Image processing for tactical UAV

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RTO SET SYMPOSIUM

Advanced Sensor Payloads for UAV

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OUTLINE

- SAGEM Tactical UAVs
- Imagery chain
- 3 rd generation IR imaging Payload
- Image processing
- Automatic target recognition
- Target localization
- Conclusions

SAGEM : EUROPEAN LEADER FOR UAV

From Swedish Lapland Operation ...

1993

1995

1997

1999

2001

2002

... to Saudi Arabia Operation

- BATTLE & FIELD - PROVEN
- MOST ORDERED SYSTEM IN EUROPE
  - FRENCH ARMY (2+1+4 systems),
  - DUTCH ARMY (4 systems),
  - SWEDISH ARMY (3 systems),
  - DANISH ARMY (6 systems),
  - GREEK ARMY (3 systems)
- IN FULL RATE PRODUCTION

MAIN SPERWER SYSTEM CHARACTERISTICS

THE SYSTEM

Ground Segment
Launcher
AVs

THE MISSIONS ?

Artillery (30m CEP)
Intelligence

HIGHLY TACTICAL

- Catapult launch
- Parachute recovery

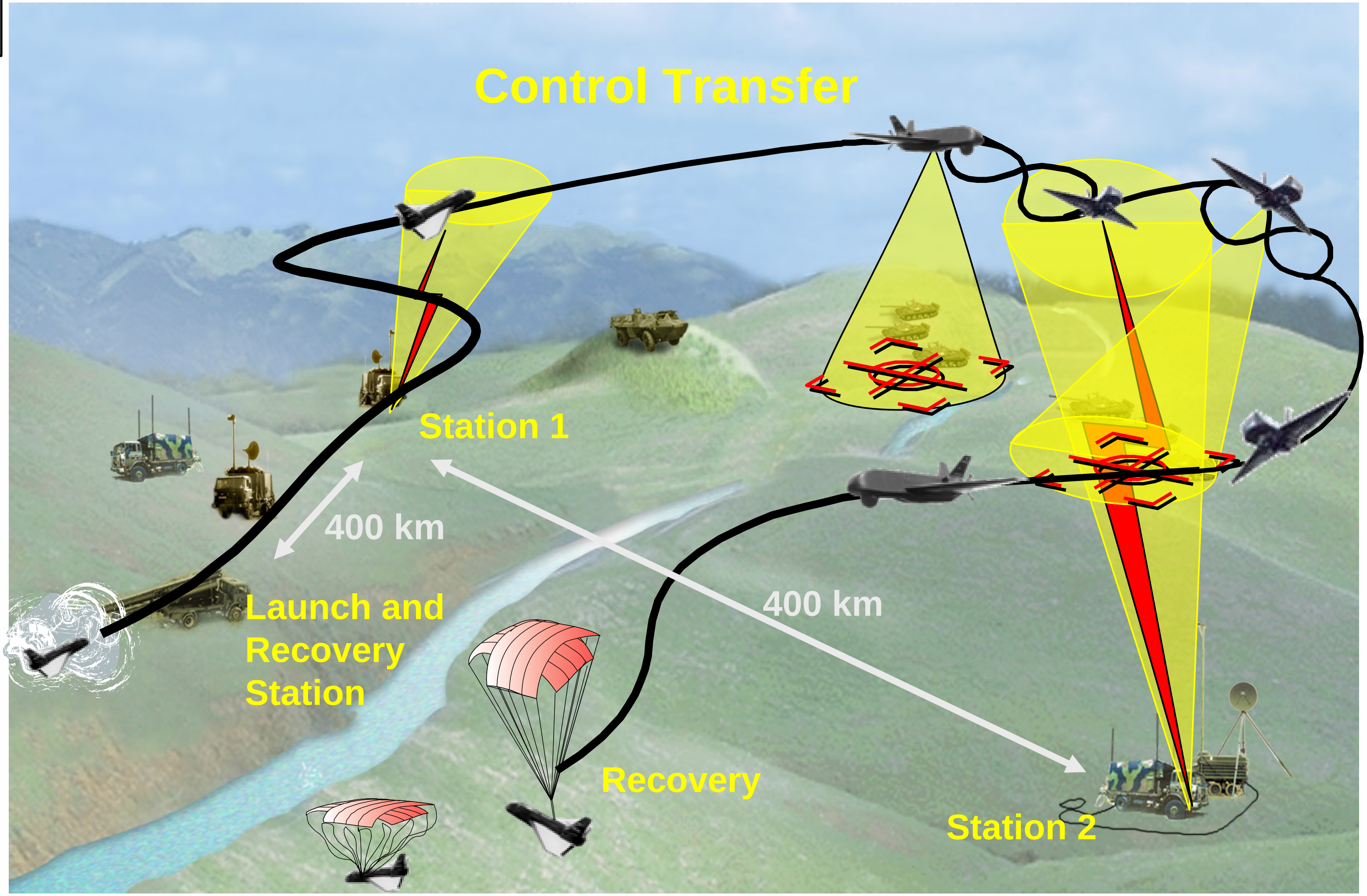
FLEXIBLE CAPABILITIES

- Multiple payload possible
- Hand Over between ground stations
- 2 aircraft simultaneously

NATO INTEROPERABLE

- C4I integrated (Adat P3)
- Ku-band data link (STANAG 7085)

Tactical UAV Mission



SPERWER AIR VEHICLES

- Common avionics
- Common ground segment
- Common data link
- Common logistic support

SPERWER - STANDARD

Endurance 6+ hours

MTOW 330 kg

Span 4.2 m

Speed 150 km/h

Ceiling 4500 m

Mission radius 200 km

SPERWER - LONG ENDURANCE

Endurance 12+ hours

MTOW 350 kg

Span 6.5 m

Speed 148 km/h

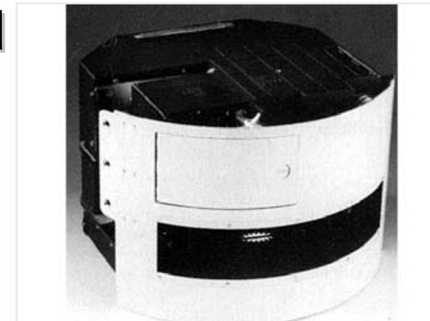
Ceiling 6000 m

Mission radius 200 km

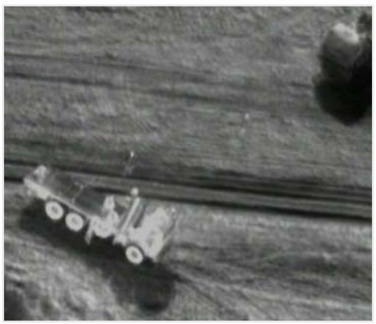
- Stealthy (RCS, IR, acoustic)
- Airworthiness
- Robust delta design
- Anti icing
- Typical time to reach 2000m < 10 mn

