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SIGNAL PROCESSING IQ : FPGA EXPERTISE

CHALLENGES FOR VEHICULAR VISION SYSTEMS

WHITE PAPER

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Commercial-in-Confidence

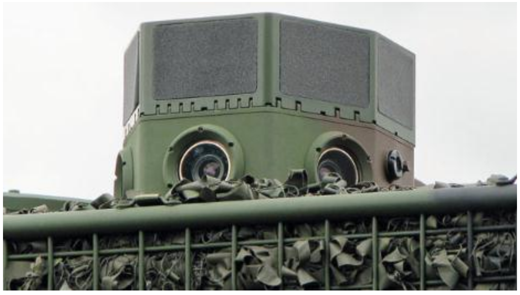
1 Summary

This white paper presents the game changing performance advantages available when equipping military vehicles with emerging video processing systems. It explores the operational problems, outlines their potential solutions and shows how RFEL's HALO™ product provides extreme performance in a low size weight and power (SWaP) implementation. Furthermore HALO™'s modular design enables users to select only the features they require and product integration is accelerated by the flexibility of a hybrid processing architecture.

RFEL is a wholly owned subsidiary of Rheinmetall Defence, a large defence supplier of weapon systems, wheeled vehicles and mission equipment to armed forces around the world. RFEL is Rheinmetall's centre of excellence for FPGA signal processing products and HALO™ has been designed, in part, to complement and enhance Rheinmetall's military vehicle product portfolio.

2 Benefits of using the HALO™ Vehicle Vision System

Sophisticated vision systems are playing an increasingly important role in military vehicles. Remote video systems provide two key functionalities: as a driver aid, to improve control, safety and reduce fatigue; and as an enhancement to systems mounted on vehicles, such as remote weapons stations (RWSs) and surveillance equipment. In combat situations, and when faced with challenging operating conditions, such as night time operation, uneven terrain and poor weather, a quality vision system can be a deciding factor in the success of a mission and the survival of its crew.



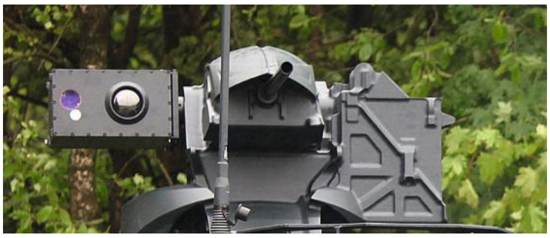


Figure 1: Vehicular mounted video devices support a range of missions

The HALO™ vehicle vision system achieves not only these objectives, by providing the best possible multi-sensor, high definition (HD), stabilised video, but also realises it for low, size, weight and power (SWaP). This capability is made possible through close integration of emerging technologies: high performance daylight and infrared (IR) sensors; and hybrid, power efficient, processing electronics running extreme performance firmware under flexible software control.

The result is a vision capability that, from a single display, can provide 360° ground-to-sky visibility around a vehicle, with the elimination of vulnerable blind spots. HALO™ can adapt the display automatically to follow changes in illumination of a scene, thereby revealing threats and targets hidden within shadows while suppressing glare. When driving over rough terrain, HALO™'s digital image stabiliser can eliminate camera shake and allow the identification of features that otherwise would have been impossible to follow visually. The use of IR sensors can radically improve visibility in low light or darkness, and when there is high humidity or smoke. HALO™'s image fuser can combine IR and daylight video streams, in an optimum manner dictated by the prevailing conditions, to provide a fused video stream that retains the best features from both modalities to maximise target detection and identification, while mitigating operator overload.

The greatest strength of contemporary electro-optic sensors is the wealth of information they provide. However, this strength is also a weakness, in that enormous amounts of image data must be processed and displayed in real-time to capitalise upon this capability. For this technology to become ubiquitous, RFEL has recognised this limitation and has made it their primary focus for the HALO™ product.

In addition to equipping the latest vehicles, the HALO™ vision system provides a cost effective solution to upgrading the capabilities and safety of existing equipment to maximise service life. Prospective customers are encouraged to submit their own video data for processing by HALO™ so that the potential benefits can be demonstrated.

3 Technical Requirements and the Capabilities of HALO™

The requirements of using vehicular video systems like HALO fall into three main categories:

- Enhanced visibility;
- Heightened situation awareness;
- Improved reconnaissance, surveillance and target acquisition.

