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TRI-SERVICE COMBINED ALTITUDE RADAR ALTIMETER (CARA)
THE ARMY PERSPECTIVE

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Biographical Sketch

Mr. Gill is Project Leader for Radar Altimetry the at USA Avionics R&D Activity. Current projects include the Army Standard Radar Altimeter, the AN/APN-209A(V) and the Tri-Service Combined Altitude Radar Altimeter (CARA).

Mr. Gill received a B.S. Degree in Engineering Physics from South Dakota State University in 1967 and an MSEE from Fairleigh Dickinson University in 1975. He is a member of the IEEE and the Association of the U.S. Army.

The CARA is being developed under an Air Force contract as a replacement for thirteen different types of radar altimeters now in the Air Force inventory. These thirteen types of radar altimeters range in age from seven to thirty eight years and in MTBF, from 39 to 570 hours.

The Army requirements for CARA are for fixed wing aircraft; the OV-1D Mohawk and the new JVX Joint Services Advanced Vertical Lift Aircraft for which the Army is the executive agency.

The OV-1D requirement provides a replacement for the AN/APN-171A(V).

The CARA requirement planned for 1,086 JVX aircraft was dictated by:

-high altitude requirement. CARA provides radar altitude from 0 to 50,000 feet; JVX mission altitudes go to 30,000 feet. The standard Army altimeter, the AN/APN-209A(V), optimized for helicopter usage has a range of 0-1,500 feet; the standard Navy altimeter, the AN/APN-194(V), has a range of 0-5,000 feet.

-MIL-STD-1553B Bus Compatibility. The CARA system being designed for the F-16 aircraft will have 1553B compatibility. Since the JVX will utilize a 1553B bus, the Army will attempt to standardize on the CARA system, including the 1553B bus, Interface Adapter, being designed for the F-16.

-Nuclear Hardening. The Army is coordinating the nuclear hardening requirements for CARA with the Air Force, in an attempt to standardize on requirements and also to fully satisfy the JVX requirements.

The Army has been participating in the development of the CARA indicator, required for the OV-1D, to assure ANVIS-Compatibily. An Infrared suppression filter under development by the Army for the AN/APN-209A(V) Radar Altimeter will provide a standardized solution to ANVIS-Compatibility problems, and will have tri-service applicability.

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THE CARA PROGRAM

Program Initiation

The CARA program began in FY-77 as an Air Force investigation into the low reliability and high support costs associated with Air Force radar altimeters. The Air Force had thirteen different types of radar altimeters in inventory, ranging in age from seven to thirty eight years and ranging in MTBF from thirty nine to 570 hours. Annual support costs for these altimeters exceeded $10 million per year.

A Class IV C modification program[1], with Warner-Robins Air Logistics Center as manager, was authorized in September of 1980. This program was to replace approximately 4000 existing Air Force altimeters with the CARA, using interface adapters for each type of aircraft. No aircraft wiring changes were to be required. Warner-Robins contracted ARINC to write a specification[2] for the CARA. This specification was coordinated with the Army and the Navy. Subsequently, a fully coordinated RFP was let to industry and a contract was awarded to Gould, Inc.[3] in Jan 82.

CARA Technical Description

The CARA (Figure 1) is an all solid state FM/CW radar altimeter system which provides accurate altitude (+/-2 feet +/-2 percent) data from zero to 50,000 feet AGL. Each CARA system consists of a receiver-transmitter (R/T), two antennas, height indicators as required, an interface adapter as required, a mount for the R/T, antenna mounting plate adapters as required, and adapter cable assemblies as required. All of these various subsystems are divided into Group 1 items, where design is independent of aircraft type, and Group 2 items which are peculiar to the aircraft type or series.

The R/T consists of a one-watt maximum power output transmitter with power management circuitry that will reduce the power output depending on terrain and altitude. The RF sweep is segmented into seven segments for resolution and accuracy and is swept both up and down to compensate for doppler effects. The receiver utilizes low-frequency band-pass tracking filters to track the leading edge of the return signal, allowing measurement of altitude to the nearest object. Built-in test circuits provide fault detection on a continuous, interruptive, and manual self-test basis.

