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ACTIVE CAMOUFLAGE FOR INFANTRY HEADWEAR APPLICATIONS

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Abstract

This report was prepared as a trade study review of current and projected active camouflage systems. While numerous applications were discussed, the focus was for systems that could be used by infantry soldiers, and specifically for infantry helmet applications.

A review of the current and projected active camouflage systems revealed that there are many systems under development for aviation, maritime, and ground operations. Early prototypes for infantry soldiers were presented in detail.

A system overview was prepared in order to present camera, image processing, and display solutions. Finally, a discussion focusing on technology limitations, applications, and future considerations was presented. This trade study showed that numerous technologies for active camouflage systems are under development; however major technical roadblocks must be addressed before systems will be ready for infantry applications.

Résumé

Le présent rapport a été rédigé sous forme d'étude commerciale des systèmes de camouflage actif, actuels et futurs. Bien que de nombreuses applications aient été discutées, l'accent a surtout été mis sur les systèmes pouvant être utilisés par les fantassins, en particulier pour les applications destinées aux casques d'infanterie.

Un examen des systèmes de camouflage actif, actuels et futurs, révèle que de nombreux systèmes sont en voie d'élaboration pour les opérations aériennes, maritimes et terrestres. De nouveaux prototypes destinés aux fantassins ont été présentés en détail.

Un survol des systèmes a été préparé afin de présenter des solutions de caméra, de traitement d'image et d'affichage. Enfin, on a discuté des limites de la technologie, de certaines applications et de considérations futures. L'étude commerciale a montré que de nombreuses technologies relatives aux systèmes de camouflage actif étaient en voie d'élaboration. Cependant, d'importants obstacles techniques devront être surmontés avant que les systèmes ne soient prêts pour les applications destinées à l'infanterie.

Executive Summary

Active camouflage in the visual spectrum differs from conventional camouflage in that it replaces the appearance of what is being masked with an appearance that is not only similar to the surroundings (like in conventional camouflage) but with an exact representation of what is behind the masked object. Furthermore, active camouflage does this in real time. Ideally active camouflage would not only mimic nearby objects but also distant ones, potentially as far as the horizon, creating perfect visual concealment.

This report was prepared as a trade study review of current and projected active camouflage systems. While numerous applications exist or are in development, the focus of this investigation was on systems that could be used in infantry operations. It was the intention of this study to assess the form, future availability, and shortcomings of an active camouflage system specifically for infantry helmet applications. Moreover, the goal of this study was to present information to be used for assessing the current feasibility of active camouflage systems, and to aid in projecting future readiness.

A review of the current and projected active camouflage systems revealed that there are many systems under development for aviation, maritime, and ground operations. Early prototypes for infantry soldiers include camera, image processing, and display solutions. This trade study showed that numerous technologies for active camouflage systems are under development; however major technical roadblocks must be addressed before systems will be ready for infantry applications.

Sommaire

Le camouflage actif dans le spectre du visible est différent du camouflage conventionnel. En effet, il remplace l'apparence de ce qui est masqué par une apparence, non seulement semblable aux alentours (comme dans le cas du camouflage conventionnel), mais avec une représentation exacte de ce qui se trouve derrière l'objet masqué. En outre, le camouflage actif se déroule en temps réel. Théoriquement, le camouflage actif imite, non seulement les objets à proximité, mais aussi les objets éloignés, potentiellement aussi loin que l'horizon, créant ainsi une dissimulation visuelle parfaite.

Le présent rapport a été rédigé sous forme d'étude commerciale des systèmes de camouflage actif, actuels et futurs. Bien que de nombreuses applications existent ou sont en voie d'élaboration, la présente enquête porte sur les systèmes susceptibles de servir dans les opérations de l'infanterie. L'étude visait à évaluer la forme, la disponibilité future et les lacunes d'un système de camouflage actif, en particulier pour le casque de l'infanterie. De plus, elle visait à présenter l'information nécessaire pour évaluer la faisabilité actuelle des systèmes de camouflage actif et aider à planifier l'état de préparation opérationnelle à venir.

Un examen des systèmes de camouflage actif, actuels et futurs, révèle que de nombreux systèmes sont en voie d'élaboration pour les opérations aériennes, maritimes et terrestres. De nouveaux prototypes destinés aux fantassins comprennent des solutions de caméra, de traitement d'image et d'affichage. L'étude commerciale a montré que de nombreuses technologies relatives aux systèmes de camouflage actif étaient en voie d'élaboration, mais que d'importants obstacles techniques devront être surmontés avant que les systèmes ne soient prêts pour les applications destinées à l'infanterie.

