# Ground surveillance and fusion of ground target sensor data in a Network Based Defense.

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**Abstract** - *This paper outlines how a future ground surveillance system can be designed and how such a system could work within the framework of the Swedish Network Based Defense, (NBD), concept. The material presented in this paper is in part an executive summary of the results from the project Fusion node 2 within phase 1 of the Swedish LedsystT study.*
*The paper discusses the general demands that the NBD concept will put on a ground surveillance system, how such a network based multisensor system should be designed and how the creation of vital parts of a Recognized Ground Picture can be achieved through a system for distributed sensor data fusion. Furthermore, an NBD ground picture simulator developed for testing and demonstrating key issues in this field is presented.*

## 1 Introduction

The role for the Swedish Armed Forces, SwAF, will change in the coming years. In the future their tasks will change not only to encompass military responsibilities on Swedish territory but will also include support to civilian authorities during crises and international peace keeping missions. During the last years Swedish authorities have initiated major technological, methodical and operational changes to develop a new concept of operation called Network Based Defense, (NBD). However, these ideas about network based command and control infrastructures are not exclusive to the military realm. Similar ideas are also pursued on the civilian arena in the case of emergency situations and network centric cooperation between civilian authorities. However, the adjustment to the NBD doctrine will pose major technological and conceptual problems to be solved and information fusion will be a key function in order for NBD to work properly.

The principles of superior situation awareness and decision superiority are fundamental cornerstones in NBD. The interpretation of this is that when superior situation awareness and decision superiority are achieved one should be able to

- see the situation first
- understand the situation first
- act first
- finish decisively

How these aims are achieved during a conflict or crisis depends to a large degree on the nature and extent of the situation. The technical systems and methods developed for NBD must therefore be adaptive and easily configurable. The ability to quickly put together suitable forces, command & control systems and sensor resources into a taskforce well adapted to the situation at hand will be essential. In this way the flexibility needed to perform a multitude of different tasks in a way best suited for the task at hand is created. The adaptivity of modern sensor-, command & control- and communication technology will enable us to design powerful multifunction systems suitable for both military and civilian operation.

### 1.1 Situation awareness

In order to achieve a good situation awareness and fast decision cycles it is important to have the ability, at every given moment, to surveille or at least to be able, with short notice, to redirect sensor resources to any part of the area of conflict or crises. Furthermore, when the surveillance information is obtained and the updated situation picture is created one must also have the ability to pass on relevant parts of this picture to any commander within the organization no matter what his geographical position is or what type of access terminal he has. Full connectivity, full mobility and full flexibility are important features in this kind of system

- Full connectivity - “anything to anyone”
  Commanders, units and physical resources are fully interconnected for joint operations at any level.

- Full mobility - “anywhere, anytime”
  An individual’s access to C4ISR functions relates to his/hers current role, irrespective of geographic location or type of access terminal.

- Full flexibility - “just in time, on demand”
  The command structure is independent of the physical communication structure - situation specific OODA cycles may emerge.

However, the creation of superior situation awareness can not only rely on gathering and analyzing surveillance and intelligence data. In the case of conflict it is equally important to have the ability to degrade the adversary's surveillance capacity. Electronic warfare and information warfare will therefore become important tools when trying to achieve superiority on the information arena.

These abilities must be sustained for all four possible theatres of conflict, i.e. ground, air, sea and the information domain at all time.

# 2 Ground surveillance capabilities and the network based defense

## 2.1 Sensors and information gathering systems

We will now focus our attention on capabilities needed in a future ground surveillance system within the NBD framework. As pointed out above the most important task for such a ground surveillance system is to provide the users with superior ground situation awareness and decision superiority. The system must be able to perform both proactive and reactive reconnaissance missions providing both large area coverage per time unit to secure high detection assurance and high information resolution to secure target classification and target identification capability. The system must be a multi purpose system providing a multitude of different ground surveillance capabilities such as constantly updated ground target pictures, capabilities for intelligence gathering of background information, capabilities for target acquisition, targeting capabilities for slow moving or stationary objects and also for damage assessment.