IR PAYLOAD MUST BE ADAPTED TO THE MISSION AND THE AIRCRAFT SPECIFICS

IRLS 8 - 12 µ



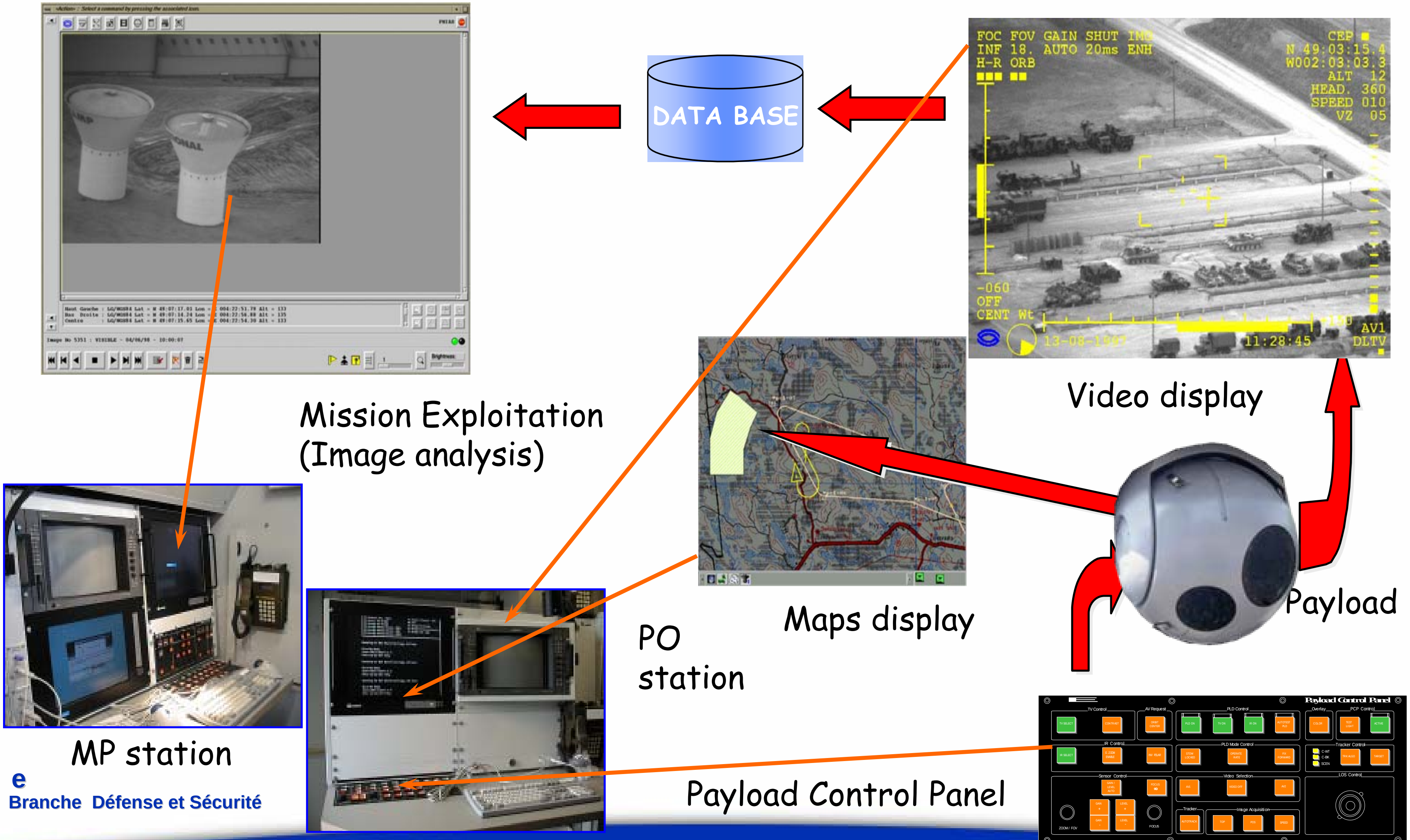
8 - 12 µ IRIS 2nd Generation & IR 3 - 5 µ MATIS 3rd Generation IR Camera



OLOSP & ARTEMIS

Stabilised gimbal

Payload system control and monitoring Image analysis



MATIS 3-5 µm CAMERAS

BINOCULARS

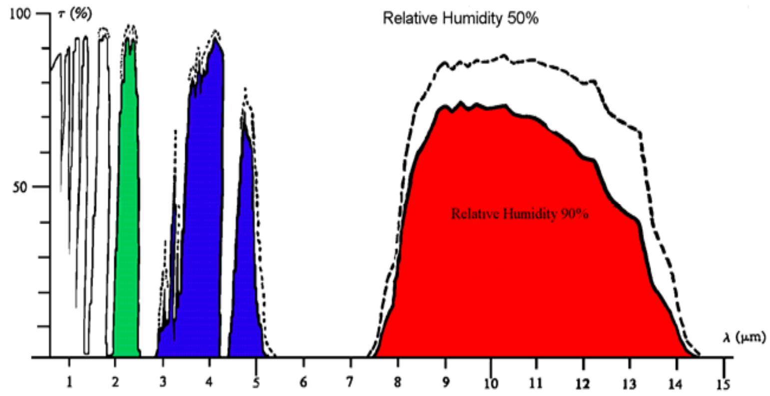
MANPORTABLE / STANDARD

LONG RANGE

SELECTION CRITERIAS for IR PAYLOAD

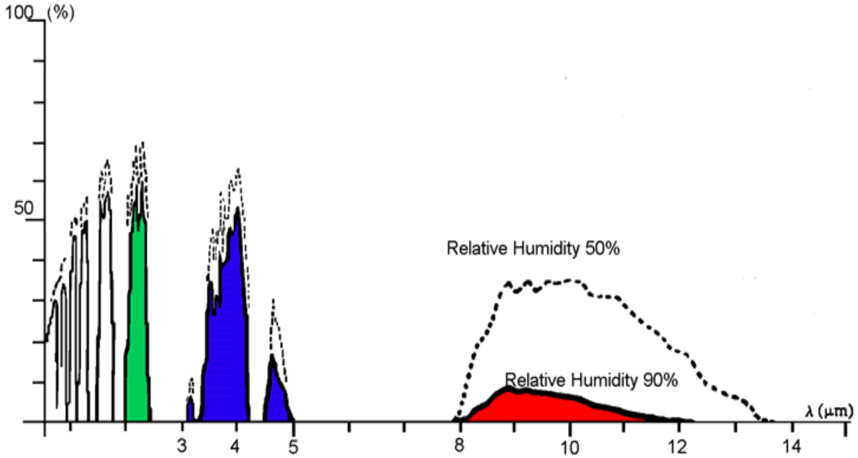
- Compactness to be fitted into a platform with other equipment's (visible camera, Laser Range Finders/Laser Designator,..)
- Consistency with the mission and the environment
- Image quality (high definition)
- Sensitivity (low NETD)
- Maturity of technology
- Affordable cost

