Publishable summary

Study on EO Sensors Performance Improvement in Degraded Visual Environment (SPIDVE)

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SPIDVE **"Study on EO Sensors Performance Improvement in Degraded Visual Environment"** is a project developed by a consortium led by Leonardo S.p.A. with Flyby S.r.l. (SME) and CNR-INO (public research Institution) in response to the EDA call for tenders devoted to an OB study with code 19.ESI.NP3.291. The project started in February 2019 and ended in March 2020.

Operations in **Degraded Visual Environments (DVEs)** are frequent during military actions, due to either natural (poor light, fog, glare etc.) or man-made (smoke, dust etc.) conditions. These conditions adversely affect the performance of Electro-Optical (EO) sensors by reducing their range of effectiveness in terms of Detection, Recognition and Identification (DRI) and navigation capability, and therefore hamper the situational awareness and safety of the personnel.

SPIDVE addressed the problem bymitigating the impact DVE conditions in operations have on the EO sensors, in order to restore their imaging capabilities and thus re-establish the safety and reliability of the operations even under unfavorable visibility conditions.

The effectiveness of the EO systems have seen a considerable improvement in recent years due to the availability of large focal plane array detectors with higher performance, as well as a strong increase in processing capabilities. Both in homeland surveillance and in military situational awareness, the use of EO systems (operating from Visible to Infrared) has grown dramatically.

The amount of visual information that is now possible to acquire, due to the availability of cameras operating in many spectral bands (from Visible to Long Wavelength Infrared (LWIR)), exceeds the human capability of exploitation and therefore requires appropriateprocessing in order to convey to the operator only the relevant information.

The activities of SPIDVE addressed the following questions: how DVE conditions influence the different spectral bands? Which bands, sensor technologies and image enhancement algorithms are the best suited for a defined scenario (haze, fog, dust, etc.)? How can DVE impact be mitigated? How can images coming from different spectral bands be fused a final image reporting the most important information and minimising artifacts?

These objectives were pursued in the various Work Packages (WPs) of the project by:

- Carrying out an extensive survey of the state of the art on DVE modeling, simulation and measurement; image enhancement and fusion, new optical technologies for DVE mitigation.
- Identifying the most relevant cases in terms of scenarios, applications and DVE conditions by directly consulting the military end users.
- Identifying the most promising technologies for the DVE mitigation of the selected scenarios.
- Providing a roadmap for the required technical developments addressed to the improvement of the EU Defense Capabilities.

An extensive analysis of the current methodologies (WP1) allowed for the identification of the most suitable spectral bands, the selection of most promising algorithms to enhance sensor data and the identification of methodologies able to measure the quality of images.

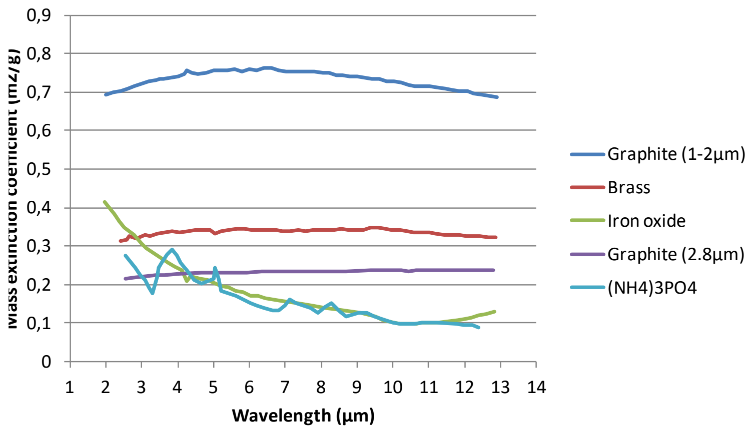


Figure 1 - Mass extinction coefficient for different kinds of infrared smokes. Data from open literature sources[1]

A workshop (WP2) with the participation of military representatives was dedicated to the definition of the real-world user needs (Rome, IT, April 5th, 2019), preceded by a questionnaire distributed to several stakeholders (Optronics Captech members, military personnel of the Member States). Realistic military situations, where the safety and reliability of the operations strongly depends on the performance of EO sensors, were identified, discussed and prioritised. The highest priority was attributed to the navigation, surveillance and self-protection of helicopters in urban scenario, with fog, rain and war smokes as DVE causes, in presence of both symmetrical and asymmetrical threats.

