# Information Fusion and Visualisation in Anti Asymmetric Warfare

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## Abstract

*Information fusion is a key factor for insuring information superiority in various military and civil surveillance systems. These may be found in combat management, ground based air defence or in coastal surveillance systems addressing more civil areas. A new aspect in all these applications is the issue of new types of threats, e. g. anti asymmetric warfare and low intensity conflicts. Consideration of these new types of asymmetric threats leads to new requirements and very new concepts for design, implementation and integration of the information fusion and visualisation process. Also the usage of network information on different abstraction levels and its visualisation becomes an essential issue in anti asymmetric warfare. This paper presents some of the aspects and concepts related to information fusion and its visualisation within the mentioned systems realizing anti asymmetric warfare aspects.*

## INTRODUCTION

In modern applications of information fusion systems new requirements related to the so called asymmetric warfare or low intensity conflicts have to be addressed. Examples of such applications may be found in the civil and military area: coastal surveillance and defence systems, the surveillance in the urban environment, the newest generation of combat management systems of navy ships, or future air defence systems. The operational frame may be e.g. counter-terrorism, peace keeping and peace support operations.

The classical situation of symmetric conflicts was determined by uniformed forces. The utilisation of weapons was assumed to comply with international treaties and conventions and with national laws. All targets should comply with the principles of the laws of armed conflict: military necessity, discrimination, proportionality, and minimization of unnecessary suffering. The tactics is based on large numbers of entities combined with mobility, weapons/systems effects, etc. to activate capabilities achieving desired results.

The asymmetric scenario is different to the classical battlefield, e.g. in the following aspects: Here, the objective of an adversary is to create instability using irregular forces. These may include prohibited weapons, improvised devices, the use of civilian facilities and equipment as weapons, or the use of legitimate weapons in an unlawful way. Also, civilian and protected targets (both inside the conflict area and elsewhere) may be attacked by the adversary if such actions serve his objectives. So one may expect utilisation of low cost platforms against expensive own platforms. These may be sports/micro light planes, hang gliders, airliners, divers, mines, UAVs/UUVs, dinghies, car/floating bombs, bazookas, grenades, artillery fire or snipers instead of the potential threats carried out by high tech platforms in the symmetric warfare. The asymmetric scenario is guided by the willingness to use to advantage irregular forces and unconventional weapons.

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However even in these situations of asymmetric threats the countermeasures are restricted to legal responses, taking care of

- The principle of military necessity: It justifies those measures not forbidden by international law, which are indispensable for securing the complete submission of the enemy as soon as possible.
- The prohibition of superfluous injury or unnecessary suffering
- The principle of distinction: The parties of a conflict must at all times distinguish between combatants and non-combatants, and between military and non-military targets. Neither the civil population as a whole nor civilians in particular may be subjected to attacks.
- The principle of proportionality: It is forbidden to attack a military target if such an action would cause excessive damage to civilians and civilian objects.

The answer to these threat scenarios is different. It consists both of operational concepts and technical solutions [8], [9], and [10].

The search for operational concepts leads already to different national and multi-national tactics, e.g. [1], [2], [7].

Technical solutions address the issues of information superiority and intervention capability by realising situation awareness and decision support even in stress situations of the operator. Further one has to take into account the uncertainty and reliability of the information in the anti asymmetric warfare area. These are covered by:

- An adapted and integrated information fusion.
- Adapted visualisation and HMI concepts
- Specialized sensor suite
- Specialized effectors suite

# 1 INFORMATION FUSION

To describe the process levels of information fusion the JDL model is very useful (figure 1). Level 0 fusion or sub “object refinement” is related to the sensor hardware environment. It deals with the extraction of plots and closely hardware related signal processing. Therefore, it is performed within the sensor itself. Level 1 considers the object refinement. The overall aim of this process level is to find a unique representation of all objects in the environment considered. The real objects within the surveillance area are described by so called tracks, which are built by data association and state estimation techniques. The 2nd and 3rd levels deal with situation and impact refinement. Within these parts the relationships between several objects are studied. These relationships may be of different origin, e.g. spatial-temporal, organizational, causal, and similarity. The process refinement in level 4 tries to optimise the ongoing fusion process itself, resulting in e.g. adaptive data acquisition and processing. Through a 5th level called “cognitive refinement” and a human machine interface the result of data fusion is presented to the operator [5], [10].

