failed to meet were noted for future reference.

An analysis of the operational requirements was performed concurrently with the survey. These requirements were then used to generate camera specifications, resulting in recommendations for changes to the current specifications. Many of the recommendations relax the requirements, increasing the probability that off-the-shelf hardware will be able to meet them. Cameras identified in the survey were then compared with the revised specifications. The recommended changes to the purchase description are presented in Appendix A with each paragraph numbered accordingly.

In addition to examining available cameras, several other options have been examined to determine their suitability. These involve making changes to the ILARTS architecture, as opposed to just replacing the camera. The options examined are replacing the camera with a FLIR, and implementing image processing techniques to reduce the effects of blooming in the imagery.

In order to satisfy the requirement for maintaining the ILARTS system it is desirable to expedite vendors' ability to provide a system that is useful to the LSO and other users and practical to maintain. We must keep in mind that ultimately the imagery is viewed subjectively by the user. Thus there is a certain amount of latitude in the specifications. The numbers obtained through analysis are dependent to a certain extent on quantifying the user's perception of the imagery. While we have attempted to minimize this dependence it is not completely avoidable. In general, when quantifying requirements that depend on human perception we have where possible used the results of psychophysical studies and generally accepted rules-of-thumb to make conservative estimates. By conservative we mean that the specifications should be more than adequate to achieve the desired levels of performance. Thus some "requirements" can be treated more as guidelines than firm specifications. This factor, combined with the desire to acquire a suitable replacement system consisting of off-the-shelf components has a significant impact on how the results of this study are used.

The first option is to modify the system specification according to the recommendations in this report and initiate a technology development program to develop a camera system that will meet the specification in all its particulars. This will produce a system that performs just as desired. This "best performance" is bought at the expense of the time and funding required for development and initiating production, the amount of which depends on what sort of modifications need to be made to available equipment.

The second option is to test cameras that come closest to meeting the specification. Upon finding one or more systems that produce acceptable (but not necessarily the best) performance, a purchase description may be written that matches the capabilities of available hardware. The distinction that needs to be made between these options is the difference between technology development and procurement. Neither of these options excludes the possibility of developing add-on hardware to enhance system performance.

2 SYSTEM SPECIFICATION

The purpose of this section is to provide an analysis of the current ILARTS specification and operations requirement. Only the optical specification and requirements will be considered here. Specifications relating to system ruggedness and environmental suitability will be addressed in a following section. All of the paragraphs in Section 3 of the purchase description have been reviewed. Only those for which changes or clarifications are recommended are listed here.

The purpose of the ILARTS system is to provide a video adjunct for the LSO during launch and recovery of aircraft aboard fleet aircraft carriers. Optical requirements will be examined within the context of this mission and its use by the LSO. We begin by examining the operational geometries and user requirements. These are then related to optical system parameters. The purchase description is then examined to check for self consistency. The specifications are compared to parameters derived from the operational requirements.

Finally, recommendations for changes to the purchase description are made to ensure self consistency and consistency with the operational requirements without making the specifications unnecessarily stringent.

2.1 OPERATIONAL REQUIREMENTS

ILARTS aids the LSO in detecting and identifying approaching aircraft. In addition it can help determine if the aircraft is approaching on the correct glide slope and is within an acceptable roll, pitch, and yaw envelope. The video image presented to the LSO must have sufficient resolution and contrast so that he can observe any significant deviations from the nominal flight envelope and factor them into his decision. Table 1 quantifies the operational requirements. These must be related to the aircraft light geometries before they can be converted into camera specifications. Figure 1 depicts the relative locations of the landing and navigation lights of fixed wing carrier based aircraft as seen from a nose-on view. The relevant dimensions are indicated in Table 2. Figure 2 depicts the carrier deck. The camera positions are indicated as well as the location of the aircraft after landing. A typical value for the distance between the aft centerline camera and the aircraft position is 140 feet. This value will be used in the analysis as the closest range at which the aircraft will be imaged.

2.2 SYSTEM PERFORMANCE AND OPERATION

2.2.1 Light Range

We recommend that the light range be expressed in terms of illumination at the camera focal plane (face plate illumination) instead of scene illumination. The light range is range over which the camera must operate. It is bounded on the low end by the faceplate illumination expected from the airframe at night and at the high end by the illumination from the landing lights and from the airframe during the day. This is the usual parameter specified by manufacturers for sensitivity. This also relieves the camera manufacturers from having to determine the measurement scenario parameters.

The illuminances produced by the sun, moon, stars, and low pressure sodium deck lights are listed in Table 3. The lunar and stellar illuminance have been computed from the visual magnitude of the full moon and the distribution of visual magnitudes of the stars [Suits, 1978]. The illuminance is related to the visual magnitude by

$$m = -2.5 \log_{10} \frac{E(m)}{E(0)} \qquad (1)$$

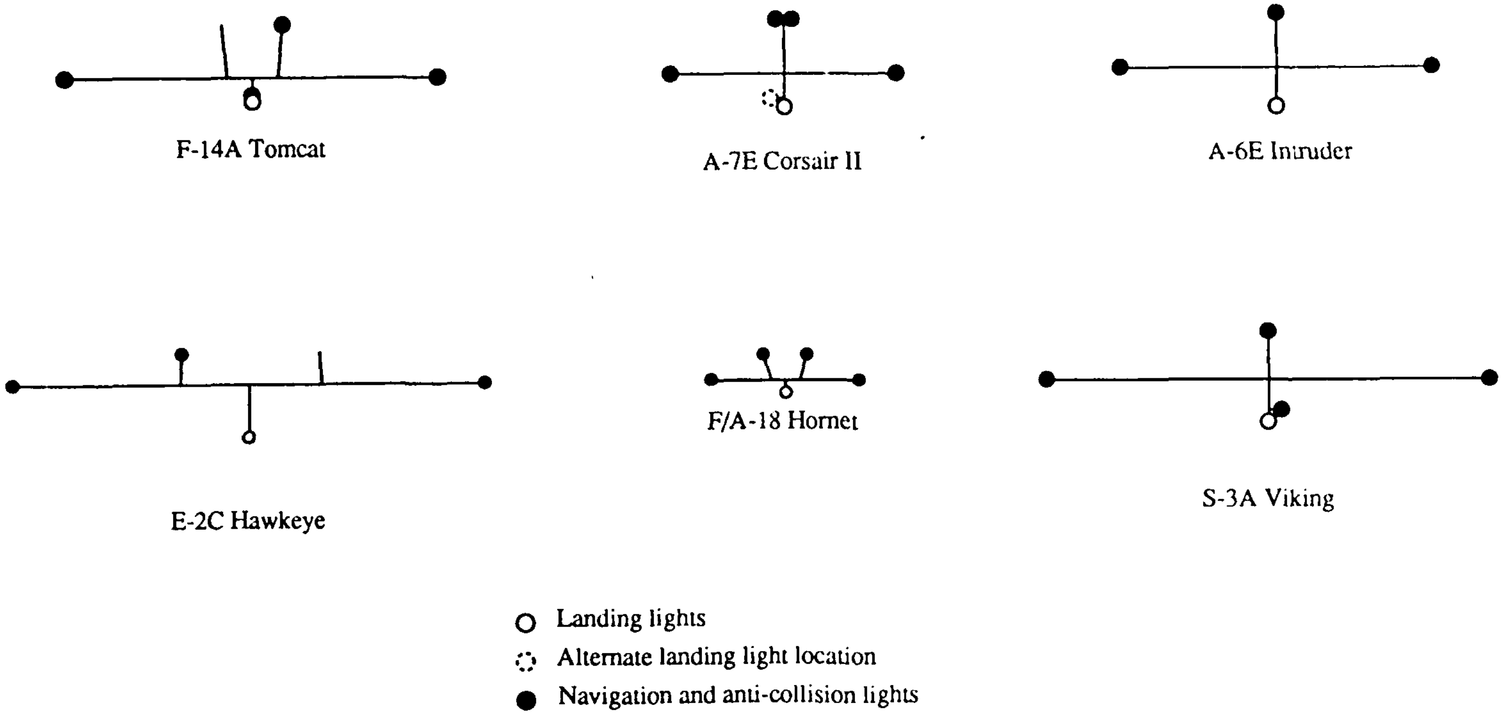

Figure 1. Aircraft lighting configurations

Table 1: ILARTS Operational Requirements

- 23 km visibility assumed
- At 10 nmi
  - Detect approaching aircraft
  - Indicate whether aircraft is on 3.5° glide slope
- At 3 to 0.5 nmi
  - Identify aircraft from lighting configuration
  - Provide orientation information
    - Roll limited to ±10°
    - Pitch limited to ±5°
    - Yaw limited to ±3°
  - Determine if aircraft is approaching on centerline

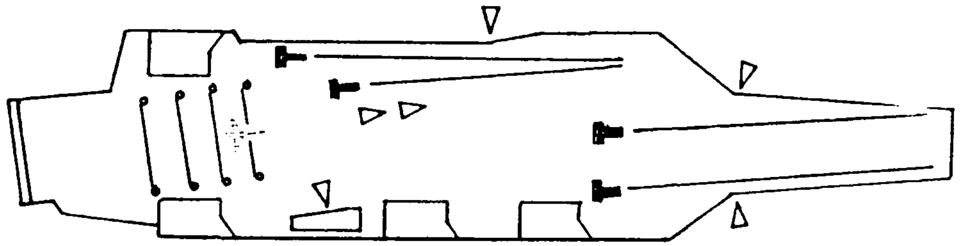

Figure 2. Plan of carrier deck showing ILARTS camera locations.

