Data & Image Fusion for Multisensor UAV Payload

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1.0   INTRODUCTION

The recent spread of the use of Unmanned Air Vehicles (UAVs) for military purpose over the past two decades have led the industry to develop various payloads, matching the operational needs for the various missions committed to the UAV systems. In this context, SAGEM has positioned as a main actor in Europe in the field of UAV:

- European leader for the tactical UAV systems (SPERWER).

- Major sub-contractor for observation payloads dedicated to medium altitude long endurance UAV.

- Proposition of "Over-the-Hill" mini-UAV concepts in the frame of FELIN.

This position has notably been acquired thanks to the long term know-how of SAGEM in several domains, particularly critical in the design of a UAV system:

- European leader of optronic systems.

- European N°1, World n°3 for Inertial Navigation Systems.

- Expert in Global Positioning Systems, RF communication and Data Links.

In the frame of these developments in the field of UAV systems, a study has been dedicated to the definition of new observation payloads, in order to anticipate the various needs for the future UAV systems. This study put a particular focus on the possible commonalties between the different payloads responding to the various needs, and on the synergies which could be obtained between the different sub-elements of the observation payload, and with the other payloads embedded on the UAV.

The next sections of the paper will cover the following topics:

- General presentation of the usual architecture of the UAV observation function.

- Functional evolution of the SAGEM airborne observation payloads.

- Specificity of the UAV context, with respect to other airborne platforms.

- Presentation of different data and image fusion techniques which can be implemented in the UAV observation payload, and discussion on their functional interest.

- Proposition of an UAV observation function architecture optimised for data and image fusion.

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2.0 ARCHITECTURE OF THE UAV OBSERVATION FUNCTION

The observation (or imagery) function of a UAV system has long been the main function for the final user, and remains one of the primary functions even since the use of UAVs for other applications, as signal jamming, target designation, or weapons carrying. This observation function is ensured by several elements of the UAV system, constituting the UAV Imagery Chain:

- On the UAV:

    - The UAV observation payload (UAV-OP) itself, constituted of various sensors and electronics depending of the operational needs, integrated in a mechanical assembly allowing possibly the orientation of the line-Of-Sight (LOS).

    - The UAV Video & Data Link Payload (UAV-VDLP), which compress (if necessary) the motion imagery and the data coming from the UAV-OP, and send them to the ground station, possibly through the medium of a satellite or another UAV.

    - The UAV Management & Control Unit (UAV-MCU), which receives the operator commands through the UAV-VDLP, transmits or translates them in lower level commands to the various payloads embedded in the UAV.

- On the ground station (GS):

    - The GS Video and Data Link Module (GS-VDLM) is the symmetrical element to the UAV-VDLP, in charge of imagery and data coding / decoding.

    - The GS Video & Data Processing Unit (GS-VDPU) is in charge of additional processing on the imagery and data sent by the UAV, and of processing of data and commands collected through the Man-Machine-Interface.

    - The GS Man-Machine-Interface (GS-MMI) ensures the collection of commands and parameters necessary to the mission and the presentation of imagery and data to the UAV system operators.

An example of UAV system architecture is given in the figure below:
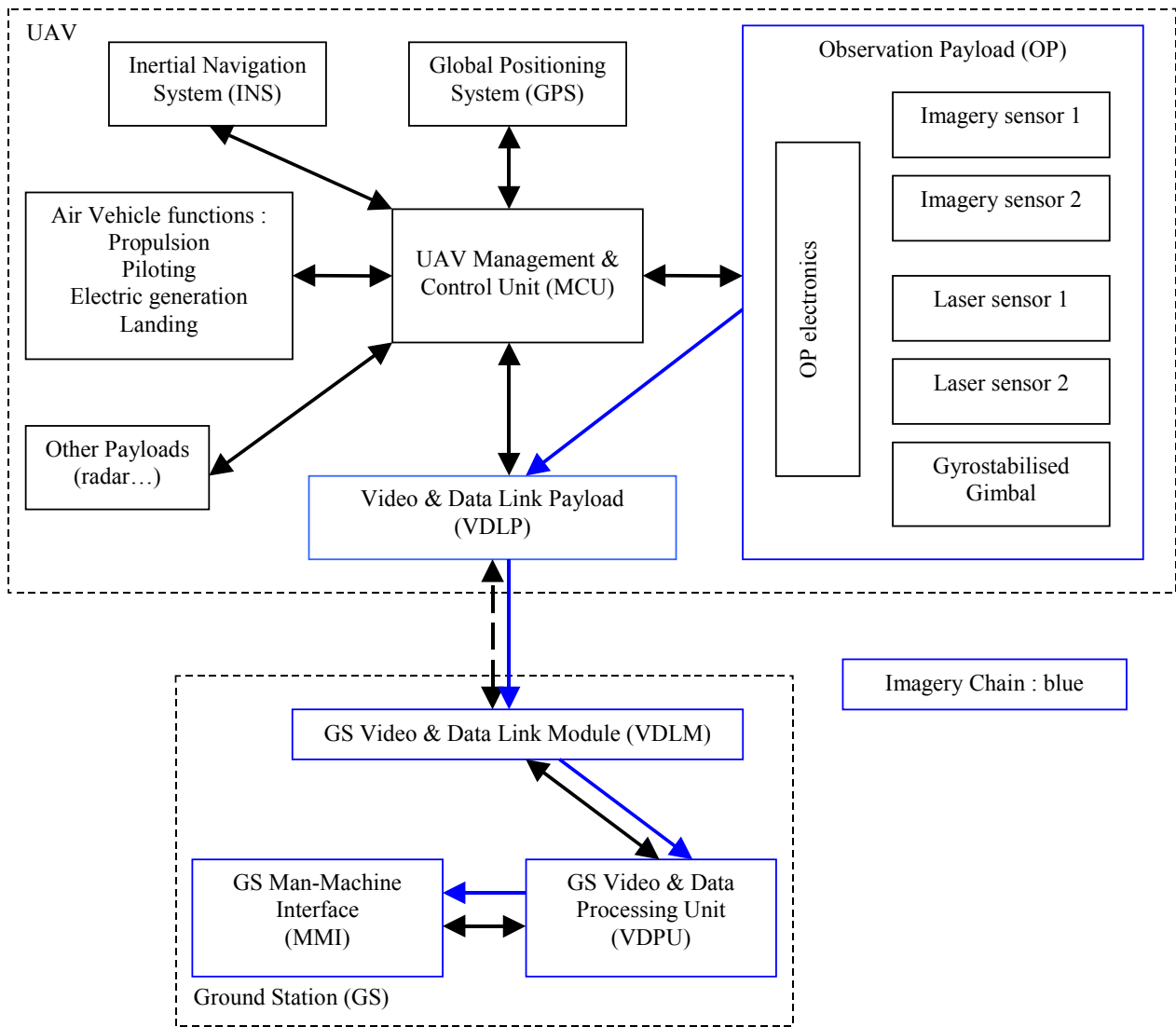
Figure 1: An example of UAV system architecture.

Each element of the imagery chain play a significant role in the final performance of the function, but their respective intrinsic weight in the system performance varies according to the type of UAV system.

3.0 EVOLUTION OF THE AIRBORNE OBSERVATION PAYLOADS

During the last three decades, the optronic devices used for observation purpose have known a continuous progress, on various airborne platforms (helicopters, planes, UAV). This constant evolution has been made possible by major technical improvements on different sub-elements of observation payloads:

- Development of compact EO/IR sensors,

- Increased capabilities of embedded electronics (sensor management, signal processing),

- Robust LOS stabilisation,

- Lightweight structure for platforms…

The two major trends coming out of these evolutions are:

- The increase of the number and diversity of sensors embedded in airborne observation payloads, due to compactness improvement.

- The enlargement of the functional area covered by the observation payload sub-system, gained on the functional responsibility of the Host System.

3.1 Embedded Sensors on Airborne OP

Early observation payloads featured an only sensor, a daylight camera or a thermal imager, which allowed to cover day & night operations. Depending on the maximum weight devoted to the payload, these two types of sensors could be embedded simultaneously on the same carrier.