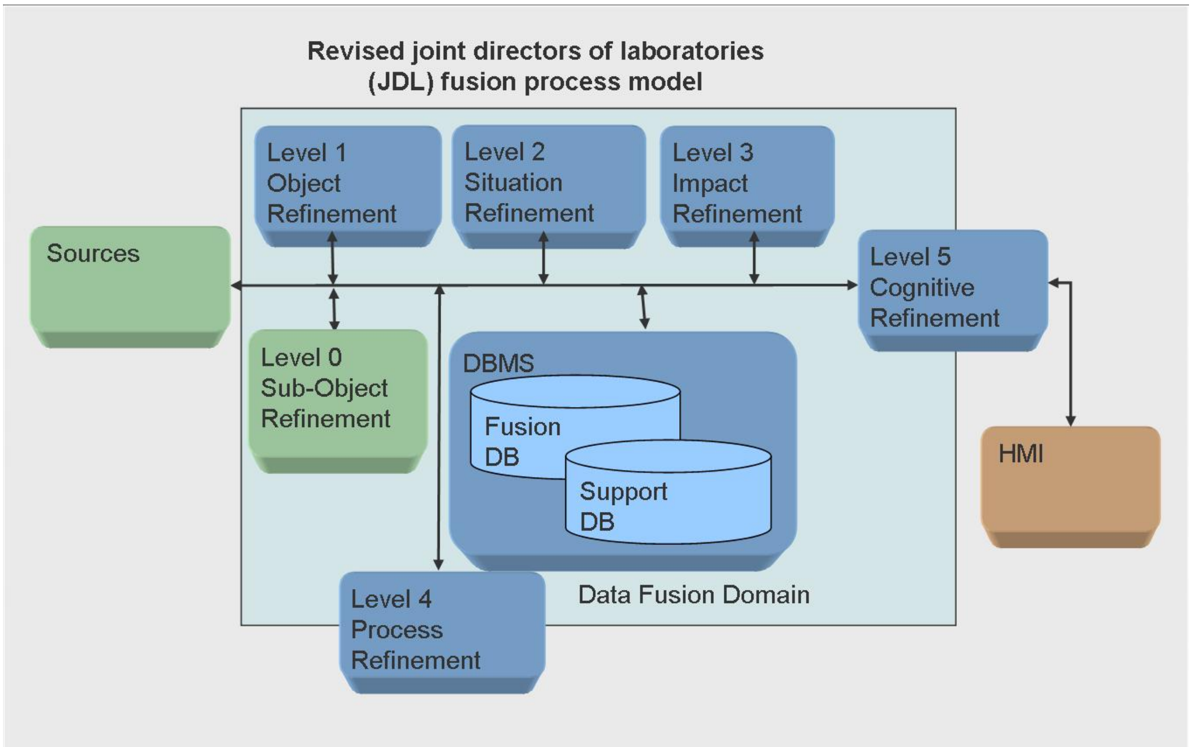


**Figure 1: Revised joint directors of laboratories (JDL).**

The paper presents aspects and possible realisations of these fusion levels most applicable to the anti asymmetric warfare framework presented above: The applicable sources of information are analysed and evaluated. The specifics of the fusion levels and the benefit of their interaction in integrated multi sensor systems are discussed. Finally possible concepts of visualisations suitable for anti asymmetric warfare are demonstrated.

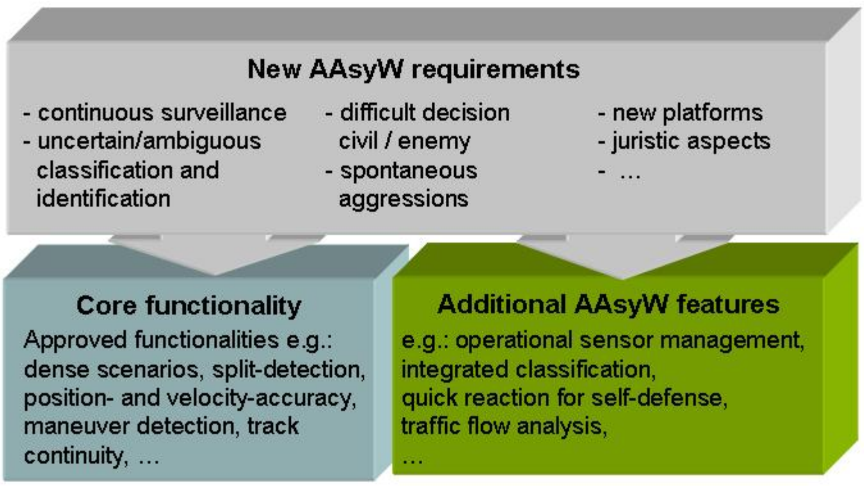


**Figure 2: AAsyW requirements and solutions.**

## 1.1 Sources

The information about symmetric as well as asymmetric targets is collected by sensor systems or by other internal and external sources.

### 1.1.1 Sensors

These may be sensors like

- primary radar
- question and answer systems like
    - secondary radar (IFF)
    - automatic identification system (AIS)
- electro optical sensors
- electronic support measurement systems (ESM)
- acoustic sensors (e.g. sonar, sniper detection systems)

#### *1.1.1.1 Radar*

The challenge for the radar suite with respect to  asymmetric surface targets are small and only slowly moving targets, like kayaks, rhibs or swimmers. These must be considered within different climate and sea state conditions. Also small air targets like RC models must be taken into account, operating also in lower altitudes. The problem of these targets is their detection with radar. Therefore, the related propagation effects have to be considered. This may be sea-, land- and rain-clutter, multipath and evaporation ducting.

To separate sea skimming air targets and surface targets form sea clutter a moving target indicator can be used. In the littoral environment this has also the additional benefit, to suppress land clutter.

