Methods of Implementing NVIS Compatible Cockpit Lighting

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Abstract

On average, half of a 24 hour day is darkness. Military flight operations do not stop during hours of darkness, and use of night vision goggles to facilitate such operations is widespread. For best visual acuity of the intensified outside scene, aircraft cockpit lighting must be compatible with (not be sensed or intensified by) a night vision imaging system (NVIS). Multiple methods of implementing NVIS compatible cockpit lighting exist and, with two exceptions, the methods are designed for permanent installation. Because aircraft program managers are faced with many choices when implementing NVIS compatible cockpit lighting systems, descriptions of each of the lighting methods are provided to help assist in selection of the optimal system for a given aircraft.

Concern about the quality of illumination provided by temporary chemical light sticks has resulted in the recent development of a new NVIS compatible illumination system based on light emitting diodes (LEDs). The LED system is inexpensive and is intended for temporary applications. The system has proved popular, and its design and effect on existing cockpit lighting design paradigms is discussed.

Introduction and Background

When used in an aircraft cockpit, the primary function of night vision goggles (NVGs) is to provide intensified imagery of distant objects in the outside environment. NVGs are very sensitive to light, and it is undesirable for an NVG to sense and intensify light from any sources other than those in the outside world. Cockpit instruments and displays must remain readable at night by the unaided eye, but any cockpit lighting that is sensed and intensified by the NVG may cause circuitry in the NVG to automatically decrease the intensifier gain, degrading the NVG-aided visual acuity (VA) of the outside scene. One incompatible cockpit light source is more than sufficient to degrade NVG-aided VA. The object then is to tailor the spectral emission of all cockpit light sources such that they are easily read by the unaided eye but invisible to the NVG; and similarly, to tailor the spectral response of the NVG so it responds to light from the outside world but is insensitive to light from cockpit sources. Cockpit lighting that is not sensed and intensified by (and thus does not interfere with) night vision goggles is termed Night Vision Imaging System (NVIS) compatible. Such lighting typically is green, with no red and near-

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **MAR 2000**	2. REPORT TYPE	3. DATES COVERED
4. TITLE AND SUBTITLE **Methods of implementing NVIS compatible cockpit lighting**		5a. CONTRACT NUMBER **F41624-97-D-5000**
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER **63227F**
6. AUTHOR(S) **John Martin**		5d. PROJECT NUMBER **2743**
		5e. TASK NUMBER **B3**
		5f. WORK UNIT NUMBER **2743B301**
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Raytheon Systems Company, ,6030 South Kent Street,Mesa,AZ,85212-6061**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
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15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**		**29**	

infrared (IR) spectral components. To complement such lighting, filters are installed in the NVG that allow it to respond only to red and near-IR light, thus rendering it blind to the cockpit lighting. Multiple methods exist for implementing NVIS compatible cockpit lighting. Brief descriptions of the methods follow.

Lighting Methods

Integral illumination

Most if not all existing cockpit instruments contain integral (internal) lamps to illuminate the given display as needed. Most existing lamps are incandescent and, along with visible light, they emit large amounts of near-IR energy that is invisible to the unaided eye. The near-IR energy will be sensed by and may interfere with NVGs in the cockpit, so emission of the near-IR energy must be prevented.

NVIS compatible integral illumination is implemented by the installation of special filters around the existing internal lamps, or by installation of non-IR-emitting light sources inside the instrument case. With either approach the internal sources emit no red or near-IR energy, and the illuminated display, although easily read by the unaided eye, appears invisible to NVGs. Integral lighting is durable, requires no aircraft wiring changes, and usually provides very good display readability because the integral light sources are located in those positions determined as optimal for uniformity of illumination by the instrument designer. Integral lighting is installed either when the instrument is manufactured, or as a retrofit when the instrument is disassembled at a qualified repair facility.

In addition to the instruments, all warning, caution, and advisory indicators also must be NVIS compatible. Such indicators usually consist of an alphanumeric legend behind a window, back-illuminated by one or more lamps. NVIS compatibility typically is achieved by replacing the conventional legend/window with a new legend/window incorporating a special glass or plastic filter. The special filter blocks the transmission of red and near-IR, but passes other chosen wavelengths. Alternatively, some recently available indicators contain light sources (i.e., LEDs) that are intrinsically NVIS compatible.

The integral illumination approach has a relatively long history and has proved to be satisfactory in terms of compatibility and display readability; it is well suited for 'new start' aircraft and/or cockpit programs. Although the integral illumination approach requires no changes to aircraft wiring, it can be costly if not designed into an instrument from the beginning. Unless externally marked, an integrally lit NVIS compatible instrument usually is not apparent as such (especially when it is unpowered). All similar instruments in the entire supply chain must also contain the same type of lighting, or else a flying unit runs the risk of receiving a non-NVIS compatible replacement when exchanging instruments for repair. One incompatible instrument can be sufficient to render NVGs ineffective in a cockpit. Instrument configuration and logistics controls therefore are important.

Post and Bezel

Post and bezel illumination consists of small light sources (typically small incandescent lamps) in short post-like towers external and adjacent to the instruments, or in ring-like bezels placed over the instrument faces. Light from the sources is directed at the faces of the instruments, functionally flood-lighting them from very close range. NVIS compatibility is achieved by integrating special filters or sources in the posts and bezels such that red and near-IR wavelengths are not emitted. Location of posts is important, both in preventing reflected glare on the glass instrument faces and in uniformity of illumination. Bezels are mounted directly over the instrument faces, and the light "throw distance" is very short, so bezel design also is critically important for uniformity of illumination. Bezels often incorporate special glass windows that "trap" and distribute the light across the face of the instrument as uniformly as possible.

As with integral lighting, the cockpit warning, caution, and advisory indicators must be NVIS compatible. The same approach used for such indicators in an integral lighting installation typically is used in post and bezel installations.

Power must be supplied to the lamps in the posts and/or bezels, so installation of a post and bezel system involves modification of aircraft wiring and passage of wires through the instrument panel. In some installations one of the (typically four) screws mounting an instrument is removed and the wires are passed through its opening, the remaining screws being sufficient to secure the instrument in place. In other installations new holes for mounting posts or passing wires may be drilled. Existing lighting circuit wires typically are removed at each instrument connector, disabling the integral illumination sources in the instruments. Because the integral sources in the cockpit instruments are not used, configuration control of instruments having different internal illumination systems is not an issue. However, if post and bezel electrical loads differ from the original lighting system electrical loads, adjustment of aircraft lighting circuitry may be required to maintain uniform illumination across the cockpit.