The height indicator, when used in the given aircraft configuration, controls all of the functions of the CARA system, such as power, manual self test, low altitude warning set, and display dimming. The display provides analog altitude from zero to 5,000 feet, digital altitude from zero to 50,000 feet, visual R/T fail warning and low altitude warning. The indicator utilizes two microprocessors to format the altitude data received from the R/T and to also control the self test functions.

The interface adapters are used to process the R/T altitude data and provide outputs to make the CARA compatible with other onboard avionics systems that previously received this data from the replaced altimeter. The interface

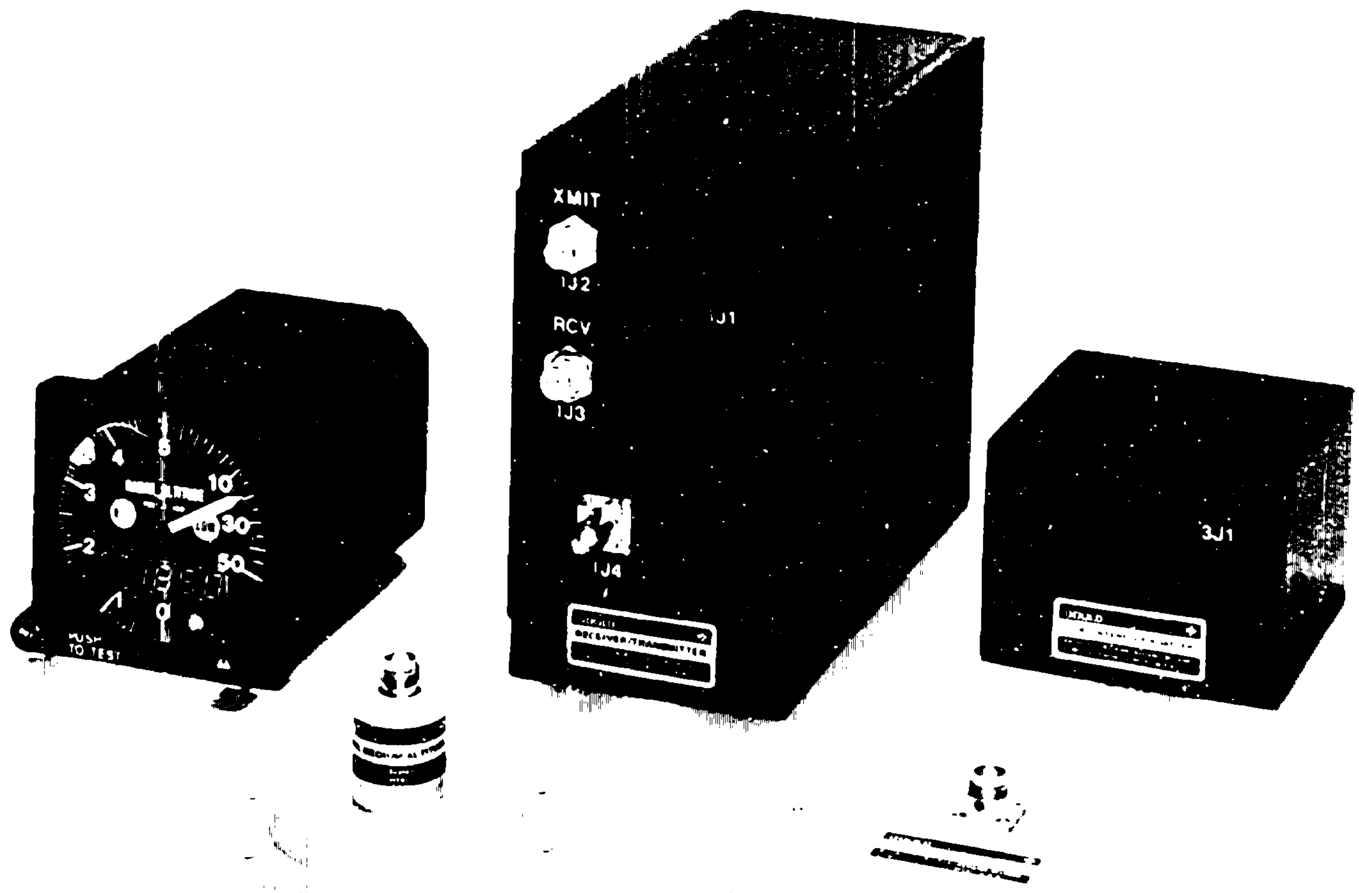


FIGURE 1
CARA COMMON ITEMS

adapters provide the electrical signals peculiar to any aircraft to allow the CARA to be a standard altimeter and yet be compatible with the many retrofit and forward-fit installations.

Three antenna configurations are available with CARA: (1) Fixed Wing aircraft with a 40 by 60 degree three dB beamwidth, (2) Rotary-Wing aircraft with a 35 by 35 degree three dB beamwidth and (3) A-7 aircraft antennas with a 65 by 65 degree beamwidth. In some aircraft installations, the CARA antennas are placed on adapter plates so they will exactly replace the existing antennas, with no aircraft changes.

THE ARMY REQUIREMENT

Retrofit Applications

The Army currently has two types of aircraft that utilize the aging AN/APN-171A; the OV-1D Mohawk and the EH-1H Quickfix. The APN-171 has a terminal logistics date of 1988, after which it will no longer be supportable. The cost to retrofit these old altimeters exceeds the CARA acquistion cost. Also, the APN-171 has only a 5,000 foot range, whereas the CARA provides a 50,000 foot range. An aircraft product improvement is planned for FY-85 to retrofit the fleet of 170 OV-1D aircraft with the CARA. The APN-171 altimeters released by this retrofit could be utilized to support the APN-171's in the ten EH-1H aircraft.

The JVX Aircraft

The main thrust of Army interest in the CARA program is to provide a high altitude radar altimeter for the Joint Services Advanced Vertical Lift Aircraft (JVX), for which the Army is the executive agency. Since the JVX mission package requires a radar altimeter that operates to 30,000 feet, neither the Army Standard AN/APN-209A(V) with a range of 1500 feet, nor the Navy Standard AN/APN-194(V) with a range of 5,000 feet would suffice.