ATMOSPHERIC TRANSMISSION
Influence of the Relative Humidity



Visibility : 25 km
Transmission 1 km,
Altitude 0 m
Temperature : 20°C
Pressure 1013 mbar; 1013 hPa

Visibility : 25 km
Transmission 10 km,
Altitude 0 m
Temperature : 20°C
Pressure 1013 mbar; 1013 hPa



DIFFRACTION

★ **Angular Resolution is Limited by Diffraction:**

$$\alpha = 1.22\, \lambda \,/\, Ø$$

α : angular resolution λ: wavelength Ø: pupil diameter

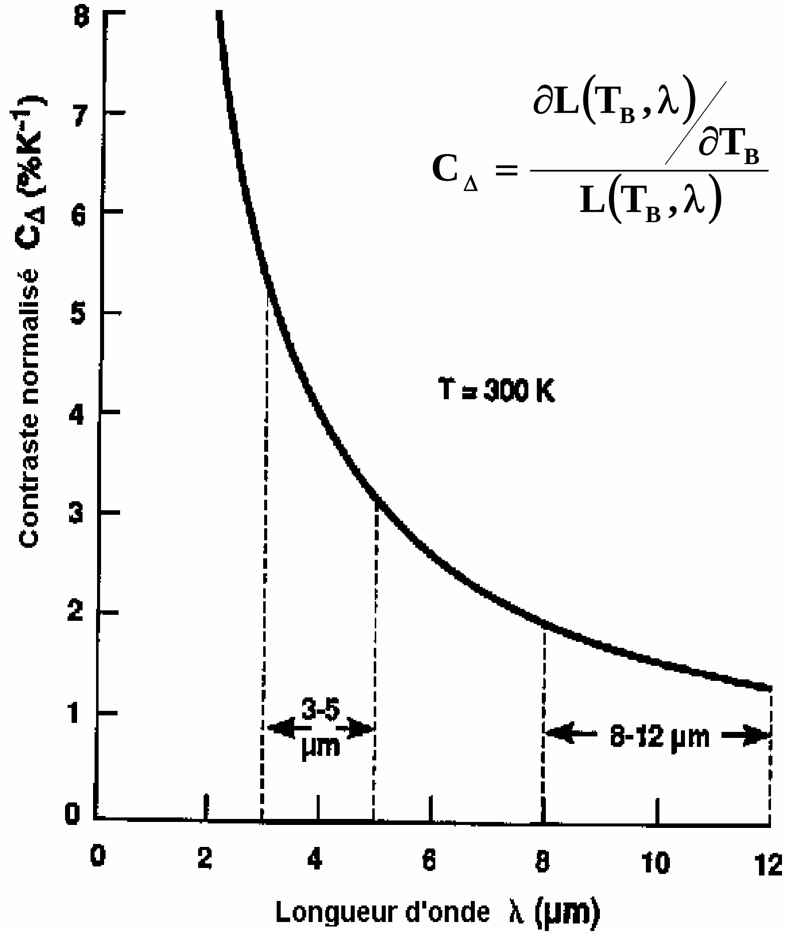
★ **2 possibilities:**

- ❑ **Increase Ø : Ineffective as already limited by the available space**
- ❑ **Decrease λ : move from 8-12 µm to 3-5 µm thermal imager, X2.5 benefit in term of resolution**

Background limited NETD for a 2 D Array

$$NETD_{min} = \frac{1}{C_{\Delta T}}\sqrt{\frac{2}{N_{max}}}$$

- ★ N_{max} : Maximum storage charge in ROIC capacitance (Nb of electrons)
- ★ $C_{\Delta T}$: Thermal contrast in the bandwidth



$$C_\Delta = \frac{\partial L(T_B,\lambda) / \partial T_B}{L(T_B,\lambda)}$$

MATIS image processing

- ★ Usual : non uniformity correction:
  - ❍ Gain table
  - ❍ Shutter to show a uniform scene
- ★ Improvement : use of optical flow estimate from scene and camera movement
  - ⇒ Better image quality
  - ⇒ New image processing capabilities

Optical flow

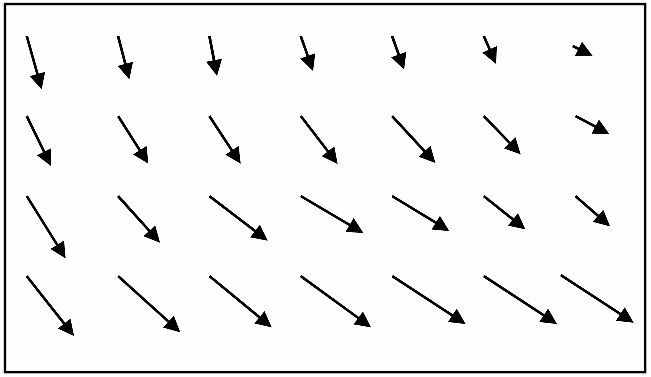
In a visible image sequence , the value of the intensity I(x,y) at a point x,y of the image plane may fluctuate because of two phenomena :

- A movement of the scene objects or a movement of the camera,
- An intensity variation of the scene objects

The optical flow detection consists in finding the velocity field of the video sequence elements in the image plane.

Optical flow

- pixels movement 2D Field



- Basic equation :

$$\frac{\partial I(x,y,t)}{\partial x}dx(x,y,t)+\frac{\partial I(x,y,t)}{\partial y}dy(x,y,t)+\frac{\partial I(x,y,t)}{\partial t}dt=0$$

IR Optical flow : algorithm description

- Hypothesis :
  - The scene optical flow is principally linked to camera movements
  - In the IR, intensity is a combination of incoming flux (through the lens) and a parasitic flux (eg narcisus).
  - To simplify the equation, we can make two observations concerning the optical flow of the IR camera :
    - There is no fast movements for the parasitic radiation
    - Intensity variations are linked to thermal phenomena, and consequently have time constants that are broadly superior to the image periodicity.

IR Optical flow : algorithm description

– Image pre processing : to avoid aliasing

– Gradient calculation

– Use of a predictive model to reduce the intensity variation

– Select N more convenient pixels

– We express movement in the focal plane as a function of 3 angles (roll, yaw and pitch), 3 translations and a zoom factor by a projection in the image plane of the movement model

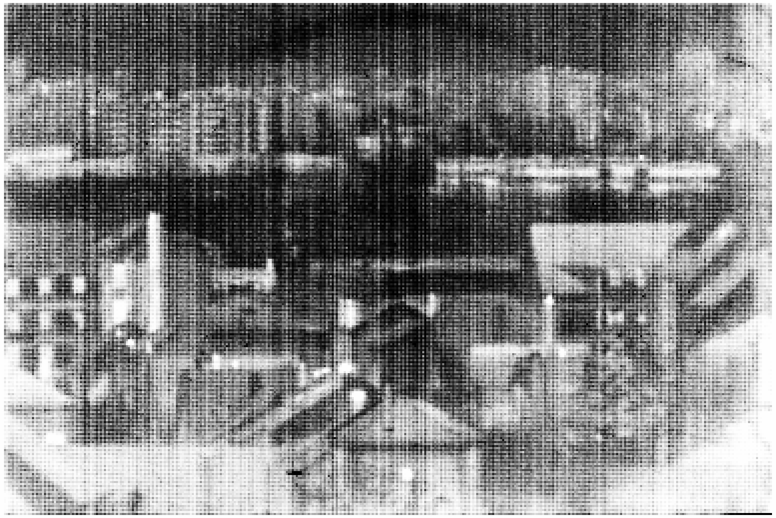
– These expressions are injected in the Optical flow equation