With due design consideration given to lighting balance and elimination of reflected glare, a post and bezel system can provide satisfactory lighting. The cost of a post and bezel installation usually is substantially less than that of NVIS compatible integral lighting.

Floodlighting using Existing Fixtures

In addition to the integral lighting installed in instruments, most aircraft also have a floodlighting (secondary) system to illuminate the cockpit if the instrument primary lighting system fails. The floodlights typically contain incandescent lamps, are capable of high luminous intensity, and are located in appropriate positions around the cockpit to illuminate all critical areas. The apertures of floodlights can be fitted with filters that block the transmission of red and near-IR light, thus rendering them NVIS compatible. The filters usually must be made of glass to withstand the heat generated by the incandescent lamps in the enclosed fixtures.

As with integral lighting, the cockpit warning, caution, and advisory indicators must be NVIS compatible. The same approach used for such indicators in integral lighting installations normally is used in floodlighting installations.

NVIS compatible floodlighting typically utilizes existing fixtures, and no change to aircraft wiring is required. Existing integral lighting in the instruments is turned off but is unaltered and usually remains connected, so incompatible integral lighting may be used as a reserve system (without NVGs) if floodlighting fails. Floodlights usually are located at intervals, and those instruments or displays closest to a given floodlight will receive greater illumination than others. Intervening objects also may cause shadowing of some controls or displays. However, floodlighting is relatively inexpensive and can be an effective means of implementing NVIS compatible lighting.

Floodlighting using LED Projectors

In some applications NVIS compatible integral instrument lighting, post and bezel lighting, and floodlighting using modified existing fixtures may be undesirable. In such situations, flood illumination of controls and displays may be provided by a system of modular light sources ('projectors') mounted in selected locations in the cockpit. Each module consists of a small metal enclosure containing a light emitting diode (LED) and optics, and projects uniform NVIS compatible illumination across a localized area. Modules generally are identical and are positioned above the surface area being illuminated. All modules are held in proper position with brackets that in turn are mounted using existing screw locations in the cockpit. The modules are interconnected with dedicated wiring that is separate from existing aircraft lighting system wiring. Such wiring is routed in an unobtrusive and noninvasive manner, and is clamped or otherwise secured in place to prevent movement and snagging wherever the wiring is exposed along panel surfaces. Power for the modules may be provided either by battery or aircraft, and the power switch, battery, and intensity control typically are located on a small box mounted near the existing interior lights control panel.

The LED projector module system is relatively inexpensive and easy to install. Given installation of sufficient modules in proper locations, the system generally can provide satisfactory illumination of cockpit controls and displays. However, uniformity of illumination is partly dependent on the locations of existing screws on cockpit surfaces, which in turn determine the design and locations of brackets and modules. Each different cockpit type requires a different set of custom brackets. If modules are not installed in optimal locations, the geometry of the installation may result in shadowing of some controls or displays; in fact, slight shadowing may be difficult to avoid in a practical installation in certain cockpits. Depending on the cockpit layout, the configuration of the installation, and the location and height of the mounting brackets, modules also may be vulnerable to damage in some locations. Filtering of warning/caution/advisory indicators is accomplished either as in integral lighting installations or with external removable filters.

External Filters

When neither aircraft wiring changes nor NVIS compatible integral illumination are options, external filters that block transmission of red and near-IR may be installed over instrument faces. Such filters are the same size as the clear glass windows on instruments, and typically appear light aqua in color. Unmodified integral instrument lighting is retained and used; the window simply does not transmit red and near-IR wavelengths. Each filter is mounted in a thin bezel-like metal frame that may be quickly and semi-permanently installed over the face of an existing instrument using the existing instrument mounting screws. No modification to the instrument is required, and the filter frame typically adds no more than 7 mm to the face height of the instrument. Alternatively, the filter may be permanently installed in place of the existing clear glass window on each instrument, although such an installation must be performed either at the point of instrument manufacture or at a qualified repair facility. In such a case, spares configuration issues will arise if all similar instruments in the entire supply chain have not been similarly fitted with filter windows because, if a filtered instrument must be replaced, the replacement may have a clear glass window, making it incompatible.

When using the external filter approach, the filter characteristics are critical. The filter must possess good optical qualities to prevent distortion when viewing instrument or display information. The filter also must exhibit high transmission in the visible portion of the spectrum because, during daytime, instrument illumination (and thus instrument readability) is due to ambient light. The ambient light must pass through the filter to illuminate the instrument face, and that portion of light reflected by the instrument face must pass through the filter again as it exits. Therefore, during daytime the light reaching the viewer has been attenuated twice by the filter. Assuming a perfectly reflective (diffuse dazzling white) instrument face and a filter with 50% transmission in the visible region, only 25% of the incident light (50% x 50%) would exit the instrument and reach the viewer. During darkness, light from the instrument's integral illumination must pass through the filter only once.

Each different instrument window shape or mounting configuration requires a matching piece of glass, and/or a matching machined frame to ensure a proper fit and to prevent light leakage. The initial investment in external filters therefore may be relatively high. However, when installed using metal frames, external filters neatly circumvent NVIS vs non-NVIS compatible configuration issues. If an instrument must be replaced, the filter/frame simply is transferred to the face of the replacement instrument. Cockpit warning, caution, and advisory indicators typically are addressed as in integral lighting installations.

Chemical Light Sticks

For aircraft in which NVGs must be used, but in which permanent NVIS compatible lighting or filters are not installed, green chemical light sticks may be used to provide temporary close-distance flood lighting. A small amount of near-IR energy is emitted by green light sticks, and although the energy is sensed and intensified by the NVG, it generally is insufficient to seriously degrade NVG-aided VA. However, reflections of glowing light sticks often are visible in the canopy, and NVG-aided VA usually is severely degraded when attempting to view the outside world through such reflections.

Light sticks are available in several sizes. 150 and 100 cm lengths are most commonly used for cockpit illumination; a small 40 cm "fish lure" size sometimes is used for short term illumination of a small area. Each 150 or 100 cm light stick is placed in an opaque cylindrical plastic holder having a slot aperture along its length. The effective width of the opening, and the amount of light allowed to exit the enclosure, is varied by rotating an outer opaque plastic sheath with a similar aperture. Each plastic holder is mounted near the instrument(s) to be illuminated and affixed to the cockpit structure or instrument panel with Velcro™. The small 40 cm units are held in place and shrouded with black tape.