Visibility of the environment around a vehicle may be enhanced in several ways. Remote observation by cameras is desirable because the operator can remain within the protection of the vehicle and armour is not compromised by the presence of windows. 360˚ ground-to-sky coverage, using both daylight and IR wavebands, provides maximum visibility in all likely operating conditions including night-time operation. HALO™ can be used to adapt brightness and contrast dynamically, with no need for input from the user. Features can be resolved and identified at ranges of several miles for the entire panoramic view, even when subject to haze or smoke. The streamed video can be corrected for lens distortion in real-time, so that wide angle lenses can be used without compromising performance. Telephoto lenses can be used for detecting distant targets, while using digital image stabilisation to eliminate camera shake. HALO™ is a modular design that enables all of these capabilities to be realised in a low SWaP format.

Figure 2: HALO™ Intelligent Fusion capability: Increase DRI in all weathers, day and night

Intimate knowledge and understanding of the threat prone zone around a vehicle is known as situational awareness (SA). SA is optimum when users are given all available relevant information in a format where it can be rapidly assimilated and understood, so that future events can be reliably predicted. Sight is the dominant human sense and therefore vision systems are the primary asset for SA.

The steps involved in an SA vision system are: image acquisition, data extraction, and optimum visualisation based on the extracted data. The data extraction part of SA is used to calculate parameters such as the mean brightness of a scene, the translational and rotational movements of the camera due to unwanted shake, and image registration coefficients. Optimum visualisation may involve the processing steps of image mosaicing, for platforms with multiple cameras; image contrast enhancement, for maximising the definition of critical image features; fusion of daylight and IR images, to form a single best composite display; and digital image stabilisation to eliminate camera shake. A mosaiced panoramic view can be pre-distorted for correct presentation on a curved display.

A post processing stage may be used to aid reconnaissance, surveillance and target acquisition. Computer analysis of a scene can help reduce the fatigue of interpreting video and minimise sensory overload in emergency situations. For example, targets can be detected and tracked, or changes in scenery may be detected within a potential blast radius for identification of improvised explosive devices (IEDs).

Critically, the whole system must operate with a processing delay (latency) of less than ~60 ms to ensure that control of the vehicle is unaffected. This requirement is extremely difficult to satisfy when there is an uncoordinated chain of separate and distributed processing steps. The HALO™ product targets this problem by coordinating the processing and performing all real-time operations in a state-of-the art field programmable gate array (FPGA). This ensures that latency is fixed and can be guaranteed, which is vitally important for safety critical applications.

4 The HALO Vehicle Video System

HALO™ provides crews with enhanced vision and therefore a tactical advantage for day and night time operation in diverse theatres and weather conditions. The product is supplied in five low SWaP variants: a ruggedized, fully enclosed, sub-system, and various open frame or IP form factors. At the heart of HALO™ is a highly integrated and optimised real-time video processor based on the latest generation of hybrid processors. The base level HALO™ architecture accommodates one or two video inputs and outputs at 1080p (full HD), at frame rates of up to 60 fps, or 150 fps for a reduced Region of Interest (ROI).

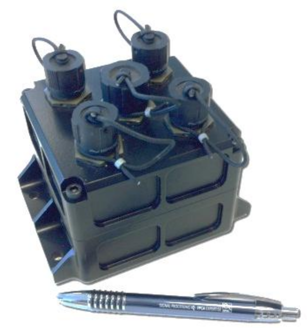


Figure 3: HALO™ Rugged Sub-system form factor

The over-arching aim of a vehicular vision system is to perform all image processing functions using an integrated, readily configurable and low SWaP solution. The video streams from individual cameras must be gathered from around the vehicle; and the raw or processed video must be distributed to serve multiple users. These streams may use contemporary network links, and would require modern compression protocols such as H264/5 and JPEG2000, all of which are supported by HALO.

The operational requirements for military vehicular vision systems are particularly demanding, due to the harshness of the operating environment and the criticality of performance. Military solutions like HALO™ must comply with a multitude of standards, such as Def-Stan 23-09 and MIL-810, to ensure adequate robustness. Budgets are limited and therefore vision systems need to be compatible with in-service equipment, so that performance can be enhanced and successively upgraded without costly reinvestment. Applications and requirements are diverse and therefore solutions need to be modular and adaptable to specific operating theatres. HALO™ supports standardised interfaces and maximises interoperability with other systems to promote integration, sensor fusion and seamless operation.