Low radar frequency minimises the reflectivity and therefore the sea clutter effect with respect to power. However, to maximize the signal to clutter ratio, one is interested to take advantage of a good resolution. The Doppler shift increases with the frequency and therefore also the resolution and accuracy of Doppler measurement. Also the range and azimuth resolution can be optimized for higher frequencies, using shorter pulses and smaller beam widths.

Further the risk of signal cancellation due to multipath effects is smaller for high frequencies. Taking into account sea clutter horizontal polarisation should be used versus vertical polarisation.. Finally, considering many targets in close, respectively closest distance to the own platform electronically scanned antennas (azimuth) have several advantages against mechanical ones, e.g. priorisation of targets in multi target scenarios [6], [3], [14], [15].

#### *1.1.1.2 Electro-Optical Sensors*

IR systems use the short IR wavelength (SWIR, 1-2.7 µm), the medium wavelength (MWIR, 4-5 µm) or the LWIR (8-14µm). The capability of the SWIR is restricted due to absorption. MWIR is most sensitive to high temperature targets but susceptible to solar glint. The long IR wavelength (LWIR, 8-14µm) realises the best sensitivity to lower temperature targets and is resistant against solar glint. Further, it requires in general less cooling. There are two different types of infrared detectors. Quantum detectors and thermal detectors (e.g. bolometers). They used the MWIR and LWIR part of the IR spectrum. Quantum detectors realize an image rate of over 100Hz while microbolometers reach up to 60 Hz. The high update rate is a main feature of IR systems, especially to detect asymmetric threats in shortest distance.

Operationally one distinguishes, in accordance with the sensor agility between EO surveillance and EO designation. The task of EO surveillance sensors is the surveillance i.e. detection of contacts in the surveillance area, taking advantage of the high image rate. One distinguishes between mechanically scanning systems and non rotating systems delivering a panorama image by image fusion of several sensors components. EO designators are distinguished through their agility and increased resolution capabilities. These are used to track a target of significant track value and to produce images, which allow the classification of targets [15].

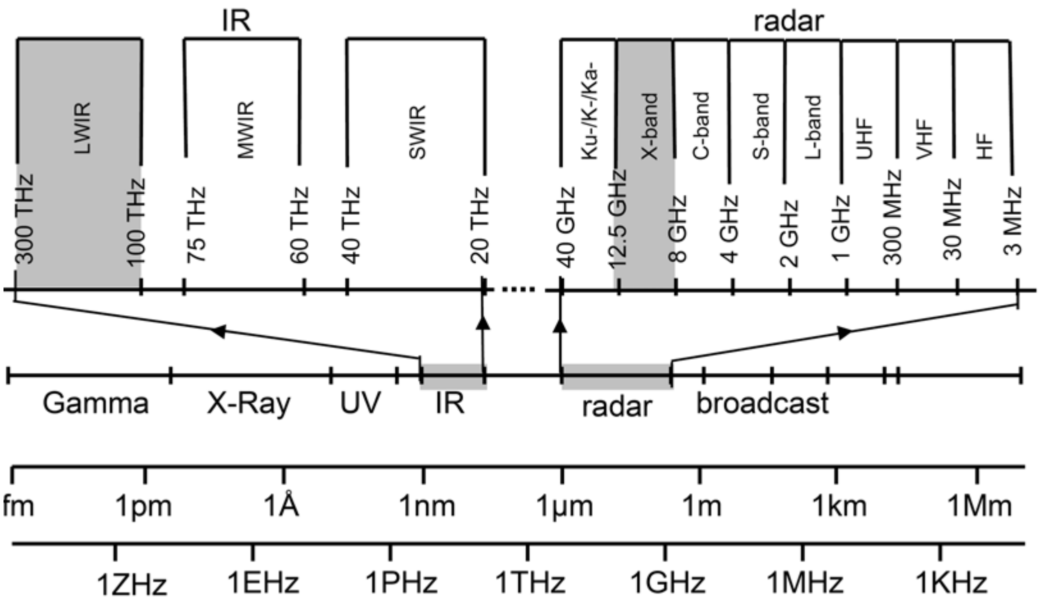


**Figure 3: Coverage of the spectrum through sensors.**

### *1.1.1.3 Acoustic Sensor*

Acoustic sensors may be applied under water as sonar systems e.g. for diver detection or mine avoidance. However there are also new developments to use acoustic sensor systems for sniper detection, which may be also have an impact on the anti asymmetric warfare area.

### *1.1.1.4 Question and Answer Systems*

Information of cooperating systems may be used to exclude platforms as asymmetric targets (e.g. IFF) or to check the plausibility of an assumed intention (e.g. IFF or AIS).