Light sticks emit light as a result of a chemical reaction between two liquids. Both liquids (one contained in a thin glass capsule) are sealed inside the plastic body of the light stick, but the liquids are kept separate from each other until the light stick is to be used. The light stick is 'activated' by twisting or flexing its plastic body, thus fracturing the internal glass capsule and allowing the liquid chemicals to mix and react.

The luminous intensity of a light stick typically is greatest immediately after activation and gradually decays thereafter. However, similar light sticks may exhibit significant differences in luminous intensity after activation, and individual light sticks may decay quickly or simply fail to emit light. Visible light normally is emitted for up to twelve hours depending on the volume of chemicals involved, but the useful life of a 150 cm light stick (the period during which it produces sufficient light to be useful for cockpit illumination) usually is limited to 90 minutes or less. The luminous intensity of smaller light sticks decays more quickly. Light sticks are sensitive to temperature, and colder temperatures will significantly reduce the luminous intensity. For adequate illumination, chemical light sticks therefore must be properly located and replaced at specific intervals. Replacement is particularly important because the eye continuously adapts as the luminous intensity of the light stick decreases, and there is no warning that the instruments are about to become unreadable.

In keeping with the temporary nature of cockpit illumination using chemical light sticks, warning and caution indicators typically are covered with a thin, flexible green filter film commonly referred to as "Glendale Green." The film is held in place with black tape, and is installed for night operations and removed for day operations. Those incompatible light sources that cannot be extinguished and are not critical during flight often are simply covered with black tape. The filter film substantially reduces emission of red and near-IR wavelengths from the display over which it is placed, but one layer usually is insufficient to adequately block such emission, and several layers of film over a given light source usually are required. When two or more layers are used, bubbles often form between the layers, and display readability is degraded accordingly.

Chemical light sticks and filter film provide an inexpensive means of implementing partially NVIS compatible temporary cockpit lighting, but for safe and effective use it is important that operators recognize and account for the shortcomings inherent in the approach. A dedicated installation time is required before each flight. At least 26 light sticks (including spares) are required for a single F-16D mission, and the filter film must be replaced periodically due to wear and degradation (bubbling and cloudiness) caused by its repeated installation and removal. Recurring costs therefore can become significant over time.

Light Emitting Diode Illumination

In response to concerns about the adequacy and NVIS compatibility of illumination provided by chemical light sticks, a new interim NVIS compatible illumination system based on light emitting diodes (LEDs) was developed at the Air Force Research Laboratory (AFRL/HEA) at Mesa, AZ. The LED system provides illumination that is fully NVIS compatible, and has proved popular to date. It is designed to replace chemical light sticks in temporary installations.

The LED illumination system consists of special discrete LEDs located in unobtrusive locations throughout the cockpit, floodlighting the controls and displays. The LEDs have an estimated minimum lifetime of 10,000 continuous operating hours, are capable of very high luminous intensity, and have a narrow bluish-green emission spectrum; virtually no red or near-IR wavelengths are emitted. Several LEDs are mounted in a small module measuring about 25 x 40 mm, and multiple modules in turn are located throughout the cockpit, affixed to existing structures using Velcro™. The modules are interconnected with thin electrical wiring that is routed inconspicuously between modules and held in place with clamps secured by existing screws or with Velcro™. All LEDs in a cockpit are powered by one set of alkaline C-cells contained in a small box that typically is mounted with Velcro™ adjacent to the existing cockpit lighting control panel. The LED system power therefore is independent of aircraft power. The power switch and intensity control(s) are located on the battery box. The cable leading to the LED modules interfaces with the battery box through a connector, allowing the battery box to be removed for service without disturbing the placement of the modules. The LED modules do not interfere with normal instrument viewing and may be left installed in the cockpit indefinitely.

Unlike lithium cells, which typically exhibit a "stair-step" discharge curve having a rapid (and often unpredictable) fall-off in power at the end of their useful life, alkaline cells have a gradual, well defined discharge curve. By subjecting such cells to a defined heavy load and measuring the voltage sustained across the load, remaining cell life can be predicted with reasonable confidence. To take advantage of this trait and predict remaining life of the alkaline cells powering the LED system, a battery tester incorporating a switchable load resistor, voltage comparator, and indicator is built into the battery box. Pilots may readily assess remaining battery life before flight. Experimental data indicate that a set of fresh C-cells will power an LED system for more than 100 continuous operating hours with no discernible decrease in intensity.

In concert with the LED illumination system, cockpit warning and caution indicators are covered with a removable filter matrix composed of dark green plastic filter 'tiles' bonded to a single layer of flexible green filter film commonly referred to as "Glendale Green." The film acts as the mounting surface for the filter tiles, which are cut to size and positioned over illuminated indicators as required. The flexibility of the film allows illuminated switches to be depressed, and the film also acts as a secondary filter by blocking most near-IR energy that leaks around the edges of the filter tiles. The filter tiles are of reasonable optical quality and transmit virtually no red or near-IR wavelengths. Indicator legends viewed through the filter tiles are easily read with the unaided eye but are essentially invisible when viewed with NVGs. The filter film and tile matrices are permanently bonded to the edges of lightweight plastic frames that in turn are affixed with Velcro™ to the structures around the indicators; the filter matrices are installed for night operations and removed for day operations.

For cockpits with color electro-optical displays, filters of good optical quality plastic are installed over such displays. The filters suppress emission of red wavelengths and block most near-IR wavelengths, allowing most color coded information to remain visible. The filters are precision cut to closely fit the display area opening in the existing instrument bezel, and typically are affixed in place using Velcro™. In allowing color information to remain readable, the filters transmit a small amount of red and near-IR energy. Displays therefore must remain at lower brightness settings in order to avoid affecting NVG performance. The filters are installed for night operations and removed for day operations.

The cost of the LED system varies depending on the configuration of the cockpit and the filter requirements. Current recurring costs range from about $1000 for small cockpits having only monochromatic (NVIS compatible) green displays to as high as $5000 for large cockpits requiring multiple color electro-optical display filters.

Paradigms and Trends

Approximately fifteen years ago, when US military night fixed-wing programs first were formalized, NVIS compatible cockpit lighting typically was approached from a paradigm of integral lighting. For example, integral lighting was utilized in the Navy F/A-18 and Marine Corps AV-8B night attack aircraft programs from their inception, and the Navy's entire instrument spares and logistics chain was modified accordingly to support this approach. The effectiveness of integral lighting has been proved over time, and some (but not all) more recent aircraft programs also have incorporated integral NVIS compatible lighting. However, a number of aircraft programs currently exist in which night missions are flown and NVGs are used, but in which the cockpits have yet to be equipped with permanent NVIS compatible lighting.

