

# SPECIALISTS' MEETING - SET- 222 on Swarm Centric Solutions for Intelligent Sensor Networks



## Metrological Characterization and Semantic Annotation of Space-Aided Distributed Sensor System for Hydrogeological Disaster Management

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Politecnico di Bari



## Agenda

- Scenario: hydrogeological distress
- Context outline
- Swarm intelligence model
- Reasoning in disaster management
- SMART: **S**pace for **sMA**rt **R**esource managemen**T** for disaster early warning
- Conclusions



# Scenario: hydrogeological distress

Some figures:

- ✦ **Italy**
  - ✦ **Landslides & floods in the last 70 years → 61.5 billion € damage**
  - ✦ **Areas of high criticality: 9.8% of the national area and 89% of the municipalities, where are located 6.250 schools and 550 hospitals (ref. first report Ance – Cresme)**
  - ✦ **Europe: torrential rains, storms and floods killed thousands of people and caused damage of around 23 billion €/year.**



**More prevention needed by integrating standard technology and innovative solutions**

## Context outline

- ✦ **Relationships** among phenomena are **more and more complex**
- ✦ Systems must cope with **ever changing scenarios**
- ✦ Vision of the problems based on ecological awareness
- ✦ **Ecosystems approach**: entities are related to each other by a network of interdependencies

### New system model:

- ✦ The new paradigm evolves **from** a hierarchical view **to** a decentralized view
- ✦ New architectural paradigms for complex systems:
  - *net-centric*
  - *self-organized*
  - *cooperative*
  - *adaptive*

# Smart and resilient systems

## ☼ A smart territory (or system):

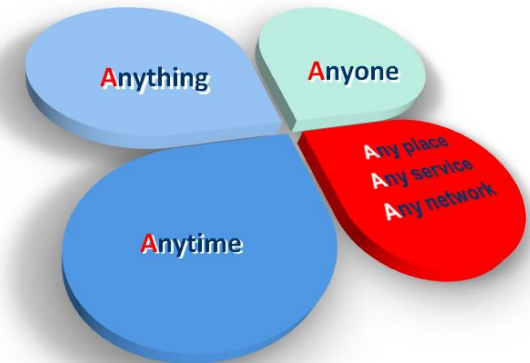
- makes a better use of **decentralized** resources
- increase opportunities for its citizens
- better accessibility to facilities and services

## ☼ A resilient territory (system) is a smart territory that:

- renews its **balance** when boundary conditions change
- **adapts** and **self-organizes** replying to the stresses resulting from changes
- expresses answers on the social, economic and environmental matter



Connecting:



Cooperative management of a territory:  
requires *cooperation* and *teamwork* such as in the **swarm inspired by nature**

# Swarm Intelligence Model: a novel approach

- **Swarm Intelligence** is inspired by social animals
- Goal: handle the complexity of critical scenarios based on **multitude** and **autonomous behaviour**
- **Common goal -> self-organization -> autonomy and interactions -> stigmergy**
- Design systems whose functions arise from the network organization of their own elements
- Adopted by **Leonardo Company** to cope with critical scenarios (scientific support of **Politecnico di Bari**)
- Several **initiatives funded** by Apulia region government and Italian MoD

## Decision Support Systems (DSSs)

- Decision Support Systems (DSS) are considered of a particular relevance for **hydro-geological distress prevention**
- **Big Data** monitoring physical or environmental conditions **rapidly processed and examined** in order to assist decision makers
- Good accuracy and rapidity are required for a **fast and reliable quantity measurements** of environmental sensors
- Proposed system based on a **swarm-oriented data distribution service** which:
  - gathers **environmental measures** as sensor output
  - **validates** them after suitable **metrological characterization**
  - annotates them in a machine understandable format and enables **deductive inferences about not-evident and implicit information**.

## Bee Data Distribution Service (Bee-DDS)

Each agent in the swarm aims at the *provision of data referred to a specific item and/or subject of the natural resource protection process.*

A given informative service may be requested to the DSS by different actors, with a different operational objective each.

**Bee Data Distribution Service (Bee-DDS)**, a *Leonardo company* message-oriented platform based on the publish-subscribe model, is the one adopted for the swarm setting.

It provides ***affordable communication among loosely-coupled agents and nodes*** to support functionalities of monitoring, safety and recovery.