This means that a ground surveillance system within the NBD framework must have short reaction times, be tenacious in all weather and light conditions, be able to provide both high detection assurance and high information resolution, provide sensitivity to target signature diversity and have foliage penetrating capabilities. Fig. 1 shows an example of a typical ground surveillance chain where multiple sensors and fused sensor information are used in the various phases.

There is presently no single class of systems that can meet all these needs. A multisensor system with multispectral and multifunction capabilities with both active and passive components is needed. Several different classes of sensor systems will together provide all the various capabilities needed. Important classes of ground surveillance sensors in such a multisensor system are

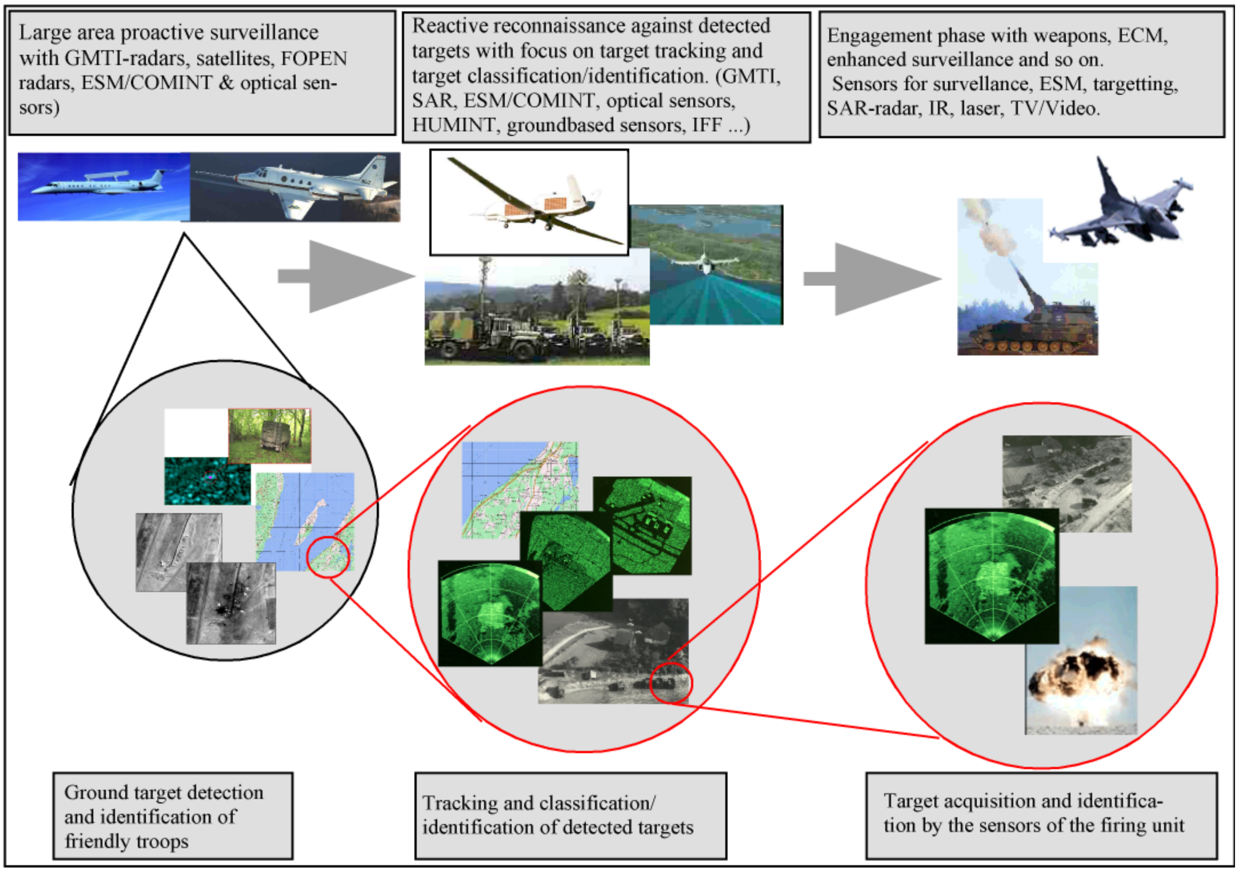


Fig. 1. Example of a typical ground surveillance chain. There are, in principle, four distinct phases where the sensors will play an important role. It is the large area proactive surveillance phase, target classification/identification phase, target engagement phase and finally a damage assessment phase.