## 1.1.2 Further Internal and External Sources

Besides the pure sensor information also further information sources can contribute. These may be

- tactical data links
- sensor and information networks
- further intelligence information.

| sensor | range | azimuth | elevation | Doppler | others |
|---|---|---|---|---|---|
| military radar | + | - | - | + | +spatial coverage<br>+ maximal range<br>+ detection capabilities<br>+ weather/climate dependency |
| navigation radar | + | - | n.a. | n.a. | + minimal range<br>+ weather/climate dependency<br>+ less emission restrictions than military radar |
| EO-surveillance | n.a. | + | + | n.a. | + update frequency<br>+ classification capability<br>+ passive sensor without own emission<br>+ minimal range |
| EO-designator | n.a. | + | + | n.a. | + zoom capability<br>+ classification<br>+ passive sensor without own emission<br>+ minimal range |
| ESM | n.a. | - | - | n.a. | + classification capability |
| IFF | - | - | - | n.a. | + identification capability of cooperating targets<br>+ exclusion of action against own forces |
| AIS | (-) | (-) | (-) | (-) | + classification / identification of cooperating targets |

**Figure 4: Sensors and their contributions.**

#### *1.1.2.1 Tactical Data Links*

Further sources may be military or civil data links. These may provide information about targets outside and inside the sensor range or provide information about the targets identity, classification or intention. Besides the obvious contribution for the fusion of positional information new concepts for the fusion of identity information in larger networks are in preparation. Here, the identification combining process IDCP (e.g. NATO STANAG 4162) and the different LINK standards like the LINK 16 (STANAG 5516), or low level air picture (LLAPI) should be mentioned. Also the air picture of the civil air traffic control (ATC) and several nation dependent extensions should be mentioned.

#### *1.1.2.2 Sensor and Information Networks*

Not only may single sensors contribute to information fusion within the recognized air picture. Also the result of whole sensor networks is a potential source of information. An example is the radar network (RADNET) of the civil and military air traffic control. Besides sensor networks there is also information which is exchanged in the so called command and control systems. Special NATO and national formats are available to support an automated processing of this information. Examples are the Allied Data Publication Part 3 (AdaTP-3), the United States Message Text Format (USMTF), the Over the Horizon

Targeting – Gold (OTHT-Gold), or the Variable Message Format (VMF).

*1.1.2.3 Intelligence Information*

Finally also the collection and evaluation of intelligence information is a significant contribution to the information fusion process within the anti asymmetric warfare area.

## 1.2 Object Refinement in AAsyW

Object refinement is the 1st Level in the classical fusion topic. The classical fusion topic contains the so called tracking, which in turn embraces data association and continuous estimation. An optimal solution with respect to data association and estimation is also significant for the anti asymmetric warfare. Besides these classical topics also newer aspects related to classification and identification become important. To ensure quick reaction times is essential, if the anti asymmetric warfare application focuses on the nearest neighbourhood.

### 1.2.1 Data Association, Estimation

The basis of data association and filtering in the anti asymmetric warfare is similar to those of the known symmetric world. Data association considers the relations between plots or sensor tracks measured by the sensors respectively coming from the data links and the targets, which generate these. Here one has to be able to deal with dense target scenarios. Asymmetric aggressors may use geographic constraints and civil shields to their own advantage. To cover the wide spectrum of possible asymmetric targets an advanced filtering algorithm is required for the continuous state estimation.

### 1.2.2 Classification / Automatic Target Recognition

A more detailed automatic classification of asymmetric platforms is required due to the possible large and different target spectrum. Because it is not always possible to keep targets off distance, this often has to be done in scenarios consisting of multiple targets. Therefore automatic target recognition based on image recognition methods is a benefit and can decrease the load of the operator. Very applicable for surveillance applications is also the automatic detection of persons. Often a more accurate classification is also necessary to ensure an optimal effector choice against the wide spectrum of asymmetric targets.


**Figure 5: Automatic Target Recognition**

### 1.2.3 Identification

In the symmetric warfare area identification is closely connected with classification. The knowledge of the plattform type renders in most situations allready an approximate idea of the possible intention. Further question and answer systems like IFF may lead to a further amplification of the identity. However they may be switched off due to silence conditions. Then network information like routing, the position of the own entities in the communication networks or the military respectively civil flight plans provides a further valuable indication for the object identity.