A typical daylight camera used in airborne OP application is based on a CCD detector with TV resolution, associated to a fixed Field of View (FOV) optics, or to a zoom lens. Main progress in the field of daylight cameras consisted in the improvement of CCD sensitivity and the increase of the optical zoom range.

The thermal imagers or infrared cameras used in airborne OP have followed the successive steps of this technology during the past three decades:

- First thermal imagers used for airborne observation where line scanners used in conjunction with whisk broom technique: a linear detector mounted on a moving arm is quickly swept along a direction perpendicular to the carrier movement to generate a panoramic image of the area below the airborne carrier.

- In 2nd Generation thermal imagers, the scanning is ensured by an opto-mechanical device integrated in the camera, allowing a drastic reduction of the sensor volume, and the production of thermal imagery at video frame rate.

- 3rd Generation thermal imagers are characterised by their Focal Plane Array (FPA) detector, producing imagery without scanning device.

- Last generation thermal imagers are based on detectors which do not require any cryogenic module to produce high sensitivity thermal imagery, contrary to previous generation IR cameras: this improvement still further reduce the total weight and volume of the detector and electronics parts.

Continuous progress in miniaturisation of sensors and electronics made possible the integration of these imaging sensors in smaller and lighter payloads, and / or the integration of bigger optics, allowing a significant increase of the optronic performances of the payload (Detection, Recognition, Identification or DRI). Another possibility offered by this size reduction was to integrate in the same volume a second sensor of the same type, with different optics to extend the zoom range in this spectral band: for example, a TV camera with very high magnification optics (named spotter) can be used next to a classical TV camera with a zoom to provide extra identification capabilities.

In parallel of this continuous evolution, the next step was the integration of laser sensors, bringing additional functionalities to the observation function: Laser Range Finder provides the operator with precise measurements of the observed target distance, Laser Pointer allows to precisely indicate a zone or a target to another observer equipped with night vision sensor… Another laser equipment embedded on airborne OP is the laser designator or illuminator: this device provides the airborne system with the capability to designate a target to a laser guided ammunition, often combined with a range-finding functionality.

Today, a state-of-the-art Sensor Pack (SP) may include up to six different sensors, operating in five or more spectral band, for example:

- B&W or Color High Definition TV (HDTV)camera (visible light) with a zoom lens,

- Thermal imager, operating in 3 – 5 μm or 8 – 12 μm, with switchable (FOV) or zoom lens,

- Spotter, operating in the visible or in the Near-InfraRed (NIR) spectrum (0.78 – 1 μm), with a fixed high magnification lens (typically < 0.5°),

- An eyesafe Laser Range Finder, with a emission wavelength around 1.5 μm,

- A Laser Pointer, compatible with night vision goggles, sensitive in the NIR spectrum,

- A Laser Designator, whose emission wavelength is 1.06 μm.

3.2   Functionalities Covered by OP

The "functional area" covered by the airborne OP itself among all the functionalities of the airborne system has kept extending between the successive improvements of the system:

1) The functions covered by the early observation payloads were reduced to the functionalities of the only sensor itself. The still or motion imagery issued by the sensor was directly sent to the host system in a raw format, and no capability of sensor orientation was available.

2) The next step of OP evolution was the association of a sensor with an orientation mechanism: the Sensor Pack, constituted of the sensor and a rate gyroscope, is mounted inside a Gyrostabilized Platform (GP) or gimbal, which provide 2-axis angular orientation of the imaging sensor Line-Of-Sight (LOS). At this stage, the SP and the GP were considered as two distinct sub-systems, piloted independently by the Host System to perform low-level functions (Examples of low-level observation functionalities: FOV change, Gain and Offset settings, Electronic zoom activation, LOS Rate piloting, LOS orientation in the carrier reference…).

3) A further improvement of the OP was allowed by progress in the field of gyrostabilised platforms: in the same external volume as the previous generation gimbals, it was now possible to build a 4-axis gyrostabilized platform, with a bigger internal volume dedicated to the sensors integration. The 4-axis gyrostabilisation provided a high quality stabilisation, necessary to perform long range observation on airborne carriers. The extended internal volume allowed the integration of several sensors. At this stage, the sensor pack and the GP was considered as two sub-assemblies of the observation payload sub-system, but they were still commanded through two separate command lines with low-level commands. But, in addition of functionalities already covered, the OP took part in high-level observation functionalities, managed by the airborne carrier. Examples of these higher-level functionalities are given hereunder:

   - Tracking: Automatic orientation of the LOS on a target detected in the sensor imagery,

   - Designation or Geo-Tracking: Automatic orientation of the LOS towards a point defined in the terrestrial reference, by compensation of the angular (Roll, Pitch, Yaw) and linear (Vx,Vy,Vz) motion of the carrier,

   - Geo-Scanning: Automatic LOS piloting ensuring full coverage on an area of interest on the ground, whatever the movements of the carrier,

   - Image enrichment, by the real-time incrustation of symbology and alphanumerical characters.

4) In the next step of this evolution, the management of above-mentioned higher level observation functionalities is transferred from the Host System management system to the OP: In airborne mission system connecting numerous and complex payloads, the reduction of the exchange between carrier management system and the payloads to high level commands significantly reduces the amount of data circulating on the mission bus.

This increase of computational work for the OP was materialised by the development of specific electronics and software, able to translate the Host System high level commands and dispatch them to the various sensors aboard the payload. These electronic boards can be integrated in a separate unit or on the sensor pack, depending on the space available inside the platform.

5) The last trends of evolution of the role of the OP in the airborne system are toward a greater integration and modularity of the OP and toward an active implication of the OP in functionalities at airborne system level. This implication may vary with the type of airborne system: On an Army helicopter, the OP may help the pilot for collision avoidance during low level flight; on a tactical UAV, the Laser Range Finding will be used to confirm the elevation of a numerical model; on mini or micro UAV, imagery will be used to assist the navigation and piloting functions…

4.0   SPECIFICITY OF THE UAV CONTEXT

The use of an observation payload in an UAV system presents some specificity when compared with the integration on other airborne carriers (helicopters, patrol planes…).

The main characteristics of OP dedicated to UAV are of course linked to the fact that the carrier is inhabited:

- First, the information gathered by the payload is not exploited on the carrier but on the ground after transmission, which makes necessary a specific processing and/or compression before transmission. On the other hand, this specificity allows to transfer into the GS a part of signal processing usually done inside the OP, and even perform in the GS additional processing which could not be done on a carrier, because of the limitation on the weight of the OP.

- Second, the delay induced by the transmission of Ground-to-UAV commands and UAV-to-Ground data leads the UAV system designer to give a high level of autonomy and automation to the UAV and to its sub-systems, and among them the OP: this issue is particularly critical to ensure continuous operation when the Data Link is interrupted. In addition, the autonomy of the UAV relies on various payloads, which provides the UAV-MCU the necessary data to perform automatic piloting, navigation… This connection of the observation payload to a rich and precise data network is another particular to the UAV context.

Another trend of UAV payloads' needs is a constant increase of the required performances, exceeding the requirements for other airborne carriers. Linked to the diversification of UAV, the required improvement may concern different characteristics and performances in function of the UAV type.

- **Optronic performances**: with the development of medium and high altitude UAV, a constant improvement of DRI range of imaging sensors is required, in order to keep at least identical operational capability at increased altitude and distance.

- **Geo-Localisation**: In relation with the increase of UAVs' altitude, the level of geo-localisation precision required demands both highly accurate LOS orientation and high quality imagery.

- **Miniaturisation**: the expression of a increasing need for UAV systems usable at platoon level, for short distance ("Over-The-Hill") reconnaissance missions, or specifically developed for military operations in urban terrain, put a strong pressure on the miniaturisation of optronic sensors, to provide the soldier with an extended observation capability, compatible with its operational requirements: night and day imagery allowing recognition at firing distance, transportability, robustness…

The last characteristic specific to UAV needs is the necessary effort on interfaces standardisation.