- VHF/UHF SAR for Foliage Penetration with large area coverage capacity for detection of targets hiding either in forests or under camouflage
- Microwave SAR for high resolution imaging from standoff ranges.
- Microwave GMTI radars for the detection of ground moving targets, with large area coverage capacity.
- ESM, SIGINT & COMINT sensors, for intercepting, locating, recording and analyzing radiated electromagnetic signals by the adversary from both communication- and active sensor systems.
- Photoreconnaissance sensors for focused reconnaissance with high resolution capacity for target classification/identification.
- Optical/IR sensors for targeting and target classification/identification.
- Unattended ground based sensors for short-range surveillance of important areas and sites. Examples of such systems are cameras, IR, acoustic, seismic and magnetic short-range tactical sensors
- Artillery hunting radars for rapid location of firing artillery.
- Identification and positioning systems, for rapid identification of friendly troops will be of the outmost importance in ground surveillance. This is needed in order to minimize the number of unknown detected ground targets as quickly as possible.

A future ground surveillance system within NBD must be designed as a networked multisensor system where each participating sensor provides the users with subsets of the needed capabilities. Airborne multisensor platforms where several sensor systems coexist on the same platform will play important roles in such a ground surveillance system
In addition to the automatic systems vital information about the ground situation will be gathered manually. Human intelligence, HUMINT, observations from individual soldiers, civilian sources such as weather information, news, etc will play important roles in the creation and maintenance of the ground situation picture. In addition to the gathering of information there are other very import contributions to the ground picture coming from manual analysis of various sorts. Image analysis, situation analysis, threat analysis and operational analysis and predictions are vital parts of a complete recognized ground picture.

## 2.2 The Recognized Ground Picture

### *2.2.1 The role of the Recognized Ground Picture*

The Recognized Ground Picture should be an authorized and authenticated situation picture containing all available processed, fused and analyzed information about the situation on the ground inside the area of conflict or crises.

- The information in the Recognized Ground Picture must be of a certain guaranteed level of quality.
- The Recognized Ground Picture will contain a number of layers of information corresponding to the various levels of the JDL fusion model [1], i.e. target positions, situation analysis, threat analysis, sensor resource status etc. (*JDL=Joint Directors of Laboratories, in USA*)
- The Recognized Ground Picture will serve as a common, quality assured basis for the situation awareness for all commanders and participants within the organization.

However, it is important to note that even if the recognized and commonly shared ground picture will play a crucial and central role in your situation awareness, qualified users must still have the possibility to create their own ground picture using data directly from the primary sources of information instead of using the fused information. Reasons for this can for example be the need for non-time delayed targeting data.

### *2.2.2 Creation and maintenance of a fused recognized ground picture*

Considering all the various sources of data and information contributing to the ground situation awareness it is obvious that data fusion and information fusion will be key functions when creating and maintaining a high quality ground picture. The heterogeneous format of the data and information to be fused will pose major technical and conceptual problems to be solved in order for a ground surveillance system to work properly within the NBD concept.

As pointed out, the complete ground picture will in the end include several layers of information, corresponding, in principle, to the various fusion levels in the JDL fusion process model [1]. In this paper our main interest is the initial sensor data fusion process, i.e. level 1 fusion, object refinement level, in the JDL model. In the level 1 fusion process the aim is to gather and process all available information within the multisensor system for all detected targets and to create the initial layer of the recognized ground target picture.