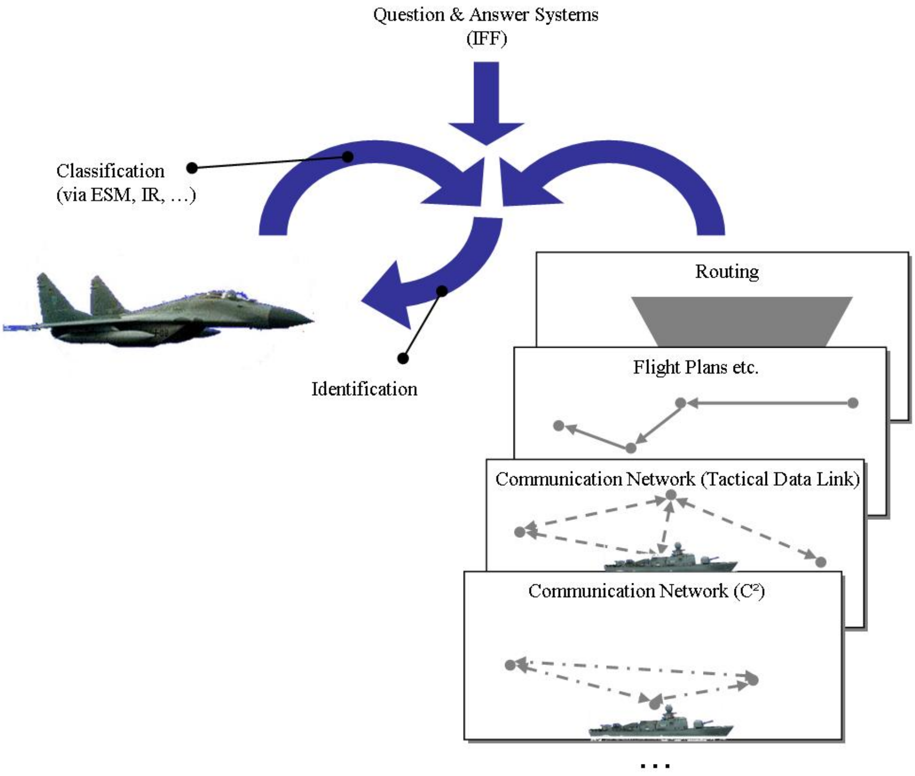


**Figure 6: Identification in symmetric warfare.**

## 1.3 Situation and Impact Refinement in AAsyW

Within anti asymmetric warfare the identification process becomes more difficult. Often the knowledge of the platform type doesn’t contribute to the identity of the platform. Further question and answer systems are often not applicable and other identity sources usable in symmetric warfare are also not suitable [17]. The identification issue depends more and more on the situation and impact assessment, i.e. on the results derived in the level 2 and level 3 data fusion.

Level 2 fusion attempts to give a description or interpretation of the evolving situation based on an assessment of relationships among entities and the environment. This contains the object aggregation based on time relationships, geometric proximity, communication or functional dependencies. Contextual interpretation (environment, weather, doctrine, tactics) are another issue. Also the links between time and events, associations, hierarchical relationships or multiperspective assessment (adversarial view vs. own view) contribute to the situation refinement.

The threat refinement is the projection of the current situation into the future to assess inferences about alternative futures or hypotheses concerning the current situations. It is an assessment of threats, risks, and impacts. Topics may be the aggregation and estimation of force capabilities, the prediction of the enemy intent, the identification of threat opportunities, the estimation of implications, and again a multiperspective assessment [5], [10].

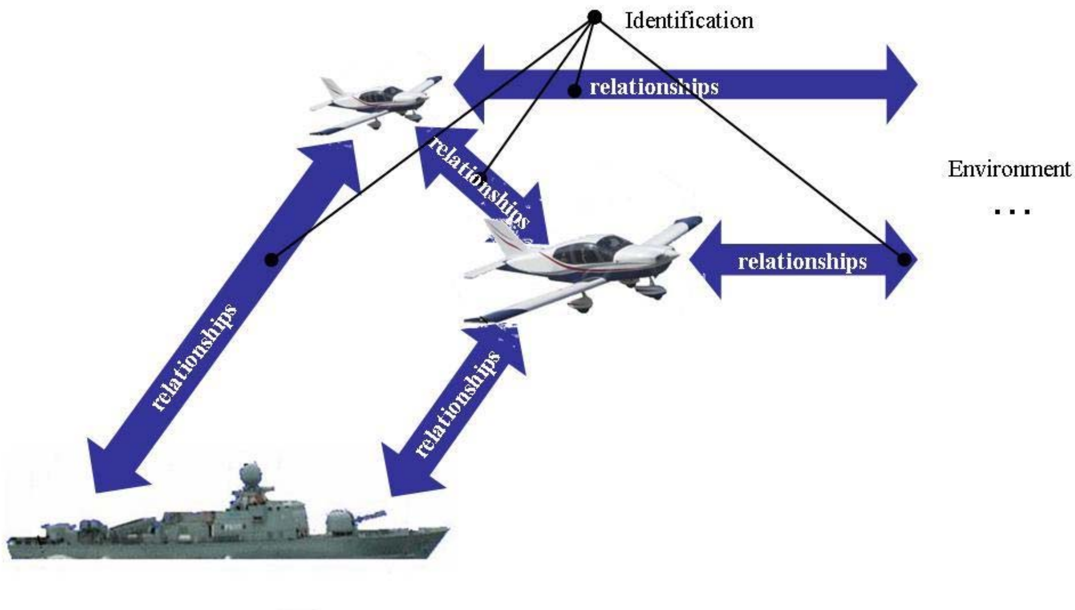


**Figure 7: Identification in antisymmetric warfare.**

Hence identification of an asymmetric target is often a result of the situation assessment. This point seems to be an essential difference to the symmetric warfare area. One has to search for new relationships which are suitable for anti asymmetric warfare (figure 7). It is more and more the interaction between objects, which characterises the object under observation as a potential origin for an asymmetric threat. Or it is the action and reaction between an own platform and an object, which makes an object suspect with respect to asymmetric warfare (figure 8). Also the principle of escalation dominance has to be taken into account, to start own countermeasures by warning suspect objects, the analysis of their response, the initialisation of further counter measures up to threatening approaching asymmetric forces with non-lethal or lethal effectors systems.