The following three examples demonstrate how HALO™ can be deployed:

Example 1: Legacy support within an evolving system

Military vehicles that use cameras to aid the crew tend to be expensive investments that require considerable justification and planning. Electro optic and related processing systems are evolving much more rapidly than vehicle hardware, so the option of using a digital video control system, to flexibly upgrade, replace or support both legacy hardware and new sensors, is highly compelling. For instance, HALO could be used to serve, enhance, and switch between several legacy video inputs, such as standard NTSC and SVGA, while also supporting modern HD sensors. A modern HDMI or DVI display could then be used for all chosen input types, with conversion performed by HALO™ to ensure seamless integrated operation. Legacy control panels can be made to plug in directly to eliminate external conversion hardware, the unit would be provided in a single ruggedized housing, compliant with military vehicle environmental standards and would be plug-and-play with the required connectors.

Example 2: Local SA System

An SA system may require the stitching of as many as sixteen video streams, captured using both daylight and infrared cameras mounted around a vehicle. For a high performance system, the separate views must be corrected for lens distortion and seamlessly mosaiced to provide a continuous 360˚ field-of-regard. Brightness and contrast must be matched and image registration must be maintained irrespective of thermal or mechanical drift. HALO™ can realise the entire system and provide a full 360 degree sliding vision system that interfaces with legacy equipment. This flexibility is possible because HALO™ has been designed from the ground up as an ensemble of interoperable processing modules that can serve diverse requirements. The extensive HALO™ processing module ecosystem supports features like cylindrical projection to provide seamless mosaicing, continuous digital zoom and digital image stabilisation. A HALO™ central processing and interfacing unit would provide a clear competitive advantage over all rival solutions.

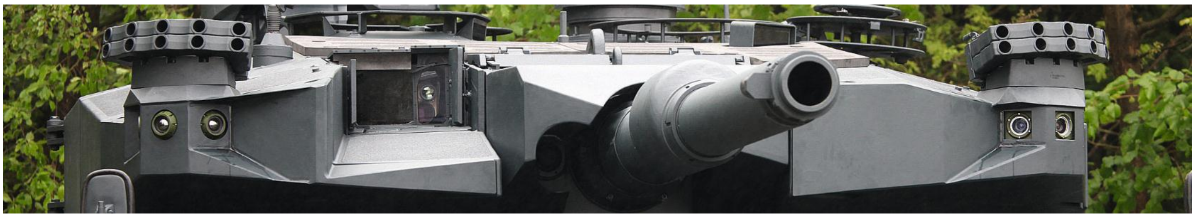


Figure 4: Multiple SA camera nodes are positioned around vehicles

Example 3: Smart Camera

A pivotal tactical advantage arises when an enemy cannot see you, but you can see them. It is therefore imperative in a combat situation that a military vehicle is equipped with the best possible vision system. The winning factor between vision systems will be their comparative performance in marginal operating conditions, such as in darkness or poor weather. The smart camera concept is to provide a system that yields the ultimate target visibility. Operation in low light is catered for by an IR sensor. An HD daylight sensor, with ICE, and optical and digital zoom, provide optimum daylight visibility. At twilight or dusk, and in challenging weather, a fusion of the best image features from both sensors, coupled with ICE, yields maximum information content in a single viewable video stream.

HALO is designed from the ground up to realise this smart sensor. The optimum balance between the strengths of the two modalities can be set automatically, or over-ridden in a graded manner, to emphasise features of specific interest. The system can rapidly select between the individual or fused video streams; and digital image stabilisation can be applied to provide a rock steady video for target identification and automated tracking. HALO™ is the product to unleash the potential of future dual camera configurations, achieving higher performance, faster reaction times and improved DRI.

5 Conclusions and Recommendations

HALO™ provides an unprecedented technical solution for implementing an extreme performance vehicular video system, in a rugged, low SWaP, plug and play form factor. HALO™ supports both legacy and modern interfaces and is highly configurable by virtue of the support of a highly optimised video signal processing IP library. By supporting retrofit applications, it addresses today's military video sensing challenges, without sacrificing existing investment. The use of a modular, hybrid, processing architecture enables the rapid deployment of new capabilities to gain a tactical advantage.