– We solve the N equations by least mean square estimate

Application of optical flow processing

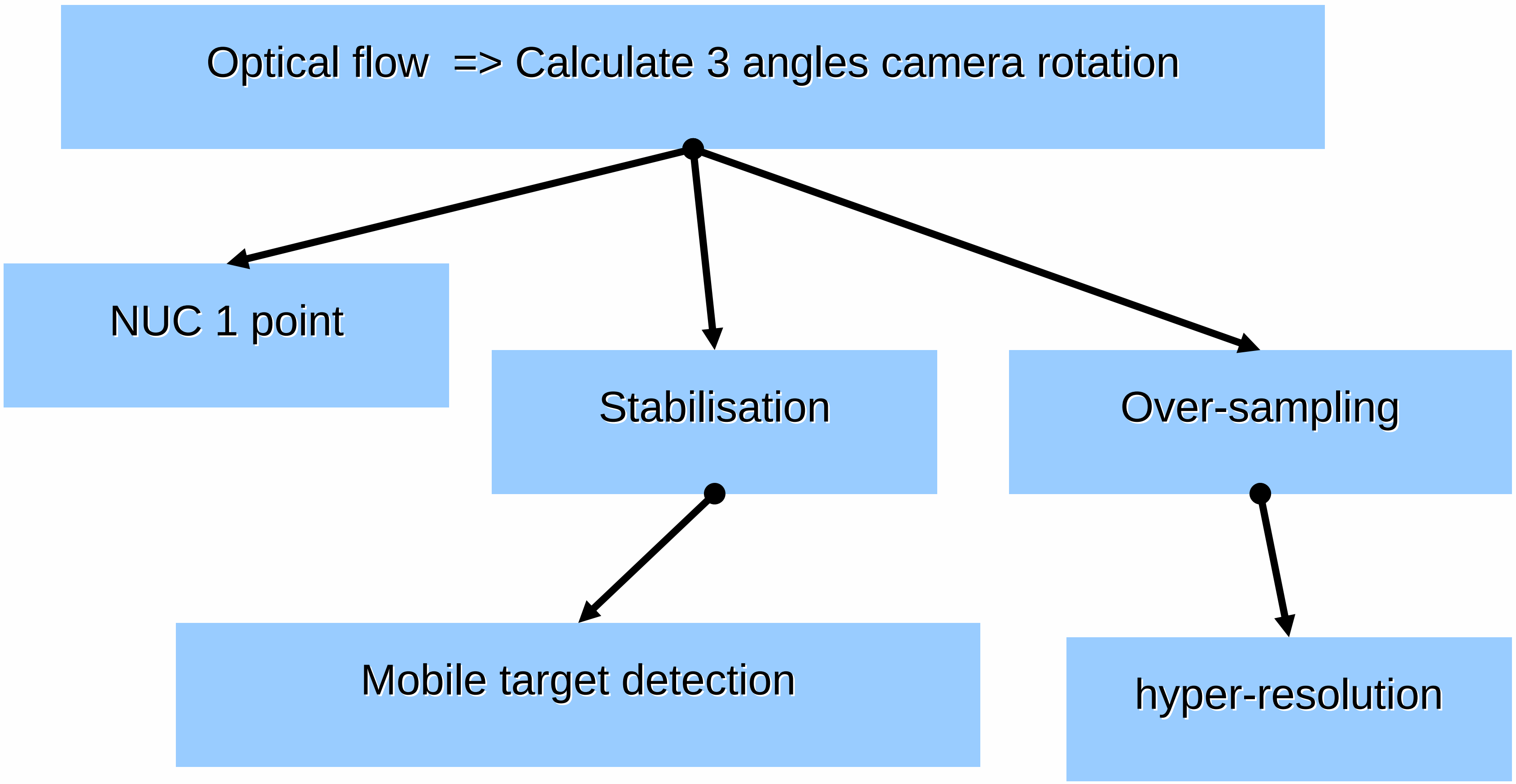
The suggested processing permits to achieve successively or simultaneously the following functions :

- the non-uniformity correction of the IR sensor
- the stabilisation in the terrestrial co-ordinate system, or the filtering of the carrier vibrations
- the extraction and the tracking of the mobile objects in the scene
- the generation of hyper resolved images combining over sampling and restoration