Table 2: Aircraft Dimensions (m)

Aircraft	Longitudinal Axis	Wingtip to Centerline	Vertical Stabilizer to Centerline	Vertical Stabilizer Height	Landing Light to Centerline
F/A-18	8.73	4.19	1.54	1.82	0.91
F-14A	13.2	9.77	1.63	2.62	1.17
A-7E	6.07	5.90	0.0	2.71	1.30
A-6E	12.5	8.08	0.0	2.85	1.99
S-3A	13.8	10.5	0.0	4.54	2.18
E-2C	14.8	12.3	3.61	2.05	2.83

where $E(0)$ is 2.089×10^{-6} *lux*, the illuminance of a zero magnitude object. Note that the luminance of the moon in the first or last quarter is one-fourth that of the full moon, not one-half, due to a tendency to retroreflect at incident angles near normal. The sodium lamp illuminance was derived by extrapolating measurements made on board the U.S.S. Lexington. The value corresponds to the illuminance at the end of the flight deck and thus represents a worst case estimate. As the aircraft approach the cameras from that point, the illuminance increases. The data is presented in Appendix A. The solar illuminance is presented for comparison. It was computed from

$$E = \Omega_s \int_{\Delta\lambda} L(\lambda, T) V(\lambda) d\lambda \tag{2}$$

where $L(\lambda, T)$ is Planck's blackbody function and $V(\lambda)$ is the photopic response function, and Ω_s is the solid angle occupied by the sun. The irradiance was computed by integrating a 5900 K blackbody function and scaling appropriately.

The face plate illuminance and irradiance are related to those of the scene by

$$M_{fp} = \frac{\pi \rho}{4(f/\#)^2} E_s \tag{3}$$

where $f/\#$ is the focal length-to-aperture ratio and ρ is the reflectance of the aircraft. The face plate illumination levels found in Table 3 were computed in this manner. It was assumed

Table 3: Estimated Scene and Face Plate Illumination

Source	Scene Illuminance (lux)	Face Plate Illuminance (lux)	Scene Irradiance (W/m^2)	Face Plate Irradiance (W/m^2)
Moon, full	0.158	1.93×10^{-3}	6.34×10^{-4}	7.76×10^{-6}
Moon, 1st quarter	0.0396	4.84×10^{-4}	1.59×10^{-4}	1.94×10^{-6}
Stars	5.71×10^{-4}	6.99×10^{-6}	2.29×10^{-6}	2.80×10^{-8}
Sodium Lamps	0.2	2.4×10^{-3}	0.23	2.8×10^{-3}
Landing Lights[1]		$3.06 \times 10^4/6.09 \times 10^5$		$122./2.43 \times 10^3$
Navigation Lights[2]		3.94/1531.		$1.57 \times 10^{-2}/6.10$
Sun at noon	1.75×10^5	2.14×10^3	702.2	8.59

1. 600 W, 600,000 Cd peak beam intensity, 2854 K filament, 20 cm diameter
2. 36 W, 50 Cd bulb, 3.5 cm diameter

that the current lens was used and that the aircraft surface is grey with a reflectance of 0.4. An average aperture size of 29.6 mm was used. In reality the illumination collected by the camera depends on the bidirectional reflectance distribution function and the illumination geometry, not just on reflectance. However, data compiled by ERIM's Target Signature Analysis Center indicates that at visible wavelengths the BRDF changes by no more than a factor of three for different incident angles [TSAC, 1972]. Thus the range of illumination levels of an aircraft may be smaller than those in the table by this amount. Although not included in the table, this factor is included in the light range requirement.

The aperture is directly illuminated by the aircraft lights, requiring a different method for computing the face plate illumination. At long ranges the lights are point sources. When the aircraft is on deck, the lights are extended but finite. Thus the above expression does not apply. The approximate face plate illumination is given by

$$M_{fp} = \frac{I A_c}{R^2 A_i} \tag{4}$$

where

I = lamp intensity in Cd or W/sr

A_c = area of camera aperture
R = range
A_i = area of lamp image

The lamp image is assumed to have a radius equal to the radius of the geometrical image plus the radius of the impulse response of the aperture.

$$A_i = \pi \left(\frac{\lambda f}{L_x} + \frac{D_s f}{2R} \right) \left(\frac{\lambda f}{L_y} + \frac{D_s f}{2R} \right) \tag{5}$$

where

λ = average wavelength
f = camera lens focal length
L_x, L_y = camera aperture size
D_s = lamp diameter

The illumination has been plotted as a function of range for the landing lights in Figure 3. One might expect that since the aperture illumination falls off as R^{-2} that there would be a five order of magnitude change in the faceplate illumination as the aircraft approaches from 10 *nmi* to its final resting place approximately 140 feet from the centerline camera. The Figure shows that this is not the case. In fact the landing light illumination only changes by about an order of magnitude. This paradoxical behavior is due to the fact that the image of the lamp at short ranges is spread over many resolution cells, reducing the flux density at the face plate by orders of magnitude. For the purposes of this calculation, the characteristics of Sylvania PAR-64 and S-11 bulbs, listed in Table 3, have been used. The two numbers presented in Table 3 for each entry correspond to ranges of 10 *nmi* and 140 *ft*, respectively.

The range specification implies that a nine order of magnitude change in light levels must be accommodated. However, the intensity of the aircraft lights will change by less than three orders of magnitude between detection at 10 *nmi* range and landing on the deck. The difference in light levels between the landing lights and the sodium vapor lights reflected from the aircraft is expected to be about eight orders of magnitude. The sodium lights are expected to provide an illuminance of about 0.2 *lux*. This is considerably higher than the specification. In fact, the lower limit in the specification is about the irradiance expected from starlight on a clear night and three orders of magnitude less than that of the full moon. Our survey of camera vendors indicates that these scene illumination levels are well below the sensitivity limits of any available cameras. For these reasons we recommend that the lower limit on face plate illumination be increased to 5×10^{-4} *lux* (2×10^{-6} W/m^2), which is adequate for imaging aircraft illuminated by either sodium vapor lights or a half moon on a clear night.