During WP3, several goals were achieved: **an ideal sensor suite was outlined**, including LWIR and SWIR imagers featuring a wide field of view (similar to the naked eye) and high image rate; a navigation LIDAR (for obstacle detection) and an improved laser targeting system were also considered as needed to obtain the desired results. A fundamental importance was attributed to suitable image fusion techniques, to merge the images coming from the different sensors in a single, high frame rate video stream to be presented to the operator. Augmented reality technologies were considered very useful to improve the man/machine interaction and to reduce the crew workload.

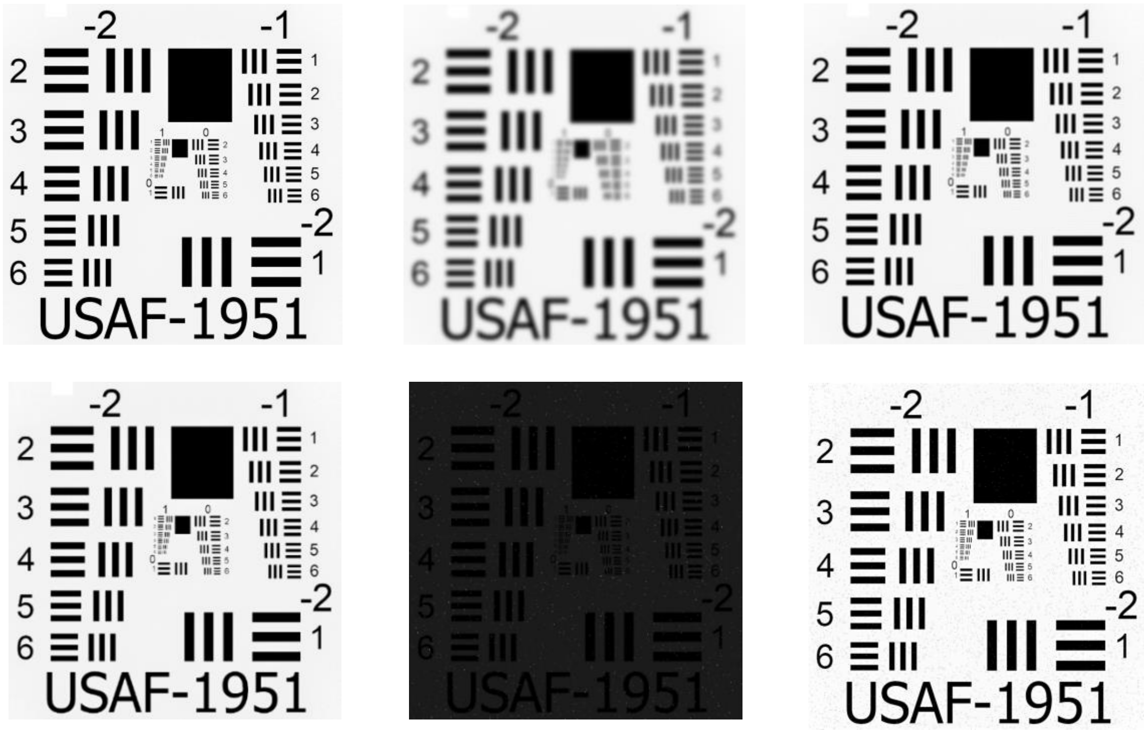
A database of the spectral properties of obscurants (including 10 different substances, in a wavelength interval from visible to LWIR) was compiled based on literature data to support this activity (figure 1).

The database contains at the same time unregistered information, in particular both scattering and absorption coefficients for each obscurant have been registered to better model the overall impact on the optical system.