IR image without any correction

algorithm description



Stabilisation of IR image

Original movie

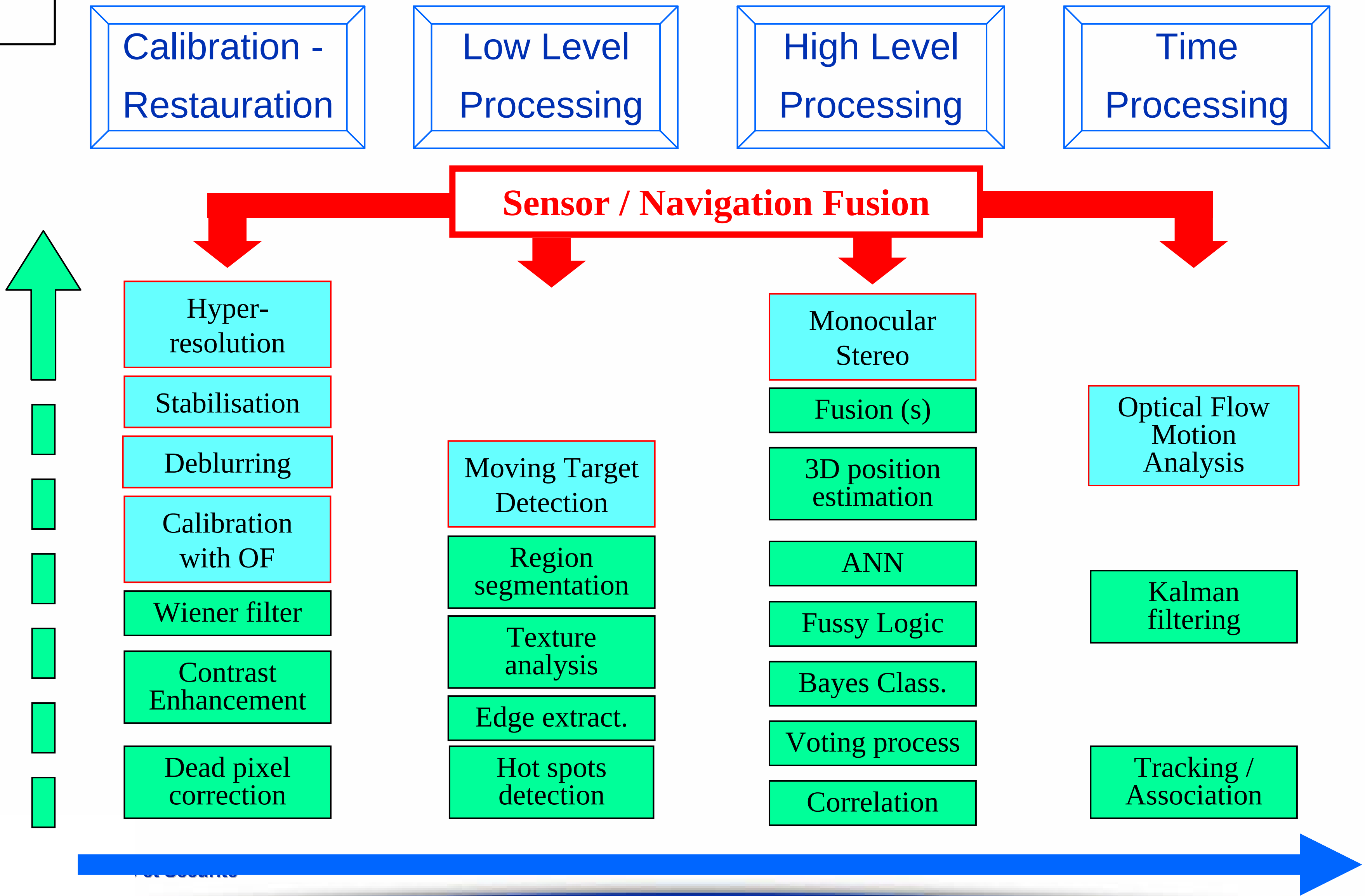
Filtered and stabilised movie

Stabilised and Referenced movie

Increased resolution with motion

Hyper-resolution

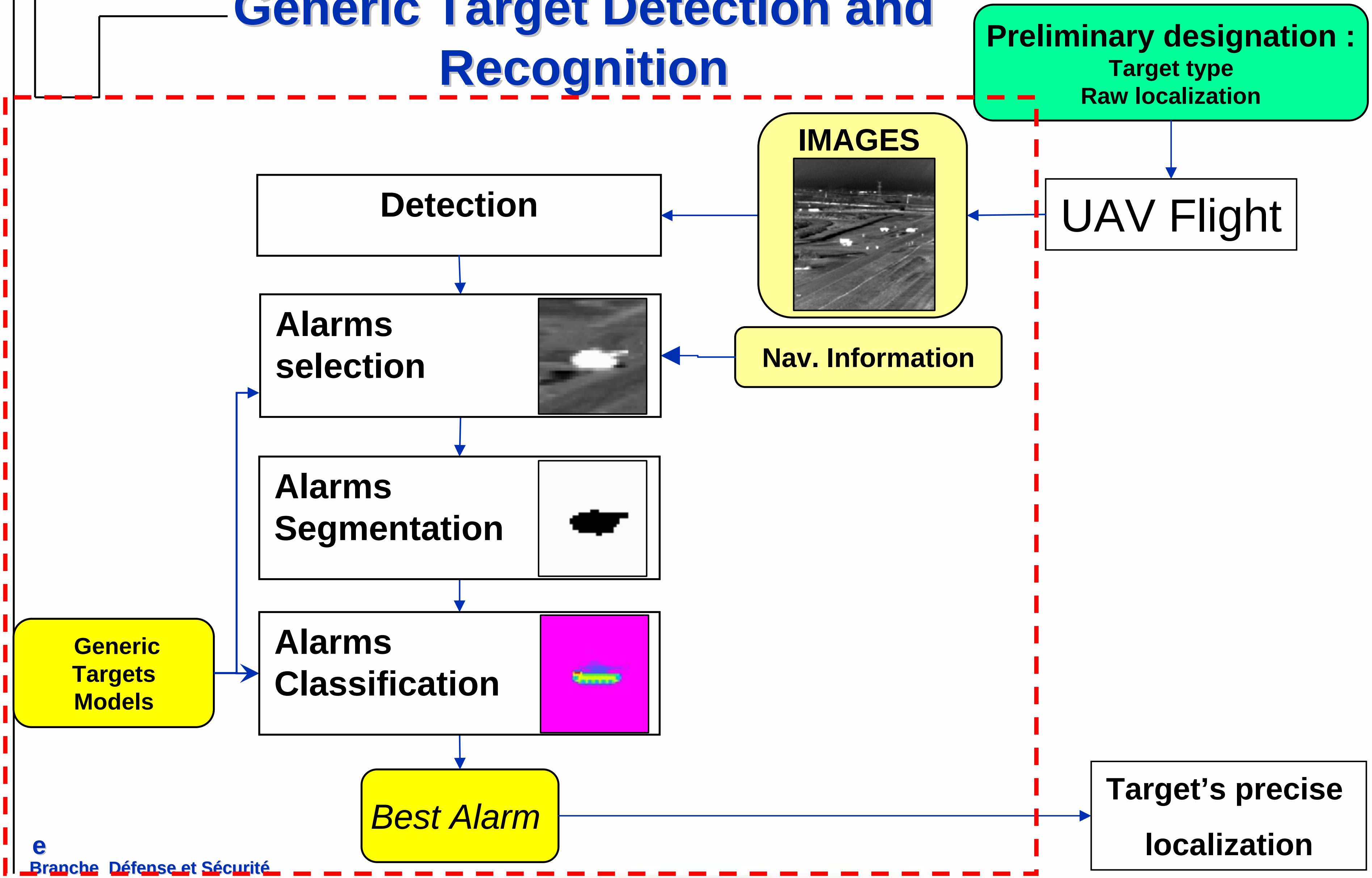
Image Processing Chain



Automatic Target Detection, Recognition, Identification and Localization

- ★ Automatic generic target detection and recognition :
  - ❍ vehicle type target : plane, tank, truck, …
  - ❍ infrastructure target : bridge, building, ….
- ★ Multi-bands, multi-contexts target identification
- ★ Precise complex target localization helped with target's area model