Also network information and network information visualisation are topics which help to understand and analyse the situations resp. threats in level 2 and 3 fusion. So one has to deal with traffic networks, communication networks [5], geographical deployment, command or organisation network. Or one tries to describe and visualise other relationships (e.g. behaviour) with suitable networks.

However, there is no unique realisation, which automatically covers all aspects of situation and threat refinement. For example Figure 9 shows one aspect of a situation refinement in the form of a traffic flow analysis, which studies the trajectories of the different vehicles within a surveillance area and tries to find potential suspect actions. It is based on neural network algorithms and it is applied e.g. in coastal surveillance and navy combat systems. It shows how network information and its visualisation may contribute to anti asymmetric warfare.

Other applications may deal with the analysis respectively visualisation of communication flows [5]. A summary of current level 2 and 3 data fusion topics can be found in [11], [12], [13], [16], and [18].

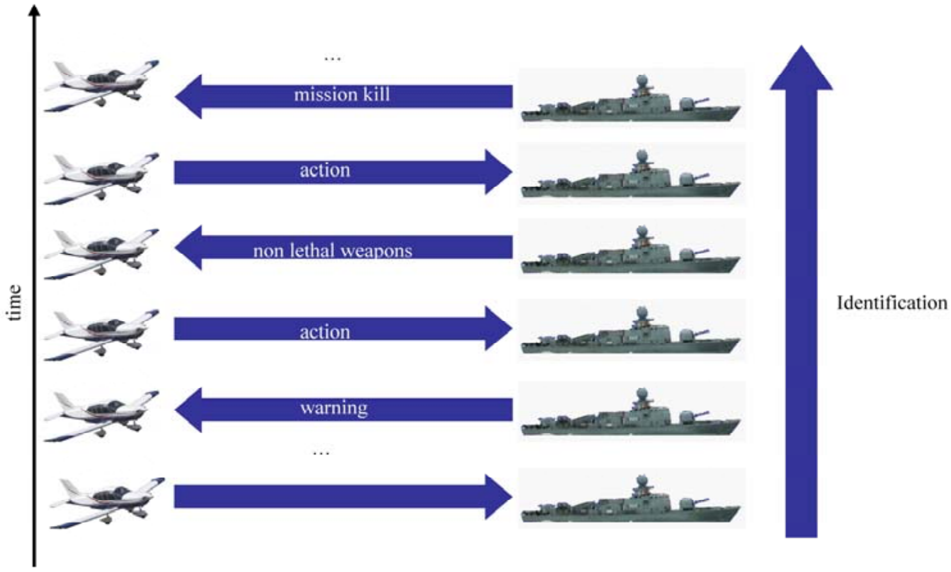


**Figure 8: Escalation dominance.**

**Figure 9: Traffic flow analysis.**

## 1.3 Process Refinement in AAsyW

Another aspect of anti asymmetric warfare is the process refinement. As an example, the optimisation of information respectively sensor sources is mentioned. For example an electro-optical surveillance sensor is preferable to observe a 360° area with high update rate, an electro-optical target designator has only a small field of view, but is capable to deliver a high resolution image of a target, and automatic target recognition is able to classify different object types. Then it is advantageous to combine these processing steps within an adapted sensor management system. New system tracks initialised by an electro-optical surveillance system without sufficient classification attributes are used for a cuing of an electro-optical target designation system. The image is automatically processed by the automatic target recognition (ATR) system and fused with complementary other information attached to the individual object (figure 10).

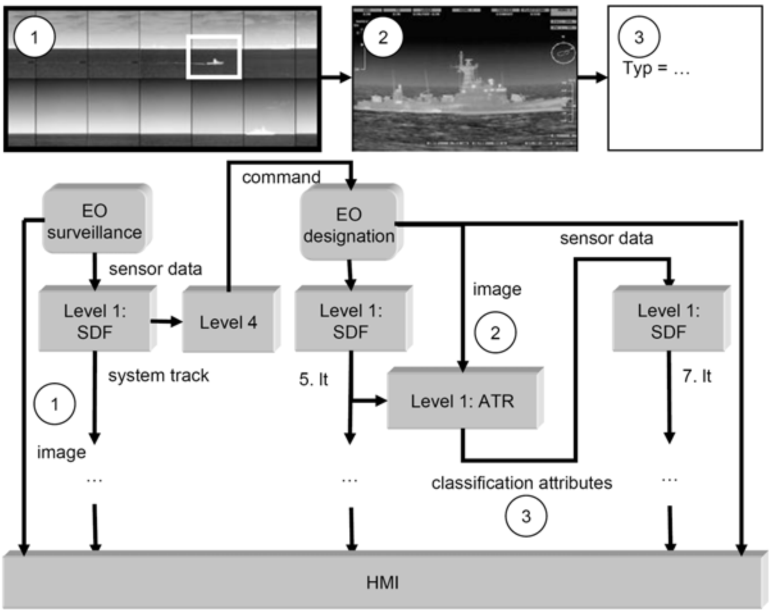


**Figure 10: Process refinement and the combination of different EO sensor types.**

# 2 VISUALISATION

The topics dealing with the operator interaction, i.e. level 5 fusion and human machine interface including the consoles itself are also a very important part in anti asymmetric warfare.