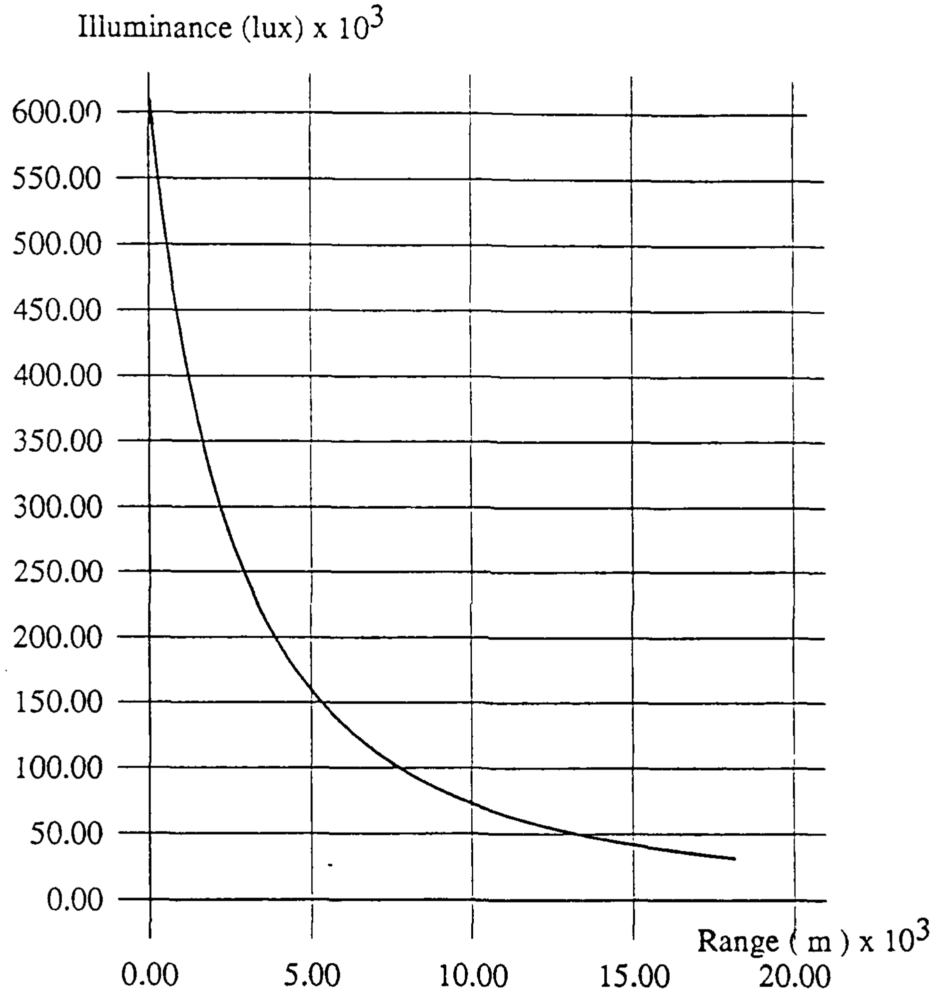

Figure 3: Focal Plane Flux Density as a Function of Aircraft Range

The upper limit is not as critical since it is not necessary to image the lights when the aircraft are close, only to prevent damage to the detectors and limit blooming. If the landing lights cause the detectors to saturate it will not significantly affect the usefulness of the imagery. Blooming is addressed in a later section. Thus the upper usable limit is determined by the intensity of the image during the day, which corresponds to a face plate illumination of 2.2×10^3 $lux(8.6\ W/m^2)$. However, the camera must be capable of withstanding up to 6×10^5 $lux(2.43 \times 10^3\ W/m^2)$.

The dynamic range required is determined by the range of intensities imaged at one time. It is desirable to image the airframe while the landing lights are illuminating the camera aperture. Table 3 indicates that this would require an instantaneous dynamic range of 10^9. Current technology is limited to orders of magnitude less than this. This operational requirement may be satisfied by allowing the lights to saturate the detectors. The tools for predicting blooming during saturation have not yet been developed. Thus we must choose another criteria. One other operational requirement places limits on the minimum dynamic range. Identifying the aircraft from the lighting configuration requires that the dimmer navigation lights be observed as well as the landing lights. This could be achieved with an instantaneous dynamic range of $44dB$, somewhat less than 10^5. Cameras claimed to have this dynamic range are readily available.

2.2.2 Scanning Mode

Many cameras on the market have 1024 lines and operate at 60 frames per second. We recommend that the option of using a scan converter with one of these cameras to reduce the performance to the specified level be stated more explicitly.

2.2.3 Limiting Resolution

The resolution required for accomplishing the tasks listed in Table 1 are presented in Table 4.

Here it has been assumed that changes on the order of ten percent of the maximum allowable roll, pitch, and yaw must be detectable. In actuality, the minimum detectable change in angle depends on the separation of the lights as well as the resolution. This is a qualitative limit and is not based on psychophysical studies. It is, however, conservative in that it should be more than adequate for determining whether the aircraft attitude is within the appropriate limits.

The most difficult case is yaw determination. In order to achieve 6 μrad resolution with

Table 4: Resolution Requirements (μrad)

Aircraft	Roll (μrad) 3 nmi	Roll (μrad) 5 nmi	Pitch (μrad) 3 nmi	Pitch (μrad) 5 nmi	Yaw (μrad) 3 nmi	Yaw (μrad) 5 nmi
F/A-18	26	160	14	82	8	50
F-14A	61	370	21	124	12	75
A-7E	37	220	9	57	6	35
A-6E	51	300	20	117	12	70
S-3A	66	390	22	130	13	78
E-2C	77	460	23	140	14	83

Range (nmi)	A/C Identification (μrad)	On Center ? (μrad)	Glide Slope (μrad)
10			5000
3	280	215	
1	830	650	
0.5	1660	1300	

a camera having 525 lines, the field of view would have to be reduced to 0.18°. A larger FOV could not be displayed all at one time on the monitor. These requirements can be relaxed somewhat by decreasing the range from 3 *nmi* to 0.5 *nmi*. However, for an aircraft approaching at 100 *kt*, the reaction time is reduced from 1.8 seconds to 0.3 seconds. It may still be possible for a trained observer to adequately determine yaw at a degraded resolution. Thus the fuzzy resolution requirement, reaction time, and camera FOV all need to be considered.

One other factor should be considered. The resolution of the video monitor ultimately dictates the image resolution. The monitor conforms to the RS-170 standard, which requires that there be at least 350 lines in the vertical direction and 400 lines in the horizontal. In order to make full use of the display capability, we recommend that the resolution limit be set by the number of lines for the minimum FOV. This results in a 90 μrad resolution. Referring to Table 4, it is reasonable to expect that the pitch and yaw can still be adequately determined at 0.5 *nmi* and the roll at 3 *nmi*. This resolution is clearly sufficient for achieving the identification, center line, and glide slope determinations as well.

We recommend that an angular resolution requirement at the center of the four degree field of view of 90 μrad be specified for the camera/lens system.

2.2.4 Modulation Transfer

The MTF of a diffraction limited lens having a circular aperture is given by [Goodman, 1968]

$$H_o = \frac{2}{\pi}\left[\cos^{-1}\left(\frac{k_r}{2k_0}\right) - \frac{k_r}{2k_0}\sqrt{1-\frac{k_r^2}{2k_0^2}}\right] \tag{6}$$

where k_r is the number of television lines and D_a the aperture diameter. The effect of lens misfocus or other aberrations is to decrease the magnitude of this function. The Rayleigh quarter-wave limit states that if the wavefront aberration, or optical path difference, varies by no more than one-quarter of a wavelength across the aperture, the image will appear to the observer to be perfect [Smith, 1978]. The high frequency cut-off is determined by the limiting angular resolution and the camera FOV. It is given by

$$k_0 = \frac{FOV}{2\rho} \tag{7}$$

Using the Rayleigh criteria in conjunction with the high frequency cutoff of 400 lines imposed by the 90 μrad resolution limit for a 4° FOV results in the following MTF requirement:

TV Lines	Square Wave Response (%)
0	100
50	78
100	56
200	27
300	10
350	4

This is compared with the diffraction limited MTF and the purchase description requirement in Figure 4. If the resolution or FOV requirements change, this requirement must also change. Note that by relying on the Rayleigh criteria, the MTF requirement may be relaxed at all frequencies. Furthermore, the purchase description requirement exceeds the diffraction limited MTF at the higher frequencies. While those performance levels could be achieved by decreasing the angular resolution requirement, there would be no gain in image quality due to the limits imposed by the display.

When evaluating the MTF of a camera it is necessary to illuminate the test target such that the aperture illumination is comparable to that expected during use. We recommend evaluating the MTF within the context of the identification task. When the aircraft is 3 nmi distant the expected aperture illumination is 1.94×10^{-2} lux (1.15×10^{-4} W/m^2).

2.2.5 Gray Scale

We recommend that the faceplate illumination level be 2.4×10^{-3} lux (2.8×10^{-3} W/m^2) when assessing the gray scale resolution, making it consistent with the suggested light range specification. This also obviates the need to specify the distance at which the test chart is viewed.

2.2.6 Blooming

Blooming has always been recognized as the largest problem that the ILARTS system must overcome. At long ranges the intense landing light can cause blooming that masks the navigation lights as seen by the camera. At short ranges it can prevent the camera from imaging the wings and fuselage.