Generic Target Detection and Recognition

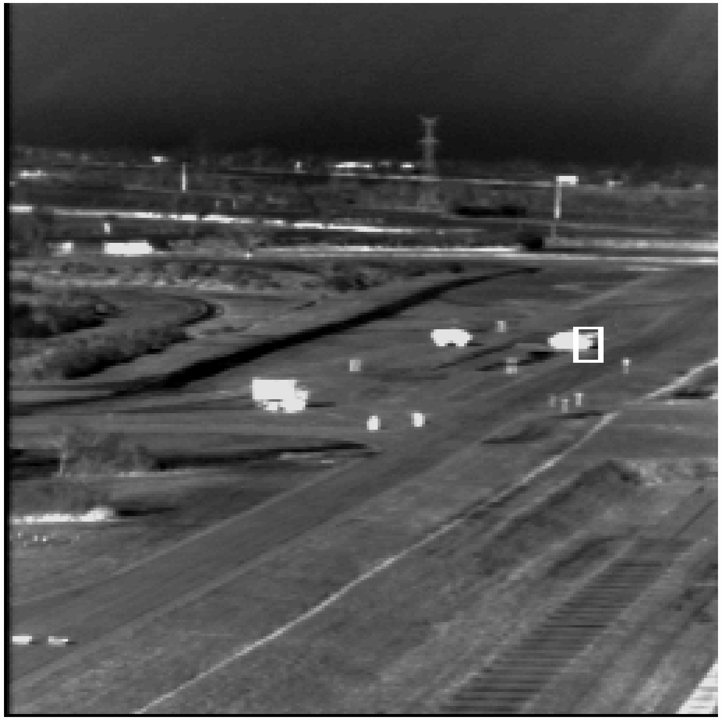


Generic Target Detection and Recognition


« Airplane » target


« Helicopter» target

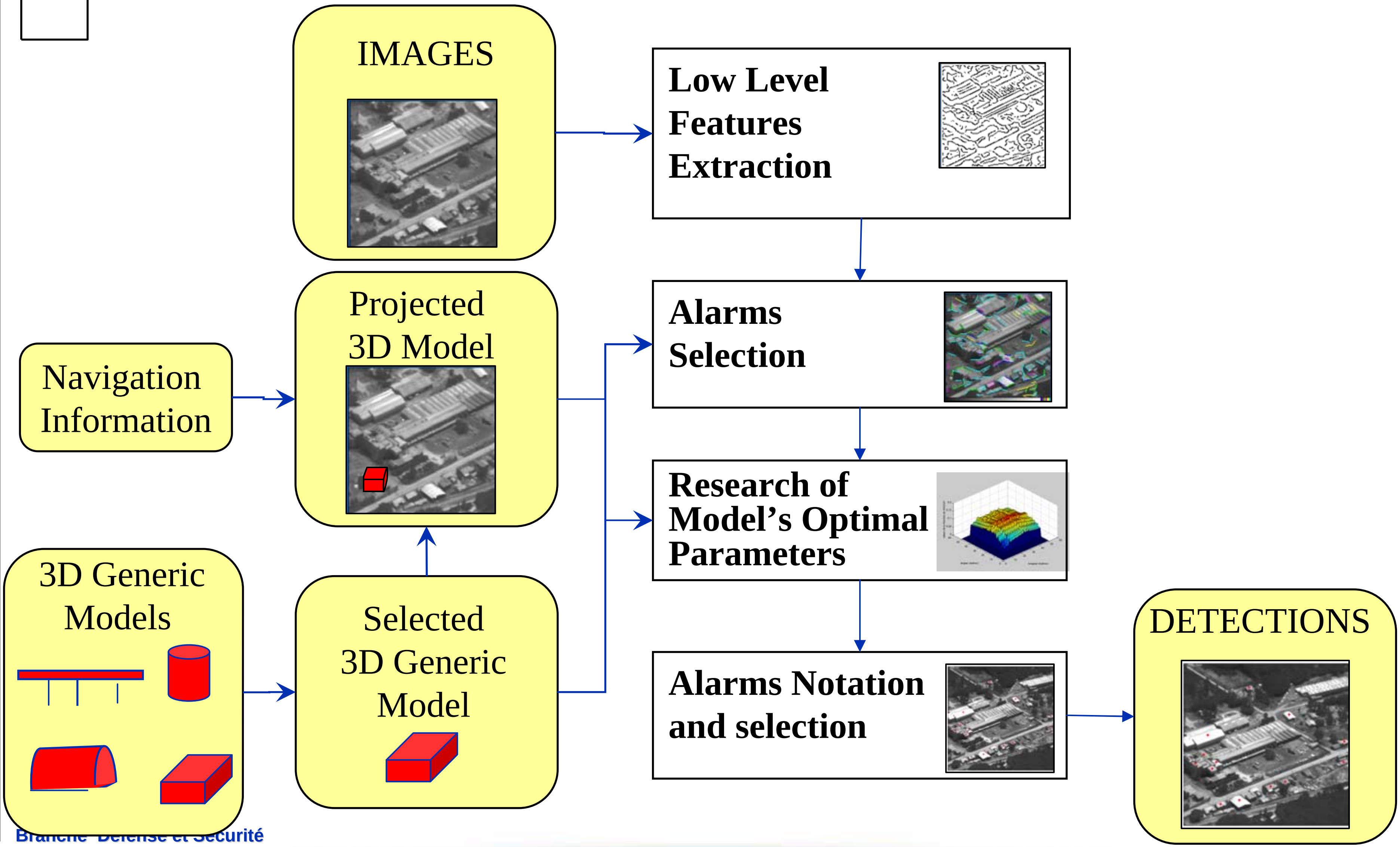
Generic Target Detection and Recognition



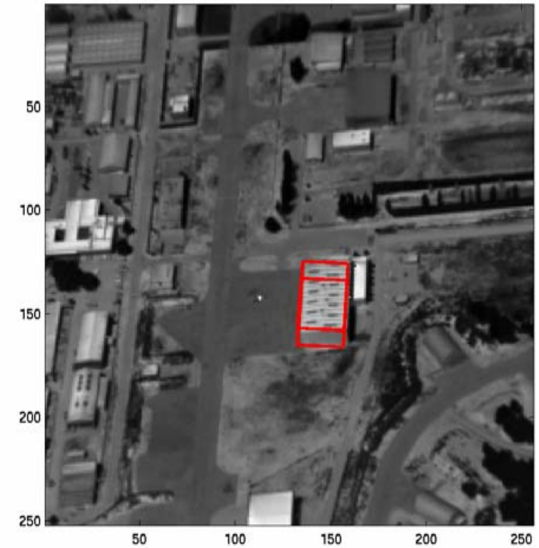
« Tank » target

« Truck » target

Generic Target Detection and Recognition



Generic Target Detection and Recognition

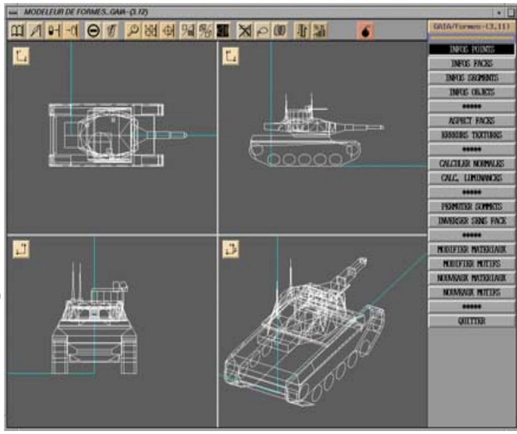


« Bridge » target

« Bulding » target

Target Identification

OFF-LINE

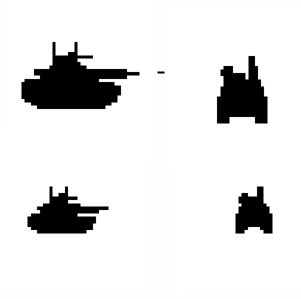


3D Models: geometry (facet) + radiometry: (emissivity, temperature)

