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ASSESSMENT OF INTERIOR MODIFICATIONS IN C-130 AND C-141 AIRCRAFT FOR NIGHT VISION GOGGLE OPERATIONS (U)

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WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

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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.

The voluntary informed consent of the subjects used in this research was obtained as required by Air Force Regulation 169-3.

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

FOR THE COMMANDER

Kenneth R Boff

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An evaluation was conducted to examine the effects of interior paint scheme modifications to C-130 and C-141 aircraft on night vision goggle (NVG) operations. The evaluation consisted of direct measurement of aircraft interior radiance levels, calculation of surface reflectivities, and a human factors assessment of effects on aircrew NVG performance.. The data were collected for both modified and original interior scheme C-130 and C-141 aircraft at Pope AFB and Charleston AFB, respectively. Reflectance values were determined for various flight deck and cargo bay surfaces. The reflectance values were calculated from the radiance levels within the sensitivity range of the NVGs. The results indicated that the reflectances were higher in modified aircraft for the majority of surfaces measured, but well within the specifications set by the relevant military standard. The human factors evaluation indicated that the vast majority of aircrew responding experienced no adverse effect on NVG performance attributable to the new interior scheme. In general, it was concluded that the modified interior scheme should not interfere with NVG operations.

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SUMMARY

An evaluation was conducted to determine if modifications made to the interiors of the C-130H and C-141B aircraft interfere with night vision goggle (NVG) operations. These modifications were completed as part of the Military Airlift Command's (MAC) Equipment Excellence Interior Material Program. The purpose of the evaluation was to determine if modifications made to the cockpit and cargo areas of these aircraft had any substantial effects on the spectral reflectivity of the surfaces involved which could in turn interfere with NVG flight operations. A subjective assessment of the modifications was also conducted, in which questionnaire results were obtained from flight crew members who had flown NVG missions in both modified and unmodified aircraft.

The evaluation consisted of two components: 1) Measurements of interior radiance levels and calculation of surface reflectances; and 2) A human factors subjective assessment of effects on NVG operations. Data were collected from 13-16 April 1992 at Pope AFB, NC, and Charleston AFB, SC.

In general, the results indicated that the interior modifications that were completed as part of the Equipment Excellence Interior Material Program should not adversely affect NVG operations. The interior surface reflectances calculated from the measurements made were in most cases somewhat higher in the modified aircraft than the original configurations. The maximum allowable NVIS radiance levels specified in MIL-L-85762A were used to interpret the significance of actual surface NVIS radiances. Only one modified surface caused serious concern. The subjective assessment showed that the majority of aircrew who participated in the evaluation did not perceive a difference between the modified and original interiors, and that no adverse effects on NVG operations are anticipated.

PREFACE

At the request of the Military Airlift Center, Pope Air Force Base, North Carolina, this evaluation was completed under work unit 7184-18-07 by members of the Visual Display Systems Branch, Human Engineering Division, Crew Systems Directorate, Armstrong Laboratory, Wright-Patterson Air Force Base, Ohio and Logicon Technical Services, Inc., Dayton, Ohio. Funding for this study was supplied by the Military Airlift Center.

The authors wish to thank Mr. Greg Bothe of the Science Applications International Corporation for his outstanding technical assistance with the video data collection and the United States Air Force Airlift Center, Pope Air Force Base, North Carolina for their tremendous scheduling effort that made this study possible.

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I. INTRODUCTION

A new program has been initiated by Military Airlift Command (MAC) headquarters for enhancement of transport aircraft. The Equipment Excellence Material Program consists of a new paint scheme, major interior refurbishment, and upgraded maintenance of aircraft appearance. One modification is a new tri-color interior, which replaces the original five color layout consisting of the following colors: dark blue, glossy beige, and light blue-green. Both the cockpit and cargo areas of the aircraft involved exhibit the new colors. In addition, changes were made to the texture of some flooring materials.

At the request of USAF Airlift Center at Pope AFB, personnel from the Visual Display Systems Branch of the Armstrong Laboratory at Wright-Patterson AFB evaluated the modified aircraft interior paint/material scheme for possible adverse effects on night vision goggle (NVG) operations. Evaluations were performed on C-130H and C-141B aircraft. Of specific concern was whether any increased surface reflectivities resulted from the interior modifications and what impact such increases might have had on NVG operations.