The JVX schedule includes a preliminary design study phase of twenty three months duration to be awarded in 1QFY83. This will be followed by a full scale engineering development phase commencing in 4QFY84. Production release is planned for 1QFY88 to meet the Marine Corps Initial Operational Capability (IOC) of Jan 1991. Present program plans call for production of 1086 aircraft over a ten year period.

The JVX is planned[4] as a tilt rotor aircraft that will perform a wide variety of missions: efficient hover and terrain flight; external load and rough field operations; efficient long range, high speed cruise; high altitude loiter; and high load factor maneuvering. The Army requires JVX to perform its Corps and Division SEMA mission replacing the OV-1D, RV-1D, RU-21, RC-12D, EH-1 and EH-60 aircraft.

The Air Force JVX will perform missions of combat search and rescue (CSAR) and special operations replacing or supplementing the H-53, the HH-60D and the MC-130.

The Navy requires a replacement for its HH-3A CSAR aircraft.

The Marine Corps, with the largest JVX requirement, will utilize the aircraft for amphibious force projection and land assault, replacing the CH-46 and the CH-53.

The JVX established unique requirements which can not wholly be met by any existing radar altimeter. Of those available, the CARA most nearly matches the requirements. These requirements include: high altitude, zero to 30,000 feet; MIL-STD-1553B bus compatibility; a nuclear hardening specification; and ANVIS(AN/AVS-6) compatibility.

MIL-STD-1553B

The CARA design requires an interface adapter to provide the embedded 1553 compatibility. For standardization and interoperability, the Army plans to utilize the interface adapter being designed for the F-16 CARA system to meet the JVX 1553B requirement. The F-16 interface adapter is being designed to accommodate both the F-16 version of 1553 as well as 1553B. The choice between these two formats will be available by pin selection on the interface adapter. In addition, the interface adapter has address select pins and an address select parity pin that allows the CARA terminal address to be selected externally. These factors are necessary for Army applications.