Blooming is produced in both CCD and tube cameras by the lateral diffusion of charge carriers in the detection plane. CCD detectors consist of areas in a semiconductor that are electrical potential wells. The wells are fabricated by doping the material and applying a voltage. When a photon strikes the doped region, an electron-hole pair is produced. The electron is then contained in the well by the potential produced by the applied voltage. A

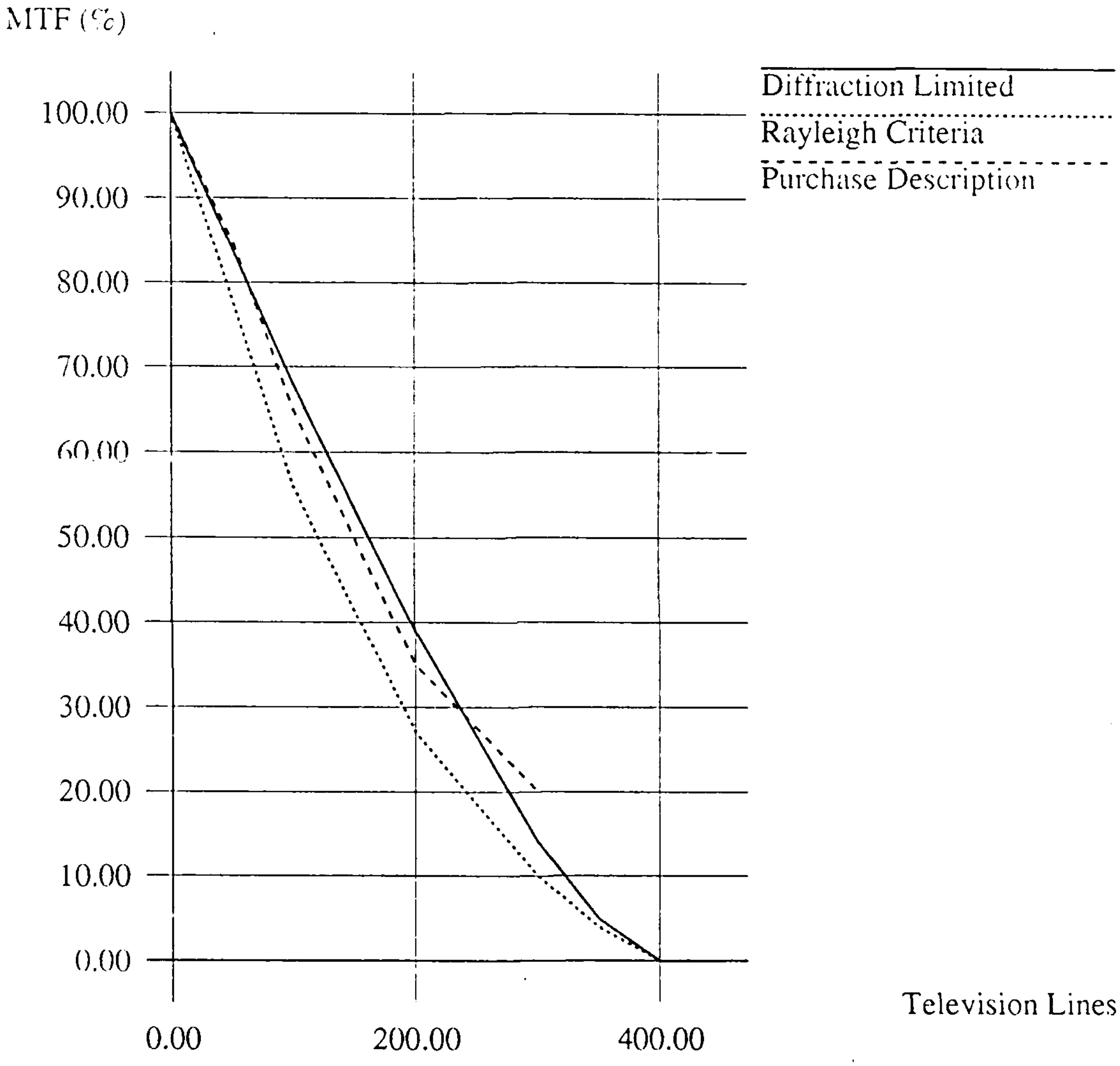

Figure 1: A comparison of the suggested MTF requirement with the diffraction limit and the current requirement

single well can only hold so many electrons, however. The capacity of the well and the electrical noise determine the dynamic range of the detector. If there is a great number of incident photons, there will be too many electrons for the well to hold. The excess electrons will diffuse laterally into the surrounding material, propelled by their mutual electrostatic repulsion. If there are enough excess electrons, they will eventually end up in another well, increasing the measured intensity of an adjacent pixel. The end result is blooming in the image.

The mechanism that produces blooming in tube cameras is slightly different, even though it still results from the lateral diffusion of charge carriers. In most tube cameras (orthicon, isocon, SIT, *etc.*, the image is focused onto a photoemissive cathode. Electrons emitted by this cathode are accelerated and focused onto a target using electric and magnetic fields. The target generates and stores a charge image that is proportional to the intensity of the optical image. This charge image is then read out using a scanning electron beam. The mechanism for generating the charge image varies. Some tubes such as the orthicon and isocon use secondary emission, while vidicons use photoconductive elements to produce the charge image directly from the optical image. SIT cameras use electron bombardment induced conductivity. In each case, however, the target must hold the image between scans. Blooming is caused by lateral diffusion of carriers between scans within these targets, which are never perfect dielectrics.

The vendor survey indicated that there is no generally accepted industry standard for measuring blooming. In fact, most manufacturers do not even mention it in their specifications. A survey of the literature for the last ten years and of national standards has not produced a single method for quantifying bloom. We shall therefore propose here a method which seems to have some utility in quantifying the usefulness of a blooming imaging system. A parametric analysis of this metric that would allow one to predict blooming given camera characteristics is possible. We were not able to accomplish it within the scope of this study, however.

An arrangement for measuring blooming is depicted in Figure 5. A small source bright enough to induce blooming is located behind a screen, illuminating the camera through a small aperture. The screen is a vertical bar chart having unity contrast. It is illuminated so that the camera sees both the chart and the bright source. The blooming may be quantified for given illumination levels by measuring the contrast of the bar chart as a function of distance from the center of the bright source.

When viewing point targets, such as when identifying aircraft from light configurations, a conservative minimum contrast level can be derived from the just noticeable difference and

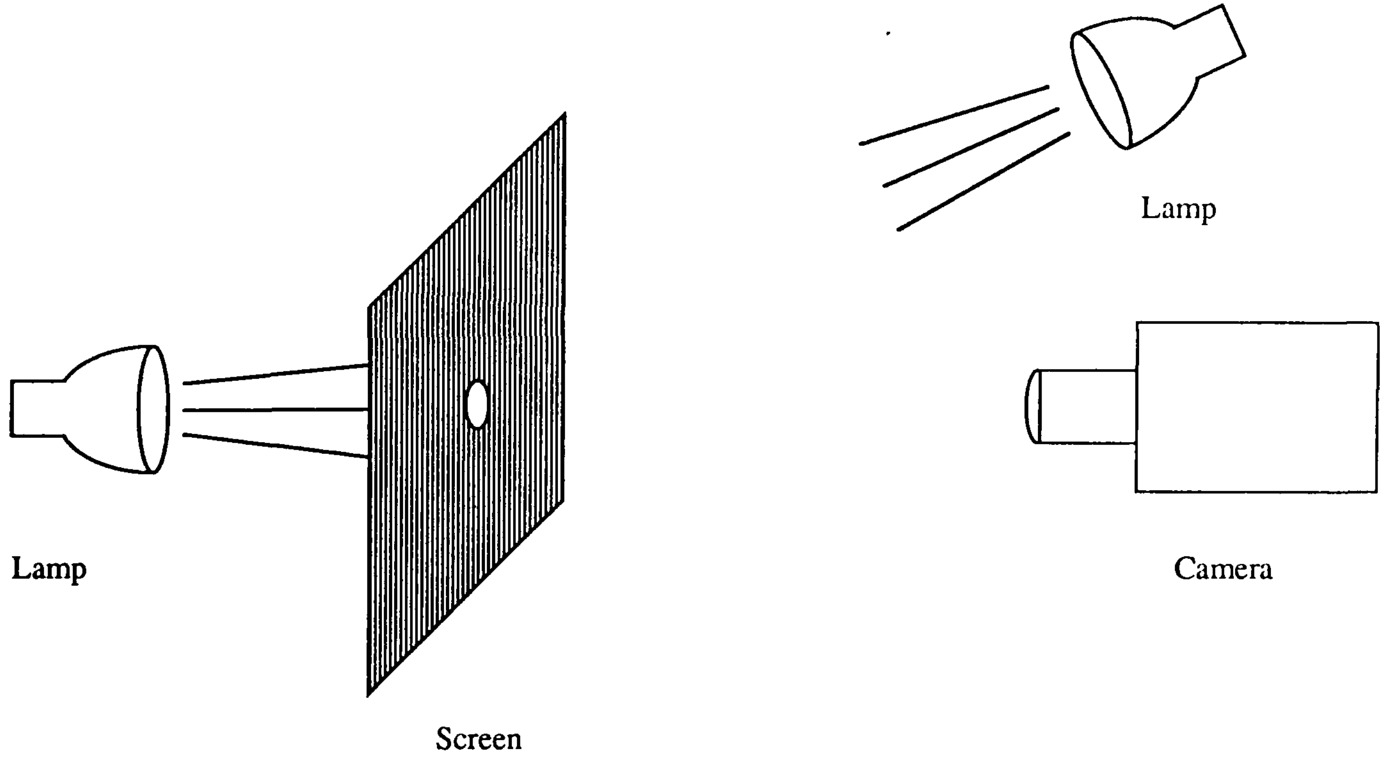

Figure 5. Depicting a method for quantifying bloom

the threshold SNR.