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1 Introduction and Background

The main goal of an active camouflage system is to enhance stealth operations. Currently, infantry reconnaissance and infiltration operations are performed with conventional camouflage designed to conceal the soldier using two basic elements: colour and pattern. However, military operations in urban environments are currently becoming more prevalent in which the optimum colour and pattern could continuously change by the minute. For example, a soldier wearing a green colouration pattern would stand out against a white wall. An active camouflage system would continuously update the colour and pattern, concealing the soldier in the current environment.

This report was prepared as a trade study review of current and projected active camouflage systems. While numerous applications exist or are in development, the focus of this investigation was on systems that could be used in infantry operations. It was the intention of this study to assess the form, future availability, and shortcomings of an active camouflage system specifically for infantry helmet applications. Moreover, the goal of this study was to present information to be used for assessing the current feasibility of active camouflage systems, and to aid in projecting future readiness.

1.1 Definition

Active camouflage in the visual spectrum differs from conventional camouflage in 2 ways. First, it replaces the appearance of what is being masked with an appearance that is not only similar to the surroundings (like in conventional camouflage) but with an exact representation of what is behind the masked object. Secondly, active camouflage also does this in real time. Ideally active camouflage would not only mimic nearby objects but also distant ones, potentially as far as the horizon, creating perfect visual concealment.

Visual active camouflage can be used to mask the ability of both the human eye and optical sensors.

1.2 Uses from Fiction

Many examples of active camouflage systems are found in fiction, and developers often choose to name the technology based on some fictional reference. These are typically for complete active camouflage (i.e. complete invisibility) and do not address the possibility of partial active camouflage, active camouflage for specific operations, or any of the current realistic technological boundaries. However, complete invisibility would obviously be useful for infantry operations such as reconnaissance and infiltration.

1.3 Types of Camouflage

Camouflage is not only considered in the visual spectrum but also includes acoustics (e.g. sonar), the electromagnetic spectrum (e.g. radar), thermal (e.g. infrared), and shape (see Figure 1). Camouflage technologies, including some forms of active camouflage, have been developed to some degree in all of these spectrums, especially for vehicles (land, sea, and air). Although this study pertains mainly to visual camouflage for the dismounted infantry soldier, it is useful to briefly consider solutions in other domains since some of the technological ideas may be transferred into the visual spectrum.

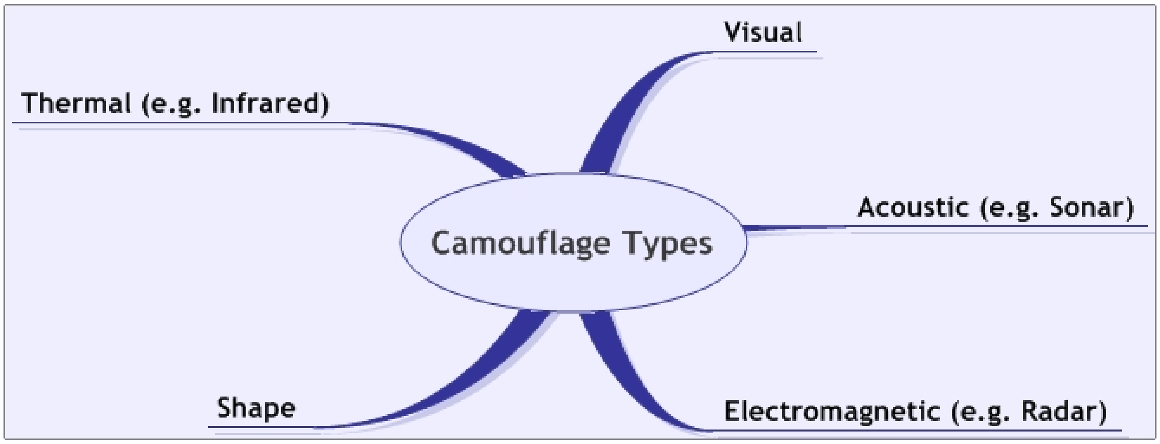

Figure 1: Camouflage Types

1.3.1 Visual Camouflage

Visual camouflage consists of shape, surface, shine, silhouette, shadow, spacing and movement (Sen, 2002). An active camouflage system would account for all of these aspects. Since visual active camouflage was the focus of this technical note, theses systems are presented in detail in the following sub-sections 2 to 5.