## 2.1 Cognitive Refinement and tactical display

The cognitive refinement in anti asymmetric warfare has to consider the following specifics:

- focus/defocus of attention
- decision support
- representing ambiguous or uncertain data

Asymmetric threats may happen during peace keeping operations, where the attention of the operator is decreased through long term missions. The asymmetric threat may happen spontaneously and may occur in a civil environment. Therefore, it is important to focus and also defocus the attention of the operator, especially in multi target scenarios.

E.g. advanced visualisation techniques help the operator to manage the combination of different EO sensors. An EO surveillance system is combined through a level 4 fusion process with an EO designator system and an automatic target classification system as described above. The operator obtains the result in the combined picture of figure 11. Through this visualisation scheme the operator keeps control of the fusion process and is able to estimate the level of confidence of the fusion result.

**Figure 11: EO sensors and information fusion**

Also the decision of an operator concerning effecor usage may lead to consequences for the civil population, e.g. collateral damage has to be taken into account. Hence, it is difficult for the operator to predict all the consequences of his decisions immediately. Here decision support tools are believed to be helpful. How this information may be visualised within a 3-dimensional visualisation scheme is shown in Figure 12 and 13.

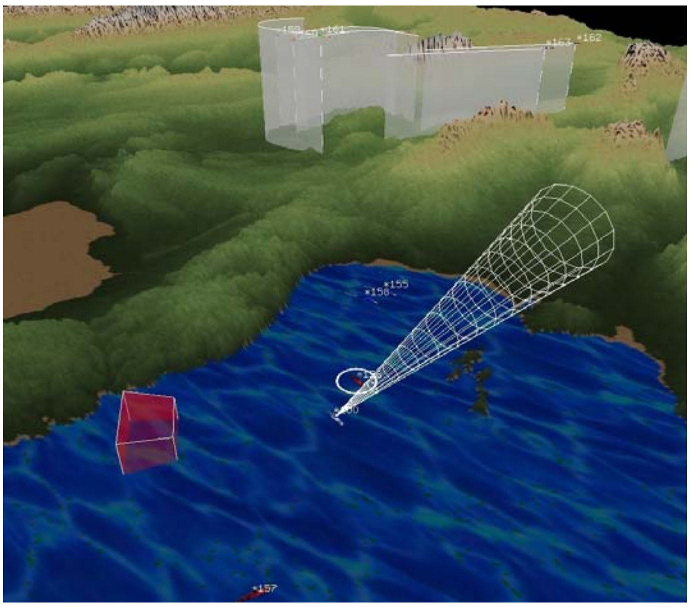

**Figure 12: 3 dimensional visualisations with zones of potential collateral damage.**

Further anti asymmetric warfare is characterised through the uncertainty of identification resulting from the normal uncertainty of the intention prediction. One has to find methods to symbolise this uncertainty to the operator, so that he is able to interpret the fusion results in an adequate manner.

Within the maritime domain the geographical terrain of asymmetric warfare is the littoral environment. Aggressors may act from sea, land or air against own naval forces. To improve the operator knowledge about such terrain constraints and possible consequences for the own surveillance capabilities the switch between a 2 dimensional and 3 dimensional tactical display is advantageous. This is shown in figure 13 and figure 14.