A software tool was set up: ***i)*** to simulate the effect of obscurants on image, ***ii)*** to evaluate the degradation using reliable quality indexes; ***iii)*** to apply different image restoration approaches (inverse

[1] Owrutsky, J. C., Nelson, H. H., Ladouceur, H. D., & Baronavski, A. P. "Obscurants for infrared countermeasures II" (No. NRL/FR/6110-00-9945). NAVAL RESEARCH LAB WASHINGTON DC, 2013

modelling techniques and contrast enhancement methodologies); ***iv)*** to evaluate the quality of the restored images.



a) *b)* *c)*

Figure 2 – Results: a) reference image, b) degraded image, c) restored image.
Upper line: LWIR images; lower line: SWIR images

The software was used to **test and compare several restoration algorithms** for DVE mitigation in the SWIR and LWIR spectral bands. The use of the software tool brings to the following conclusions (figure 2):

a) in the SWIR spectral band the high values of both absorption and scattering coefficients introduce a significant attenuation in the signal coming from the target. Besides, the aerosol scattering at large angles from light sources introduces a featureless background in the image (airlight). Both effects reduce the signal to noise ratio with respect to the intrinsic device noise and lower the contrast. In this condition best results are obtained by the **adoption of contrast enhancement methodologies**, especially the ones that exploit a **local dynamic redistribution** of the image histogram.

b) In the LWIR the overall extinction is lower than in the SWIR and the effect of airlight is usually much less important because of the low sun irradiance, but the image deterioration due to **blur** generated by scattering is more pronounced and not negligible. In LWIR best results are obtained by the adoption of **inverse modelling approaches**. The difficulty of these methodologies lies in the knowledge of the aerosol scattering properties to be used by the restoring process, which must be determined by modelling or by an iterative optimization.

Finally a **data acquisition and processing campaign** was carried out to evaluate the behavior of the spectral bands in a composite scenario, using proprietary Short Wave IR (SWIR) and LWIR cameras with similar field of view and resolution (Figure 3).

The experiment demonstrated that during daytime SWIR overcomes haze better than Visible, due to longer wavelength, but the lack of colors reduces small objects visibility (e.g. cables). Night conditions hamper VIS sensors, whereas the SWIR ones can exploit night glow and moon irradiance. LWIR was considered indispensable as it is not affected by darkness (Figure 3).

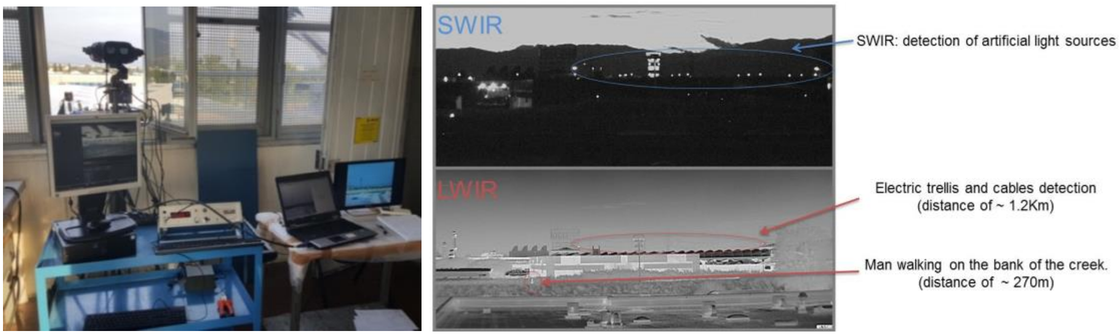


Figure 3 – Set-up for simultaneous image acquisition in different spectral bands at Leonardo premises (left) and comparison of imaging capabilities in different spectral band (right), in urban scenario, during nighttime. Images acquired during the experimental tests.

A project roadmap was outlined in the **WP4** on the basis of the SPIDVE results, articulated in different development phases:

- novel image processing algorithms aimed to DVE effect mitigation (image enhancement, data fusion), field tested and including emerging technologies as Artificial Intelligence.
- a prototypal, modular hardware platform for the collection and the fusion of data from multiple sensors (passive, active, in different spectral bands) exploiting specific sensors, both active and passive, featuring robustness against DVE conditions.

These development phases will be exploited in the Cat-B project: **DVE-DELETE** (DVE mitigation by means of Deep lEarning in signaL EnhancemenT and sEnsors) and in the following EDA EOST TBB-based project proposals **: HiPAD** (High performance active EO imaging systems in Degraded Visual Environment) and TADID: Target detection improvements in Degraded Visual Environment).