As an initial assumption for the target description we attach a data tag to every detected ground target in which all known information about the target are recorded. The target data tag will be constructed following a target information template for recording all available information about the detected ground target into a standardized data structure. The ground target template will include information about detected positions, speed, direction of movement, target tracking data, IFF or affiliation data, target classification or identification data, availability of photo-, IR or SAR-picture material, SIGINT-, COMINT- and ESM information, and, if available, HUMINT-information. The template must also include data quality or data reliability estimates for every piece of information included in the template. The estimation of the data quality or reliability will play an important role when evaluating and fusing information from different sources for the detected ground targets. Especially in situations when information from different sources contradict each other. Traceability is also of vital importance and therefore every piece of information within the template must be marked with the source as well. In the fusion process the available data within the entire ground surveillance system about a certain target is recorded in the target data tag.

The question then is how this fusion process should be organized for a spatially dispersed multisensor system, with very heterogeneous types of sensor data and probably also within a heterogeneous network environment.

There are, in principle, two distinct types of possible architectures for the data fusion process, illustrated in figures 2 and 3. The data fusion can either be implemented as a central, fig. 2, or as a distributed, fig. 3, function in the network.

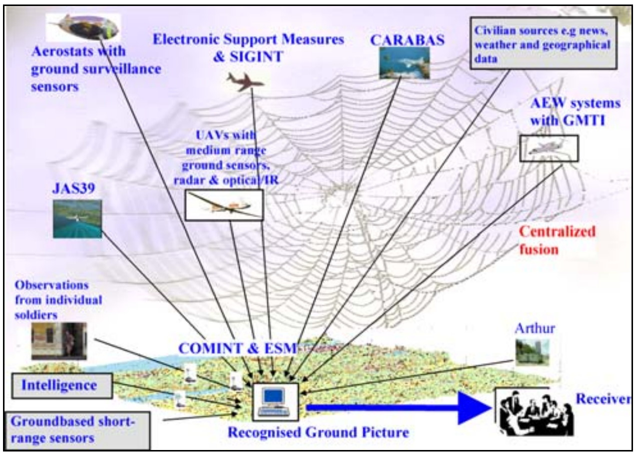


Fig. 2. Centralized data fusion. The sensors send their target data to a centralized fusion node, which creates the recognized ground picture.

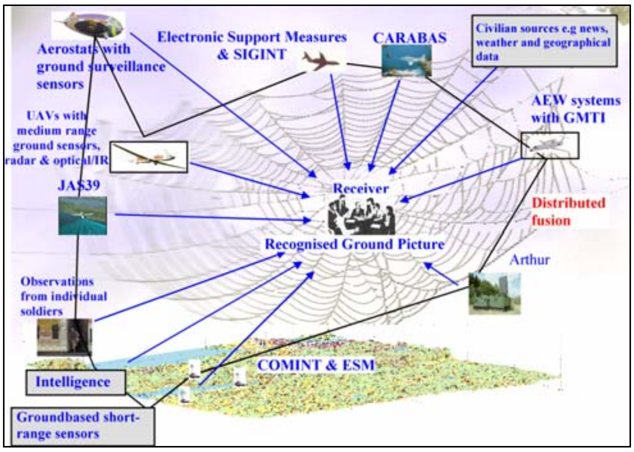


Fig. 3. Distributed data fusion. The sensors share their target data between each other and after target correlation they decide, for each separate target, which sensor has the best quality data. This best sensor will be responsible for that specific system target and it will fuse all available data for that target. When asked for it the sensor will then send the fused target data for the system targets that the sensor is responsible for to the receivers.

In a centralized solution the target data from the individual sensors is sent to central dedicated fusion nodes where the information from the multisensor system is fused and the Recognized Ground Picture is created. Relevant parts of the picture are then distributed to everyone requesting ground picture information. This solution, however, has serious problems with robustness. If the fusion node or the network connection to it is destroyed or malfunctioning the entire capability is lost.