The evaluation was divided into two parts. The first consisted of measuring NVIS radiances of a variety of interior surfaces in both modified and unmodified aircraft and then calculating surface reflectances in the NVIS spectral region. NVIS radiance values were collected with a field portable instrument designed for cockpit lighting inspections. Surface reflectance was chosen as the primary evaluation metric to provide a consistent basis for comparison between aircraft versions. In addition, because the amount of windscreen glare is so important to aircrew members, attempts were also made to measure the NVIS radiance of several windscreen locations in each aircraft. This was followed by an aircrew subjective human factors assessment of possible influence on NVG operations. This assessment consisted of a questionnaire and interviews with NVG-qualified aircrews that had flown NVG missions in modified aircraft. The major findings of the evaluation are outlined in this report.

II. METHODS

Radiance Measures

Measurements of surface NVIS radiance values were made in modified and unmodified versions of the C-130H and C-141B aircraft under similar interior lighting conditions. NVIS radiance limits specified in MIL-L-85762A were used as thresholds to identify surface areas of particular concern. The radiance data were used to calculate surface reflectances in the NVIS spectral region. NVIS radiance values alone collected for any specific interior position were judged to be overly affected by variables beyond the control of the evaluators, most notably time varying levels of in-cockpit infrared energy due to exterior sources, to serve as a basis for accurate absolute comparisons between aircraft interior designs. However, given the availability of a reflectance standard, an accurate reflectance could be calculated for each type of surface. Based on these calculated surface reflectances, a comparison was made between the modified and unmodified versions of each respective aircraft to determine the potential for interference with NVG operations.

An NVG-103 Night Vision Imaging System (NVIS) Cockpit Inspection Scope manufactured by Hoffman Engineering Corporation was configured for AN/AVS-6 NVG emulation and used to collect quantitative radiometric data on the flight deck and in the cargo bay. The AN/AVS-6 (ANVIS) system is the type of NVG currently used by crews of the aircraft types involved and is based on a Generation III (Gen III) image intensifier tube. The NVG-103 design is based on matching the brightness of an adjustable reference provided within the instrument's field of view to the apparent brightness of the target. The uncertainty inherent in brightness matching was reduced by collecting twelve data at each location, six measures of the surface of interest and six of a barium sulfate tablet. Barium sulfate presents a greater than 95% reflective, Lambertian surface throughout the visible and near infrared portions of the electromagnetic spectrum. Further, half of all measures were initiated with the brightness reference set below that of the target and half with the initial reference setting brighter than the target. To further document the color and material modifications, 35mm color photographs and conventional super-VHS video were obtained. In addition, image intensified video in super-VHS format was collected for qualitative evaluation purposes.

All measurement sessions were conducted after local sunset in aircraft located in their normal parking ramp spot. The windscreens were covered with black cloth to minimize the effects of exterior lights to the greatest extent possible. Prior to each measurement set, cockpit lighting levels were established by qualified flight crews. Eight measurement locations were selected in each aircraft; four locations on the flight deck and four locations in the cargo area. In addition, because the amount of windscreen glare is so important to aircrew members, attempts were also made to measure the NVIS radiance of four windscreen locations in each aircraft. Windscreen areas exhibiting both low and relatively high levels of glare as seen by NVGs were evaluated. Reflectances were not calculated for these windscreen locations. These NVIS radiances were interpreted in terms of the guidelines in MIL-L-85762A. The measurement locations for the C-130H and C-141B flight decks are shown in Figures 1 and 2, respectively.

To establish the total NVIS irradiance from all sources incident on each cockpit surface being evaluated, a measurement was made of the NVIS radiance of a barium sulfate tablet placed upon that surface. Total NVIS irradiance at any interior location was comprised of energy emitted from the cockpit and from external sources such as moonlight and ramp lighting bleeding through the black tarps covering the windscreens. The NVIS radiance of the cockpit surface itself was then measured. The ratio of these two NVIS radiance values is effectively the broadband reflectance of the surface of interest in the NVIS spectral region.

Mathematically, this can be represented by:

$$R_{NVIS} = \frac{\int_{450}^{930} S(\lambda)*N(\lambda)\, d\lambda}{\int_{450}^{930} T(\lambda)*N(\lambda)\, d\lambda} \qquad (1)$$

where R_{NVIS} = NVIS broadband reflectance,
$S(\lambda)$ = Radiance of the surface under test,
$T(\lambda)$ = Radiance of barium sulfate, and.
$N(\lambda)$ = Gen III spectral response.