There are some minor format differences between the CARA data word codings and the draft word codings of the SAE A2K Task Group, which was tasked to develop standard 1553 word coding formats.[5] For example, the CARA data word coding shows a least significant bit (LSB) of 2.5 feet, whereas the draft A2K format guidelines specify an LSB of two feet.

Since the CARA interface adapter is being designed with a microprocessor controller, it will be possible to program the adapter with different scale factors to make the unit fully meet Tri-Service/Army requirements. A suggested approach is to design an interface adapter that is standard so no changes, not even software changes, would be required. This is the Army's objective for its participation in the CARA interface design process.

Nuclear Hardening

There are two general types of damaging radiation to be considered in nuclear hardening.[6] The electromagnetic pulse (EMP) is caused by a rapid expansion of ionized gasses that displace the earth's magnetic fields. The effect of the EMP on electronics could be compared to the effects of a lightning strike. Hardening against EMP, at least for military systems, is an established set of design criteria and is well in hand. The CARA EMP design generally meets Army requirements.

The second type of damaging radiation is collectively referred to as TREE (Transient Radiation Effects on Electronics). TREE consists of total dose, high transient dose rates and neutron fluence.

Total dose includes neutrons and gama rays which, when they pass through the crystal lattice structure of semiconductors, cause release of charged carriers. These charged carriers then cause a high level of leakage, which either destroys the semiconductor or as a minimum causes a system malfunction. Of the three TREE effects, total dose, as a result of fallout could cause the most problems on the battlefield, while dose rate and neutron damage effects would occur only close to a nuclear detonation.

Dose-rate effects are most damaging to computer memories, especially of the NMOS variety. Other effects are latchup, which is a high current, low voltage condition that can rapidly cause component burnout.

Neutron fluence damage tends to be inversely proportional to the gain-bandwidth product of the semiconductor component. For switching and power transistors, which have a low gain-bandwidth product, damage can occur at a level well below that which would seriously harm a person.

The CARA has a relatively severe nuclear hardening requirement, compared with other Air Force avionics systems. But as severe as these requirements are, the JVX has nuclear hardening requirements considerably more severe. The Army standard AN/APN-209(V) Radar Altimeter meets the JVX hardening requirements.

In summary, it appears that the tactical mission of Army aircraft with their battlefield operations, establishes nuclear hardening requirements that are quite different than those imposed on Air Force equipments. These differences present a standardization issue which must be addressed to provide the systems developers adequate guidance to allow standardization.

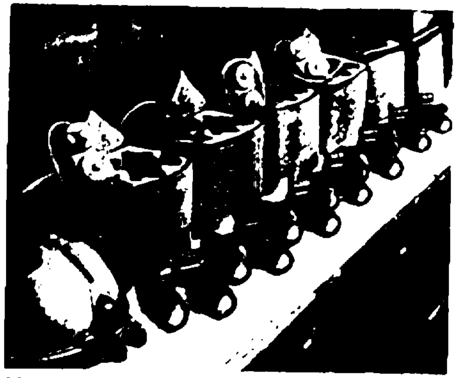
Compatibility with Night Vision Goggles

A particularly difficult design problem encountered with the CARA was to make the indicator compatible with the Army's new Aviator's Night Vision Imaging System (ANVIS, AN/AVS-6),(Figure 2). This is a third generation night vision goggle system that is extremely sensitive in the red visible and infrared portion of the spectrum (wavelength 600-1100 nanometers), (See Figure 3). The CARA, and other recent radar altimeters such as the Army AN/APN-209A(V), utilize three separate lighting systems, namely, the light-emitting diode (LED) digital readout, the low altitude warning light and the integral edge lighting that lights the dial face. For existing designs, such as the APN-209 which utilizes red LED's and incandescent lamps (with their inherent high infrared emissions) for the warning and edge lighting, the retrofit problem is very difficult to resolve. The Army has solved the problem by changing the red LED's to green LED's and developing a compound optical filter that is laminated to the altimeter cover glass to filter out the red and infrared from the incandescent lamps. (See Figure 4). This filter utilizes both absorptive and "hot mirror" reflective techniques and can be made extremely thin (.020 inch). Filters that were available, with the proper filtering characteristics, tended to crystallize under certain environmental conditions and hence were unacceptable for this application. Also, available filters were relatively thick and would not fit the existing altimeter bezel.