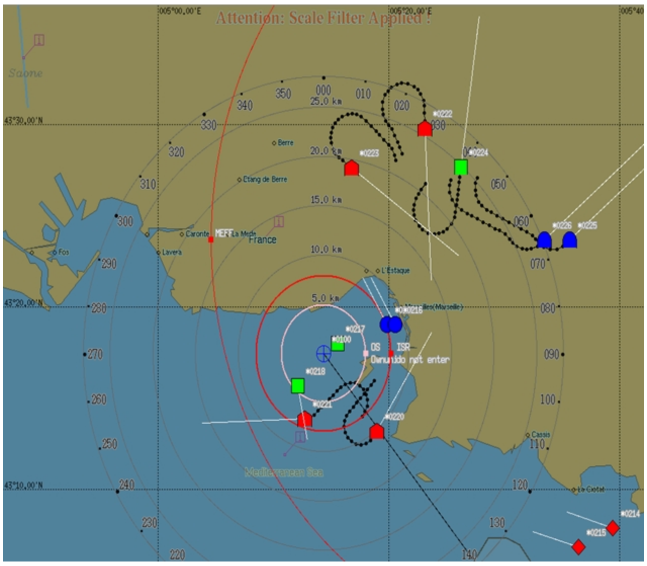


**Figure 13: 2d tactical display**

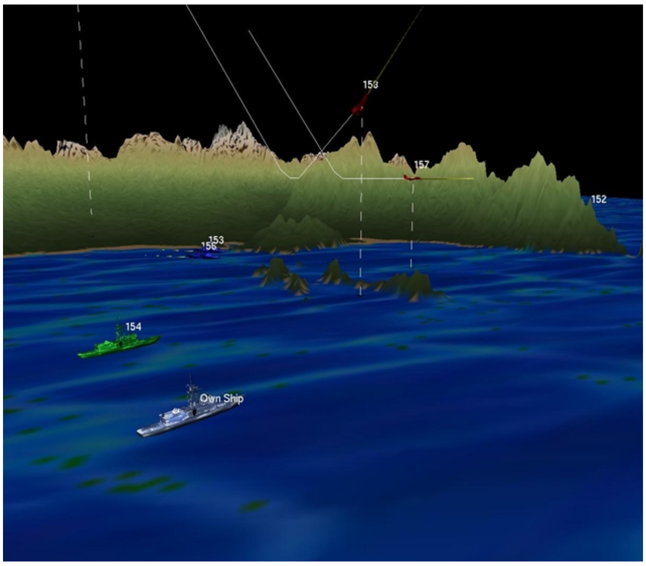


**Figure 14: 3d tactical display**

Also use of automatic recording, including the decision process and other relevant data and may lead to juristic applicability of the process output.

### 2.2 Operator Workstation

Finally, the tactical displays are integrated into new types of consoles, taking into account ergonomic aspects of the system user, like information flow and communication needs. Figure 15 demonstrates a new type of operator workstation optimised in accordance with these new operator needs.

**Figure 15: Modern OMADA operator workstation**

## 3 CONCLUSION

Different Concepts for information fusion and visualisation with respect to anti asymmetric warfare are described. Also the usage of network information on different abstraction levels and its visualisation is an essential contribution to anti asymmetric warfare. These concepts may be applied within coastal surveillance, combat management and air defence systems. The aim is to ensure information superiority and intervention capability by realising situation awareness and decision support in the specific scenarios of anti asymmetric warfare while avoiding collateral damage.

## REFERENCES

[1] Non-Lethal Weapons and Future Peace Enforcement Operations, RTO TECHNICAL REPORT TR-SAS-040.

[2] Mark A. Gammon, Maritime Concept Development Approach for a Force Protection In-Harbour Transit of a Canadian Patrol Frigate, Defence R&D Canada – Atlantic Technical Memorandum, TM 2005-148, September 2005.

[3] Felix Opitz, Thomas Kausch, Werner Henrich, Data Fusion Development Concepts within complex Surveillance Systems, Proc. 7th Int. Conf. on Information Fusion, Stockholm, Sweden, 2004.

[4] Bedworth, M. and O´Brien, J., The Omnibus model: a new model of data fusion?, Proc. 2nd Int.

Conf. on Information Fusion, 1999.

[5] Alan N. Steinberg, Christopher L. Bowman, Revisions to the JDL Data Fusion Model, in David L. Hall and J. Llinas: Handbook of Multisensor Data Fusion, CRC Press, Boca Raton, 2001.

[6] F. Opitz and G. Kouemou: An Unified Approach to Radar System Simulation & Development, Proc. International Radar Symposium IRS 2005, Berlin, Germany, 06-08 September 2005

[7] D. S. Alberts, J. J. Garstka, R. E. Hayes and D. A. Signori: Understanding Information Age Warfare, CCRP, 2001

[8] M. G. Vickers and R. C. Martinage: The Revolution in War, CSBA, 2004

[9] K. F. McKenzie: The Revange of the Melians: Asymmetric Threats and the Next QDR: Institute for National Strategic Studies, 2000

[10] D. L. Hall and Sonya A. H. McMullen, Mathematical techniques in multisensor data fusion, Artech House, Boston, 2004.

[11] James Llinas: On the Scientific Foundations of Level 2 Fusion, Military Data and Information Fusion, RTO meeting proceedings MP-IST-040, Prague, Czech Republic, 20 to 22 October 2003.

[12] Per Svenson: Technical Survey and Forecast for Information Fusion, Military Data and Information Fusion, RTO meeting proceedings MP-IST-040, Prague, Czech Republic, 20 to 22 October 2003.

[13] Joachim Biermann: A Knowledge-Based Approach to Information Fusion for the Support of Military Intelligence, Military Data and Information Fusion, RTO meeting proceedings MP-IST-040, Prague, Czech Republic, 20 to 22 October 2003.

[14] M. I. Skolnik: Introduction to Radar Systems, McGraw-Hill, Singapore, 1981.

[15] S. Blackman; Popoli, R.: Modern Tracking System. Artech House, Boston, 1999.

[16] H.-J. Kolb, M. Towsey, S. Maetschke and U. Uebler: The Visualisation of diverse Intelligence, Military Data and Information Fusion, RTO meeting proceedings MP-IST-040, Prague, Czech Republic, 20 to 22 October 2003.

[17] Thomas Kausch, Felix Opitz: Modern Principles of Identity Fusion, NATO RTA SCI-143 Workshop:Design Considerations and Technologies for Air Defense Systems, Istanbul, Turkey, 12 - 14 October 2004.

[18] Alan Steinberg: Principles of Situation Assessment, NATO ASI: Multisensor Data and InformationProcessing for Rapid and Robust Situation andThreat Assessment, Albena, Bulgaria, 16-27 May 2005.