In a distributed fusion system there are no such problems with robustness [2]. In a system where the fusion capacity is distributed in the network the sensors share target data with each other and every sensor platform function as a fusion node. In each node the fusion process is started with a target correlation and association process where it is decided whether the target data from different sensors originates from the same ground target. For every unique target that can be identified in the correlation process a so-called system target is created in the Recognized Ground Picture. For every system target a best sensor is assigned. This assignment is done after a negotiation to decide which of the contributing sensors that has the best quality of data for that specific target. This sensor is, for the moment, said to be the best sensor and will be responsible for that specific system target in the recognized ground picture. Only one sensor at a time can be assigned best sensor for a specific target. After being assigned best sensor this sensor is responsible for collecting and fusing all available information within the ground surveillance system for this target.

Since the negotiation is performed frequently the best sensor for a system target change from time to time when another sensor can deliver the best quality of the target data. It is this feature that will guarantee the robustness of the distributed fusion system. If for some reason the best sensor disappears from the network or stop delivering target data, the role of best sensor for the system targets will quickly be assigned to another sensor during the frequent system target negotiation process.

When someone in the network request information from the Recognized Ground Picture all nodes in the network will send their system target information directly to the recipient no matter where he or she is situated. This means that an updated Recognized Ground Picture will be created every time it is requested and that the target information presented will always originate from the best available sensor at that specific moment. It also means that everyone who has access to the Recognized Ground Picture will be presented with target information from the same information sources. Hence all commanders in the organization will operate on the same quality assured basis for their situation awareness.

*2.2.3 Development of a NBD ground picture simulator*

A suitable starting point for the development in this area is to simulate data and information from various ground information sources such as sensors, databases and intelligence in order to test new concepts and methods for creating fused ground situation pictures. At Ericsson

Microwave Systems, (EMW), a simulation framework, Ground Target SIMulator, GTSIM, [3], has been developed to be used as a test bench, when developing new methods and concepts for sensor data- and information fusion.

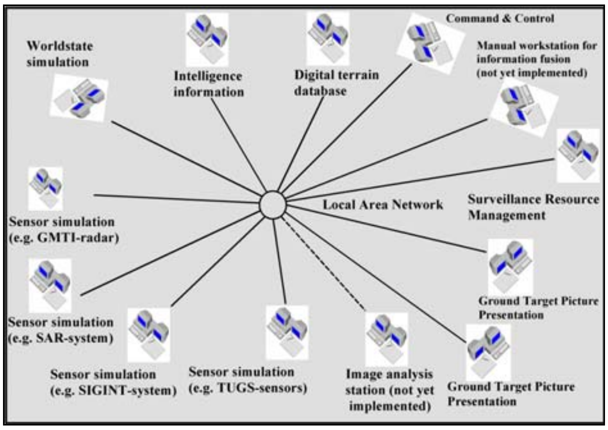


Fig. 4. Principle layout of GTSIM test bench. The simulator emulates different sensors, functions and information sources within a spatially dispersed multisensor system for ground surveillance within NBD.

The fundamental idea behind GTSIM is to create a simulator which emulates the spatially dispersed multisensor and information system and the network environment outlined above, see fig. 4. The simulator is therefore designed as a multithreaded program running on several computers in a local area network using CORBA to emulate the communication between different parts of the sensor and information network.

GTSIM is built around a world state simulation containing a digital terrain database and a scenario based ground target model. An arbitrary number of sensor- and information source simulations fetch data from the world state simulation and generate, in real time, the sensor data and information environment from which the Recognized Ground Picture should be created and updated from.

The test bench is designed in such a way that different architectures and algorithms for the data and information fusion process can be tested and evaluated for the ground surveillance scenario.