For a new design such as CARA, the problem is not as difficult. The CARA will utilize green LED's for the digital readout. The edge lighting may be either filtered incandescent lamps, in an externally replaceable lamp module, or electroluminescent (EL) lighting, which is ANVIS compatible. The warning lamps could be a dual light configuration using incandescent lamps for daytime visibility and green LED's for night goggle compatibility.

OPTICS DIVISION

BELL & HOWELL



Nominal Specifications *(Applies to both 2nd and 3rd Generation unless otherwise indicated)*

	3rd Gen.	2nd Gen.
Resolution		
Moonlight	*86cy/mr*	*72cy/mr*
Starlight	*55cy/mr*	*40cy/mr*
Photocathode Type	*Gallium Arsenide (1000 micro ampsper lumen)*	*S 25 (300 micro ampsper lumen)*

Focus Range . . . . . . *25cm to Infinity*
FOV . . . . . . *40°*
Magnification . . . . . . *Unity + 5%*
f stop *1.2*
Fit Adjustments
Line of Sight . . . . . . *8°*
Eye Relief . . . . . . *16mm travel*
Vertical Adjustment . . . . *16mm travel*
Interpupilary Distance 52mm to 72mm
Image Tube . . . *18mm prox Focus MCP*
Distortion . . . . . . *1% max*
Diopter Range . . . . . *+2 to 6 diopter*
Weight of Binocular . . . . *463 grams*
(Total system weight varies with helmet interface)
Power Source . . . . . . *2.9 VDC*
(Battery or aircraft power)
Environmental
Altitude . . . . *Sea level to 15,000 ft.*
Shock . . . . *48-in. drop in ship. case*
Vibration . . . . *2G (5HZ-500HZ)*
Humidity . . . . *95% (min.)*
Operating Temp. . . . . . *-32°C to +52°C*

Ordering Information
ANVIS system
Part No. 022753
Soft cloth carrying case
Part No. 022791
Shipping and storage container
Part No. 022790
Daylight training accessories
Part No. 022780
Special purpose test set
Part No. 022430
Maintenance manual
Part No. 263-20 and 263-30
Aircraft power converter
Part No. 022749