$$C = \frac{I_{max} - I_{min}}{I_{max} + I_{min}} \tag{8}$$

$$= \frac{SNR\, jnd}{2} \tag{9}$$

The jnd for the average observer is approximately 3% [Conrac, 1980]. The threshold SNR is the SNR required for detecting an object embedded in noise having a Gaussian distribution. Psychophysical studies indicate that this number is approximately 2.8 for the conditions tested [Rosell, 1979]. There is some question as to the generality of these results, however. A general rule of thumb indicates that an SNR of 6 is sufficient to produce reasonable probabilities of detection and false alarm rates. In other words, an observer will easily see a point source if the SNR is 6 or more. Half this may be sufficient. In this application, the point sources are obscured by a slowly varying bias, not noise, making detection easier. Thus a contrast threshold of 0.084 to 0.18 should be adequate for the identification task. This must be achieved within 280 μrad of the landing light location in order to identify an F/A-18 at 3 nmi.

The contrast threshold for viewing the airframe on-deck while the landing light is on is more difficult to determine. It depends on the location of the region of interest relative to the landing light. It also depends on the size of the object of interest. In order for an experienced image interpretor to make a technical analysis of an aircraft from a photograph, a nominal resolution of 0.03 m is required [Krass, 1985]. This corresponds to a 235 μrad resolution when viewed at 128 m, the approximate distance between the centerline camera and the end of the flight deck. For a 4° FOV, a 90 μrad camera resolution, an 11 *inch* monitor and a viewing distance of 18 *inches*, the 235 μrad requirement translates to a 10 *cycles/degree* spatial frequency. The corresponding contrast threshold for the human eye is approximately 0.01 [Bennett and Rabbetts, 1984].

While the limits presented here are reasonable based on analysis, psychophysical measurements, and experience, it is still necessary to consider the current capabilities of available hardware. Before defining the specification for inclusion in the purchase description it is preferable that the performance of several cameras be measured to determine a realistic range of performance.

It should be noted that in the dynamic range discussion, it was predicted that in order to image the navigation and landing lights simultaneously a camera dynamic range of 10^5 is required. Several manufacturers claim to provide this range. If these claims prove to be true, the blooming problem can be minimized during aircraft identification by reducing the aperture. This may result in a slight degradation in resolution, but the current clear aperture of 41.7 mm has a diffraction limited spot size of approximately 12 μrad. This is well below the 90 μrad requirement recommended above.

2.2.7 Signal to Noise Ratio

At low light levels, the SNR is dominated by shot noise. Shot noise is due to the discrete nature of photons and influences the level at which the camera SNR should be measured. The SNR quoted by the manufacturer is limited by the thermal noise of the electronics and is in most cases irrelevant.

The shot noise SNR is simply the square root of the number of photo-electrons collected by a single pixel during the detector integration time. It is given by

$$SNR_{sh} = \frac{\lambda \Phi A_d}{hct_i} \tag{10}$$

where

Φ = flux in the focal plane (W/m^2)
A_d = detector area (m^2)
h = Planck's constant ($6.63 \times 10^{-34}\ Js$)
c = speed of light
t_i = integration time (s)

This is smaller than the thermal SNR at low light levels and should be used when evaluating the cameras.

The 42dB SNR at 3×10^{-3} lux seems excessive. This implies a noise level that is 32dB below the minimum signal level. The just noticeable difference (jnd) of intensity is generally accepted to be 3% of the average intensity [Conrac, 1980]. Thus an image with an SNR of 15dB would appear to be noise free to the average observer. In addition, psycho-physical temporal integration will reduce the perceived noise to even lower levels.

We recommend that the SNR requirement be changed to 15dB at a face plate illumination level of 2.4×10^{-3} lux ($2.8 \times 10^{-3}\ W/m^2$).

2.2.8 Color Temperature

We recommend that this section be re-worded to state: The camera shall meet all performance specifications when scene illumination is provided by a source having a color temperature of 2854K, with the exception of the SNR specification. The camera shall meet the SNR specification when scene illumination is provided by a source having the spectral properties of a low pressure sodium vapor lamp.

2.2.9 Stray Light

When extremely bright sources are within the field of view, multiple reflections from the surfaces of the lenses become significant. Scattering from imperfections in the optics and dust particles and may also be important. In order for this stray light to be below the detection threshold, the ratio of stray to signal light must be less than 0.03. Note that the signal is not the peak beam intensity, which may be saturating the camera detectors, but is the intensity of the interesting part of the scene.

The amount of light reflected from the two surfaces of a lens and transmitted to the focal plane is given by

$$I_t = (1 - \rho)\rho^2 I_i \qquad (11)$$

where I_t is the transmitted stray light, I_i is the incident light, and ρ is the surface reflectance. Electron beam multilayer broad-band coatings are capable of reducing surface reflectances to less than 0.25% across the visible region. For a single lens, this will reduce the multiple reflections of the landing lights by a factor of 6.23×10^{-6}. This is about five times the level of the signal from the body of the aircraft. The actual flux density on the focal plane will be somewhat lower due to the fact that the stray light is out of focus. However, additional lenses will produce higher levels of stray light. It is likely that this will not be acceptable for viewing the aircraft itself while the landing lights are within the field of view.

There are two modifications that may be made to the optical system to reduce the stray light. First, the periscope tube may be modified by painting the interior with a highly absorbent paint. In addition, baffles may be inserted, particularly one at the focal plane between the relay lenses, to minimize the amount of stray light that propagates through the system. This will only reduce the light reflected off the surfaces of the first lens, however.

Second, we may then take advantage of the fact that the aircraft is illuminated by sodium vapor lights which have a spectral distribution very different from that of the landing lights. Since all of the energy of the low pressure sodium lights is emitted at 589.0 *nm* and 589.6 *nm*, an appropriate narrow-band interference filter may be placed in front of the camera system to filter out most of the landing light illumination. A 10 *nm* wide filter will reduce the unwanted light to about 0.3% of its unfiltered value, bringing the multiple reflections well below the level of the image of the aircraft.

We recommend that the optics of the camera system be required to have broad-band anti-reflection coatings having a maximum reflectance of 0.25%. If it is desired to view the aircraft on deck while the landing lights are illuminating the camera, we recommend that provision be made for inserting a narrow-band filter in front of the camera as well. This will not only reduce the stray light to minimal levels, but it will also reduce blooming.

2.2.10 Automatic Light Compensation

We recommend that the requirement of reacting to light level changes remain. If a proposed system could be permanently damaged by exposure to an extremely bright source, it should also be required to have an automatic safe-guard to prevent it from being damaged. Performance requirements discussed in previous sections will dictate the use of some sort of automatic gain control/iris. We recommend that specific implementations not be mentioned, however, since that is inconsistent with the fact that this document is a set of system requirements and not a system definition. If the vendors can meet all the system requirements, the actual method used is moot.

2.3 SYSTEM CONFIGURATION AND CONSTRUCTION

Most of the paragraphs in Section 3.3 of the purchase description are intended to ensure that the system meets various MIL-spec standards. Many of these will already be fulfilled by off-the-shelf equipment, or by straight-forward and inexpensive design modifications. We recommend, however, that a full life cycle cost-benefit analysis be performed on modifying off-the-shelf equipment to conform to these standards. The pros and cons of purchasing expensive, reliable units that require regularly scheduled maintenance versus inexpensive less reliable units that must be replaced may then be evaluated.

One paragraph that deserves additional consideration is 3.9.2.1, "Preventive Maintenance". The requirement that improper preventive maintenance be correctable in five minutes seems excessive unless the possibility of total system or component replacement is considered to be acceptable. As examples, consider the time required to clean a thumb print off of the lens, or to repair circuitry that has had a cup of coffee spilled onto it. The only five minute solution in these cases is replacement.