Measurements were made of one modified and one unmodified version of the C-130H and the C-141B aircraft (a total of four aircraft). Results from the unmodified aircraft were used as a baseline for comparison with the modified versions. To ensure consistent initial overall cockpit NVIS radiance levels between modified and unmodified versions of the same aircraft type for measurement repeatability, a black surface and a gray surface on the instrument panel were chosen as reference points and measured. These particular locations were chosen because the colors and finishes were the same in all four aircraft evaluated. Figure 3 shows the approximate location of the reference points for the C-130 and C-141 cockpits.

Four locations were evaluated in the cargo area of each aircraft, consisting of the paratroop doors, and several points on the ceilings. The same measurement procedures described for the flight deck were used in the cargo areas. Due to the extremely low light conditions prevailing in the cargo bays, it was necessary in most cases to use infrared chemical lights to provide sufficient irradiance for measurements. The blue and glossy beige paints used in the cargo areas of the modified aircraft are identical to those used in the cockpit.

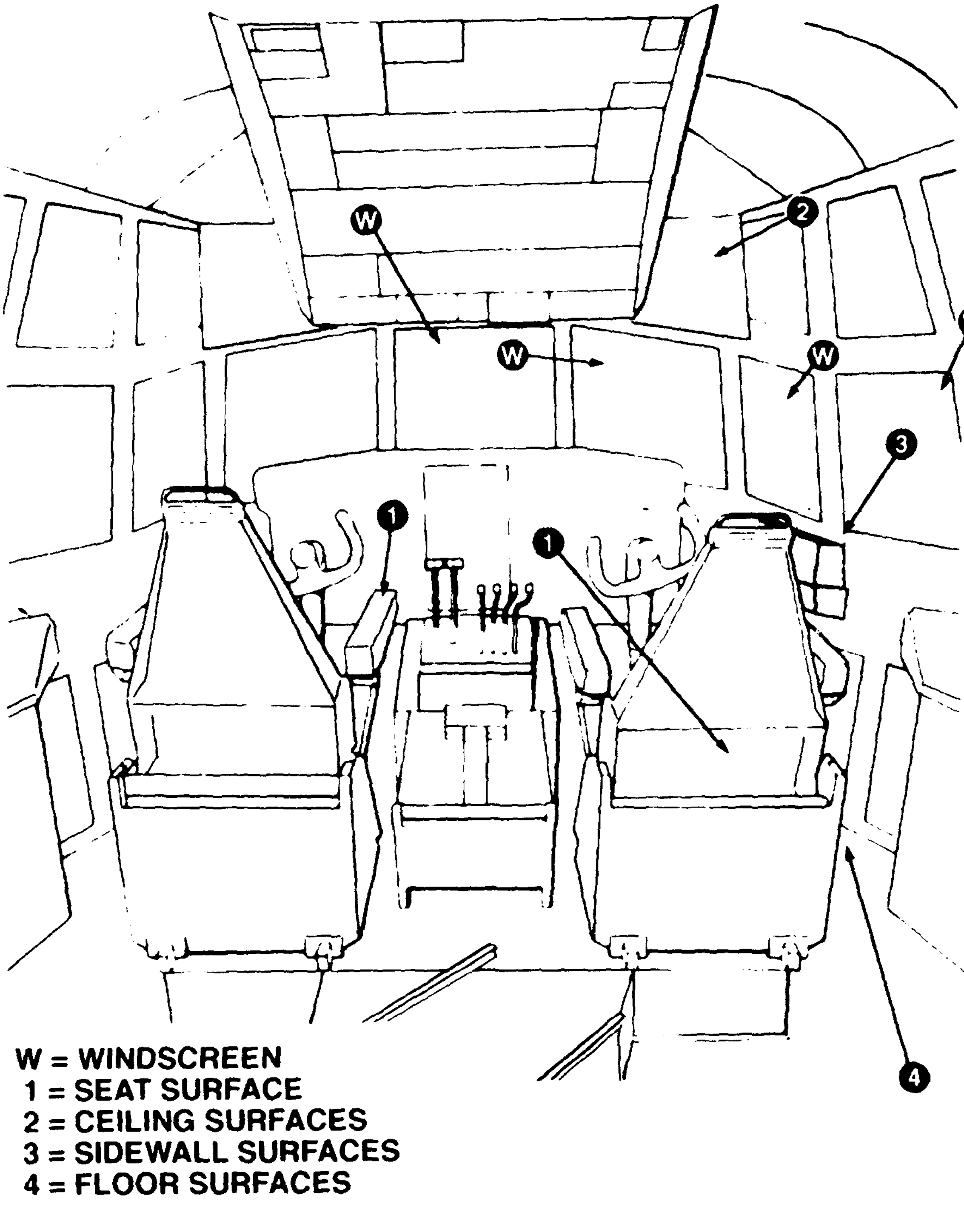

Figure 1: Radiance Measurement Locations on the C-130 Flight Deck.