*2.2.4 Implementation of a distributed ground picture creation algorithm*

One of the key goals for the Swedish NBD System demonstrator 05/06 [4] is to be able to create a global situation picture, GP, from sensor data and other information independently of which military unit it stems from. The fusion of a global situation picture is preferably done in a distributed way due to robustness and flexibility issues, and can be seen as a first step of information and services processing in the network itself. In specific, this part of the paper describes how sensors, which are connected to a network, together can create, in a

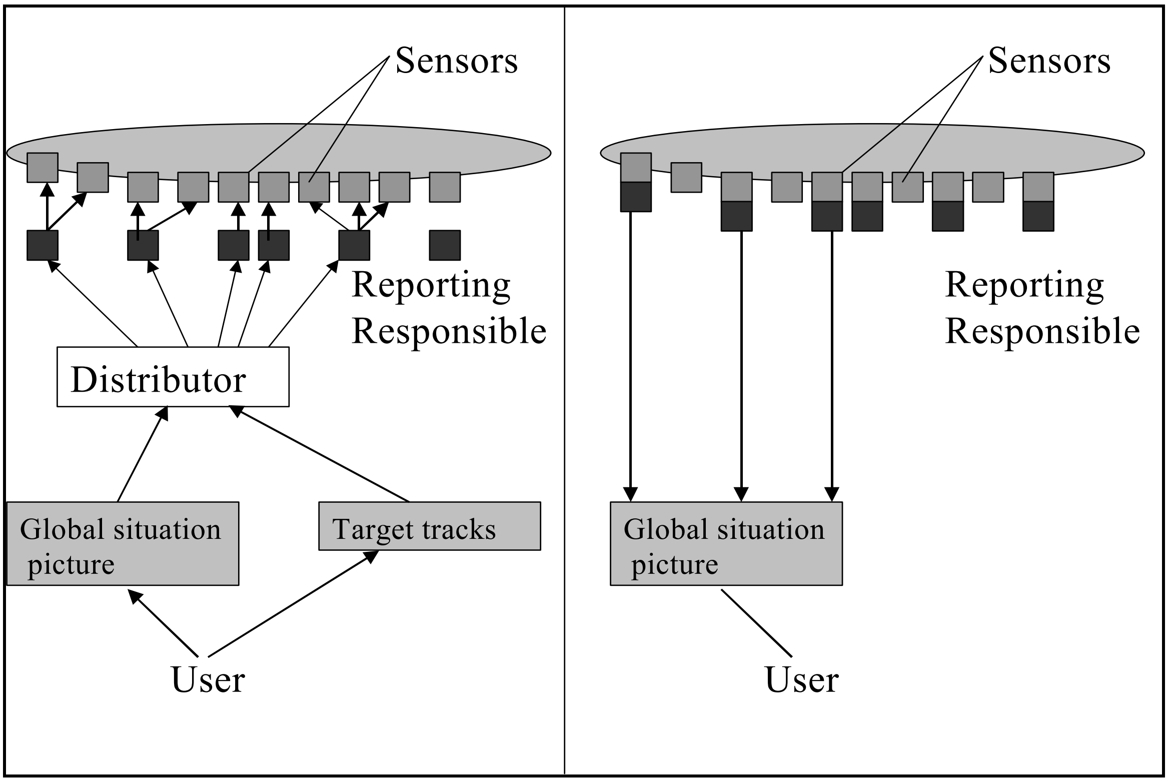


Figure 5. The picture on the left displays (using lines with arrows) which component that know the existence of other components. The user knows the distributor, the distributor knows the reporting responsible, the reporting responsible knows the sensors. The picture on the right displays the data flow from the reporting responsibles to the GP when the connection is established.

distributed way, a fused ground picture of , the GP. It also shows how different users can access the GP as a net service. Below follows a brief technical overview of how this was accomplished.

As outlined above the data needed for the creation of the GP does not exist inside one single component, instead it is distributed among the components which has the reporting responsibility for each target. Crucial roles in this process are the reporting responsible and the distributor:

- The reporting responsible has the responsibility of reporting data for each target. In our implementation, this role, which can be dynamically changed, is taken by the sensor, which delivers the most accurate track of a certain target. The reporting responsible also performs the correlation (and fusion) process if two or more sensors observe the same target. Globally it is crucial that each target has only one reporting responsible.
- The distributor handle and manage the different users subscription of target tracks within different geographical areas and thus this component must know each sensor which actively delivers data within these areas. Note that the distributor only manage the delivery of different components addresses for establishing the co-operation. When the connection is established, and e.g. the tracking data are interchanged, the distributor does not take part in the co-operation.