The cost of any NVIS compatible lighting system is comprised of not just cockpit hardware, but also non-recurring engineering (NRE), documentation, installation, and support costs for the life cycle of the system. On a per-aircraft basis the cost of supporting a permanent NVIS compatible cockpit lighting system can easily outweigh the purchase price of the cockpit hardware alone – which by itself can be very expensive. Previous estimates of the per-aircraft cost to install NVIS compatible integral lighting fleet-wide in a single seat aircraft have run over US$100,000, not counting NRE and support. Such figures have become increasingly unattractive in light of recent defense budget trends, and many aircraft programs have postponed integration of permanent systems while seeking more affordable approaches. Vendors of lighting system components, having recognized this trend, have begun offering increasingly innovative and less expensive alternatives. For example, the cost of a post and bezel system may be estimated at between 20% and 30% of the cost of an integral system. A floodlighting system based on modified existing fixtures can cost even less.

Regardless of the approach taken, implementation of NVIS compatible cockpit lighting across an entire aircraft program takes time. Some aircraft programs, already tasked to fly with NVGs but scheduled to receive permanent NVIS compatible cockpit lighting at some future date, have filled the gap by using chemical light sticks and 'Glendale Green' filter film. Certain shortcomings associated with the use of light sticks and filter film have been known for some time, but until recently no other temporary source of (almost) NVIS compatible light was available. Recent development of the temporary LED-based lighting system, directed by the Air Force Research Laboratory, proved that NVIS compatible lighting need not be costly. Although only intended to be a temporary expedient, the success of the LED system to date has caused a shift of previous paradigms concerning design of NVIS compatible lighting systems. Customers now expect affordability in addition to performance, and out of necessity these expectations have been (and will continue to be) a stimulus for further innovation.

Many aircraft with legacy cockpits having incompatible lighting will remain flying for years to come, and increased use of NVGs will drive a corresponding demand for affordable NVIS compatible cockpit lighting systems. The gradual transition of night vision devices into civilian aviation, which just has begun in the US, may make the cockpit lighting and pilot training issues currently faced by the military appear minor compared to those engendered by the diversity of civilian aircraft types involved. The cockpit lighting methods being developed and lessons currently being learned should prove useful in the future.

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NVIS: Night Vision Imaging System

Night vision goggles (NVGs) are very sensitive to light from any source.

Intensified imagery of the outside scene is of primary importance to the pilot. It is undesirable for NVGs to sense and intensify light from any sources other than those in the outside world.

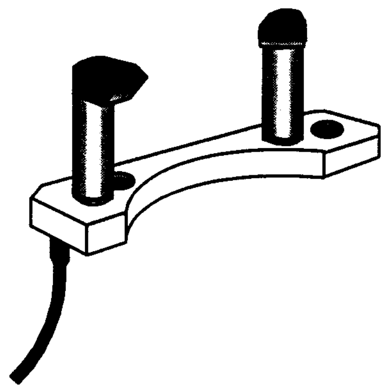
Light from cockpit sources that is detected by the NVG will be intensified and may reduce NVG gain, thus degrading the image quality of the outside scene.

- NVIS compatible lighting results in instruments and displays being easily read with the unaided eye at night, while at the same time ...
- NVIS compatible lighting is not sensed by and generally is invisible to night vision goggles
- NVIS compatible lighting is implemented by tailoring cockpit lighting so instruments and displays only emit wavelengths to which the eye is most responsive; little red and no near-IR emission
- Filters integrated in NVG objective lenses pass only deep red and near-IR wavelengths, blocking all other wavelengths and making the NVG 'blind' to them
- Ideally, cockpit spectral emissions and NVG spectral response are mutually exclusive

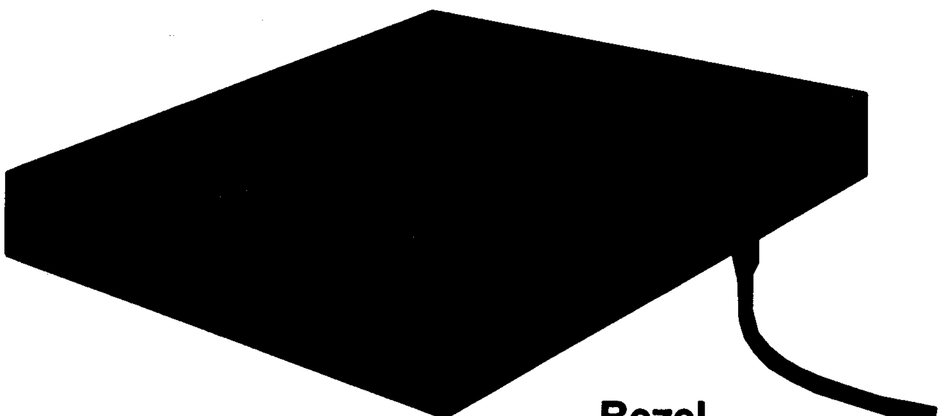
- **Permanent**
  - **Integral (internal) instrument / display lighting**
  - **Post and bezel lighting**
  - **Flood lighting using existing aircraft light fixtures**
  - **Flood lighting using LED-based light sources**
  - **External filtering**
- **Temporary**
  - **Chemical light sticks**
  - **Light emitting diodes**

- **Internal light sources in instruments that are filtered or modified to emit no red or near-IR energy. Implemented during manufacture, or retrofitted at a qualified instrument repair facility.**
- **Usually provides excellent illumination; light sources are optimally located in instrument design.**
- **Requires no aircraft wiring changes.**
- **When unpowered, an integrally illuminated NVIS compatible instrument externally appears no different from an incompatible instrument. Labeling is important.**
- **Supply chain spares and logistics issues arise if all similar instruments are not also NVIS compatible.**

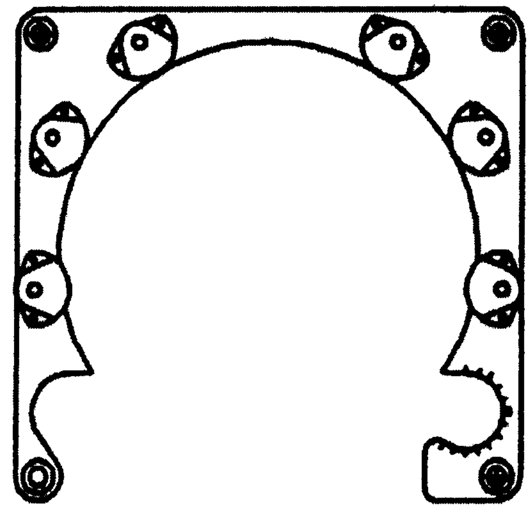
- Small NVIS compatible light sources, external but immediately adjacent to the instrument faces.
- A bezel surrounds an instrument, contains light sources around perimeter, usually covers instrument face with a special window that directs light inward.
- Post lights stand out a short distance from panel, directing light down toward instrument face. Careful location is required in order to avoid reflected glare.
- Very close range of lighting (particularly with bezels) results in a short "throw distance." Design is important in achieving uniform illumination.
- Requires aircraft electrical system changes (and sometimes drilling).