1.3.2 Acoustic Camouflage (e.g. Sonar)

Since the 1940's many countries have experimented with sound absorbing coatings to reduce sonar reflection on submarines. Gun silencing technologies are a form of acoustic camouflage. Also, active noise suppression is an emerging field which could potentially be developed into acoustic camouflage. Active noise suppression headphones are currently available to the consumer. Near-Field Active Noise Suppression systems are being developed which are placed in the acoustic near-field for the active minimization of primarily tonal noise from axial flow fans (Sommerfeldt, 2000). It is foreseeable that future systems could be developed for the long-range acoustic field to mask infantry operations.

1.3.3 Electromagnetic Camouflage (e.g. Radar)

A Belgian company "Transact" has developed anti-radar camouflage nets for the armed forces of several NATO countries (Jewish and Sweetman, 1997). These nets combine special coatings and the use of a micro-fiber technology, providing broadband radar attenuation of greater than 12dB. The use of optional thermal blankets extends protection into the IR bands.

The Barracuda Multispectral Ultra Lightweight Camouflage Screen (BMS-ULCAS) uses a garnishing material attached to a backing material (Jewish and Sweetman, 1997). The material reduces broadband radar detection and also reduces IR and visible bands. Each screen is designed specifically to match the equipment that it is protecting.

1.3.4 Shape Camouflage

In the future, active camouflage might entail the masked object to adapt to the shape of the environment. This technology is known as SAD (Shape Approximation Device), and could potentially reduce edge detection. One of the most convincing examples of active shape camouflage is the octopus, which can blend into its surroundings not only by changing colour, but also the shape and texture of its skin.

1.3.5 Thermal Camouflage (e.g. Infrared)

South African industry and Armscor, the country's arms-procurement agency, are sponsoring an Armoured Technology Demonstrator involving electro-optical signature reduction (Jewish and Sweetman, 1997). The demonstrator, based on a Reumech Ratel wheeled vehicle, uses a combination of low-emissivity paints and thermal layers that are shaped and colored to provide a camouflage pattern. Together, these reduce an actual surface temperature of 40 degrees C to 28 degrees C when viewed through a thermal imager.

Spectro Dynamic Systems Inc. has a US Army contract to develop an advanced face paint system that reduces the likelihood of individual soldiers being detected by thermal imagers (Jewish and Sweetman, 1997). A material is being developed that suppresses the thermal signature of exposed skin by diffusing thermal emissions with silver-coated hollow ceramic microballoons (cenospheres), averaging 45 cm in diameter, incorporated into a binder to produce a pigment with low emissive and diffusive properties. The microballoons act like a mirror, reflecting the surrounding environment and each other, thereby diffusing the emission of thermal radiation from the skin.

1.3.6 Multi-spectral Camouflage

Some camouflage systems are multi-spectral, meaning that they work for more than one camouflage type. Barracuda Inc. has developed a multispectral camouflage product, the High Mobility on Board System (HMBS), which protects equipment such as howitzers when they are both firing and redeploying (Jewish and Sweetman, 1997). Signature reductions of up to 90 per cent are possible, and the suppression of thermal emissions allows engines and generators to remain idling in order to permit a rapid start. Some parts of the system are reversible, allowing soldiers to carry double-sided camouflage for use in different terrain.

2 Current and Projected Solutions for Visual Active Camouflage

Numerous active camouflage designs are currently under development. Although the main focus of this paper is for infantry and in particular the headwear system, it is relevant to discuss current solutions in other domains since technology is being developed that could be applied to headwear. Therefore, this section briefly describes some of the solutions found in the aviation and marine domains, ground transportation, and then focuses on the infantry environment.

2.1 Aviation

2.1.1 Project Yehudi (WWII)

In the early 1940's, an example of active camouflage was called "Project Yehudi" (Jewish and Sweetman, 1997). Airplanes were modified with lights on their wings that would turn on as they got closer to the surface thereby matching the bright sky background. This could enable them to approach surfaced submarines without being seen. Colour camouflage alone is not sufficient since, as the aircraft altitude gets lower, even a very light colour will appear darker against a brightly lit sky.

2.1.2 Lockheed's Have Blue Stealth Prototype

In the 1970's Lockheed produced a prototype aircraft that had active light ports on the bottom surface (Jewish and Sweetman, 1997). These light ports were connected to fiber optic lines that were modulated by a detector on the opposite side of the aircraft. Depending on the altitude of the aircraft and the colouration and brightness of the environment, visual detection of the aircraft was reduced.

2.2 Maritime

In the mid 1980's US Navy developed a ROV (Remotely Operated Vehicle) which resembled a small wave (Jane's International Defense Review (2002)).

Global Atlantic Inc. in collaboration with Olin's Smart Boat Corporation and Boston Whaler are attempting to produce a working, active camouflage for a small multipurpose vessel (Sen, 2002). It uses OLED's in conjunction with a small 360 degree camera to display images of the vessel's surroundings on its surface.