Synthetic Images

(Ray tracing,sensor model)

Models Data Base



Shapes for each position:distance/target

ON-LINE

Target Segmentation

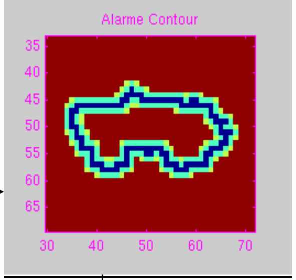
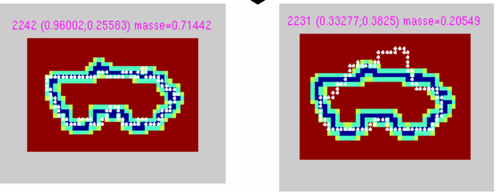
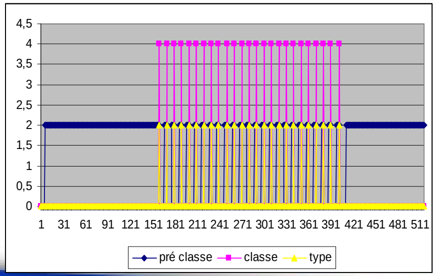


Image: distance to edge



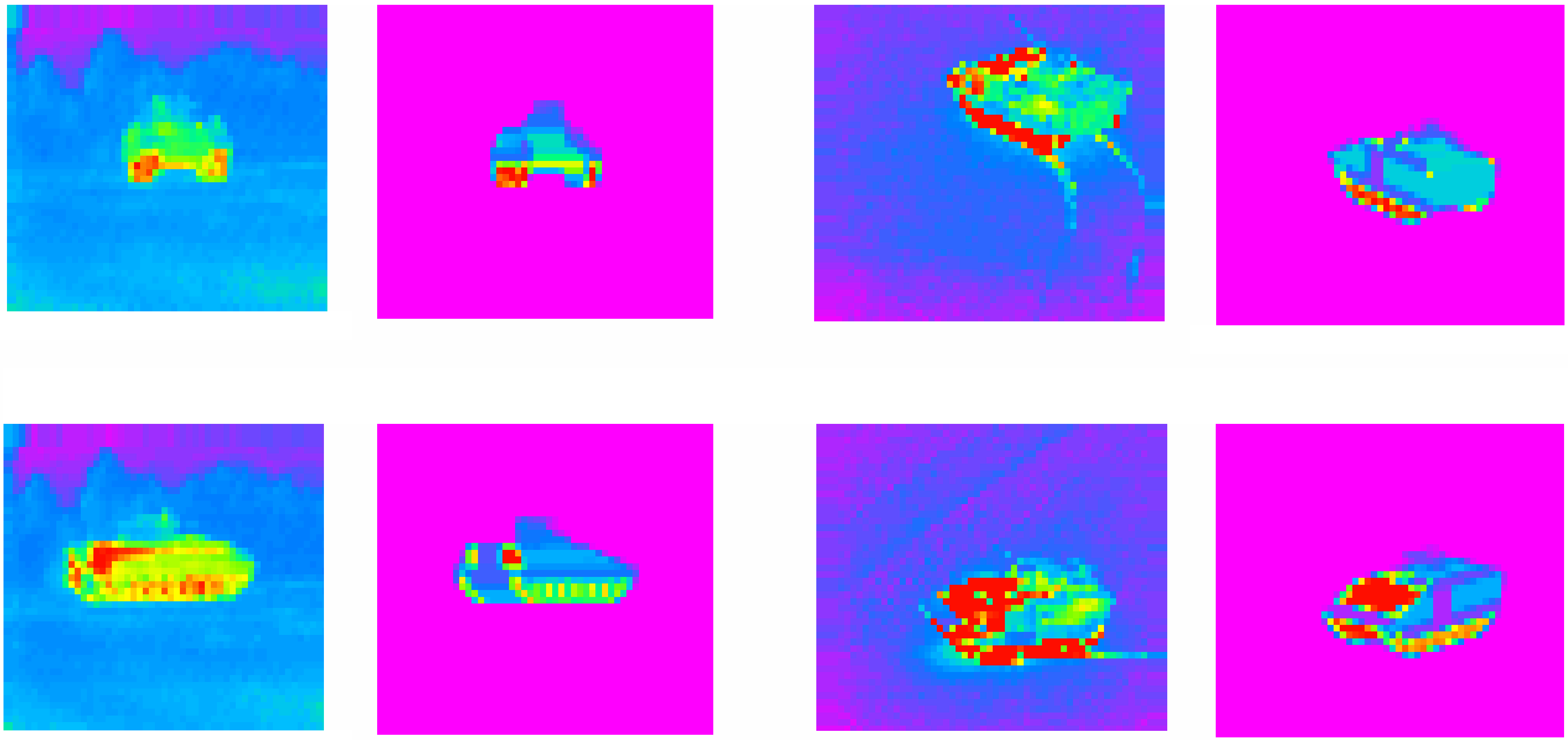
Shape recognition



Notes and decisions

Target Identification

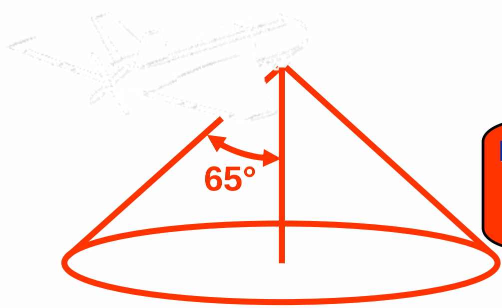
MARDER **AMX 10**

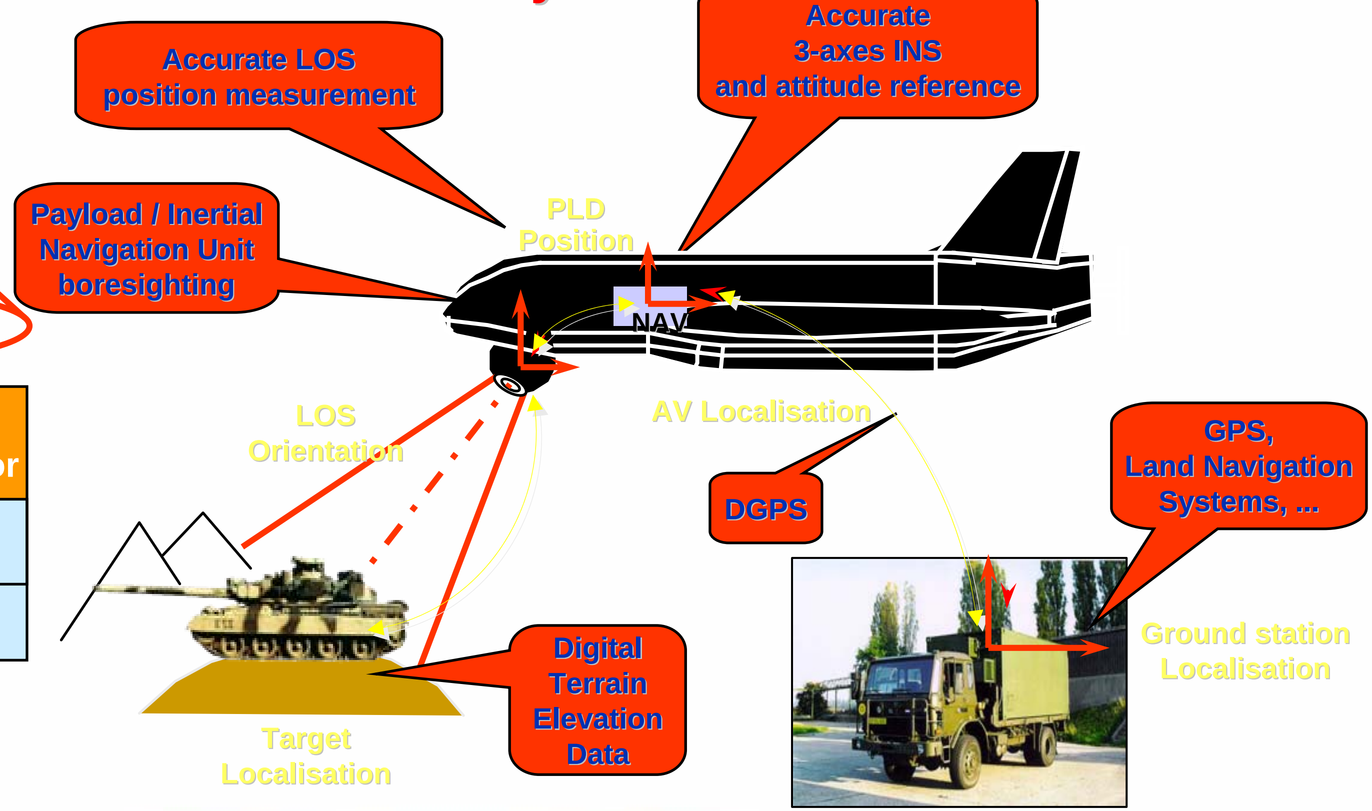


Input Image **Identification result** **Input Image** **Identification result**

TARGET LOCALIZATION

- ★ Performance constant and independent from GCS/AV distance
- ★ Automatic real time calculation (no human interpretation)
- ★ Target co-ordinates available from video and still images