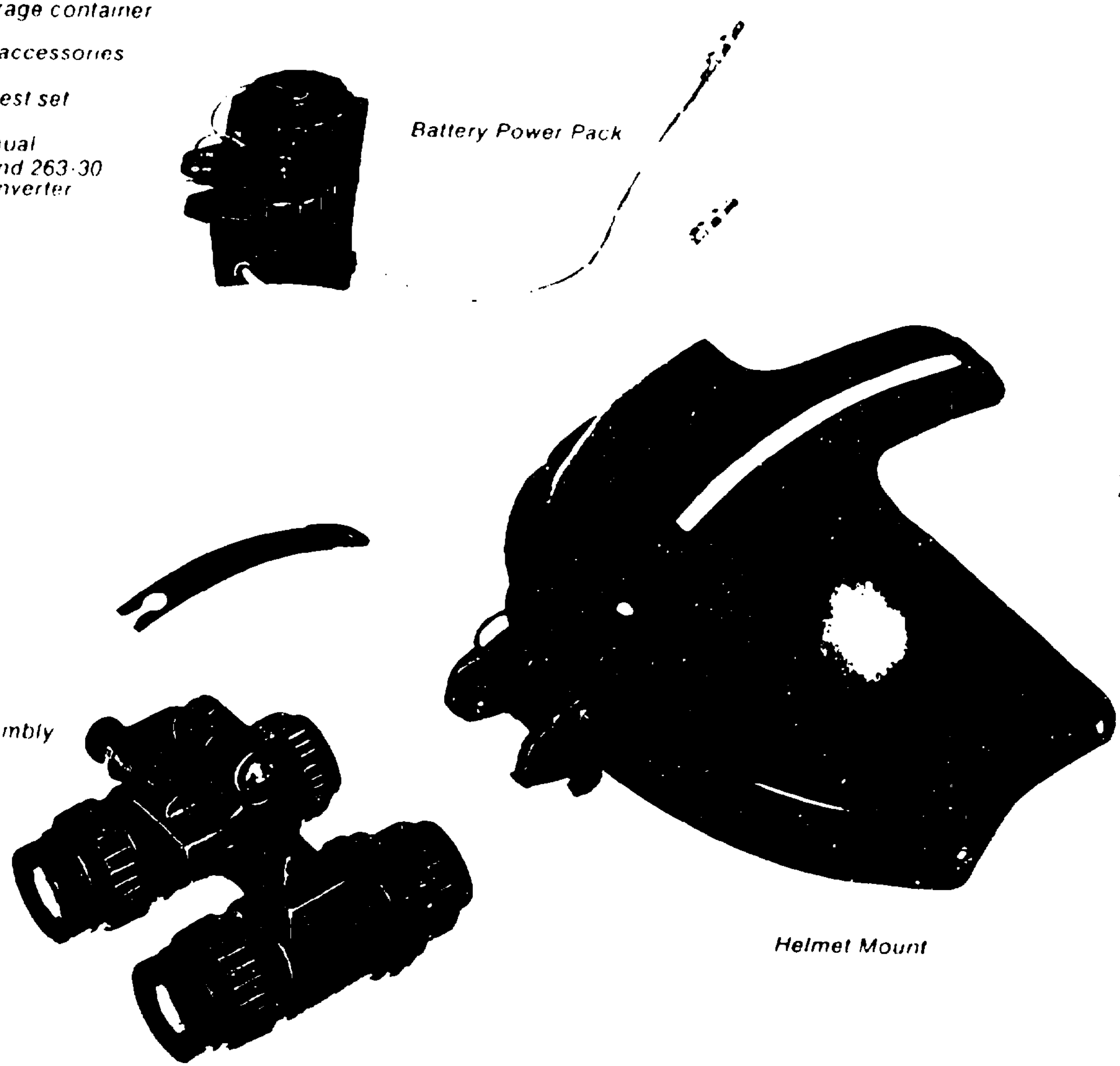


FIGURE 2

EYE EFFICIENCY/ PHOTOCATHODE RESPONSE: 3rd GENERATION