2.3 Ground

The production of an effective active camouflage system on the ground depends on successful progress along two key lines of research: The continued development and miniaturization of photoelectronic systems (such as OLEDs and CCDs), and research in the areas of neurology, psychology, biology, Artificial Intelligence (A.I.) and machine vision (Clayton, 2005).

2.3.1 Cloaking Tanks

NASA's Jet Propulsion Laboratory has proposed lightweight optoelectronic systems that use image sensors and display panels (Moynihan and Langevin, 2000) that display the background image of terrain behind the object being camouflaged. The display panels would be sized and configured so that they could be used to cloak a variety of objects. The volume of a typical image sensor would be less than about 1 cubic inch (16 cubic cm). A system to completely cloak an object 10 m long by 3 m high by 5 m wide would weigh less than 100 lb (45 kg). If the object to be cloaked were a vehicle, then the adaptive camouflage system could potentially be operated on power provided by the vehicle electrical system. Figure 2 depicts the proposed design concept.

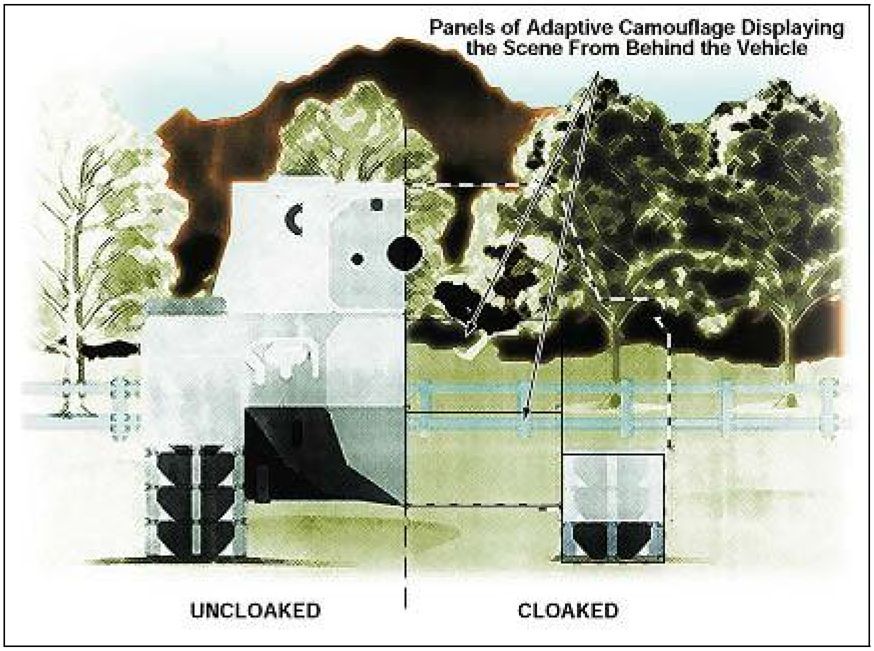

Figure 2: Active Camouflage Panels (Moynihan and Langevin, 2000)

2.3.2 Project Chameleo

Richard Schowengerdt has filed a US Patent for a cloaking system using "optoelectronically" controlled camouflage (Schowengerdt, 1992). The system involves a device designed to conceal an object by placing a thin "video screen" between the observer and the object being concealed. Schowengerdt calles his company "Project Chameleo" and plans to allow for both stationary and moving vehicles and soldiers.

2.4 Infantry

2.4.1 Optical Camouflage: Projection

The Tachi Laboratory at the University of Tokyo has developed numerous applications of Retro-reflective Projection Technology (RPT) (Tachi, 2003). One of them involves a system for active camouflage in which a camera and projector are set up in front of the eye of an observer, as shown in Figure 3.