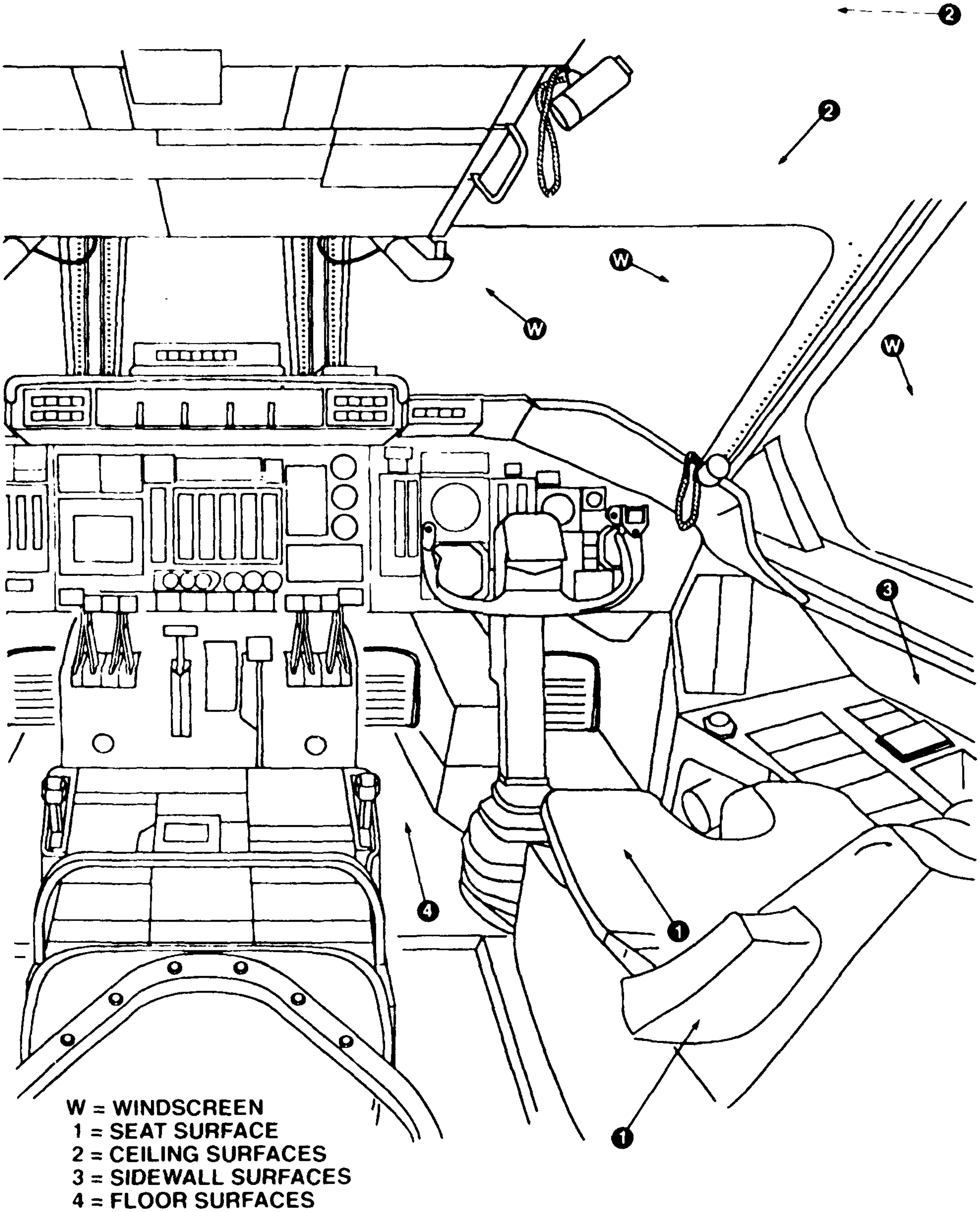

Figure 2: Radiance Measurement Locations on the C-141 Flight Deck

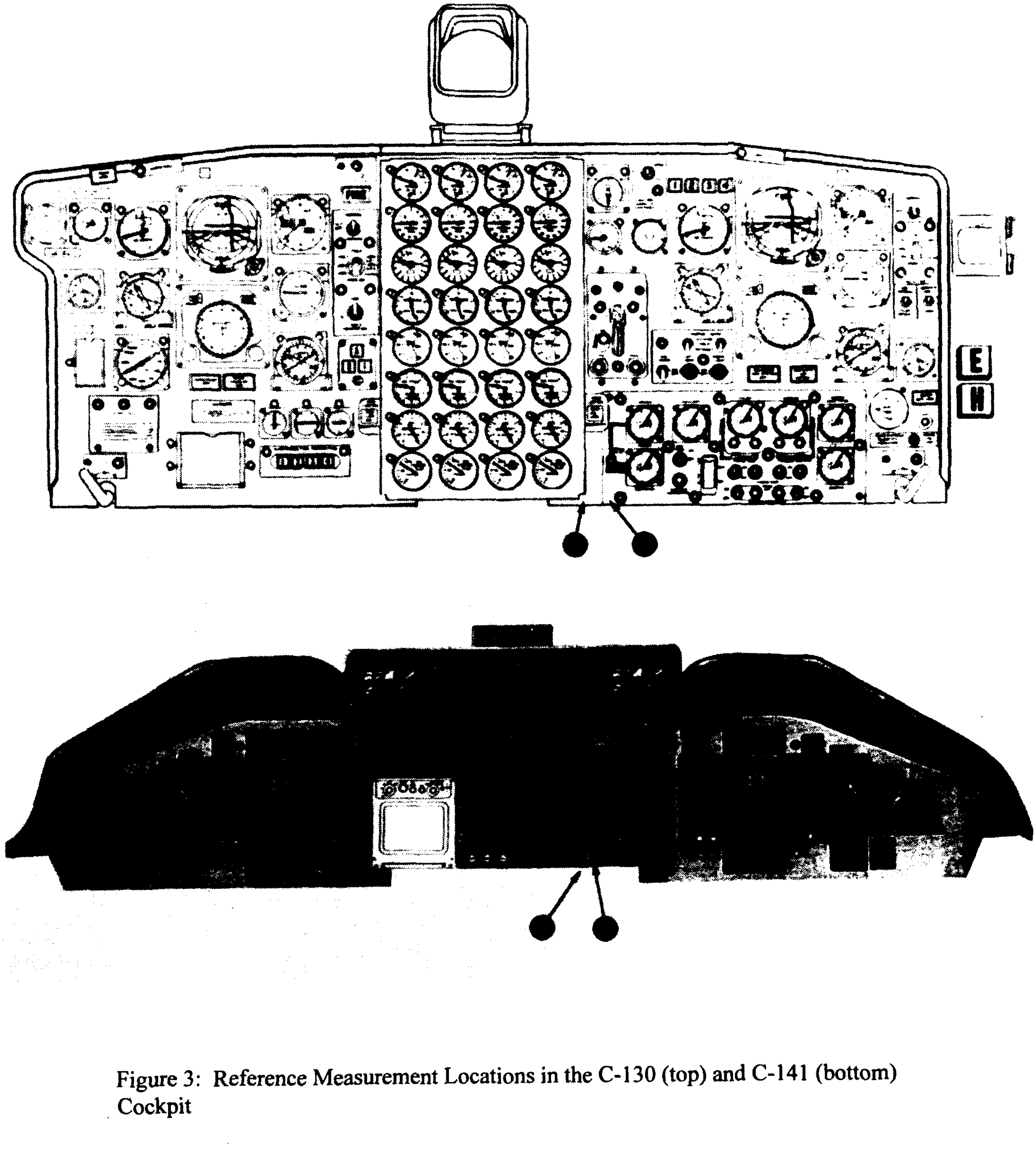

Figure 3: Reference Measurement Locations in the C-130 (top) and C-141 (bottom) Cockpit

Human Factors Evaluation

A brief questionnaire (shown in Appendix A) was administered to ten C-130 and eleven C-141 crewmembers. The questionnaire was designed to elicit opinions regarding the perception of differences for NVG performance for the modified and unmodified interiors, respectively. The questionnaire specifically addressed the effects of the modified interior on the performance of visual tasks and the presence of any noticeable reflections. Crewmembers completing the questionnaire had an average of 17.5 NVG hours experience in modified aircraft. The number of aircrew responding to the questionnaire is displayed in Table 1 as a function of aircraft type and crew position.