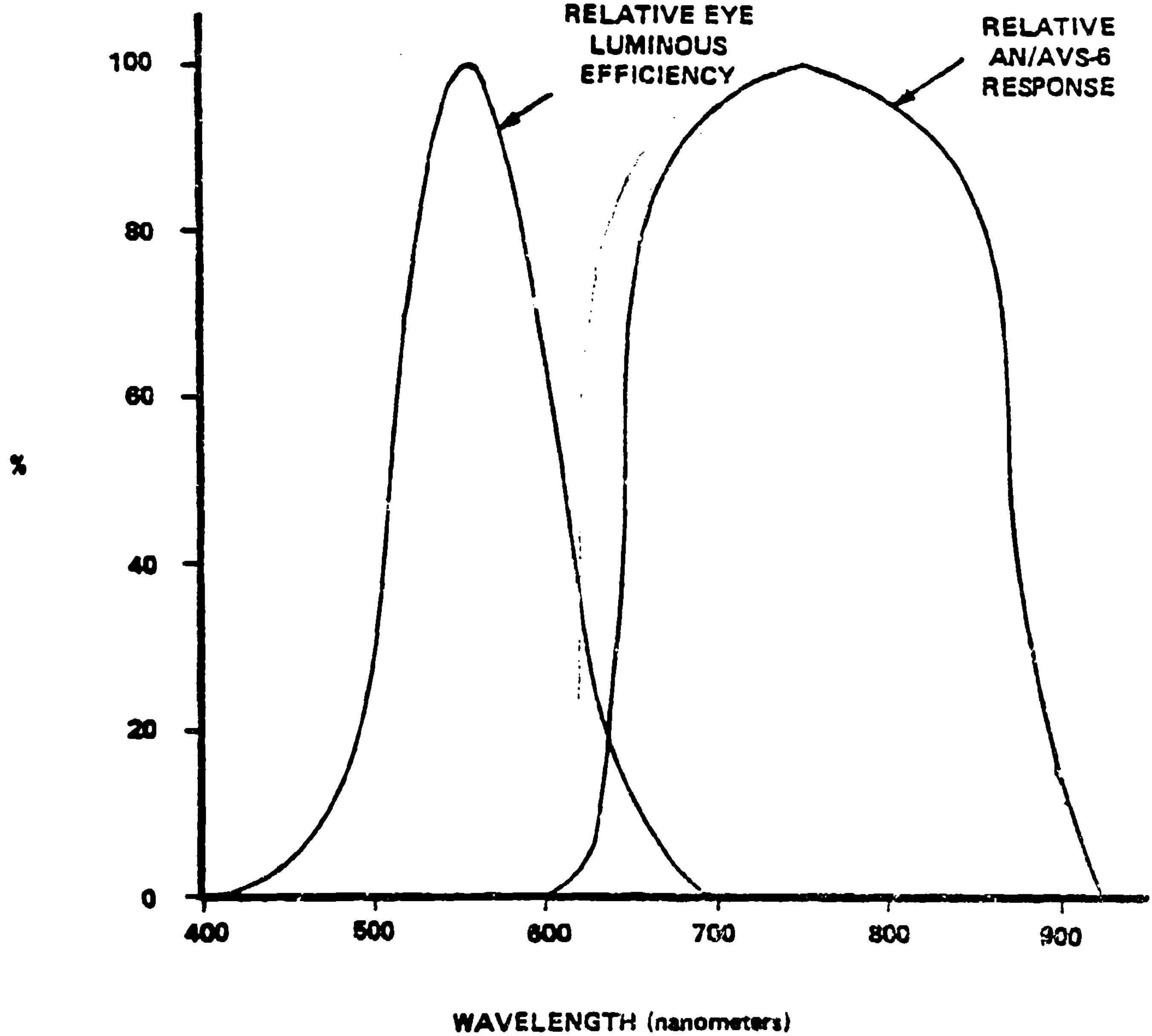
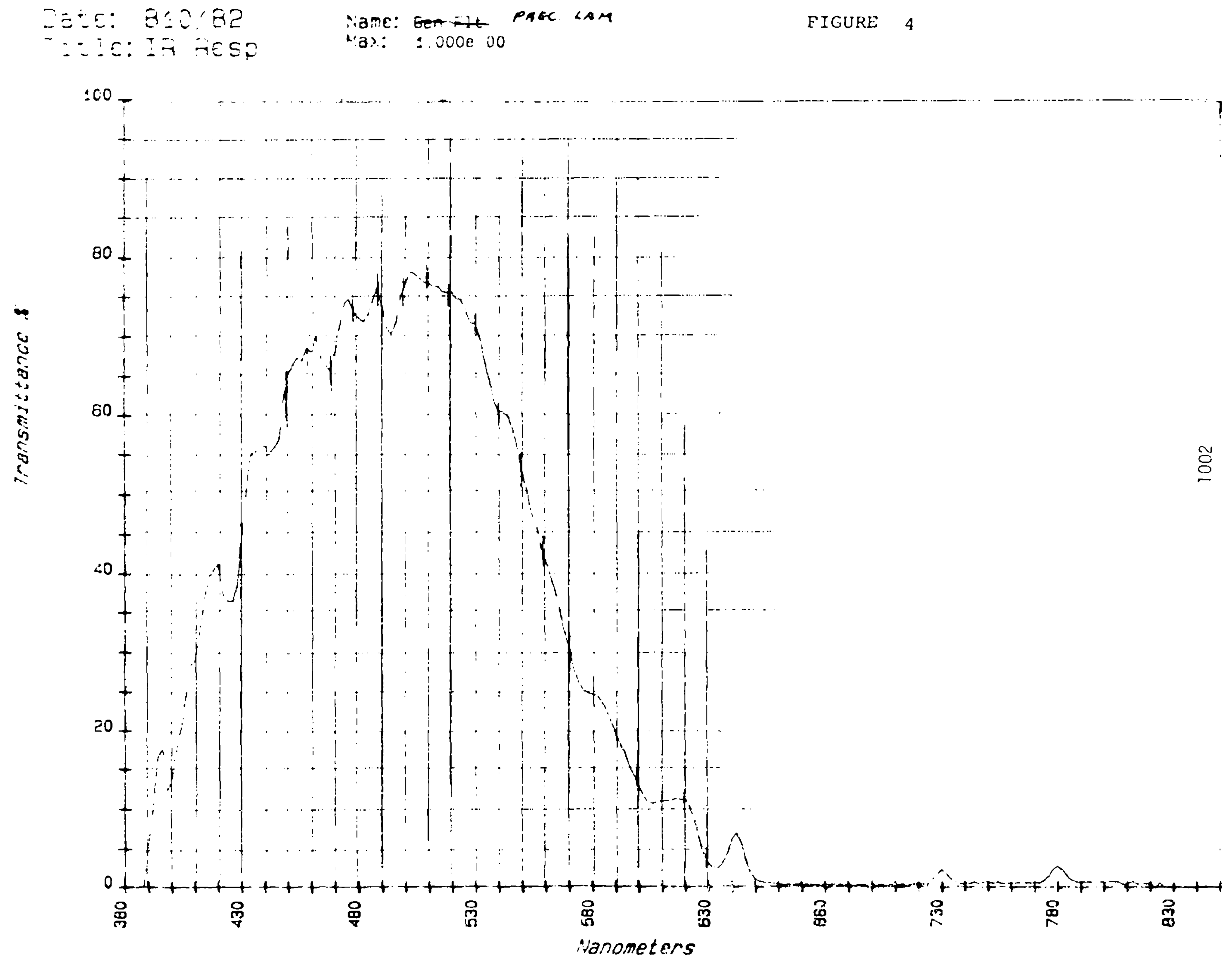