Fig. 5 displays which component that knows the existence of other components (on the left), which is crucial for establishing the connection, and the data flow between the reporting responsible and the GP when the connections are established (on the right).

A flow chart of the distributed correlation algorithm is depicted in Fig. 6. It can be noted that changing to real sensors, instead of sensor simulators, does not change the implementation of the distributed correlation (and fusion) process. In addition, work is in progress of extending the correlation box ( in Fig. 6) to the fusion level in order to improve the result compared to the single sensor performance. The distributed correlation and fusion process is general and other type of information, like measurements from other sensors (than radars) or intelligence information can be incorporated in the same distributed manner. The only part, which needs to be specially designed is the correlation and fusion algorithm.

# 3 Summary

The basic demands on a ground surveillance system within the NBD framework is outlined. An important conclusion is that in order to meet the NBD demands the ground surveillance system must be designed as a multisensor system with multifunction and multispectral capacity. In order to assure both target detection capability and target classification/identification capability a hierarchy of different types of sensors are needed. By using a distributed architecture for the sensor data fusion and also for the information fusion a robust system for creating a common Recognized Ground Picture can be created and distributed. By using a best sensor concept in the fusion process it is guaranteed that the best available quality of target data is included in the ground picture. However, it is important to note that the heterogeneous format of the data and information to be fused will pose major technical and conceptual problems to be solved in order for a ground surveillance system to work properly within the NBD concept.

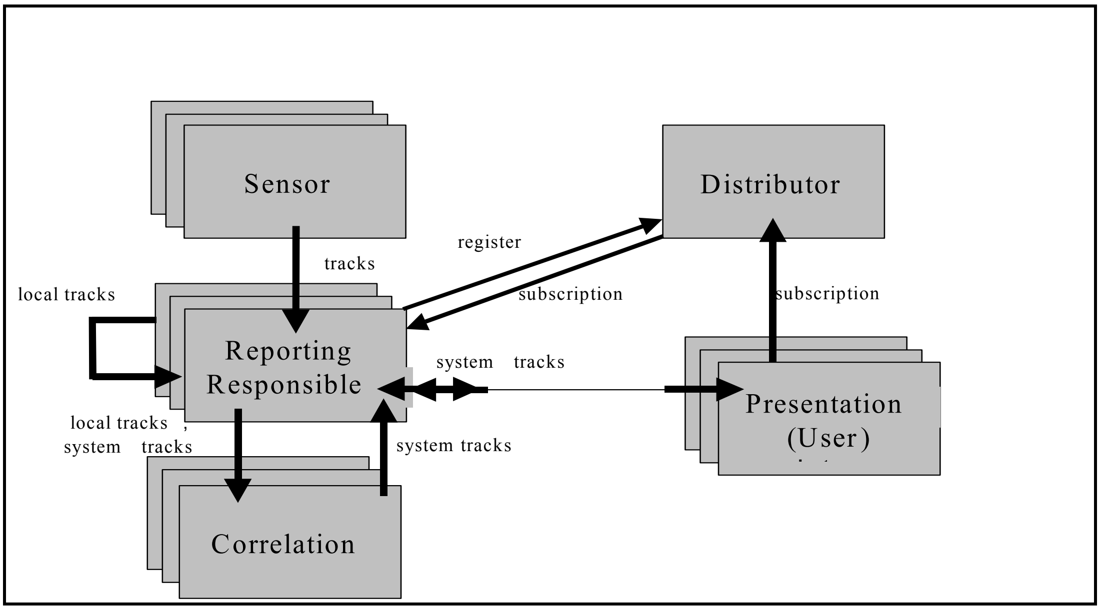


Figure 6. A flow chart of the distributed correlation algorithm. A sensor detects a target and starts a track, which is delivered to the reporting responsible. The local track is correlated with system tracks. The distributor manages different users subscription of target tracks within different geographical areas.

## Acknowledgements

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