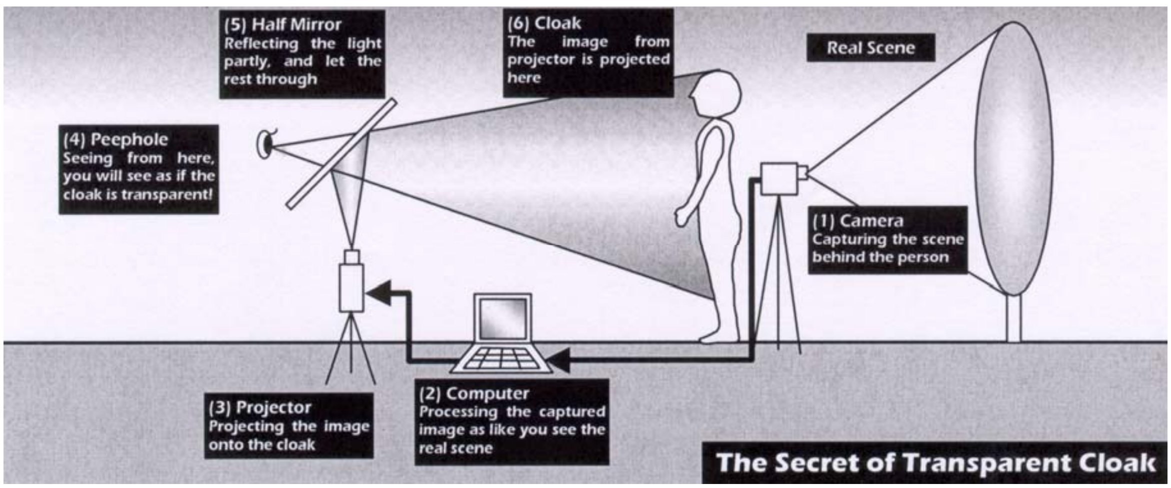

Figure 3: RPT System for Active Camouflage (Tachi, 2003)

The image is projected onto a retro-reflective material. From the eye of the observer, the retro-reflective material appears invisible as shown in Figure 4.

Figure 4: RPT with projection on a retro-reflective cloak (Tachi, 2003)

2.4.2 Other Developments

Canadian and German military researchers are developing a chameleon-like armored vehicle capable of altering its appearance to conceal itself from the enemy (Highfield, 2002). The British defence research agency QinetiQ is working on an active camouflage system called “rugged smart skins”. NASA has commissioned studies of this invisibility technology, called "adaptive camouflage”.

All of these developments typically include a network of electronic flat-panel display units, each containing a camera, configured into a flexible array (Highfield, 2002). Light direction, colour, intensity, and other information is required to produce the image on the displays in front.

3 System Overview

3.1 Cameras

Some proposed active camouflage systems have cameras mounted directly onto the object being masked, and some systems have remotely installed cameras. If the system design is such that the camera is to be mounted directly on the object being masked, one limitation would be that the camera must either be actively camouflaged or else be extremely small. Currently numerous micro cameras are available to the consumer, and off-the-shelf miniature color cameras may be suitable for some types of active camouflage systems (McCarthy, 2003). Figure 5 shows a 9 gram (1/3 oz) colour video camera available from Helihobby Inc.

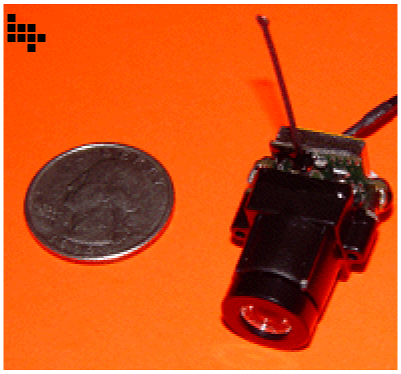

Figure 5: Colour Micro Video Camera (Helihobby, 2005)

3.2 Resolution and Imaging

When considering resolution of the display, the distance from the display to the viewer must be taken into account. If the viewer is only 2 meters away, the resolution need not be much finer than the granularity of human vision at that distance, approximately 289 pixels per square centimeter (McCarthy, 2003). If the viewer is closer, the resolution must be higher.

Imaging must take into account the way the observer's view changes depending on the distance they are away from the display. For example, a person viewing a display at a distance of 20 meters would see more of what is behind the display than a person at a distance of 5 meters. Therefore the system must detect where the viewer is looking from in order to adjust the image or else the size of the image and the edges will be detectable.

One solution for imaging is to create a 3-D digital model of the environment (McCarthy, 2003). It is proposed that the digital model would be constructed in real time since it would most likely be impractical to model real-world locations ahead of time. Stereoscopic pairs of cameras would allow the system to detect location, colour and brightness. A process called ray-trace rendering is proposed in order to turn the model into a 2 dimensional image on a display.

Current standard displays (including flexible ones) are only intended for straight-on viewing. Therefore, a system must also be developed that allows viewing from angles. One solution would be to use a display based on an array of hemispherical lenses (McCarthy, 2003).

Depending on the position of the sun and the observer, the display could be noticeably brighter or darker than the environment (Hewish and Stweetman, 1997). If there are two observers, two different display brightnesses would be required.