3 VENDOR SURVEY

Numerous vendors were contacted to obtain the specifications for their cameras. A complete list of the cameras investigated is presented in Table 5. The specifications for each camera were reviewed. The specifications are not listed in the table due to the fact that manufacturers are inconsistent in their definitions.

The extremely low light levels preclude the use of unintensified solid state and tube cameras, such as CCD, CID, and vidicons. The data sheets readily show that the most sensitive of these devices require more than 10^{-2} *lux* face plate illumination to produce a usable signal.

Two choices are available for intensified cameras. The first is to add an intensifier tube system to a camera using the appropriate relay optics. One such prepackaged front end is available from PULNiX America Inc. A more convenient choice is a camera with built in intensifier technology. These cameras fall into two groups, an intensified charge coupled device (ICCD) or an intensified tube such as the silicon intensified target (SIT) device. An ICCD consists of an image intensifier tube fiber-optically coupled to a CCD detector array. The ICCD retains some of the advantages of solid state imagers, such as freedom from lag, no geometric distortion, and a larger dynamic range. The best candidates were identified directly from the data sheets provided by the vendors. A careful examination of this smaller list produced three cameras that are most likely to achieve the desired performance. These cameras are listed in Table 6 with their published characteristics suitably interpreted so as to provide a legitimate comparison with the revised specification presented earlier in this report.

The dynamic range is limited by the camera damage threshold on one end and the target sensitivity on the other. As mentioned previously, the landing light intensity does not need to be measured. The lights may saturate the camera as long as they do not damage the target or cause unacceptable amounts of blooming. The dynamic range was thus calculated from the damage threshold and not from the saturation threshold quoted in some of the literature. Note that the damage threshold can be dependent on the number of operating hours. A greater dynamic range may be accommodated at the expense of camera lifetime.

The SNR listed in the table is not the thermal noise (the figure usually quoted by the manufacturer) but the shot noise at the lowest light level. Note that the performance of off-the-shelf hardware may vary from the published data. These cameras should certainly be tested before making a purchase decision to ensure that they live up to their potential under operational or quasi-operational conditions.

A comparison of ICCD and SIT cameras shows that many of the published parameters

Table 5: Cameras Investigated in ILARTS Vendor Survey

Manufacturer	Technology	Model
Amperex	Frame CCD	NXA 1010
Burle	ICCD	TC400
Burle	SIT	TC1030/H
Burle	ISIT	TC1040/H
CID Technologies	CID	CID2710
COHU Inc.	CCD	Model 4810
DAGE-MTI	Vidicon	66 Series
DAGE-MTI	SIT/ISIT	Intensified 66 Series
Fairchild	Interline CCD	222
General Electric	CID	TN 2200
General Electric	CID	TN 2500
General Electric	CID	TN 2505
General Electric	CID	TN 2506
Micro Luminetics	CCD	Model 80
Photometrics	CCD	Star I
PULNiX	Image Intensifier	DN-5034
PULNiX	Interline CCD	TM-34k
RCA	Frame CCD	SID-504
RCA	Frame CCD	SID-006
RCA	Frame CCD	SID-501
Reticon	MOS-XY	100x100 array
Reticon	MOS-XY	128x128 array
Reticon	MOS-XY	256x256 array
Sierra Scientific	CCD	MS-4030
Sony	Interline CCD	XC-37
Spin Physics	MOS-XY	SP-2000
Tektronix	Interline CCD	TK512M
Tektronix	Interline CCD	TK2048M
Texas Instruments	Line Address CCD	
Thompson-CSF	Frame CCD	TH7851
Thompson-CSF	Frame CCD	TH7861
Thompson-CSF	Line Addressed CCD	TH7862

Table 6: Specifications Compared With Camera Performance

Manufacturer	Model	Type	Light Range (*lux*)	Dynamic Range (*dB*)	Resolution (TV lines)	Grey Scale	SNR (*dB*)
Specification	-	-	5E-4/2.2E3	44	400	10	15
Burle	TC400	ICCD	2.5E-4/2.5E4	36.0	520	10	20.6
Burle	TC1030/H	SIT	2.7E-4/2.4E5	35.7	550	10	21.7
DAGE-MTI	66 Series	SIT	1E-4/1E4	43.0	700	10	21.7

are comparable. As mentioned previously, ICCDs do not suffer from lag or geometric distortion. While the DAGE-MTI SIT may seem to have a much greater dynamic range, it is a function of tube lifetime. The SITs are slightly more sensitive and have higher resolution. SIT cameras are more susceptible to damage by high contrast images and high illumination levels. In addition, the SIT tubes wear out and must be replaced approximately every two years. A major unresolved issue is the relative amount of blooming experienced by the two architectures. Laboratory and field measurements will be required to determine which type of camera has less blooming.

4 ALTERNATIVE ARCHITECTURES

4.1 FLIR

In this section we shall examine the possibility of using a FLIR as the ILARTS imaging device. The primary advantage of using a FLIR is that the glass covers on the landing lights absorb the radiation between 8 and 10 μm. Thus the only energy collected by the FLIR is that which is emitted by the hot cover glass, which is at a considerably lower temperature than the filament. The FLIR will therefore not have the dynamic range and blooming problems that a visible light camera has.

There are several other factors to be addressed that may offset this advantage. Resolution is of primary concern, since the wavelength increases by a factor of 20. Also, the smaller signal from the lamp and increased atmospheric absorption may decrease the maximum detection range. The contrast will also be reduced by atmospheric radiance. Finally, there is a question of sensitivity; FLIRs tend to be noisier than visible light cameras, especially when pattern noise is considered. The scope of this study has permitted only a cursory investigation of these issues. We will confine our discussion to resolution, dynamic range, sensitivity, and some logistical considerations.

4.1.1 Resolution

The angular resolution of a rectangular aperture is given by the ratio of the average wavelength and the aperture size. For the centerline camera aperture the resolution spot size is 720 $\mu rad \times 250$ μrad. This exceeds the resolution requirement for determining roll, pitch, and yaw. Identification from the light configurations would be difficult for ranges greater than 1 *nmi*. A 10 *cm* diameter aperture is required in order to achieve a 90 μrad resolution. This suggests that two options are available for implementing a FLIR. First, the aperture for the centerline camera could be enlarged. This is not likely to be very desirable. Second, the FLIR could be used only at the deck edge or island stations.

4.1.2 Dynamic Range

Many of the FLIR requirements are dependent on the temperature of the landing light cover plate. We have attempted to estimate this temperature, but it must be remembered that any quantities derived from it are only rough estimates. They will, however, indicate whether the concept is feasible. It was not possible to obtain more refined results within the scope of this study.

We estimate that the face plate of the 600 *Watt* lamp described in Table 3 will absorb approximately $100W$ of power. If we ignore the wind chill, the lamp will radiate as a 500 K blackbody. This is probably too high, but it will serve to put an upper bound on the dynamic range required. Assuming an aircraft skin temperature of $285K$ and an emissivity of 0.87, a $10dB$ dynamic range is required to image the landing lights and the airframe at the same time. This is eight orders of magnitude smaller than required in the visible.

The radiance of the exhaust plume also needs to be considered. The hottest portions will be masked by the airframe, however. It is expected that the unobstructed portions of the plume will have temperatures on the order of 370 K to 420 K [LaRocca, 1978], which is lower than the temperature assumed here. Thus even when considering the plume radiance, 10 dB dynamic range should be sufficient.

4.1.3 Sensitivity

The noise equivalent temperature requirement is determined by the maximum detection range. The noise level must be low enough that the lamp plus sky radiance can be reliably distinguished from the sky radiance. Using the lamp assumptions from the previous section and assuming atmospheric transmittance of 0.56 and an IFOV of 100 μrad, an $NE\Delta T$ of $0.04°C$ is required to detect the aircraft at 10 nmi. This is easily achieved by commercially available FLIRs. Note, however, that this is not a lower bound, but rather a rough estimate. The landing light must be characterized more accurately to obtain a better estimate.

4.1.4 Logistics

The most sensitive FLIRs use liquid nitrogen to cool the detectors, reducing the thermal noise to acceptable levels. This requires a considerable supply of liquid nitrogen for extended cruises. In addition, as the nitrogen boils away it must be vented. Although completely nontoxic, it can displace the oxygen in a confined space, creating a hazard for personnel. Thermoelectric cooling is used in some cases in place of liquid nitrogen, but it does not keep the detector as cold. The higher noise levels may not be acceptable.

