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# CREW AND COCKPIT EQUIPMENT FOR NOE NIGHT FLIGHT PRATICAL SOLUTIONS AS SEEN BY AEROSPATIALE

By

B. FOUQUES

*Director of Flight Test*

AEROSPATIALE HELICOPTER DIVISION

MARIGNANE, FRANCE

**FIFTEENTH EUROPEAN ROTORCRAFT FORUM**

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## PRACTICAL SOLUTIONS AS SEEN BY AEROSPATIALE

**Bernard Fouques**

*Director of Flight Test*
*Helicopter Division*
*Aérospatiale*
*13725 Marignane Cedex*
*France*

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## 1 – THE PROBLEM

### 1.1 - At Night It's Dark Outside

"Nighttime is just like daytime, except that it's night!" As shown in Table I, there isn't very much light at night: the illumination level can be up to a billion times lower than during the day.

**Table I - Extreme Illumination Range**

| | External Conditions | Illumination (LUX) |
|---|---|---|
| DAY | Clear sky<br>Sun 60° above the horizon | 100 000 |
| | Very cloudy sky<br>Sun 60° above the horizon | 10 000 |
| | Clear sky<br>Dusk | 1 000 |
| NIGHT | Incandescent lamp | 100 |
| | Candle | 10 |
| | Clear sky<br>Full moon 60° above the horizon<br>(very bright night) | $100 \times 10^{-3}$ |
| | Clear sky<br>Half moon 30° above the horizon<br>(bright night) | $10 \times 10^{-3}$ |
| | Clear sky<br>New moon<br>(dark night) | $1 \times 10^{-3}$ |
| | Very cloudy sky<br>New moon<br>(very dark night) | $0.1 \times 10^{-3}$ |

The estimated average occurrence of the different nighttime brightness categories in Western Europe is indicated in the following table.

**Table II - Nighttime Illumination in Western Europe**

| Type of Night | Frequency (%) |
|---|---|
| Very bright | 15 |
| Bright | 25 |
| Dark | 30 |
| Very dark | 30 |

## 1.2 - The Eye Can't See Much at Night

The next table compares the photopic (daytime) and scotopic (nighttime) charactéristics and performance of the human eye.

**Table III - Characteristics and Performance of the Human Eye**

| Parameter | Day | Night |
|---|---|---|
| Characteristics | | |
| Type of vision | photopic | scotopic |
| Sensitive organ | cones | rods |
| Maximum spectral sensitivity | yellow-green | blue-green |
| Performance | | |
| Color perception | yes | no |
| Angular resolution | 1′ | 10′ (very bright night) to 1.5° (very dark night) |
| Vehicle identification distance | 2000 m | 200 m to 20 m |
| Glare tolerance and dark adaptation period | good | poor 20 – 30 minutes for full adaptation |

## 1.3 - Helicopters Must Fly at Night

Some night missions can be flown on instruments, in the same way as daytime IFR flight in planes or helicopters. In other cases, visual flight at a minimum safe height of at least 150 meters is possible using external references for navigation purposes, as in "field hopping" by small planes in nighttime VFR flight.

Nevertheless, some helicopter missions must be carried out at night at low altitude, including:

- civil or public helicopter rescue or emergency transport missions,
- ship-to-shore missions for harbor pilots or for Naval operations,
- Army helicopter operational missions including reconnaissance, observation or attack flights.

In very low altitude "nap of the earth" missions the pilot uses *external* references for attitude control, navigation and terrain avoidance; additional information is supplied by the aircraft instruments as in daytime flight. This is true *visual* flight, even if under degraded conditions.

### 1.4 - It's Not Easy!

The naked eye is suitable only for certain missions at a minimum safe height under very bright nighttime conditions, or only about 15% of the time.

Natural methods to increase night visual acuity are quickly limited by the amount of carrots or blueberries a pilot can eat. The solution lies in night vision enhancement technologies.

## 2 – SCIENTIFIC BACKGROUND

### 2.1 - Electromagnetic Radiations

Light is a form of electromagnetic radiation constituted by photons, massless elementary particles traveling at the speed of light ($c = 300\,000\ km \cdot s^{-1}$).

Electromagnetic radiation is characterized by its wavelength ($\lambda$) or frequency (f): these two parameters are related by the equation $f = c/\lambda$.

Table IV lists some of the principal types of electromagnetic radiation.