- ★ Relative co-ordinates : Accuracy 6 m

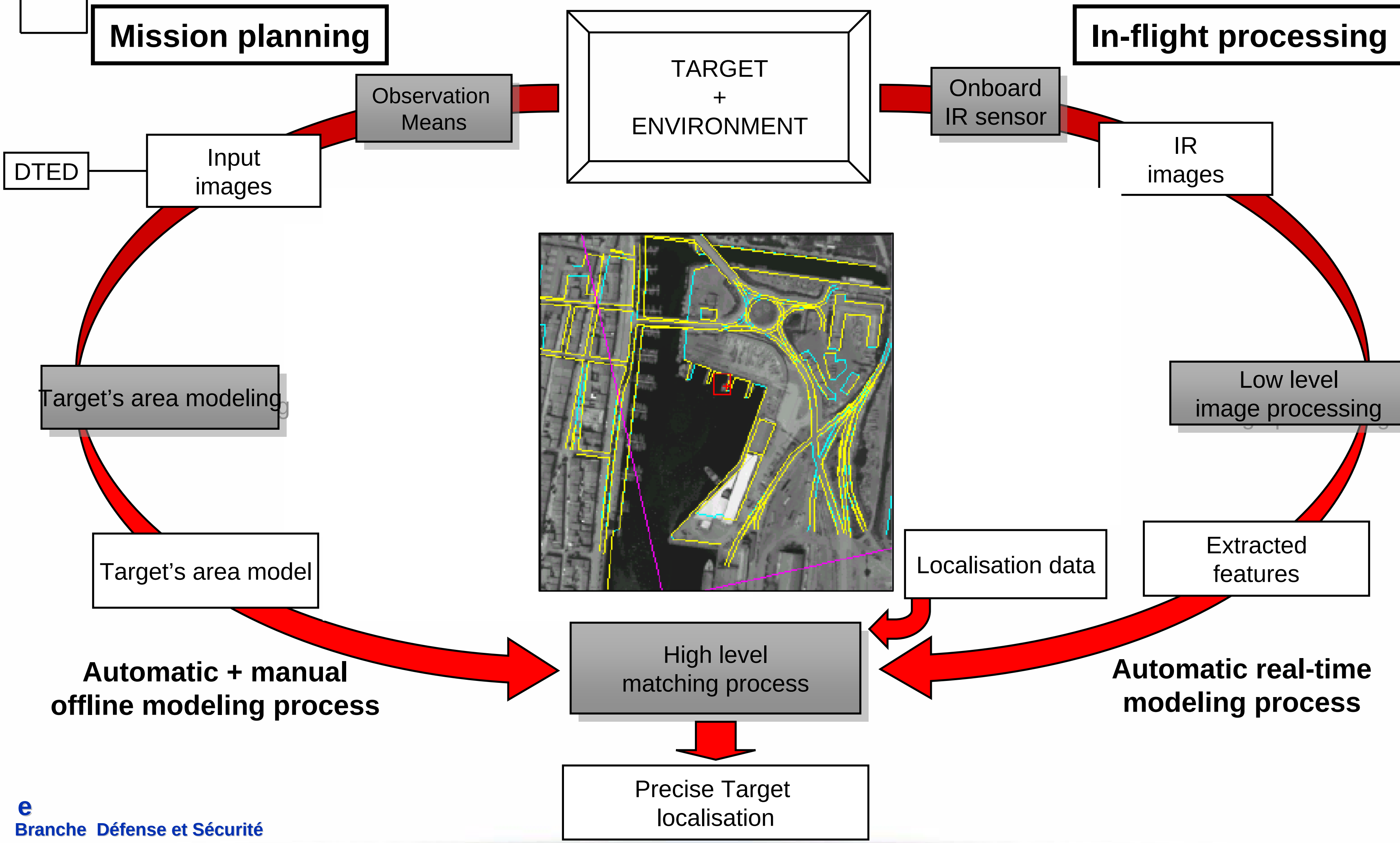




1/2 angular cone	Target Location Error
65°	< 50 m
10°	< 20 m

(CEP 50, altitude 1000 m)

Target localization improvement by image processing



Conclusions

IR image sequence processing can offers new capabalities for target detection.

- ★Motion is usable to make over sampling and provides better resolution with 2D arrays by aliasing reduction.
- ★Improved target detection, recognition and identification
- ★Precise target localisation by mixed processing between navigation system, image datas and terrain modelling

To day, large FPGA permits fast design of hardware implementation from new algorithms

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