Post

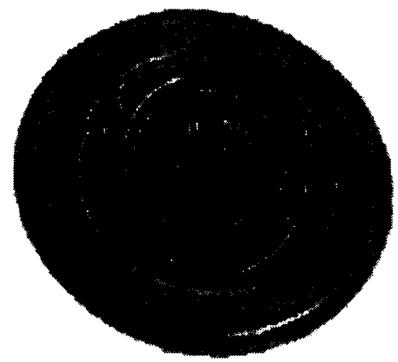


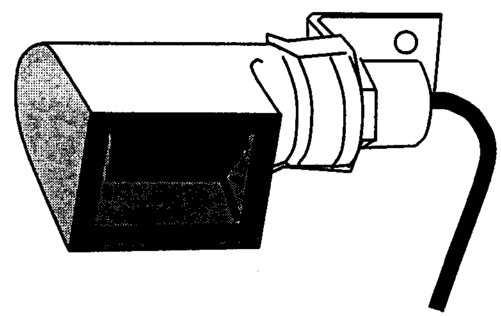
Bezel



Hybrid

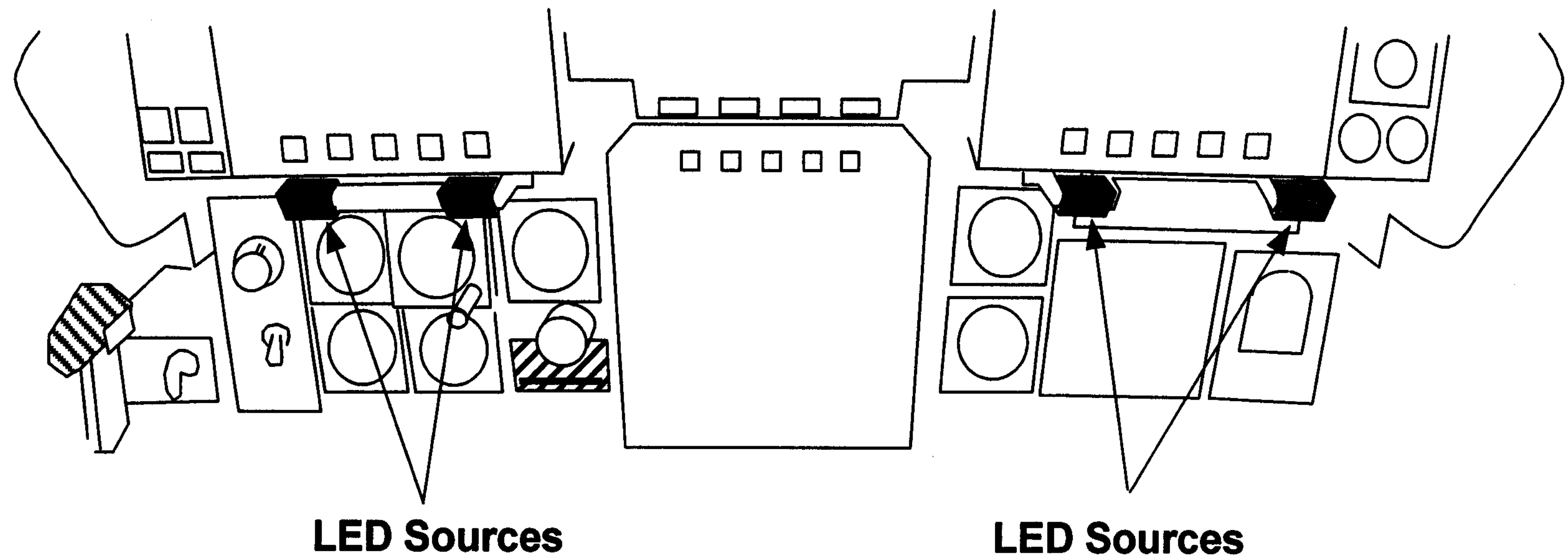
- NVIS compatible light sources, external to (and usually some distance away from) instruments, strategically located throughout cockpit. Existing fixtures and/or locations typically are used.
- Relatively inexpensive and easy to retrofit. Implementation may be as simple as substituting new filter glass in place of existing clear glass.
- Requires no changes to conventional instrument illumination system, usually no wiring changes.
- Potential shadowing problems (sometimes severe) and reflected glare from specular surfaces in cockpit.





Typical fixtures

- **NVIS compatible light produced by multiple Light Emitting Diode based sources in enclosures strategically located throughout cockpit.**
- **Relatively inexpensive and easy to install. LED-based sources are mounted with brackets using existing screw locations, interconnected with dedicated wiring. Powered by battery or aircraft electrical system.**
- **Independent permanent system, requiring no changes to conventional lighting system. Existing instrument lighting simply is extinguished.**
- **Potential for shadowing or non-uniform illumination depending on location of sources. Also possible vulnerability to physical damage depending on bracket height and location.**