Another consideration is that the germanium optics used in infrared systems are susceptible to damage by water and salt spray. While this limitation can be overcome with diamond-like carbon coatings or special windows, these features are not likely to be found on commercial FLIRs not designed for military use.

4.2 VIDEO SIGNAL PROCESSING

Light levels high enough to produce blooming will alter the image in two ways. The impact of each of these can be mitigated somewhat by a simple signal processing technique. The two artifacts are saturation at the center of the image of the source and a contrast reduction that varies slowly with radial distance from the saturated area. These may be reduced by applying a high-pass filter to the image. This can be implemented in many ways.

4.2.1 Line Filter

The video signal may be passed through a high-pass filter before it reaches the monitor. The filtering may degrade the synchronization signal and other non-image information. Some additional electronics will be required to strip the image from the video signal, filter it, then recombine it with the other information before passing it on to the monitor.

4.2.2 Digital Filtering

High-pass filtering can be accomplished on a digitized image using simple neighborhood operations. Hardware and software for digitizing, filtering, and reproducing a video signal are commercially available. While we have not conducted a vendor survey in this area, we do know that near real-time capability is available. Since the processing operation is relatively simple, we expect that real-time capability is also available.

4.2.3 Image Subtraction

This technique forms a high-pass image by subtracting an out of focus image (low-pass) from a focussed image. This may be accomplished by using successive frames from a single camera or by using registered frames from two cameras. The first method is limited by the fact that an aircraft approaching at 100 kt moves approximately 80 cm between 60 Hz frames. The second method requires that the cameras be registered. This adds to the hardware required, not just for the extra camera but also for the mounts. Of the three filtering techniques, this is the most difficult to implement.

5 SUMMARY AND CONCLUSIONS

The ILARTS operational requirements have been analyzed. System parameters which permit these requirements to be met have been quantified. The purchase description has been re-examined in light of these requirements and recommendations for modifying the purchase description have been made. In particular it is concluded that the light range, dynamic range, signal-to-noise ratio and MTF requirements may be relaxed while still achieving the required operational needs. A new technique for quantifying blooming is presented and a specification developed.

Several modifications for improving system performance have been analyzed. A narrow band filter that passes only the sodium emission lines can be used to reduce the intensity of the landing light when imaging the airframe as well as stray light due to multiple reflections. Special anti-reflection coatings on the optics and baffles may also be used to reduce the stray light. The loss of contrast in the image due to blooming may be minimized by applying a high pass filter to the imagery. Several methods for implementing a filter have been presented.

A survey of camera vendors has been completed. While it was found that none of the commercially available systems could meet the purchase description specifications, three cameras were identified that are most likely to meet the recommended changes.

A brief analysis of using a FLIR as the ILARTs imager is also presented. Resolution, dynamic range, and sensitivity have been addressed. In addition, the trade-off between the lack of blooming versus the degraded resolution, the logistics of liquid nitrogen, and the requirement for protecting the optics has been identified. The scope of this study did not permit development of a complete specification or a survey of vendors for the FLIR option.

6 REFERENCES

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A Recommended Purchase Description Changes

The following are recommended changes to the ILARTS purchase description. They are labeled with the paragraph numbers of the original description for convenience.

3.2 System Performance and Operation

3.2.1 Light Range

The camera and lens imaging system shall be capable of operating when viewing scenes that would produce face plate illumination levels from 5×10^{-4} *lux* (2×10^{-6} W/m^2) to 2.2×10^3 *lux* (8.6 W/m^2) in the absence of auto-irising or other intensity limiting techniques. Intensity limiting techniques may be used to reduce the actual face plate flux levels so long as the remaining system specifications are met.

3.2.4.1 Scanning Mode

The scanning mode shall be two to one interlace, with an aspect ratio of four to three, at 525 lines per frame and 30 frames per second. Scanning may be produced using a scan converter.

3.2.5.1 Limiting Resolution

The camera/lens system shall be capable of resolving two point sources within a four degree field of view separated by $90 \mu rad$ using the Rayleigh resolution criteria.

3.2.5.2 Modulation Transfer

The camera and lens imaging system shall meet or exceed the following requirements viewing a suitable standard test chart illuminated so as to provide a face plate illumination of 5×10^{-3} *lux* (2×10^{-5} W/m^2).

TV Lines	Square Wave Response
0	100
50	78
100	56
200	27
300	10
350	4

3.2.5.3 Gray Scale

The camera and lens system shall resolve 10 shades of gray when a RETMA test chart is illuminated to produce face plate illumination levels of $2.4 \times 10^{-3}\ lux$ $(2.8 \times 10^{-5}\ W/m^2)$.

3.2.5.4 Blooming

When viewing a point source producing a faceplate illumination of $3 \times 10^4\ lux$ $(122\ W/m^2)$, the blooming shall not reduce the contrast of a bar chart producing face plate illumination of $3.94\ lux$ $(1.57 \times 10^{-2}\ W/m^2)$ below 0.1 at a distance of $280\ \mu rad$ from the location of the point source.

3.2.5.8 Signal to Noise Ratio

The SNR shall be greater than $15dB$ at a face plate illumination level of $2.4 \times 10^{-3}\ lux (2.8 \times 10^{-3}\ W/cm^2)$.

3.2.5.9 Color Temperature

The optics of the camera system shall have broadband anti-reflection coatings having a maximum reflectance of 0.25% between 0.4 and 0.7 μm.

3.2.7 Automatic Light Compensation

The camera shall be capable of maintaining the video output signal within 3 dB over the camera and lens imaging system operating range specified in Section 3.2.1. The system shall be capable of reacting to a change in light level of 1000 to 1 within 1 second.

3.9.2.1 Preventive Maintenance

The following sentence should be added after the first two: "Substitution of major system components is acceptable if the five minute limit will be exceeded by the corrective action."

B Deck Illumination on the U.S.S. Lexington

NAEC 3905/1 (5-80)

FROM Test Department (Code 54A ~~[illegible]~~, Bldg 355, NAEC	TEST AREA AVT-16	EFFORT Normal	TPR NO. NAEC-TDTP-87-A02
TO → Program Manager (Code 51114)	TASK PERIOD 8 - 10 Jun 87		DATE 24 Jul 87
	PROBLEM ASSIGNMENT		J.O. 536317
PROJECT TITLE USS LEXINGTON - FLIGHT DECK LIGHTING SURVEY	TASK TITLE		

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSION: See page 2.

RECOMMENDATION: See page 2.

D. GEISE 5411 B. R. LAUB/D. J. SPALLUTO

TEST ENGINEER, CODE BRANCH/DIVISION HEAD

H. KARL BIESTER

~~XXXXXXXXXXXXXXXXX~~

TEST DIRECTOR

1ST ENDORSEMENT *(Indicate action being taken or recommended.)*

In regards to page 2 recommendation; three white overhead floodlights have been added to the existing bank of six fixtures for a total of nine floodlights. This new arrangement provides a more even distribution of light on the flight deck.

51132

CODE

SECOND ENDORSEMENT *(Indicate action being taken.)*

SEE FIRST ENDORSEMENT

P. Miller 5114

PROGRAM MANAGER CODE

DISTRIBUTION OF ENDORSED REPORT

5411	3	54A13	1	51131	1	511	1
541	1	5113	1	51390	1		

ISSUED BY ....

DATE 10-8-87

GENERAL

1. Because of a decrease in the number of white overhead floodlight (WOF) fixtures from 23 to 6, it was desired to conduct a survey of illumination levels at various points on the flight deck. Readings in foot-candles were taken at twenty-eight different points on the flight deck. Refer to enclosure (1) for point locations.

DISCUSSION

2. Instruments used were as follows:

a. United Detector Technologies Model 40A with cosine corrected probe.

b. Minolta Photometer

3. Light readings were taken under totally dark ambient conditions, first with all low pressure sodium (LPS) fixtures on, and then with just the six WOF fixtures illuminated. Readings designated as H (horizontal) on enclosure (2) data sheet were taken with the probe/meter lying flat on the deck. Readings designated as V (vertical) were taken with the probe/meter hand held approximately 18 inches above the deck and aimed at the light source.

4. A questionnaire outlining the major points of consideration, enclosure (3), was compiled and a response elicited from the Air Officer. The response is included in page 2 of enclosure (3).

5. It can be seen from the data and the deck plan, enclosure (1), that certain areas of the flight deck have illumination levels of less than .1 foot-candles with the WOF lights. These areas, circled on enclosure (1), include elevator No. 2, the area aft of the island including elevator No. 3, and the angled deck aft of frame 140. In addition, the bow and fantail areas were very poorly lit.