1) A major trend in the field of UAV systems is the growing diversity of applications in which they are used, resulting in the development of different UAV systems responding to these specific needs, and thus in the development of various payloads.
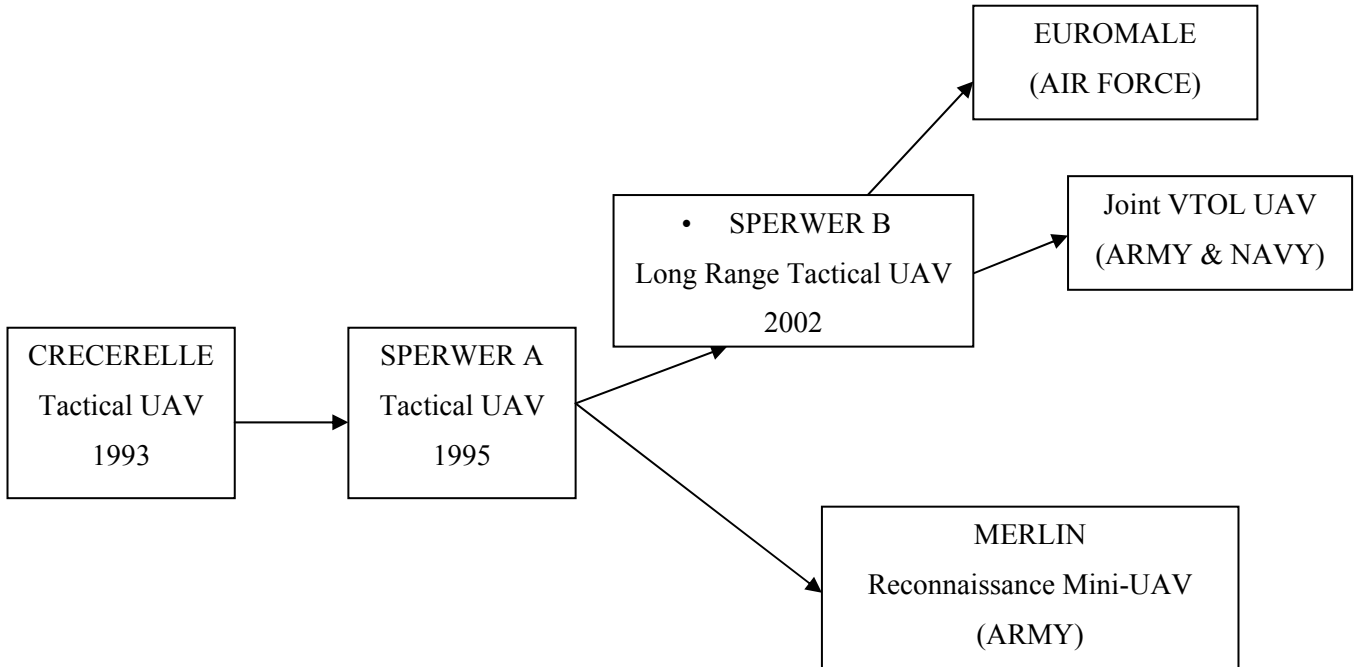
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**Figure 2: Diversification of UAV types on examples of
SAGEM present UAVs, contributions and concepts.**

2) On piloted air vehicles, imagery and data produced by the OP are mainly used on board in real-time, at the time they are displayed on the operator screen. This information may be used later if it has been recorded or transmitted, but this use remains a minor functionality with respect to the primary mission of observation (at least on existing systems). The OP only has to be compatible with the vehicle display and control unit (if not a sub-system of the OP itself) to be used on a piloted aircraft.

On the other side, in UAV systems, the link between the OP and the operator relies on several other sub-systems (see §2.1) which have to be compatible to each other in terms of functional and data interfaces. With the diversification of payloads and air vehicles specific to different missions and conditions, it appears as a necessity to standardise interfaces between the sub-systems, in order to be fully compliant with **modularity** requirements: a major advantage gained from the maximum communality between these variants is the possibility to control different combinations with the same GS, reducing the formation of operators.

3) The external interfaces of UAV systems are also concerned by standardisation, in order to meet the growing needs of **inter-operability**: transit of data by a satellite network, transmission of imagery to other services for intelligence gathering or damage assessment, information sharing during joint operations…

Recommendations of NATO through the Standardization NATO Agreements or STANAGs are the backbone of this work on standardisation: for example, STANAG 4609 on Motion Imagery is used as a basis for future systems' video chain design.

5.0 DATA & IMAGE FUSION FOR THE UAV SYSTEM OBSERVATION FUNCTION

In this section will be presented a wide variety of process grouped under the same denomination of "fusion". What we call here "fusion" is a process which, from information of a unique or several kinds, obtained from a unique or several sources, produces either an improvement of input information, or information of a new kind.

Fusion algorithms are studied now for a long time in various fields of interest, and become more and more attractive with the exponential growth of data quantity available at different stages of the decision chain: with the continuous development of data link, it became much easier to transmit a large amount of data rather than "filtrating" it. An overwhelming quantity of information (data, images, sounds…) can be transmitted to the final stage of the system, very often a human operator, which has to perform its own real-time processing, at the major risk to pick up the "wrong" information when submitted to a critical operational context. In this case, the use of fusion processes at different levels of the system may highly decrease the operator workload.

Recent developments in electronics, in terms of computation power, memory capacities, transfer rate and compactness made realistic to integrate such processing inside embedded airborne payloads, and perform it in real time with significant results.

Algorithms and combinations presented in the following paragraphs have been retained after examination of several quality factors listed in growing order of importance: ability to be embedded, robustness, operational interest. The final step of validation of these functions will be their evaluation in operational conditions by expert military operators.

Fusion processes are grouped according to the system level at which they can be applied: at the sensor level, between different OP sensors, between OP sensors and other UAV payloads, between OP information and data kept in the GS.

5.1 Inside UAV-OP Sensor

A first level of fusion can be made at sensor level, by processing images and data coming from a same sensor, to add a functionality to the sensor or to achieve significant performance increase. These process can be implemented in sensor electronics or in OP electronics, in order to apply the same processes to different imaging sensors: TI, HDTV, Spotter…

Process	Process principle	Operational interest
Image stabilisation	By comparison of successive images coming from the same sensor, a precise estimation of the sensor motion between the different images is calculated, allowing image stabilisation with a sub-pixel accuracy.	• Image quality improvement, facilitating the operator work. • Improvement of long range optronic performances (Identification), relying on high spatial frequencies in the image.
Fine detector calibration and non-uniformity correction	Motion compensation allows to compare different pixels' response to the same thermal or luminous sources in the scene, making possible to finely compensate responsivity variation among pixels of the same detector. The same algorithm allows to detect bad or "dead" pixels.	• Image quality improvement. • Improvement of optronic performances relying on exploitation of pixel size details.
Automatic target detection and tracking	After stabilisation and detector calibration, each new is compared with the preceding image of the sequence to extract the map of moving or varying objects in the image. Position, speed and size of moving objects are filtered at lower rate to perform target selection and tracking.	• Reduction of operator workload during target search / improvement of detection performances. • Reduction of operator workload during target tracking, especially for multi-tracking.
Image accumulation and restoration	Intensity accumulation applied on non-moving pixels drastically increases the Signal-to-Noise Ratio of these pixels, allowing the use of powerful restoration algorithms.	• Improvement of optronic performances, particularly on low contrast targets (Long range detection).
Hyper-resolution	An over-sampled image of the scene is obtained by high precision compensation of the sensor motion between successive images, with sub-pixel accuracy.	• Increase of image resolution. • Reduction of aliasing, making possible Wiener restoration on images initially produced with under-sampled imagers. • Improvement of optronic performances relying on high spatial frequencies in the image (Identification).

5.2 Between UAV-OP Sensors and Equipments

A second kind of fusion processes can be applied between different sensors of the observation payload.

These processes either provide an additional functionality, or increase performances of another processing.