**Table IV - Electromagnetic Radiation Spectrum**

| Radiation | Wavelength |
|---|---|
| Cosmic radiation | $< 10^{-7}\ \mu m$ |
| Gamma radiation | $10^{-7} - 10^{-4}\ \mu m$ |
| X-rays | $10^{-4} - 10^{-2}\ \mu m$ |
| Ultraviolet radiation | $0.01 - 0.4\ \mu m$ |
| Visible light | $0.39 - 0.77\ \mu m$ |
| Infrared | $0.8 - 1000\ \mu m$ |
| Radar waves | 1 mm – 10 cm |
| Radio waves | 10 cm – > 1 km* |

*MHz and kHz frequencies

## 2.2 - The Atmosphere

The atmosphere filters electromagnetic radiation, allowing waves to pass only through certain frequency "windows". We are particularly interested in three of these windows:

- visible light (fortunately for us!) and the near infrared region (0.4 – 2.5 $\mu$m)
- infrared band 1 (3 – 5 $\mu$m)
- infrared band 2 (8 – 13 $\mu$m).

## 2.3 - Light Intensification

The first technique for enhancing night vision is light intensification: moonlight or starlight *reflected* by objects (as well as any light emitted by artificial or natural sources) is detected by a gallium arsenide (GaAs) photocathode which converts light energy into electric energy (see Figure I). The resulting signal is amplified by microchannel wafers, and the output image is displayed on a phosphor screen. A pair of image intensifiers constitutes the night-vision goggles (NVG) mounted on the pilot's helmet, as shown in Figure II.

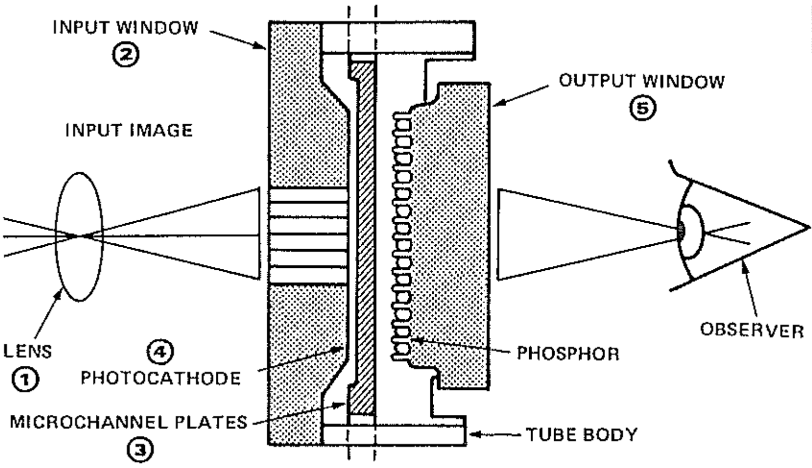


FIGURE I

FIGURE II

## 2.4 - Thermal Imaging

The second technique is thermal imaging, also known as Forward-Looking InfraRed (FLIR) systems. Radiation *emitted* by objects is detected by the device, generally turret-mounted, and visualized either on an instrument panel screen or by means of a helmet display.

According to black-body theory, the frequency of the waves emitted by objects depends on their absolute temperature; their amplitude depends on the emissivity of the object, with a maximum of 1 for the black body itself.

The highest emittance occurs in infrared band 2 (10 $\mu$m) for a body at room temperature (300 K) and in visible light (0.5 $\mu$m) for a body at a temperature of 6000 K (the sun, by a lucky coincidence).

## 2.5 - Radar

Radar need only be mentioned here.

## 2.6 - NVG versus FLIR

The two image enhancement systems can be compared from a number of standpoints:

• **IMAGE SYSTEM**

NVG: simple, relative lightweight, inexpensive, sensitive to spurious light emissions

FLIR: complicated, heavy, expensive, better pixel definition (geometric and thermal resolution)

• **AIRCRAFT MODIFICATIONS**

NVG: minor

FLIR: turret, cooling provisions

• **IMAGE QUALITY**

NVG: goggles, familiar image, binocular vision

FLIR: helmet display or panel-mounted CRT display; unfamiliar images, but identical in daytime and nighttime flight; monocular vision

• **PERFORMANCE**

NVG: satisfactory except on very dark nights (30% of the time) and in fog

FLIR: any lighting conditions except in fog; sensitive to rain and wind (temperature dilution)

Neither system is capable of positively identifying high-tension electrical lines, although a high-performance FLIR system can detect a live electrical line silhouetted against the sky.

## 3 - SOLUTIONS ADOPTED BY THE AEROSPATIALE HELICOPTER DIVISION

Except for the HAC version of the Franco-German combat helicopter, which will use a FLIR system with helmet display provisions, Aérospatiale proposes the use of third-generation night vision goggles: with only marginally lower performance characteristics, they are considerably less expensive than FLIR systems.

Night-vision compatibility raises a number of problems concerning cockpit visibility and equipment, as well as interior and exterior lighting.