3.3 Displays

Flexible display technologies have been pursued for more than 20 years (Kincade, 2004). Numerous methods have been proposed in an attempt to produce a display that is flexible, durable, low cost, and also provides adequate resolution, contrast, color, viewing angle, and refresh rate. Currently, developers of flexible displays examine customer requirements in order to determine the most appropriate technology, rather than propose one single best solution for all applications.

3.3.1 Display Types

3.3.1.1 RPT (Retroreflective Projection Technology)

The Tachi Laboratory at the University of Tokyo uses Retroreflective Projection Technology (RPT) to project an image onto a surface (Tachi, 2003). Numerous applications have used retro-reflective material, which has been available for many years. For example, stop signs are made of retro-reflective material. Figure 6 shows a person holding a object covered with a retro-reflective material, with the image of the bookcase behind the object projected onto its surface.

Figure 6: Retro-Reflective Surface (Tachi, 2003)

3.3.1.2 OLEDs (Organic Light Emitting Diodes)

The first Organic LED products to incorporate flexible displays will likely be electronic books, paper, and signage (Kincade, 2004). Philips, E Ink, and Toppan, Sony, and Matsushita are currently developing e-books. Also, in December 2003 Gyricon released the SyncroSign Message Board, which is a battery-powered wireless-network sign that incorporates a rewriteable display medium. Military, academic, and commercial groups are aiming at developing OLEDs for full-color flexible displays as shown in Figure 7.

Figure 7: Organic LED Prototype shown on a Flexible surface (Kincade, 2004).

OLEDs are self-luminous and do not require backlighting, polarizers, or diffusers (Kincade, 2004). This reduces their size and weight. In addition, they offer a wide viewing angle and low power consumption. Currently, OLEDs are not as bright as other displays. However, Kodak's Display Technology Laboratory recently announced a transparent, stackable OLED design that yields brighter, more stable color displays. The OLED manufacturing process is much more amenable to retaining optimum performance on a flexible surface than other display technologies.

Currently, OLEDs are extremely sensitive to moisture and oxygen. However, Universal Display, Philips, DuPont, 3M, and Kyocera are working to commercialize OLED-based flexible displays for a variety of consumer and military products.

Kodak has developed a class of OLEDS based on organic electroluminescence (Sen, 2002). When a charge is applied to these chemicals, light of a certain colour is emitted. The chemicals can be printed on plastic films to form screens. Protection from harsh environments can be achieved by encapsulation in epoxy resin. These screens can then be applied to a surface. If the observer views the screen with the sun behind him the device could darken its colour from that perspective; if the screen is between the sun and the observer the OLEDs could brighten it.

DARPA has a goal by 2010 is to produce a lightweight, flexible, e-page display that soldiers can roll up to store and throw away when they are finished with it (McHale, 2000). It is proposed that the display would eventually cost 10 cents per square inch.

OLED technology also benefits the military by being more rugged than liquid crystal displays (LCDs) and other glass displays because it is solid state technology that uses plastic (McHale, 2000). Moreover, LCD technology is subject to vibration problems as well as frozen crystals in extremely cold temperatures. The OLEDs will also enable displays to have better resistance to shock.

3.3.1.3 LCD (Liquid Crystal Display)

Liquid-crystal technology also lends itself to flexible displays, although the performance is different (Kincade, 2004). Transmissive LCDs, which require an additional lamp to backlight the LCD, are good for high-brightness applications. Reflective LCDs, which offer longer battery life because no additional illumination is needed, are more appropriate for applications involving ambient light, although they suffer from poorer contrast.

Because of their low power consumption, cholesteric LCDs are being pursued for e-books and other potential flexible-display products (Kincade, 2004). Several companies are working to improve the image quality of these displays. Kent Displays (Kent, OH) is commercializing cholesteric LCD technology that features a bistable, nonvolatile memory to maintain images indefinitely without consuming electrical power. The reflective nature of the cholesteric fluid yields high contrast. Therefore, high ambient lighting conditions improve the contrast, rather than degrade it like in most other current display systems.

Nematic LCDs are another type of LCD which rely on bistability to enhance contrast (Kincade, 2004). They have been introduced on glass substrates and polymers. ZBD Displays (Worchestershire, England) produces zenithal bistable displays through a collaboration with Varitronix, a leading manufacturer of passive-matrix LCDs. Solid State Displays (SSD; Austin, TX) is currently developing a polymer-dispersion liquid-crystal technology (PDLC). PDLC has been around for years and has suffered from problems with contrast ratio. However, SSD has patented a process that adds polarization to PDLCs, yielding a fast-switching field-sequential color display that is well-suited to flexible substrates.