CONCLUSION

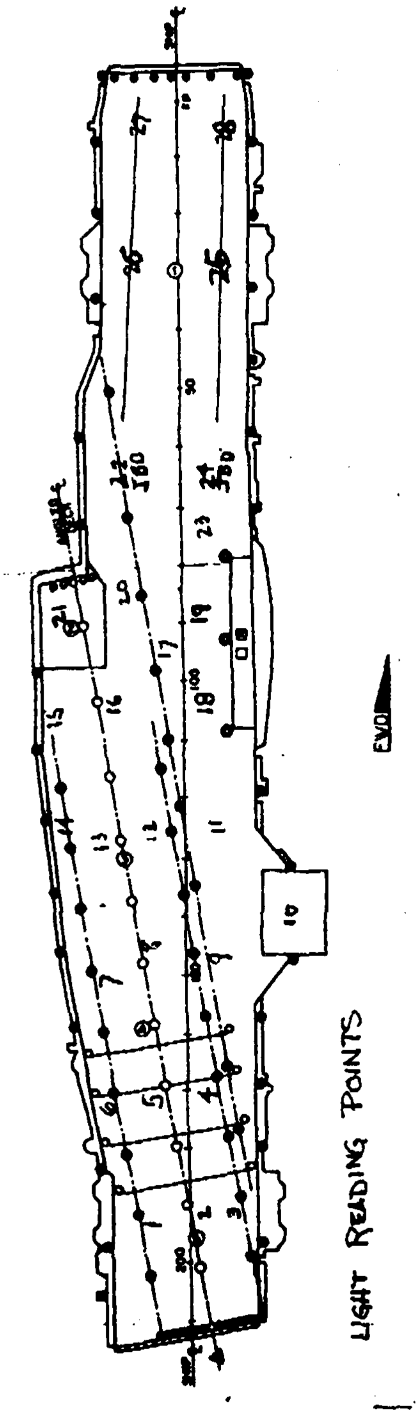
Certain areas of the flight deck, circled on enclosure (1), received inadequate lighting from the white overhead floodlight (WOF) fixtures.

RECOMMENDATION

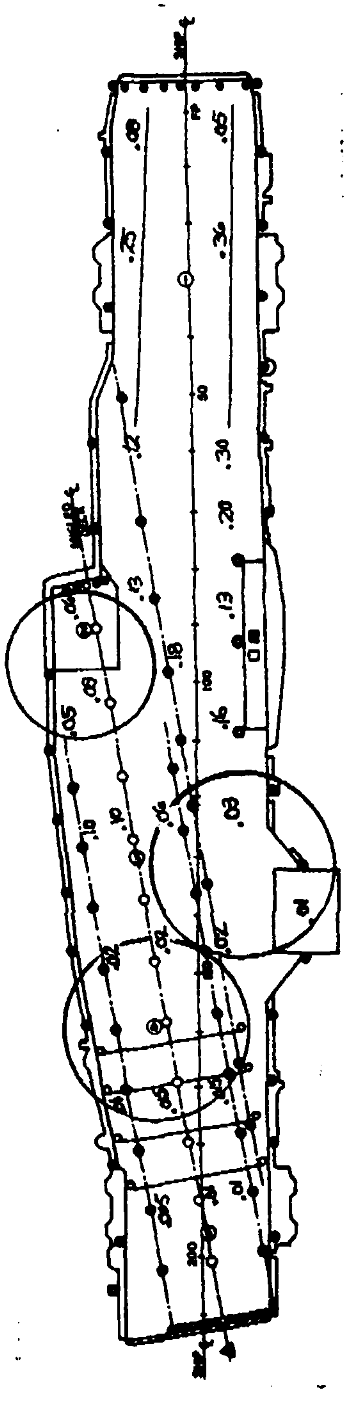
Recommend consideration be given to increasing the number of WOF fixtures utilizing existing mounting stanchions left in place from previous installation.

ENCLOSURES

(1) Light Reading Point Locations
(2) Data Sheets
(3) Questionnaire



LIGHT READING POINTS



WOF Fixtures - Readings in Horiz Foot-Candles

Enclosure (1)

6-8-87

TEST DATA
4ND-NATF 5230/9 (1-70)

AVT-16 LIGHT SURVEY

U - United Detector Tech
M - Minolta

	LPS-U		LPS-M			WOF-U		WOF-M						
SPOT	V	H	V	H		V	H	V	H					
1	.03	.005	.049	.012		.015	.005	.024	.011					
2	.03	.01	.051	.018		.02	.01	.026	.012					
3	.03	.005	.049	.011		.02	.01	.021	.01					
4	.065	.02	.105	.027		.02	.015	.03	.014					
5	.065	.02	.103	.031		.02	.015	.029	.014					
6	.06	.02	.075	.033		.02	.010	.024	.013					
7	.15	.04	.209	.055		.04	.02	.048	.021					
8	.17	.05	.243	.074		.04	.02	.044	.021					
9	.20	.06	.279	.09		.04	.02	.049	.025					
10	.20	.1	.279	.089		.018	.01	.016	.007					
11	1.2	.45	1.61	.858		.056	.03	.058	.034					
12	.8	.4	1.20	.636		.11	.06	.120	.071					
13	.5	.2	.718	.297		.24	.10	.254	.122					
14	.3	.1	.456	.663		.25	.10	.207	.121					
15	.4	.2	.551	.263		.10	.05	.097	.054					
16	.6	.2	.900	.448		.15	.08	.166	.097					
17	.8	.5	1.09	.801		.25	.18	.289	.220					
18	.45	.3	.639	.546		.22	.16	.242	.194					
19	.7	.7	.98	.99		.13	.13	.146	.148					
20	1.0	.7	1.32	.977		.19	.13	.210	.163					

6-8-87

AYT-16 LIGHT SURVEY

U - United Detector Tech
M - Minolta

	LPS-U		LPS-M			WOF-U		WOF-M	
SPOT	Y	H.	V	H		V	H	Y	H
21	.60	.27	.789	.388		.13	.06	.140	.073
22	.44	.17	.584	.287		.19	.12	.232	.129
23	.54	.37	.64	.577		.38	.20	.408	.325
24	.74	.45	.99	.549		.50	.30	.615	.368
25	.085	.022	.128	.042		1.2	.36	1.32	.378
26	.08	.022	.114	.037		.84	.25	.866	.282
27	.03	.01	.047	.012		.28	.08	.320	.079
28	.03	.01	.049	.016		.26	.05	.315	.077

QUESTIONNAIRE

"Present flight deck lighting is adequate. Installed white floodlights provide enough light for immediate emergencies and LPS lights are more than adequate for every other need". (USS LEXINGTON 081815Z May 87)

Some of the below compound emergencies/unusual situations may not have been considered in the above statement. It is requested that LEXINGTON review these and determine whether the low operational probability of occurrence combined with the ability of ship's company to function with existing lighting warrants the installation of additional overhead white floodlights. A generalized (vice itemized) reply is requested.

COMPOUND EMERGENCIES/UNUSUAL SITUATIONS

a. Night time fire on the flight deck when not conducting flight operations (i.e., when LPS floodlights are secured). Request that you also consider:
    (1) The effects of glare from turning the existing white overhead floodlights to maximum intensity to compensate for their number.
    (2) The possibility of concurrent failure of one of the existing white overhead floodlamps.
b. Simultaneous crash on the flight deck and LPS floodlight circuit failure.
c. Failure of the LPS floodlight circuit with a low state (i.e., unable to BINGO) aircraft in the pattern.
d. Failure of the LPS circuit with a plane on short final.
e. Unscheduled emergency recovery (e.g., another ship's aircraft).
f. Unscheduled FOD walkdown requiring more light than would be available from the banks of LPS lights operating at the time of the causative incident.

USS LEXINGTON CVT-16

FROM: AIR BOSS

TO:

VIA:

DATE

SUBJECT:

a. (1). Glare is not a problem with white floods.

(2.) Failure rate is very low. (Est. 3 in last 3 years) There are two per bank and they are checked daily.

b. Remote, but LPS would be on low. We operate with this light and could respond until LPS brought up.

c. Lex does not operate "blue water. I have not seen a plane below bingo at night in 2½ years. Flood lights are not required to recover an aircraft. Risk insignificant.

d. Floods could be turned on. Aircraft could be waved off. Flight deck floods (white or LPS) are not essential to land an aircraft. (but obviously desirable.)

e. Lex is the only carrier in the Gulf of Mexico.

f. We now use white floods for routine FOD walkdowns. They provide enough light.