Process	Process principle	Operational interest
Image enrichment and annotation	Data produced by OP are collected and processed to obtain higher level data: Interesting data for the UAV system operator are traduced into letters and symbols, overlaid on the video imagery.	• Reduction of operator workload, by presentation of complementary data directly on the image. Examples of sensors' data: LOS orientation and speed, target distance measured by LRF, position of the tracked target. Example of secondary level data: predicted target direction and speed obtained by processing of LRF target range, inertial LOS rate measured by gyrometers and tracking errors.
Multispectral image fusion	Video flows produced by two boresighted imaging sensors (for example a thermal imager and a TV camera) are processed to produce a single image combining the main features visible in the two spectral bands. The algorithm may also be optimised to enhance the readability of the fused image.	• Increase of detection capabilities: the fused image shows a wider spectrum than each single image, making target concealment less efficient. • Improvement of situational awareness by simultaneous presentation of complementary information sensed in different spectral bands. • Reduction of the operator workload: for surveillance missions, the operator watches a single display, without switching time and eye-brain adaptation time. • Technical interest: a single data link transmits information requiring two links without fusion.
Image stabilisation	Line-Of-Sight residual motion is measured by inertial sensors (gyrometers, accelerometers) integrated in the mechanical structure of the Sensor Pack, and filtered to perform image motion compensation.	• Same operational advantages as in 3.1.
Laser-enhanced Imagery	1) A laser is synchronised with a low-light level TV camera to increase target illumination during night-time operations. 2) Range gated laser imagery: A laser is used as target illuminator and range finder, precisely synchronised with an imaging sensor to eliminate image blur due to light scattering and reflection along flight path.	• Increase of optronic performances (D, R, I) during normal weather conditions. • Enlargement of operational domain, by compensation of degradation induced by bad weather conditions (snow, fog).

5.3 Between UAV-OP and Other UAV Modules

Onboard the UAV, the OP is placed in a very rich data environment, produced by various other payloads: Inertial Navigation System, Global Positioning System, Radar, SAR…

Process	Process principle	Operational interest
Geo-Referencing	UAV position and orientation are combined with angular measurements of the gyrostabilized platform to compute LOS orientation in the terrestrial reference in real-time. The use of a LRF to measure Surface-Sight Point range allows to know target position in 3D. After compensation of optical effects, each pixel of the image is linked to its position on the earth sphere.	• Without LRF: Medium precision, passive target localisation. • With LRF: more precise, but less discrete Surface-Sight Point localisation.
Geo-Tracking	Thanks to INS / GPS information, UAV motions are compensated to slave the LOS on a target defined by its coordinates in the terrestrial reference (Latitude & Longitude). These coordinates may be defined by the operator or sent by another payload (radar).	• Reduction of the operator workload: the operator relies on the automatic LOS slaving managed by the OP, and fully concentrates on its value-added activity: images and data analysis and exploitation.
Geo-Scanning	The same algorithms are used to slave the LOS along sweeping or scanning patterns, to ensure a full coverage of a area of interest on the ground, whatever the linear and angular motions of the UAV.	
Image depth mapping	Combination of pixel motion measurement techniques (e.g. optical flow) with data provided by INS/GPS allows to obtain distance estimation of objects in the image.	Operational interest varies following the types of UAV: • On tactical UAVs, assistance during navigation in low-level flights. • On mini-UAVs, participation to the vehicle automatic piloting function, by altitude and attitude estimation.

5.4 Between UAV-OP and GS DATA

Additional synergies can be obtained by combination of data produced by embedded payloads and information available on the ground station. These processes are applied at UAV system level.

Process	Process principle	Operational interest
Image Geo-Referencing with alignment on Digital Terrain Elevation Data and synthetic images	Main features extracted from the OP images are correlated with a 3D model of the interest area, elaborated during the mission preparation. A range measurement thanks to the OP LRF provides additional improvement of image-to-model fitting.	• High precision 3D geo-referencing of each pixel of the image.
Automatic Target DRI and localisation	Objects "silhouettes" are extracted from the image by segmentation, and correlated with a large database constituted by precise 3D modelling of possible targets: planes, helicopters, tanks, shelters…	• Automatisation of DRI tasks allows the processing of very large amount of information.

6.0   PROPOSITION OF UAV OBSERVATION FUNCTION ARCHITECTURE

6.1   Architecture Design Work

Main requirements collected in the preceding steps of the study and presented in previous sections are summarised in the following list:

- Compatibility of proposed OP architecture with existing UAV system architecture,

- Multisensor Observation Payload: Integration of several sensors of different types,

- Sensor Modularity: Multi - configuration OP payload with identical external interfaces,

- High level of autonomy and automation of the OP,

- High operational performances: DRI, Geo-localisation,

- Multi-carrier compatibility,

- UAV system inter-operability,

- Integration at sensor and OP level of data and image processes bringing operational added value,

- Transmission by the OP of information with sufficient accuracy to allow the application of fusion processes at upper system levels.

Basing on these data, we propose a UAV observation function architecture designed to allow a maximum use of data and image fusion techniques, at different levels of the UAV system. The work to build this architecture followed two main axes:

- Functionalities repartition between the different elements of the imagery chain;

- Definition of interfaces and data links between these different modules.

The repartition of functions relied on the following rules:

- Superposition of functional and hardware architectures,

- Lower-level functions management is left to lower-level sub-systems, in order to reduce control loops latency and volume of exchanged data,

- Maximum communality of high-level functions management to avoid useless redundancies.

These rules result in repartition of management capabilities and thus in increase of electronic volume among the different levels of the OP architecture; their application may be limited in function of available volume.

The definition of interfaces and data links was driven by these main principles:

- Maximization of data links capabilities (rate, bit depth) to allow the most accurate processing after data transmission to higher system level,

- Choice of internal OP interfaces to reach maximum OP re-configurability and sensor modularity,

- Standardization of external OP interfaces to reach maximum OP / UAV interchangeability (a given OP on different UAV types, or different OP on a given UAV).

6.2   Resulting Architecture

The proposed architecture is summed up by the following figure:
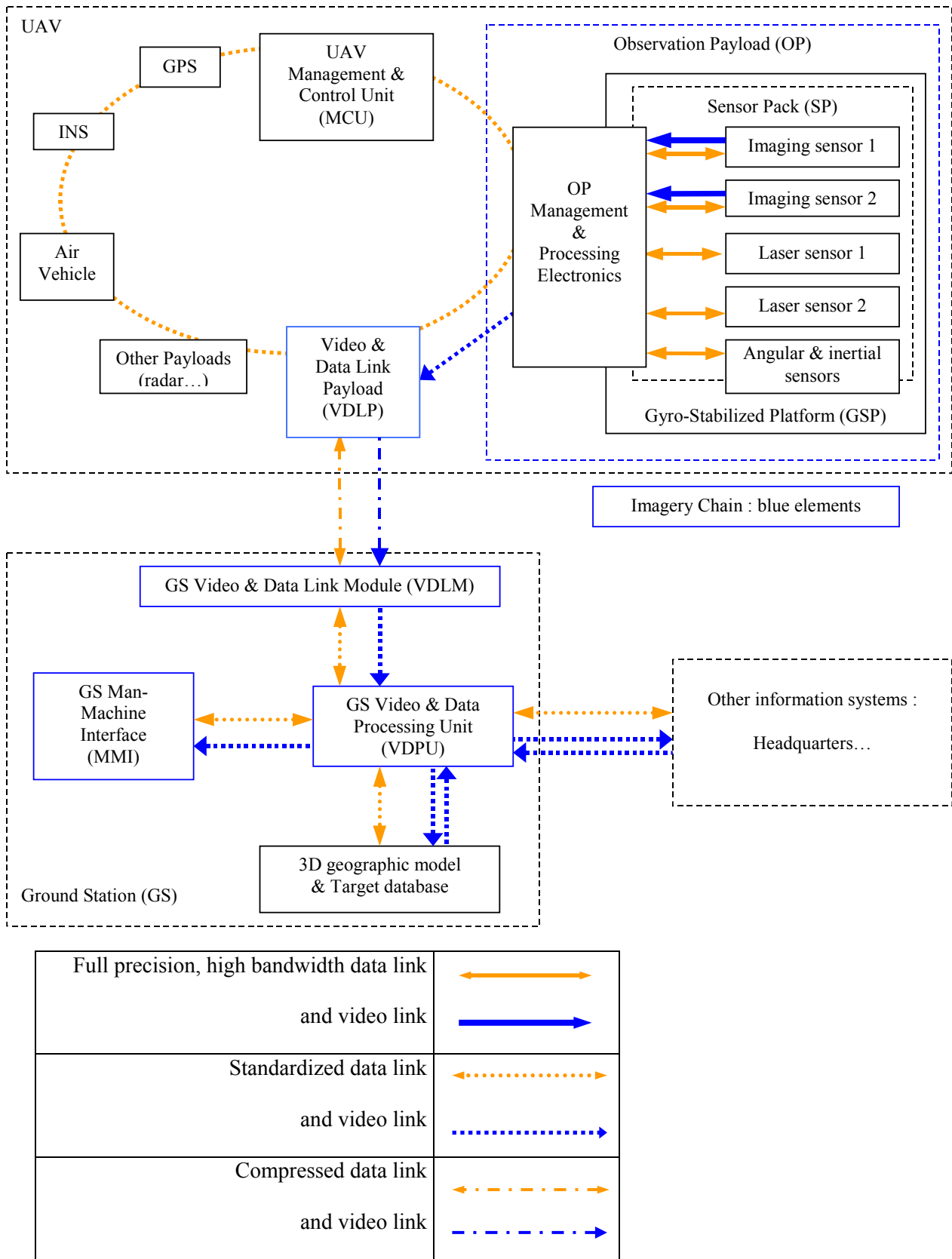
Main characteristics of this architecture are the following:

Electronics of each sensor is in charge of sensor low-level functions management, and specific data and image processing, in order to achieve sensor modularity at OP level, and to avoid overload of OP electronics (Example of TI specific image processing: Non-Uniformity correction).

Video and data links inside the OP (between OP sub-assemblies and OP electronics) are dimensioned to achieve the highest possible performances with processes implemented inside OP Management and Processing electronics; Standardisation of these links is a secondary priority, compared to data link rate, bandwidth and bit depth.

OP Management and Processing electronics is in charge of functionalities requiring multi-sensor / multi-payload information processing, with very short control loops (for example Tracking, Geo-Tracking…), and of processes which can be equally applied on different sensors: image stabilisation, hyper-resolution.

OP electronics also assumes responsibility of OP to UAV interfaces:

- For commands and data exchange, OP is connected to UAV MCU and other UAV payloads thanks to the UAV Mission Bus, defined at UAV system level.

- For video link, standardisation is the first priority to comply with inter-operability requirement, prior to video link technical characteristics: For example, STANAG 4609 on Motion Imagery recommends 10 bits digital video formats, whereas IR sensors usually produce images with more than 12 bits precision. This leads to locate in the OP Management and Processing electronics processes requiring very high image precision: for example, automatic target detection & target fusion.

Image and data pre-processing before transmission between UAV and GS are taken in charge by a specific module of the UAV System, because they are strongly related to the type and characteristics of transmission.

The choice of standardised digital data & video links allows further diffusion of information without additional degradation due to format conversion, which is necessary to perform supplementary fusion processes at higher levels of the system.
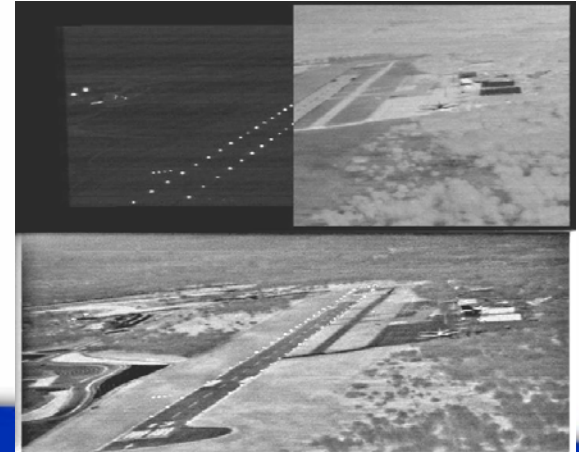
Data & Image Fusion
for multisensor UAV Payloads

P. Gosselin, H. Lamarre, P. Echard

SET-092 Symposium "Advanced Sensor Payloads for UAV »

Lisbon, May 2nd 2005

Outline

★ Introduction

★ SAGEM Airborne Observation Payloads

★ Specificity of UAV context

★ Data & Image fusion functions for UAV imagery chain

★ Architecture of UAV Observation Function for data and image fusion

Introduction

★ SAGEM : European leader for UAV

  ○ Main supplier for Tactical UAV systems in Europe

  ○ Observation Payload (OP) for Medium Altitude, Long Endurance UAV
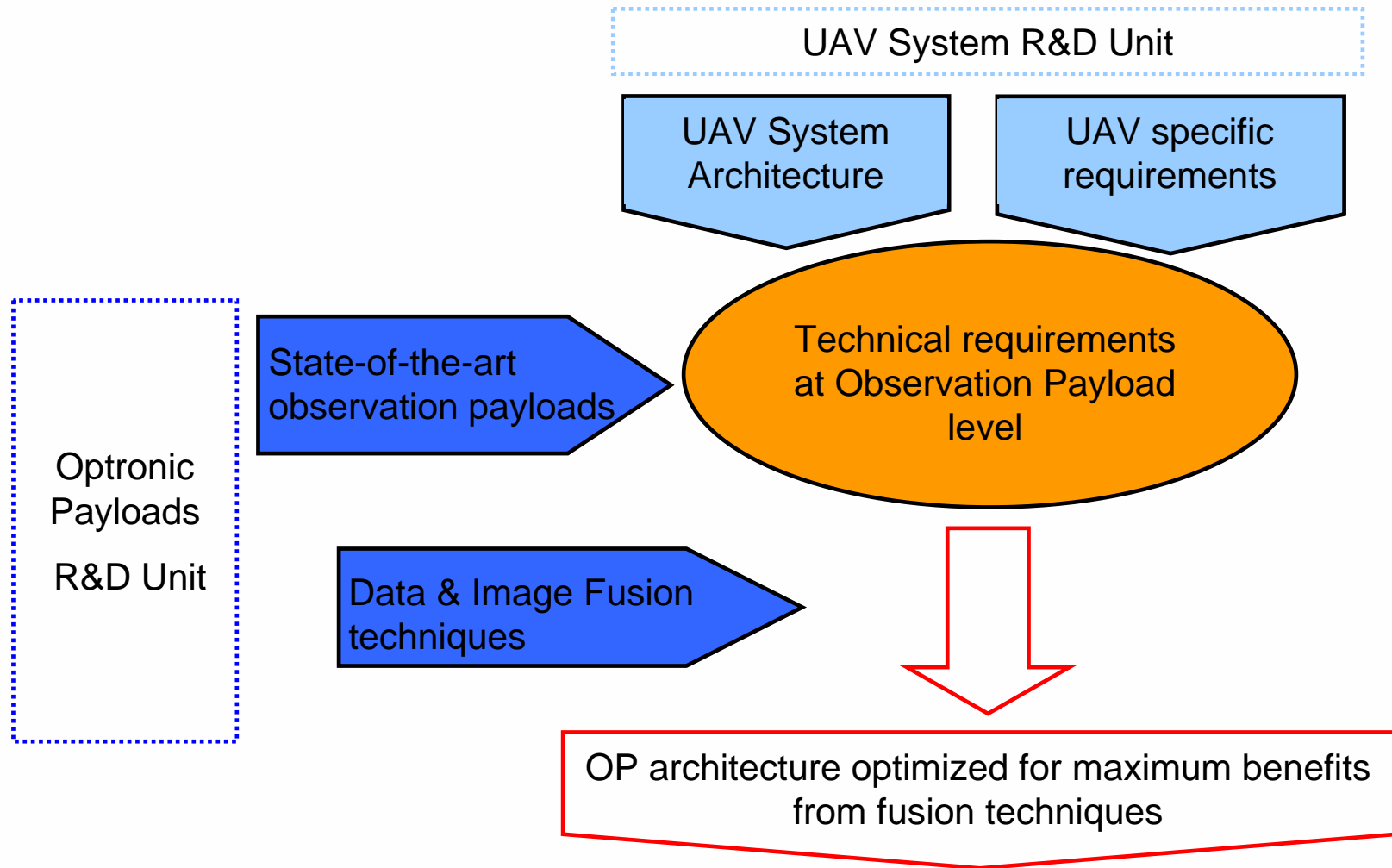
  ○ Proposition of platoon-level mini-UAV