Table 1: Summary of Human Factors Questionnaire Participants

Aircraft Type	Crew Position	Number of Participants
C-130H	Pilot	4
	Co-Pilot	2
	Flight Eng.	2
	Navigator	2
C-141B	Pilot	3
	Co-Pilot	3
	Flight Eng.	2
	Navigator	3

III. RESULTS

Radiance Measures

Since the materials and paints used in the modification are consistent between the two types of aircraft, the results of the evaluation are presented here strictly in terms of the various types of surfaces found in the four possible cockpit configurations and cargo bays, with specific aircraft type annotated for clarity where necessary. Table 2 summarizes the calculated reflectances for all significant cockpit and cargo bay surfaces. Values listed in this table should be considered representative. For some surface types, measurements were made in multiple locations, and the value shown in the table is the mean calculated reflectance.

Data obtained during measurements of both aircraft types indicate that the reflectivity of several of the new colors and finishes is greater than that of the originals. However, even though reflectance in the NVIS spectral region generally increased, all measured NVIS radiance values were still within the limits specified by MIL-L-85762A with one notable exception which is discussed in the next paragraph. Perhaps the most notable overall finding from the radiance measures portion of the evaluation was the sharply increased reflectance, vis-a-vis that of the colors being replaced, of the new glossy beige color now used on both perforated vinyl and hard ceiling surfaces.

The shiny metal floor material found in the modified C-130 cockpit at the pilot and copilot stations is extremely reflective and produced very intense specular reflections which were too bright for the NVG-103 to measure. These specular reflections reach the windscreens, particularly in the swing window area. The shiny handgrips located above the forward windscreens also tend to produce reflections in the windscreen. The dark blue flooring which is now used in both aircraft types is significantly less reflective than the original floor materials.

Data collected at the various windscreen positions tended to indicate elevated levels of energy from the cockpit incident upon the windscreens in the modified aircraft, particularly in the area of the swing/sliding windows. The swing/sliding window glare is worse in the modified C-130. However, the glare shields in both aircraft protect the forward windscreen from excessive glare. Due to bleed through of varying levels of near infrared energy from external sources through the black cloth covering the windscreens, exact quantitative comparisons cannot be made of windscreen NVIS radiance values.

Measurements in the cargo bay indicate that NVIS radiance levels are so low that it is unlikely that the new paint scheme will have any noticeable effect on NVG operations performed there.

Table 2: Summary of Broadband Surface Reflectances

Paints	Reflectance
Original Green (Both Aircraft)	22%
New Blue, Color #25414 (Replaces Original Green)	29%
Original Beige (Both Aircraft)	24%
New Glossy Beige, Color #23531 (Replaces Original Beige)	60%
Materials	**Reflectance**
Ceilings - Perforated Vinyl:	
Original Green (C-130)	23%
Original Beige (C-141)	32%
New Glossy Beige	45%
Seat Covers:	
Original Orange (Both Aircraft)	28%
New Blue/Lamb's Cloth	44%
Seat Arms:	
Original Orange Vinyl (Both Aircraft)	17%
New Blue Vinyl (Both Aircraft)	7%
Floors:	
Original Green Linoleum (C-130)	38%
Original Tan (C-141)	34%
New Dark Blue (Both Aircraft)	5%
New Aluminum (C-130)	OFF SCALE*

*Too bright to measure with equipment

Human Factors

Crewmembers were asked to list the four most critical visual tasks they perform during a typical NVG mission, and to rate the impact of the modified interior on the performance of each task. Only one crewmember reported that the modified interior had any noticeable effect on his performance. All remaining crewmembers reported "no change" for each task listed. The one crewmember who reported a difference was a C-130 pilot who indicated that the modified interior scheme was slightly worse with respect to his four most critical tasks of take-off, landing, airdrop, and low level flight. He attributed this to glare or "window shadow" caused by increased reflections in the windscreen. A C-141 flight engineer reported that the modified interior scheme had resulted in improved visibility around the rear of the flight deck for non-NVG conditions. He attributed this improvement to the reductions in glare from the floor and seat coverings at the rear of the flight deck in the modified aircraft.