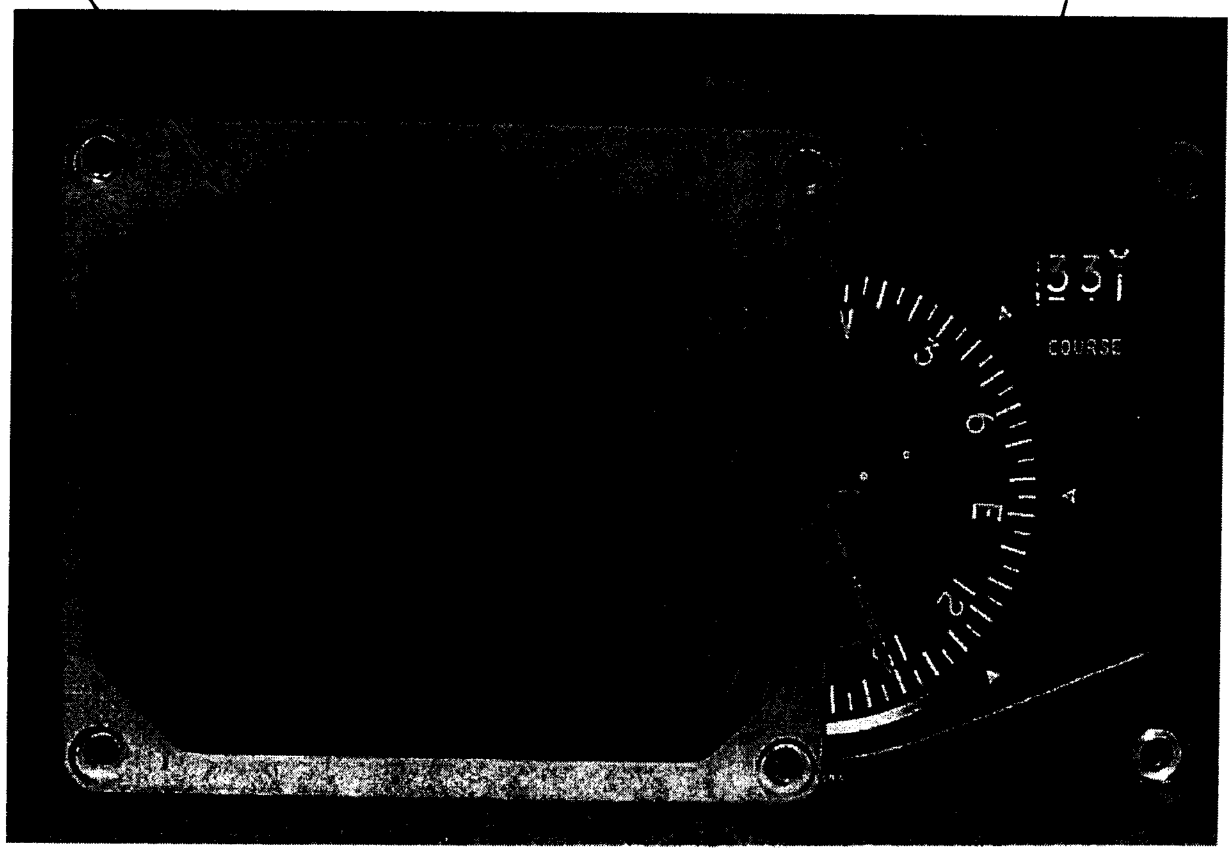


F-15E Cockpit Example

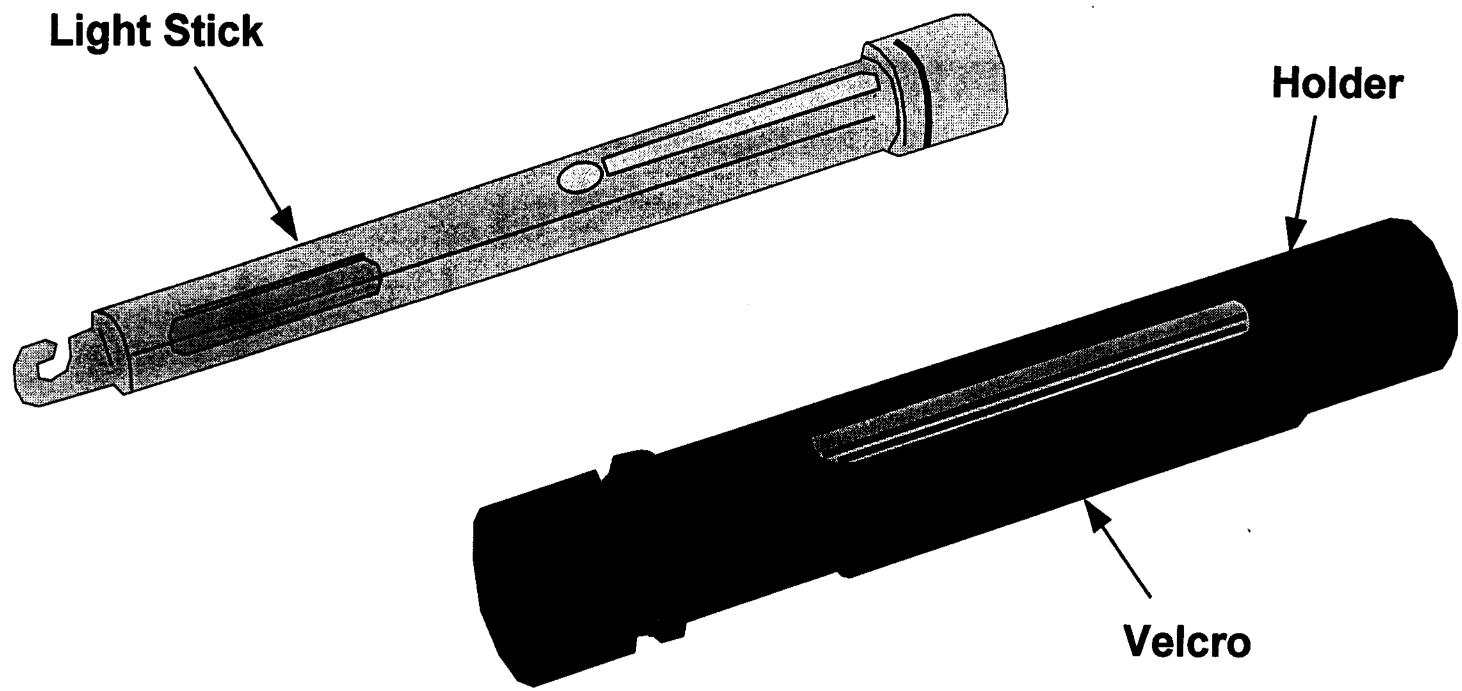
- Special glass filters, mounted in metal frames, semi-permanently affixed over faces of existing (unmodified) instruments using existing screws.
- Filter is of high optical quality, does not transmit deep red and near-IR. Filter color appears light aqua to the unaided eye.
- Existing internal instrument lighting is used.
- No aircraft wiring changes are required.
- If instrument repair and exchange is required, filter is transferred from old instrument to replacement instrument. No dissimilar spares issues.