★ SAGEM UAV success based on long-term expertise in :

  ○ Optronic systems (European n°1)

  ○ Inertial Navigation Systems (European n°1, World n°3)

  ○ Global Positioning Systems

  ○ RF communications and Data Links

★ Development of next-generation UAV observation payloads

  ○ Specific study to maximise synergies thanks to fusion techniques

Synthesis of the study

UAV System R&D Unit

UAV System Architecture

UAV specific requirements

Technical requirements at Observation Payload level

State-of-the-art observation payloads

Optronic Payloads

R&D Unit

Data & Image Fusion techniques

OP architecture optimized for maximum benefits from fusion techniques

SAGEM airborne optronic payloads

★ SAGEM : European leader for gyrostabilised observation payloads, installed on every type of airborne carrier

○ Multi-role Helicopters

○ Patrol Aircrafts

○ Transport Helicopters

○ Tactical UAV

○ More than 300 Gyrostabilised Payloads in operational service

SAGEM experience in gyrostabilised payloads (1)
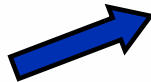
★ Evolution of sensors integrated in airborne OP

★ SAGEM IRIS
  ○ Gen. II Thermal Imager
  ○ 8-12 µm spectral band
★ TV camera

★ Infrared Line Scanner
★ 8-12 µm spectral band

★ SAGEM MATIS
  ○ Gen. III Thermal Imager
  ○ 3-5 µm spectral band
★ High definition TV camera
★ Laser Range Finder
★ Laser Designator

SAGEM experience in gyrostabilised payloads (2)

★ Constant evolution of functional area covered by OP

★ 1995 : OLOSP 350
★ 4-axis stab.
★ 2 sensors : IR + TV

★ OLOSP NG
★ High accuracy stab.
★ Modular architecture
★ Advanced functionalities

★ 1991 : PGS
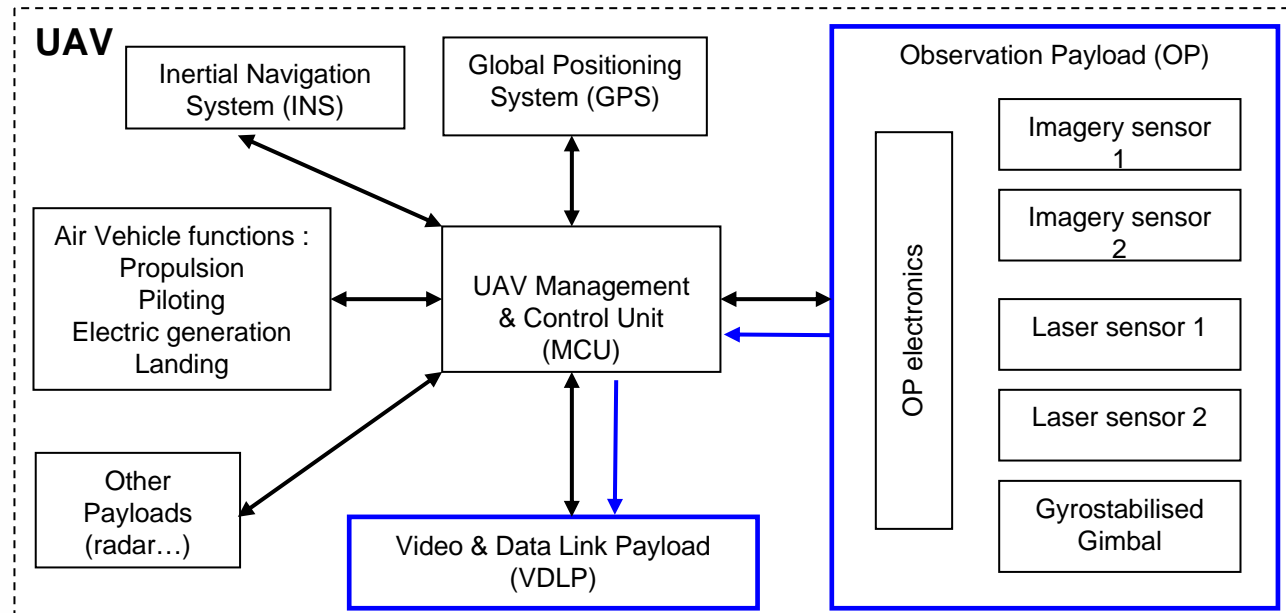★ 2-axis stabilisation
★ 1 completely independent Sensor

★ 2001 : OLOSP 410
★ 4-axis stab.
★ Multi-sensor configuration
★ Integrated management electronics

UAV Observation Function

★ Observation function performance relies on every element of the Imagery chain

UAV

- Inertial Navigation System (INS)
- Global Positioning System (GPS)
- Air Vehicle functions : Propulsion Piloting Electric generation Landing
- UAV Management & Control Unit (MCU)
- Other Payloads (radar…)
- Video & Data Link Payload (VDLP)

Observation Payload (OP)

- OP electronics
- Imagery sensor 1
- Imagery sensor 2
- Laser sensor 1
- Laser sensor 2
- Gyrostabilised Gimbal

Imagery Chain : blue

Ground Station (GS):
- Video & Data Reception
- Video & Data Processing
- Man-Machine Interface

Specificity of UAV context
for observation payloads

★ Imagery and data exploited on the ground after transmission

  ○ Specific processing to reduce loss of quality due to transmission

★ Higher level of automation

  ○ Necessary for mission permanency during possible transmission loss

  ○ Reduction of exchanged data to high-level information to comply with data link limitation

★ Unmatched operational & technical requirements

  ○ Optronic performances (D, R, I)

  ○ Contribution to Geo-localisation

  ○ Miniaturisation

★ Integration in higher-level information systems

  ○ Inter-operability requirement

Specificity of UAV context

★ Constant diversification of UAV systems

EUROMALE

EADS - THALES - SAGEM - DASSAULT cooperation

SPERWER B - 2002

Long Range Tactical UAV

SPERWER A - 1995

Tactical UAV

Joint VTOL UAV

Bell - Rheinmetall - SAGEM cooperation

CRECERELLE- 1993

Tactical UAV

★ Interchangeability of UAV and OP

★ Definition of a scalable architecture

Data & Image Fusion techniques

★ Fusion : process producing significant synergy between information produced by sensors or other data sources

★ Growing interest for fusion techniques

  ○ Increasing volume of available data

  ○ Requirement for reduction of operator workload

  ○ Development of embedded electronics

★ Applicable at different levels of the UAV observation function

Data & Image Fusion techniques

★ Inside sensors: fusion of successive images

  ○ Image stabilisation by image processing

  ○ Fine detector calibration & non-uniformity correction

  ○ Automatic target detection

  ○ Hyper-resolution

★ Inside OP: between different image & data sources

  ○ Automatic target tracking

  ○ <u>Image enrichment and annotation</u>

  ○ multi-spectral image fusion

  ○ Laser enhanced imagery

Data & Image Fusion techniques

★ Between OP and other payloads of the same aircraft: INS, GPS, radar…

- ⭘ Pixel Geo-referencing

- ⭘ Geo-Tracking: automatic LOS orientation in terrestrial reference

- ⭘ Geo-Scanning: automatic area scanning in terrestrial reference

- ⭘ Passive image depth mapping

★ Between OP and GS information (target database…)

- ⭘ Image Geo-Referencing with alignment on Digital Terrain Elevation Data and synthetic images