FIGURE 3

FIGURE 4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Green cockpit lighting, in addition to being necessary for ANVIS compatibility, is also essential for reducing the external signature of the aircraft as seen through night vision goggles, samples of which are contained in the referenced document[7].

In conclusion, I have attempted to highlight some of the difficulties encountered in the Tri-Service standardization process. I am sure that the situation depicted above, for the CARA altimeter, is not unique and probably represents the norm as opposed to the exception. My purpose is to surface these issues both in the present forum, as well as through appropriate program/product managers, to stimulate the kind of thinking, planning, and meaningful Tri-Service coordination that must take place to succeed. Since we are all challenged, in these economic times, to make the best use out of every dollar spent by the DOD, it behooves us all to provide the level of cooperation necessary to insure the success of programs like CARA and others presented at this conference.

<u>References:</u>

1. Class IV Modification Program Management Directive No. L-Y-1036(1), 19 Feb 81.

2. Military Specification, 791RCR-CARA-523A, October 1981; ARINC Research Corporation Publication 2751-01-1-2367.

3. Contract F09603-82-C-0231 issued by Warner-Robins ALC/PMWCB, Robins AFB, GA 31098.

4. Joint Services Operational Requirement for Advanced Vertical Lift Aircraft (JVX JSOR), 24 Jun 82.

5. MIL-STD-1553 Multiplex Applications Handbook, 1 May 1980, AFSC. Draft Addendum, Chapter 11, August 1982.

6. IEEE Spectrum october 1982, "Electronics in the Nuclear Battlefield".

7. U.S. Army Night Vision & Electro-Optics Laboratory, Technical Report, Night Vision Goggle Compatible Lighting by Major Mickey Potter, Feb 1981.