3.3.1.4 TFT (Thin Film Transistor)

The US Military is investing in research to combine polymer and metal-foil substrates with printable TFT (Thin Film Transistor) backplanes (Kincade, 2004). A backplane is required for E-Paper and E-Ink technologies (Section 3.3.1.5). It is hoped that this technology will benefit over the other displays because of its reducing weight, small thickness, and ruggedness. The U.S. Army has created the Flexible Display Initiative (FDI), which is a five-year, $43.6 million university-based initiative designed to speed the commercialization of emissive and reflective display and thin-film transistor (TFT) backplane technologies on polymer and metal-foil substrates.

Figure 8: Polymer and metal foil display (Kincade, 2004)

3.3.1.5 E-Paper and E-Ink

There are currently a handful of commercial e-paper technologies (Kincade, 2004). Gyricon's Smart Paper is produced in a roll like conventional paper but is actually two sheets of thin plastic with millions of tiny bichromal beads embedded in between. Each bead has a different color on each side, and the hemispheres carry either positive or negative charges. When voltage is applied to the surface, the beads rotate to present one side or the other to the viewer. The image stays in place until a new voltage pattern is applied, which erases the previous image and generates a new one.

E-Ink uses stationary microcapsules that contain white particles, black particles, and a clear fluid (Kincade, 2004). When a charge is applied to a capsule, black particles rise to the top. An opposite charge brings the white particles to the top. Philips is also developing a system with black oil and water trapped in tiny cells to create black and white pixels. An electric charge makes the water push the black oil to the side, exposing a white surface underneath. Figure 9 depicts a current TFT backplane and E-Ink frontplane system.

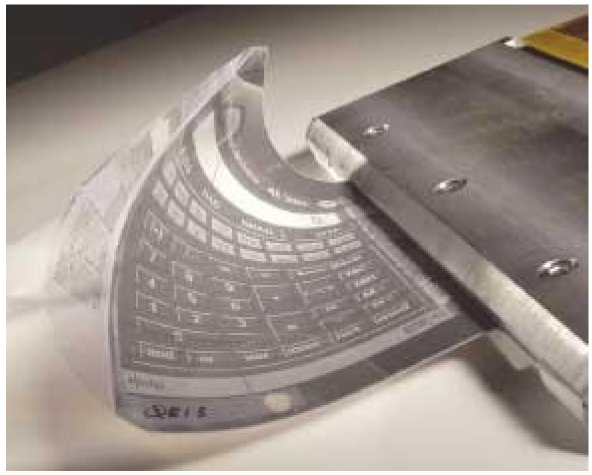

Figure 9: Philips' TFT backplane with E-Ink's Frontplane (Kincade, 2004)

3.3.1.6 Electrochromic Materials

Active camouflage systems under development for large areas of an aircraft use electrochromic materials (Jewish and Sweetman, 1997). These materials are thin films that change tone or color when an electrical current is passed through. However, even a very efficient lighting system requires a lot of energy to match the brightness of the sky.

3.3.1.7 Nanotechnology

Nanotechnology involves engineering at molecular level to produce miniaturized and highly efficient systems (Burger, 2003). It is a growing field for military uses. The U.S. Army and the Massachusetts Institute of Technology (MIT) opened the Institute of Soldier Nanotechnology (ISN) in 2003 to support the Objective Force Warrior science and technology project. Concepts include sleek, lightweight suits that serve as body armour, first-aid equipment, chemical-biological agent protection and camouflage all-in-one. Similar research includes actuated muscle fibres that add to a soldier's strength and the ability to make nearly everything a soldier wears impervious to water and bacteria growth. It is proposed that the same suit might also feature an active camouflage system that can mimic its surroundings, even adjusting to changes made by movement, so that a soldier becomes nearly invisible.

4 Discussion

4.1 Technological Limitations

Currently, numerous technological limitations are holding active camouflage systems back from being manufactured for the soldier system. Although some of these limitations are being developed, with projected availability approaching within 5 to 15 years (e.g. flexible displays), there are still some outstanding limitations that have yet to be addressed. Some of these are outlined below.

4.1.1 Display Brightness

One limitation of a display-based active camouflage system is the ability to make the image bright enough to blend in with daytime lighting conditions. The average brightness of the open sky is 150 watts per square meter, and most displays look blank in full daylight (McCarthy, 2003). A brighter display (with a luminescence closer to that of a traffic light) would be necessary, which is not necessarily a requirement in other fields of development (e.g. computer monitors and information displays would not have to be this bright). Therefore, display brightness may become one area that would hold active camouflage back from being developed. Furthermore, the sun is 230,000 times more intense than the sky surrounding it. If the system allows for passing in front of the sun without looking hazy or casting shadows, a display equally as bright as the sun would need to be developed.