- ⭘ Automatic Target DRI and localisation

Example : Multi-sensor image fusion

★ Multi-spectral image fusion on OLOSP 410
  ○ SAGEM IRIS Thermal Imager (8-12 µm)
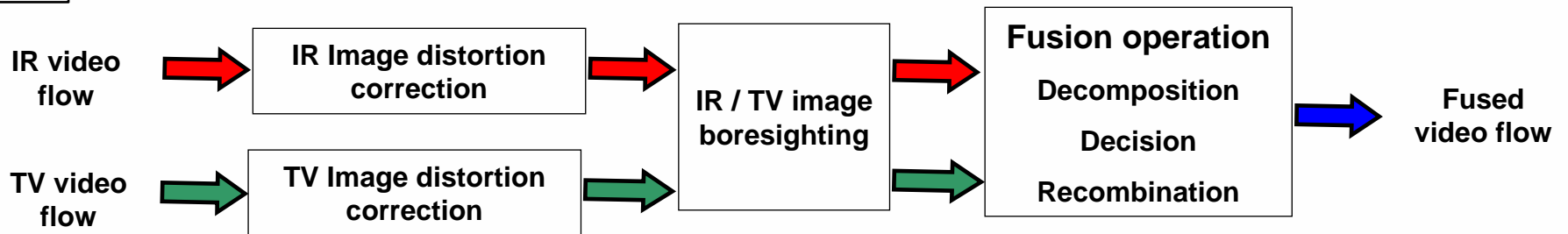 ○ Near-Infrared TV camera (0.6 - 0.9 µm)

★ Operational interests
  ○ Increased detection capabilities
  ○ Improvement of situational awareness: Reduction of the operator workload during search task
  ○ A single data link transmits images of two sensors

★ Choice of multi-level Laplacian pyramid algorithm
  ○ Robust and efficient algorithm
  ○ Well fitted to FPGA used in embedded electronics

Multi-spectral fusion with Laplacian pyramid

★ Images are pre-processed before fusion

```
IR video          ┌─────────────────┐        ┌──────────────┐       ┌──────────────────┐
flow      ──────▶ │ IR Image distortion│ ────▶ │              │ ────▶ │ Fusion operation │
                  │    correction     │        │ IR / TV image│       │                  │       Fused
                  └─────────────────┘        │ boresighting │       │   Decomposition  │ ────▶ video flow
TV video          ┌─────────────────┐        │              │       │     Decision     │
flow      ──────▶ │ TV Image distortion│ ────▶ │              │ ────▶ │   Recombination  │
                  │    correction     │        └──────────────┘       └──────────────────┘
                  └─────────────────┘
```

○ IR and TV images decomposition on Laplacian pyramid (I_{IR}^k & I_{TV}^k)

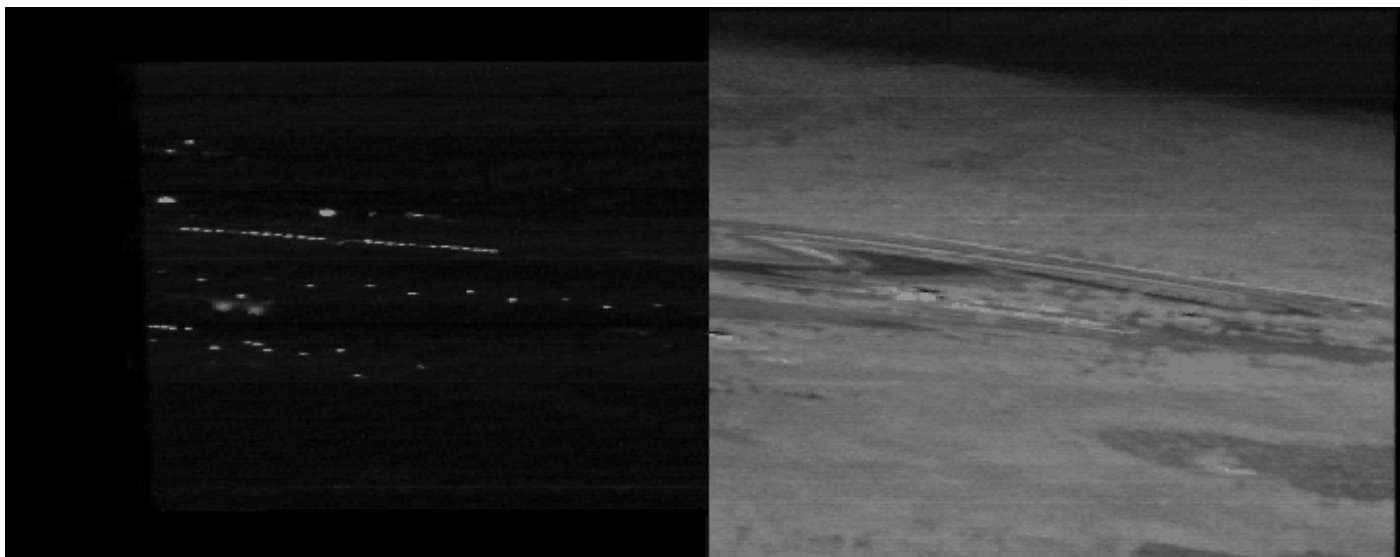I_{IR}^4 I_{IR}^3 I_{IR}^2 I_{IR}^1
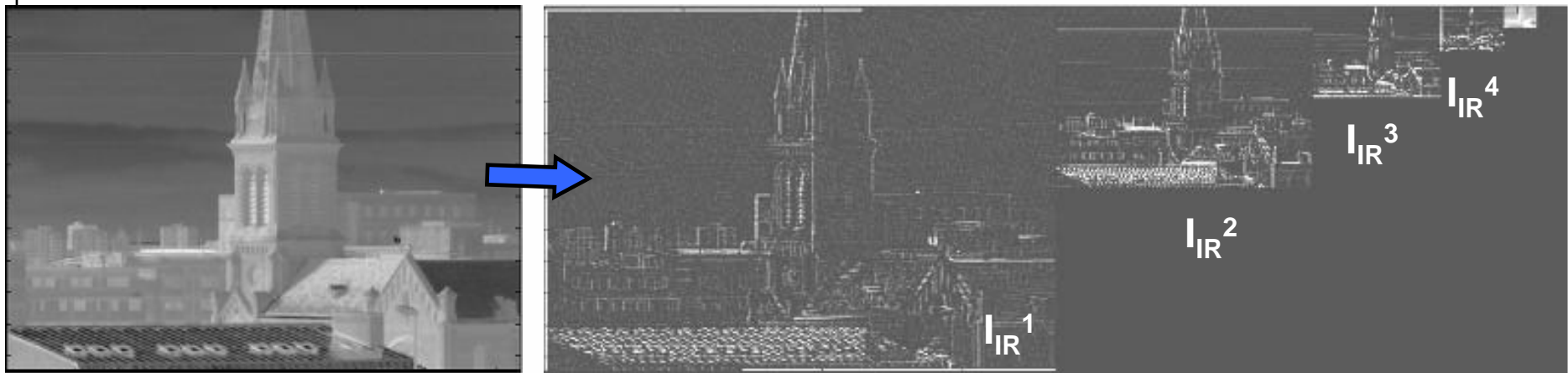
○ Application of decision mask
on each pyramid level :

$$D_k(i,j) = \begin{cases} 1 & \text{if } \left| I_{IR}^k(i,j) \right| \geq \alpha \left| I_{TV}^k(i,j) \right| \\ 0 & elsewhere \end{cases}$$