External filter

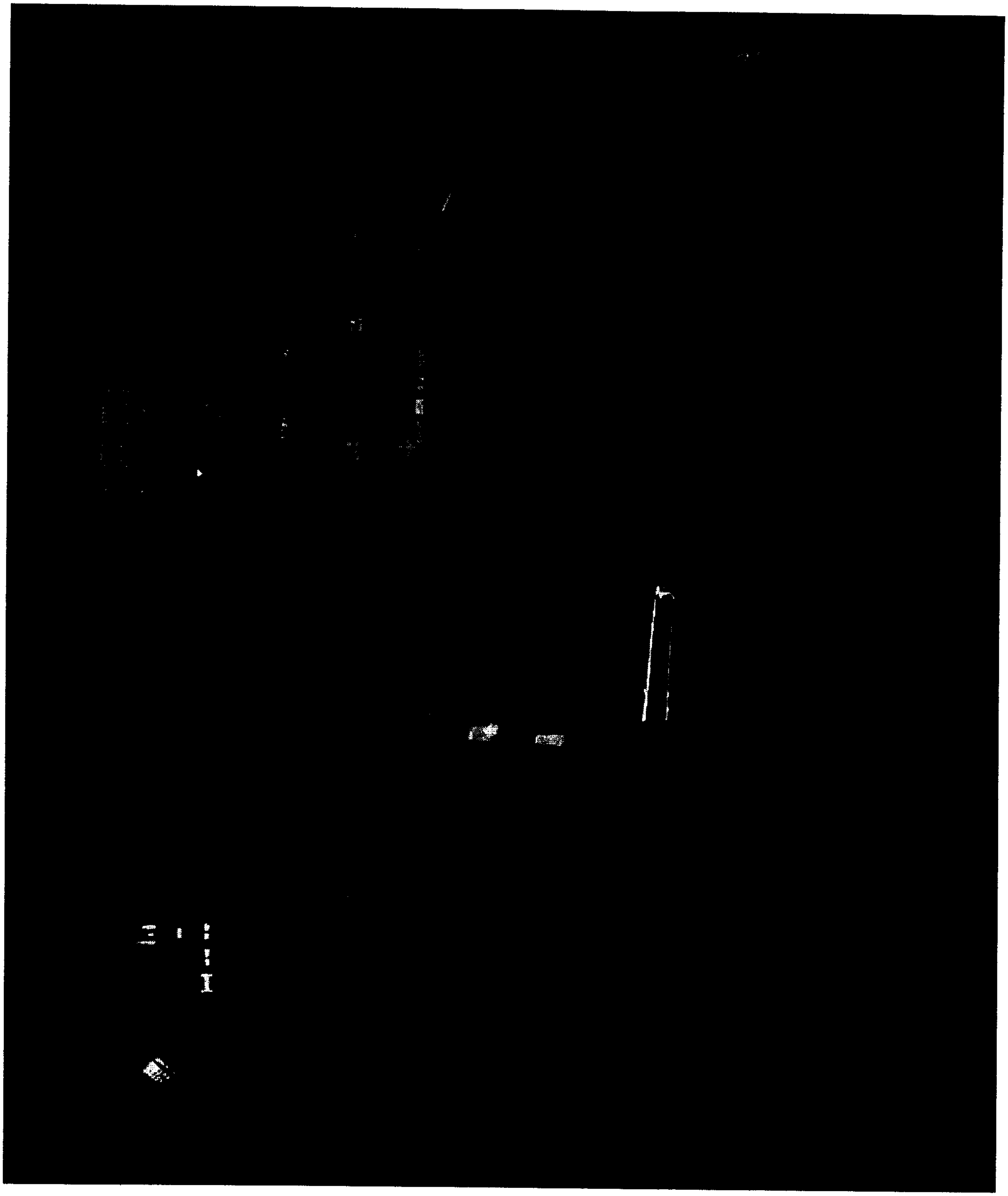
Existing instrument



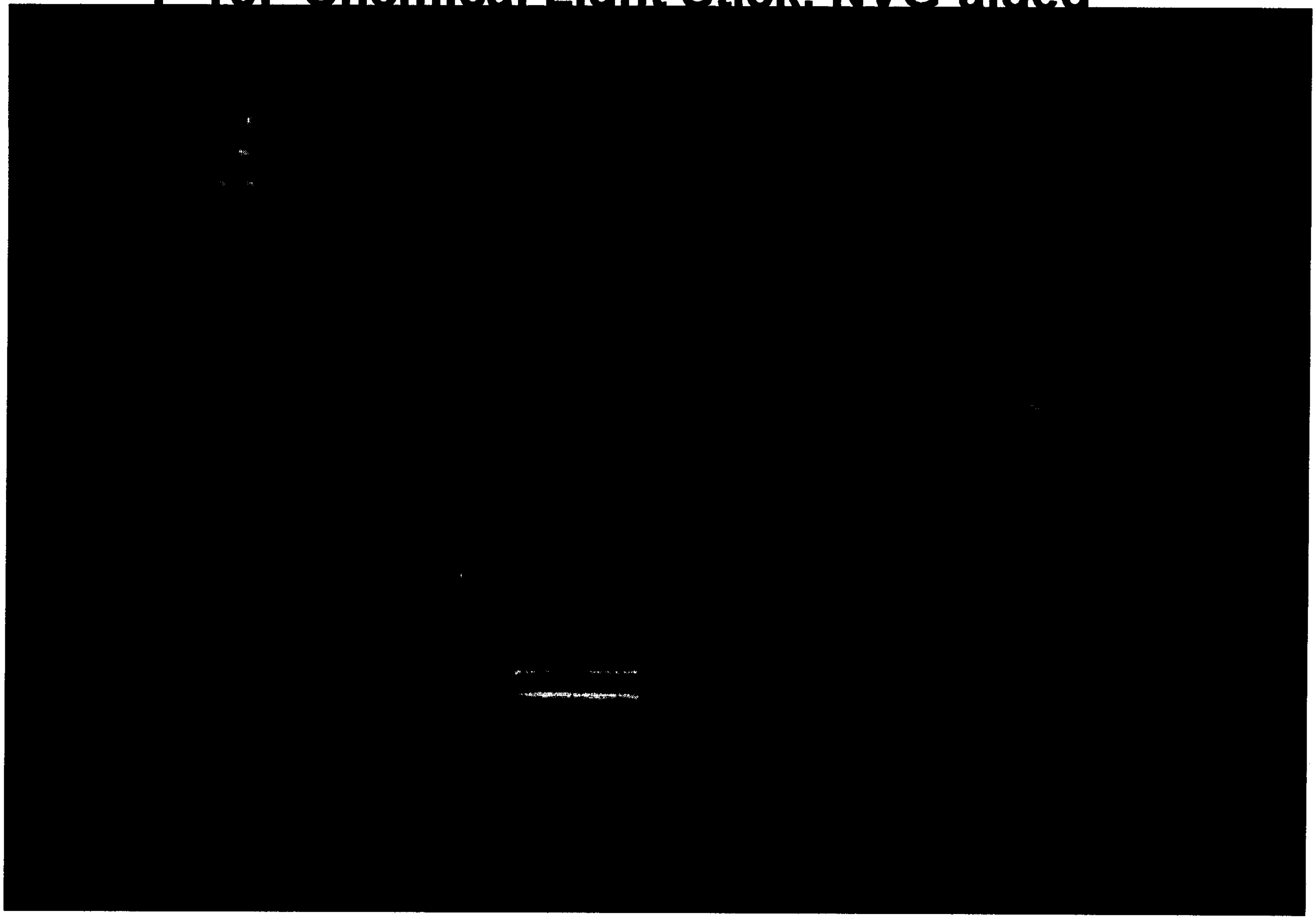
- Temporary source of illumination, currently used in aircraft for which permanent lighting installations are not available.
- Light sticks emit light as a result of a chemical reaction between two liquids. Light sticks are placed in tubular holders, affixed with Velcro™ near instruments.
- Emission is green, with slight 'tail' into the red. Energy is sensed and intensified by NVG, but adverse effects usually are minor.
- Direct reflections of light stick emissions may be visible in canopy. NVG image of outside world is severely degraded in these areas.
- Intensity peaks shortly after activation, then gradually diminishes.
- Replacement at specific intervals is important. The eye continuously adapts as luminous intensity of light sticks slowly decreases, and there is no warning that the instruments are about to become unreadable.