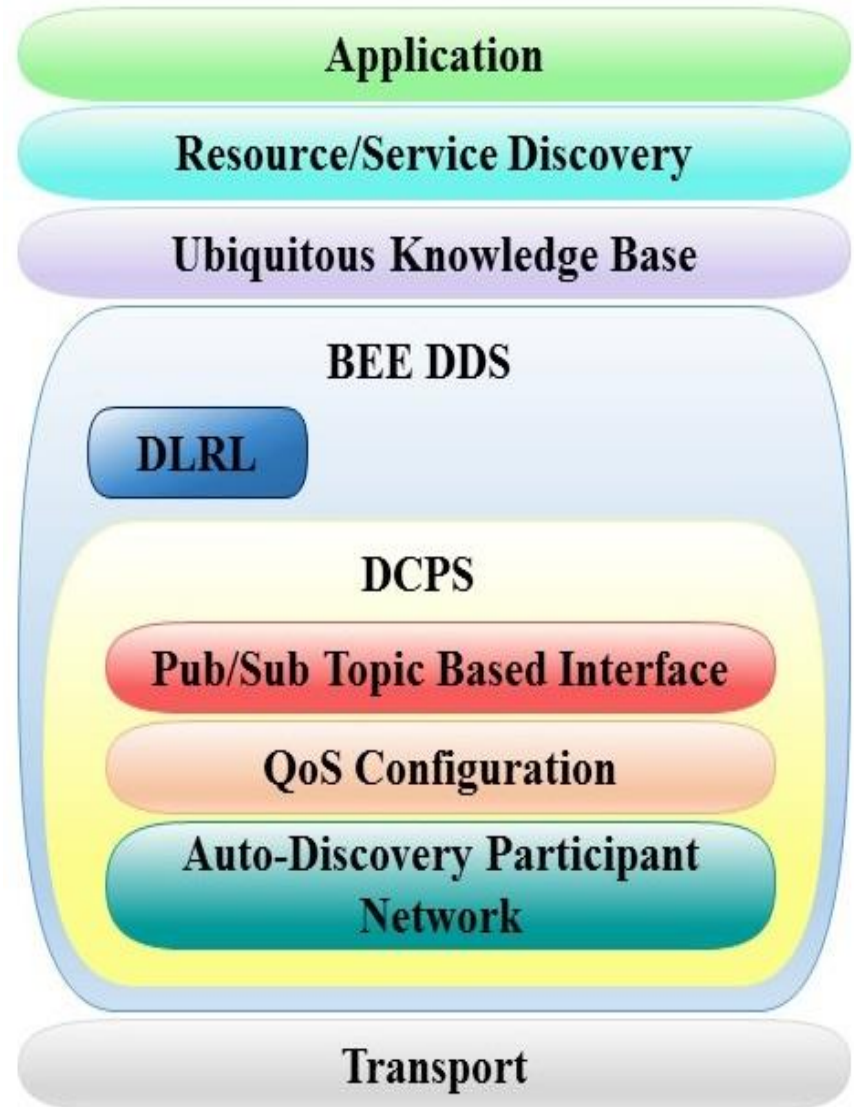
# Ubiquitous Knowledge Base model

The *Ubiquitous Knowledge Base (u-KB)* model:

- grants transparent access to information embedded in semantic-enabled objects scattered in a given environment.

Individuals are physically associated to distinct devices in a given environment (sensors, actuators, users).

The ontology is fragmented in one or more *chunks* scattered across the network nodes.



## Reasoning for disaster management scenarios

Each of the nodes scattered in the environment manages a cache of **ontology chunks**. Every cache contains a static small part of the ontology (named **Upper Ontology**, UO) as well as the chunk(s) required by detained semantic service annotations.

A **semantic service/resource request** is a logic-based annotation expressed w.r.t. a reference ontology.