○ Fused image formation by recombination of fused images (D_k) pyramid
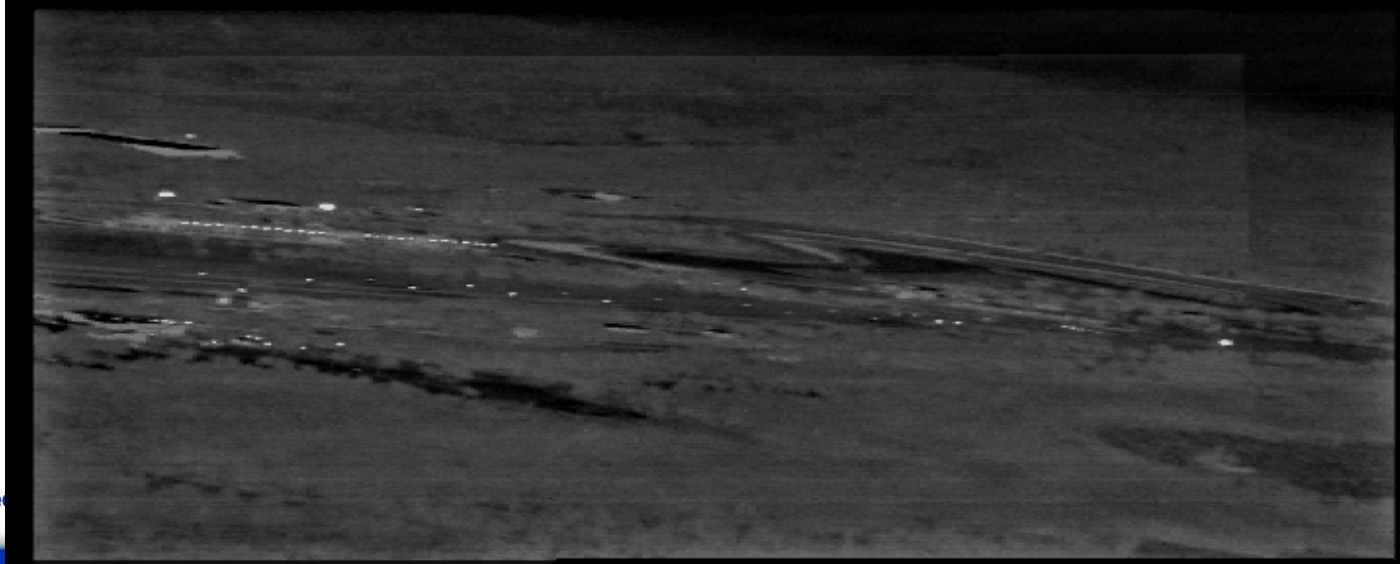
Multi-sensor image fusion trials :
Airfield approach during night flight

TV

IR

IR + TV

Observation payload design

★ **Identification of prioritary requirements**

☆ **Design rules**

★ Major design choices

> High optronic performances

> Maximum robustness

> Sensor modularity

> Multi-sensor capability

> High level of automation

> Multi-carrier compatibility

> Maximum operational benefits from fusion techniques

> Compactness

○ **Functionalities repartition among imagery chain elements**

> Superposition of functional and hardware architectures

> Repartition of management capabilities

○ **OP Interfaces definition**

> Maximum standardization of interfaces

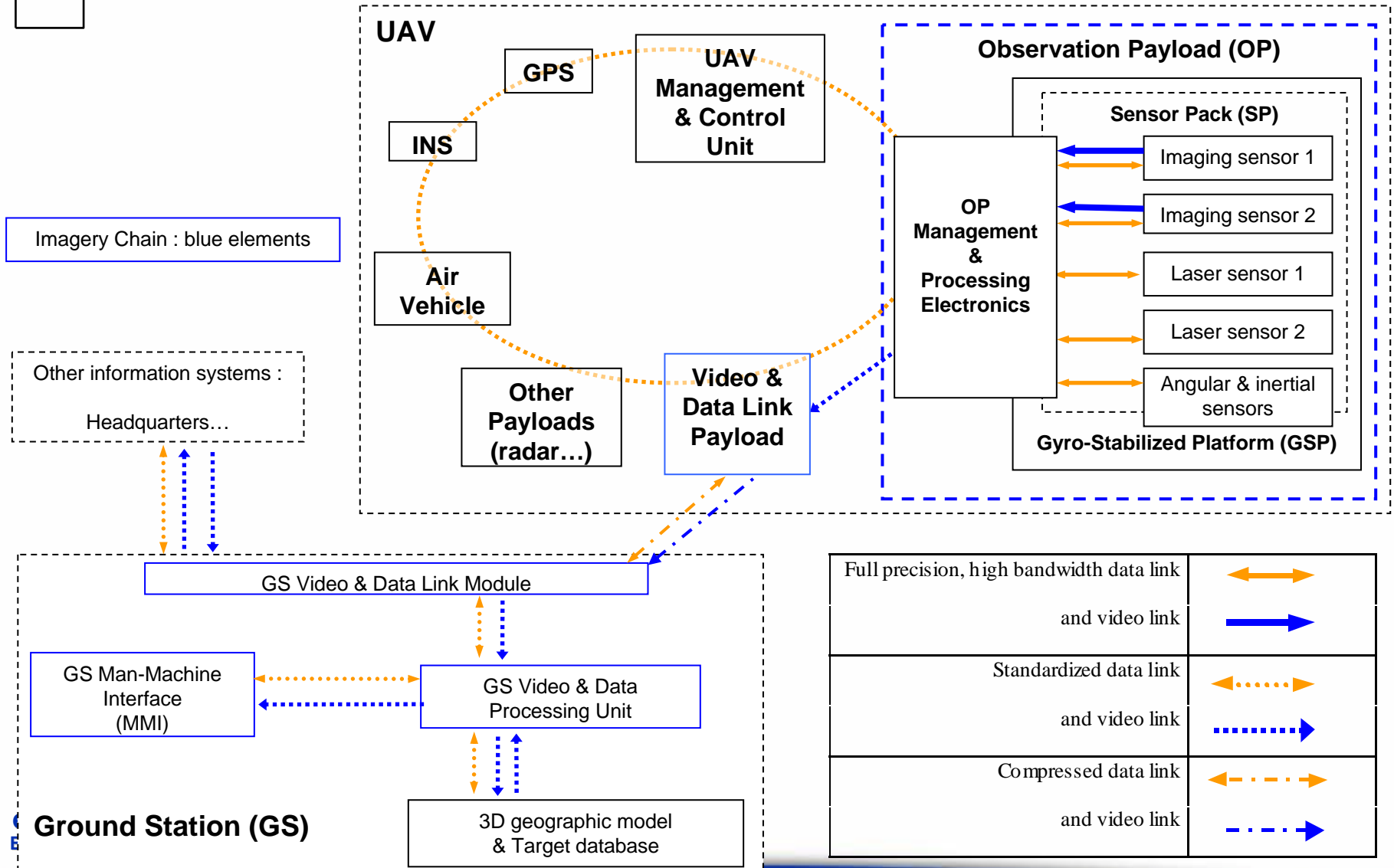> Maximum data link capabilities

○ **Minimization of mass & volume**

○ **Specific processing implemented in sensor electronics**

○ **Full precision, high bandwidth internal data links**

○ **OP electronics dimensioned for :**

➢ OP management

➢ Data & image processing

○ **Standardization of external interfaces :**

➢ STANAG 4609 for motion imagery...

Imagery chain architecture

UAV

GPS

INS

UAV Management & Control Unit

Air Vehicle

Other Payloads (radar…)

Video & Data Link Payload

Imagery Chain : blue elements

Other information systems :

Headquarters…

Observation Payload (OP)

Sensor Pack (SP)

OP Management & Processing Electronics

Imaging sensor 1

Imaging sensor 2

Laser sensor 1

Laser sensor 2

Angular & inertial sensors

Gyro-Stabilized Platform (GSP)

GS Video & Data Link Module

GS Man-Machine Interface (MMI)

GS Video & Data Processing Unit

Ground Station (GS)

3D geographic model & Target database

Full precision, high bandwidth data link	
and video link	
Standardized data link	
and video link	
Compressed data link	
and video link	

S

Conclusion

★ Application of fusion techniques results in major improvements of UAV Observation Function

  ⭘ Enhanced optronic performances (Detection, Reconnaissance, Identification) & geo-localisation

  ⭘ Reduction of the operator workload

★ Observation Payload design allows maximum use of fusion techniques @ every system level

Data & Image Fusion
for multisensor UAV Payloads

Questions ?