Light Stick
Holder
Velcro

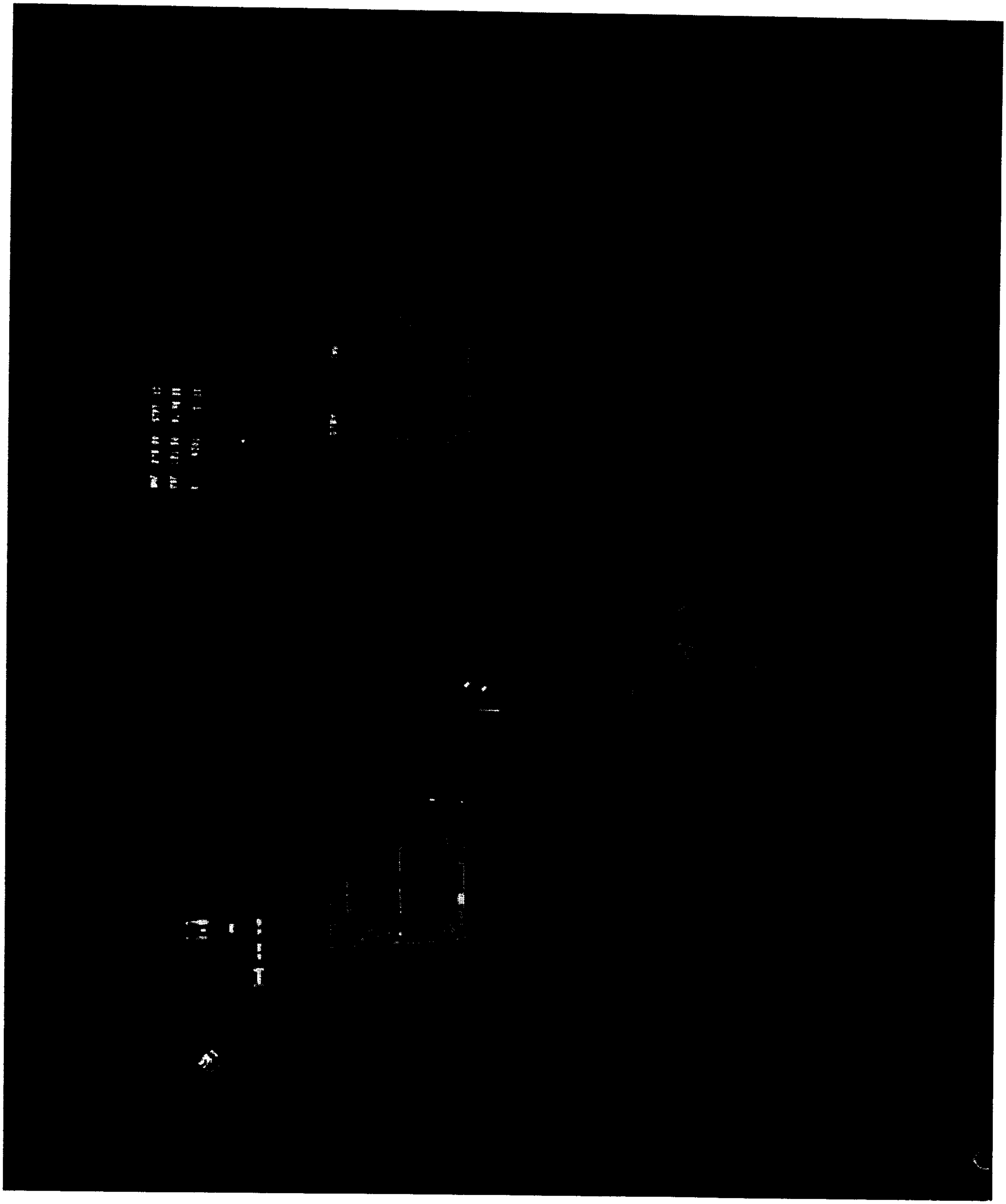


F-16: Chemical Light Stick, NVG-aided



Temporary system for use where permanent systems are unavailable.

- Inexpensive, easily installed. (Roughly 90 minutes to install in F-16.)
- LEDs used are capable of very high intensity, emit bluish-green light with virtually no red or near-IR spectral components.
- Multiple LEDs are grouped together in small modules. Modules are located on cockpit side walls and/or adjacent to instruments, affixed with Velcro™. 'String' of modules is interconnected with small wires.
- Powered by one set of alkaline C-cells, independent of aircraft power. Estimated 100+ continuous operating hours on one set of fresh C-cells.
- Battery box incorporates power switch, battery tester, intensity control(s). Removable, typically located near existing interior lighting control panel.
- Potential for shadowing or non-uniform illumination depending on location of modules. Modules also may be vulnerable to physical damage.



F-16: LED System, NVG-aided