Crewmembers were asked to indicate whether any reflections were noticeable within the NVG intensified field-of-view that they believe were due to the modified interior. No noticeable reflections were noted by C-141 crewmembers. Two C-130 crewmembers reported slight reflections on the windscreen. One of these crewmembers reported that the modified floor surface and beige ceiling at the pilot and co-pilot positions were very reflective. This crewmember reported that lights from the navigator station reflected off the ceiling of the flight deck. A C-130 flight engineer noted slight glare from reflections on the windscreen during ground operations.

Crewmembers were also asked if the modified interior scheme affected previously existing lighting compatibility problems. Only one C-130 pilot noted any change for the worse in lighting compatibility between the original and modified scheme. This individual noted that the instrument panel lighting compatibility was slightly worse because of the reflections from the shiny aluminum floor surface at the pilot station.

Finally, each crewmember was asked if he could safely and effectively perform the Special Operations, Low Level (SOLL II) mission with an aircraft refurbished with the new interior materials. All crewmembers surveyed indicated they believed they could safely undertake SOLL II missions in modified aircraft.

IV. CONCLUSIONS

The results of the current analyses indicate that reflected ambient light in the interiors of C-130 and C-141 aircraft modified as part of the Equipment Excellence Interior Material Program should not be expected to interfere with NVG operations. NVIS radiance measurements indicated that while the visible and near infrared reflectances of the new surfaces are in general increased vis-a-vis those of the original configurations, surface NVIS radiance levels were still well within the limits established in MIL-L-85762A. One notable exception is the polished aluminum floor at the pilot's and co-pilot's stations in the C-130 cockpit. The human factors analysis corroborated this finding in that the overwhelming majority of crewmembers reported that they did not notice any negative impact of the new design on NVG performance. Nevertheless, two aspects of the modified design do result in increased surface reflectance in the cockpit. These are:

1. The polished aluminum floor at the pilot's and co-pilot's positions in the C-130 cockpit. This represents a highly undesirable surface material due to the unavoidable bright specular reflections associated with such a finish.

2. The beige-colored surfaces in the cockpits of both aircraft.

There was no observed glare on the forward windscreens within one steradian of the pilot's design eye position, in conformance with the military standard. However, glare is present in the side windows of both aircraft, more noticeably in the C-130. It is important to note that if all cockpit lighting was NVG compatible, then the incidence of cockpit lighting energy upon the windscreens would not be a matter of concern.

Appendix A

C-130/141 INTERIOR PAINT SCHEME
NVG EVALUATION QUESTIONNAIRE

Name ________________ NVG Type ______________

Aircraft _____________ Position ______________

Approximate hours of NVG flight experience with:

Old paint scheme _____ hrs.
New paint scheme _____ hrs.

1. List the four most critical VISUAL tasks you perform with NVGs during a typical night mission and for each task use the scale provided to rate any differences between the old and new interior paint schemes you may have experienced in performing each task.

Task	No Change	Slight Improvement	Significant Improvement	Slightly Worse	Signif. Worse
__________________					
__________________					
__________________					
__________________					

2. For those tasks which you rated anything other than NO CHANGE, please describe the differences in performing them between the old and new interior paint scheme in the space below:

3. Please describe any REFLECTIONS within the NVG field of view that you believe were caused by the interior paint scheme for the:

Old scheme ____

New scheme ____

4. Please list the reflection and rate its effect on your performance while wearing NVGs below.

Reflection: ________________

___ No Effect on performance
___ Slight (NVG performance only slightly affected)
___ Moderate (reflections limited the ability to perform NVG operations)
___ Signifcant (reflections made it impossible to perform duties with NVGs)

Reflection: ___________________

___ No Effect on performance
___ Slight (NVG performance only slightly affected)

___ Moderate (reflections limited the ability to perform NVG operations)
___ Significant (reflections made it impossible to perform duties with NVGs)

5. Under the old interior paint scheme, what was the greatest lighting compatibility problem with NVGs at your crew position?

6. How was this problem affected by the new interior scheme?

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