4.1.2 Computing Power

The main limitations of actively controlling a display and continuously updating so that it can not be traced by the human eye are the power of the software and the memory capacity in the controlling microprocessors (Sen, 2002). Also, if we consider that a 3D model would have to be constructed in real-time based on imaging techniques from the cameras, the software and capacities of the controlling microprocessors would also be a major limitation. Moreover, if we consider this system is to be autonomous and worn by the soldier, the computer would have to be light, small, and flexible enough to be wearable.

4.1.3 Battery Power

Considering the brightness and size of the display required, and the computing power required, current batteries would be too heavy and short-lived (McCarthy, 2003). A lighter and longer lasting battery would need to be developed if this system is to be carried by soldier into the battlefield.

4.1.4 Position of Cameras and Projectors for RPT

When considering Retroreflective Projection Technology (RPT), outstanding limitations are that the cameras and projectors would need to be positioned before-hand, there could only be one enemy viewer, and that viewer would need to be positioned in a precise position behind the camera.

4.2 Infantry Headwear Applications

It is foreseeable that a flexible display could be adapted to the shape of the helmet or that an image could be projected on the helmet from above. However, active camouflage on the helmet alone without the rest of the clothing would not likely be worth the expense, computer power, or additional weight since the rest of the body would still be detectable. The helmet would more likely become only one item of the soldier's clothing to apply active camouflage.

4.3 Simpler System

The pursuit of a feasible active camouflage system alone does not appear to be important enough to drive the expensive technology development of displays, computing, and battery power. However, since all of these will be required for other applications, it is foreseeable that industries may develop technologies that will become adaptable to an active camouflage system in the future. In the meantime, there could be simpler systems developed which do not give perfect invisible results. For example, a system that actively updates approximate colour would be more useful than current camouflage systems, regardless of whether the perfect image is displayed.

4.4 Strategic Uses

By considering that an active camouflage system would be most feasible when the position of the viewer is known exactly, it can be projected that the earliest solutions could be used to camouflage in front of a single stationary camera or detector.

However, many sensors and detectors are currently available which do not act in the visual spectrum. A thermal microbolometer or a fused sensor, for example, would detect an object being masked by visual active camouflage.

5 Conclusion

Active camouflage systems for infantry soldiers would greatly benefit stealth operations, especially considering that military operations in urban environments are becoming more prevalent. Conventional camouflage systems remain one colour and shape, however in urban environments the optimum colour and pattern could continuously change by the minute.

The goal of this study was to present information to be used for assessing the current feasibility of active camouflage systems, and to aid in projecting future readiness of the technology. While numerous applications were discussed, the focus was for systems that could be used by infantry soldiers, and specifically for infantry helmet applications. A review of the current and projected active camouflage systems revealed that numerous systems are under development; however major technical roadblocks must be addressed before this technology will be ready for infantry applications.

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(U) This report was prepared as a trade study review of current and projected active camouflage systems. While numerous applications were discussed, the focus was for systems that could be used by infantry soldiers, and specifically for infantry helmet applications.

A review of the current and projected active camouflage systems revealed that there are many systems under development for aviation, maritime, and ground operations. Early prototypes for infantry soldiers were presented in detail.

A system overview was prepared in order to present camera, image processing, and display solutions. Finally, a discussion focusing on technology limitations, applications, and future considerations was presented. This trade study showed that numerous technologies for active camouflage systems are under development; however major technical roadblocks must be addressed before systems will be ready for infantry applications.

(U) Le présent rapport a été rédigé sous forme d’étude commerciale des systèmes de camouflage actif, actuels et futurs. Bien que de nombreuses applications aient été discutées, l’accent a surtout été mis sur les systèmes pouvant être utilisés par les fantassins, en particulier pour les applications destinées aux casques d’infanterie.

Un examen des systèmes de camouflage actif, actuels et futurs, révèle que de nombreux systèmes sont en voie d’élaboration pour les opérations aériennes, maritimes et terrestres. De nouveaux prototypes destinés aux fantassins ont été présentés en détail.

Un survol des systèmes a été préparé afin de présenter des solutions de caméra, de traitement d’image et d’affichage. Enfin, on a discuté des limites de la technologie, de certaines applications et de considérations futures. L’étude commerciale a montré que de nombreuses technologies relatives aux systèmes de camouflage actif étaient en voie d’élaboration. Cependant, d’importants obstacles techniques devront être surmontés avant que les systèmes ne soient prêts pour les applications destinées à l’infanterie.

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(U) SIHS; Soldier Integrated Headwear System; active camouflage; digital camouflage; helmet