### 3.1 - Cockpit Visibility

The relatively narrow field of view (40°) of night vision goggles is adequate for level flight at a minimum safe height. At lower altitudes, however, a wider field of view becomes necessary: this requirement is most critical in hover flight. The pilot must compensate for the restricted visibility by scanning from left to right as well as up and down. Under these conditions, the aircraft design should minimize obstacles in the form of door and canopy structure elements, as well as the instrument panel and antireflection glare shields. (Figure III).

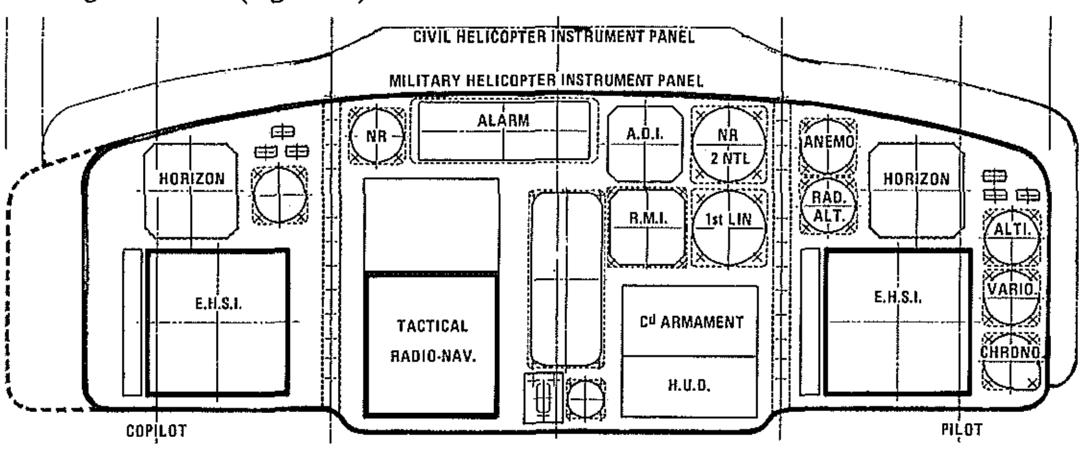


FIGURE III

## 3.2 - Internal Lightings

As during daylight flight, aircraft instruments are used as flight aids, notably the radio-altimeter and airspeed indicator, but also the engine and transmission monitoring instruments, operational system control units and the caution advisory panel. The pilot views the instrument panel by looking *underneath* the night-vision goggles. (Figure IV).

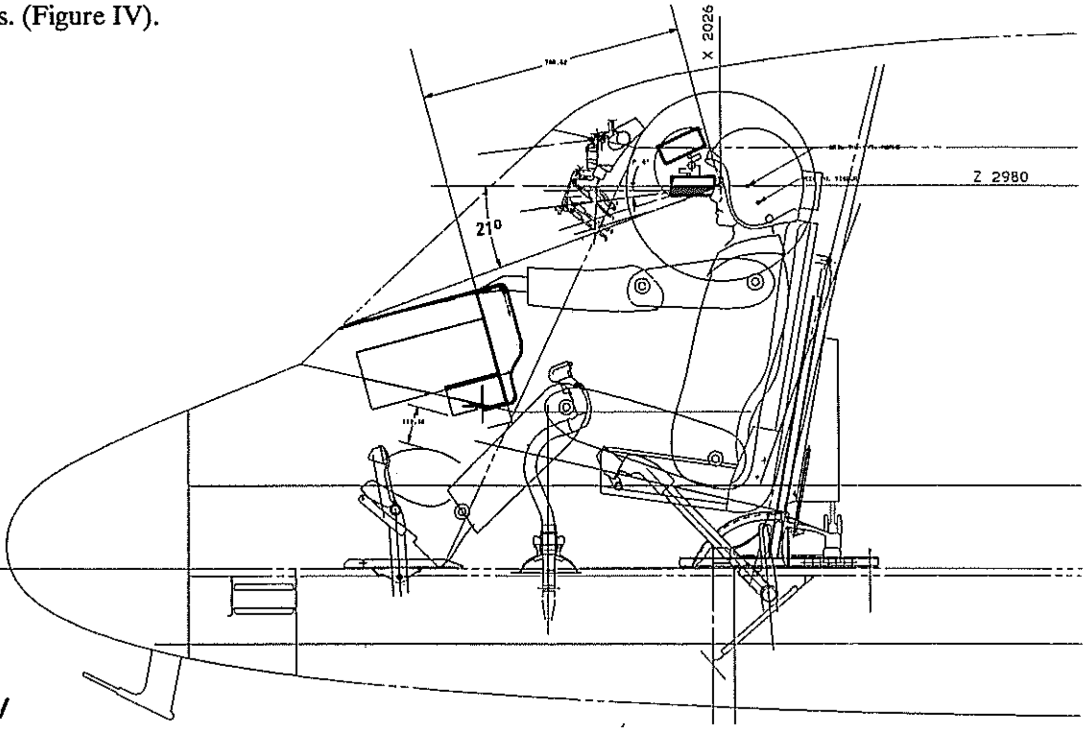


FIGURE IV

In allowing for the characteristics of the night-vision goggles and the human eye, Aérospatiale has adopted several solutions:

- Cockpit instruments are illuminated by ultraviolet lighting.
- Fluorescent *Saturn* yellow is used instead of white paint for basic instrument marking; other inscriptions (e.g. limitation ranges) are marked in standard colors.

Night vision goggles are most sensitive in the near infrared range, and the pilot's vision is not disturbed by ultraviolet light or by *Saturn* yellow markings. (Figure V). The wavelength of *Saturn* yellow is midway between the maximum photopic and scotopic sensitivity ranges, and is easily perceived by the eye looking beneath the goggles.

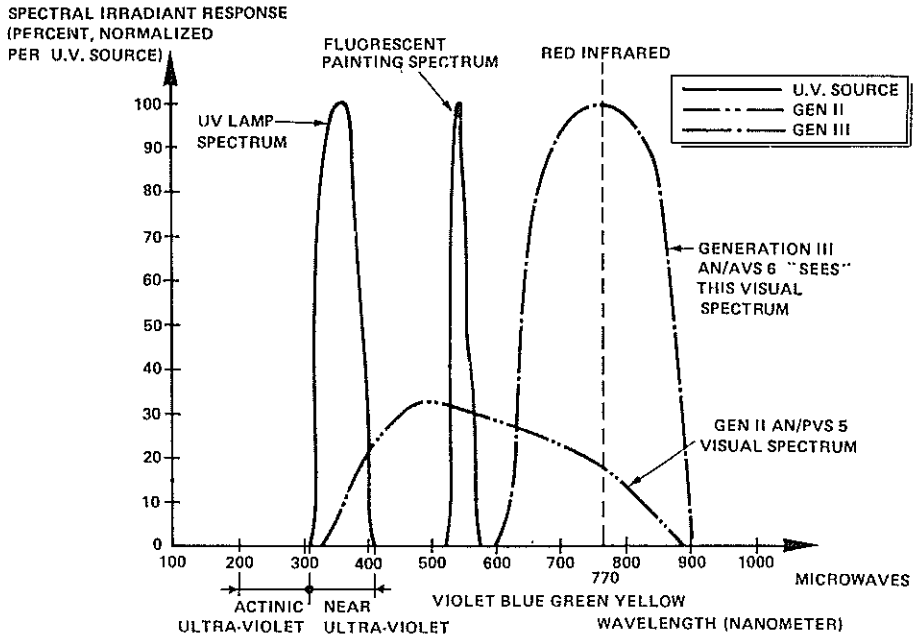


FIGURE V

- Operational system control unit illumination and markings meet the same criteria as the panel instruments or, to minimize equipment costs, may be unchanged (standard colors).
- Warning lights and annunciators are designed not to impair NVG-adapted vision by careful selection of light amplitude and wavelength, and by the use of automatic gain control provisions.
- The cockpit interior is painted flat black.
- Reflections are minimized throughout the cockpit environment.

Other types of cockpit lighting are possible, but ultraviolet lighting has the further advantage of being undetectable from the exterior.

### 3.3 - External Lightings

Night-vision compatibility also affects the exterior lighting provisions:

- The landing light must emit in the proper wavelength range and include a beam intensity adjustment control.
- Navigation lights are not used during NVG missions.
- The anti-collision light and formation lights must include intensity adjustment controls.

### 3.4 - Crew Training

Flight crews must be suitably prepared for NVG missions.

The Night Experimentation Center operated by the French Army at Le Luc en Provence currently trains Army helicopter crews for NVG night observation and attack missions.

Each session lasts a full lunar month (28 days) to cover all types of night conditions, although flights are not scheduled during very dark nights. The course focuses on safety in NOE* flight and landing, with attention to the problem of high-tension power lines, and on navigation difficulties.

*"nap of the earth" flight at a height of 50 meters above the ground

## 4 - CONCLUSION

The solution proposed by Aérospatiale comprises:

- 3rd-generation night-vision goggles
- ultraviolet cockpit lighting
- fluorescent *Saturn* yellow paint for basic markings on certain instruments in addition to standard color marking
- night-vision compatible interior and exterior lighting.

The system allows low-altitude night missions to be accomplished 70% of the time by suitably trained flight crews.