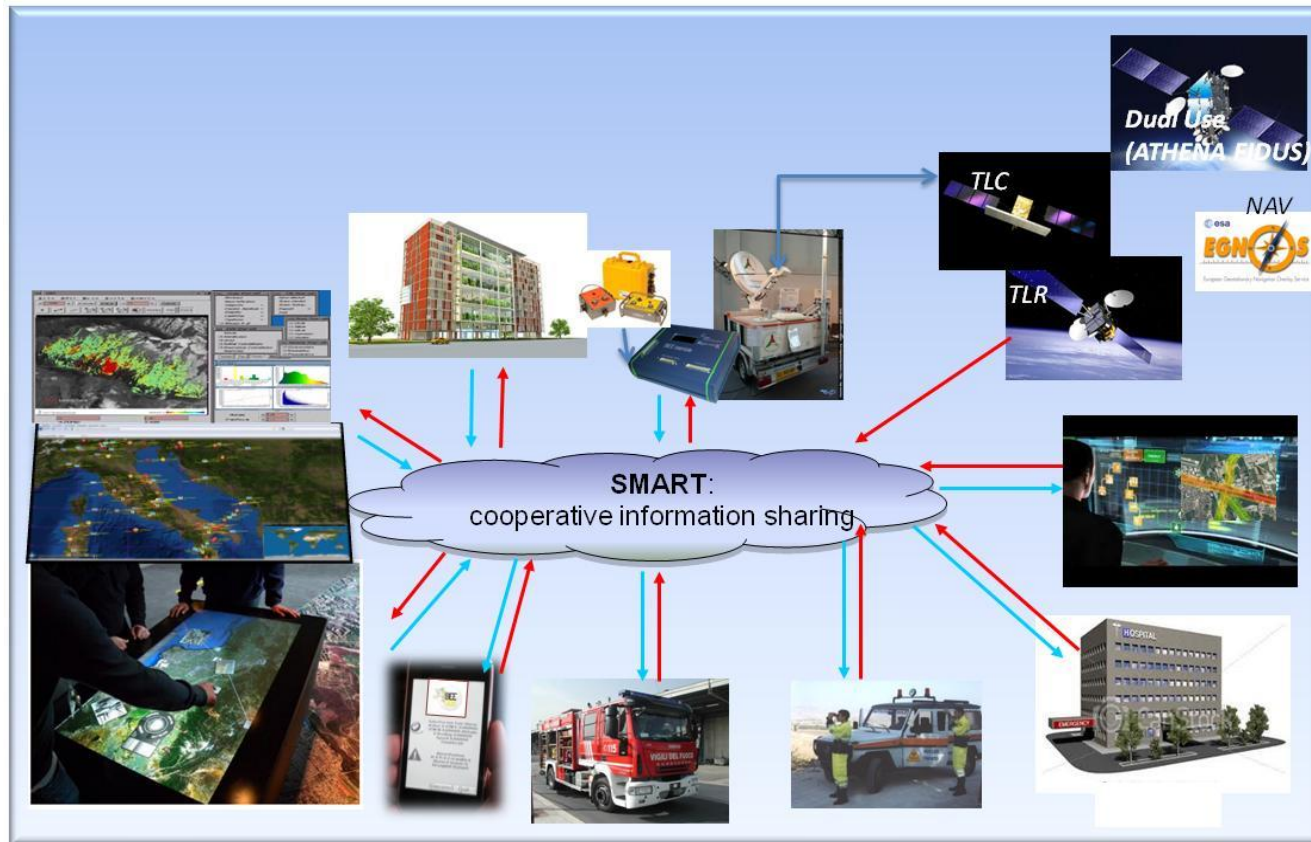
**Semantic-based reasoning** allows an **advanced decision support** as it enables novel peculiarities of resource discovery and integration:

- a node in Data Distribution System provides sensed data referred to a particular monitored area
- this information could be automatically annotated with respect to a reference ontology
- it can be exploited as request **to build a recovery team** composed in the best possible way

## SMART : **S**pace for **sMA**rt **R**esource managemen**T** for disaster early warning

SMART is a system that aims to provide a decision support for the "early warning" of a disaster/critical event and to improve the "first response" to event happened.

**esa**  
cofinancing



Users  
in the loop



## SMART: general features

The system should answer the following major questions:

- **How can we improve the forecast of hydro-geological events?**  
This aspect deals with the innovative techniques of remote sensing and positioning to *detect precursor* events for *early warning* of hydrogeological risks.
- **How can we improve the information distribution pre/post event?**  
This aspect deals with effective service provision which can be based on innovative *swarm-centric architecture* aimed to *cooperative* and *adaptability* actions.

*The proposed solution is based on the integration of satellite data (TLC, EO, NAV) and “in situ” information.*

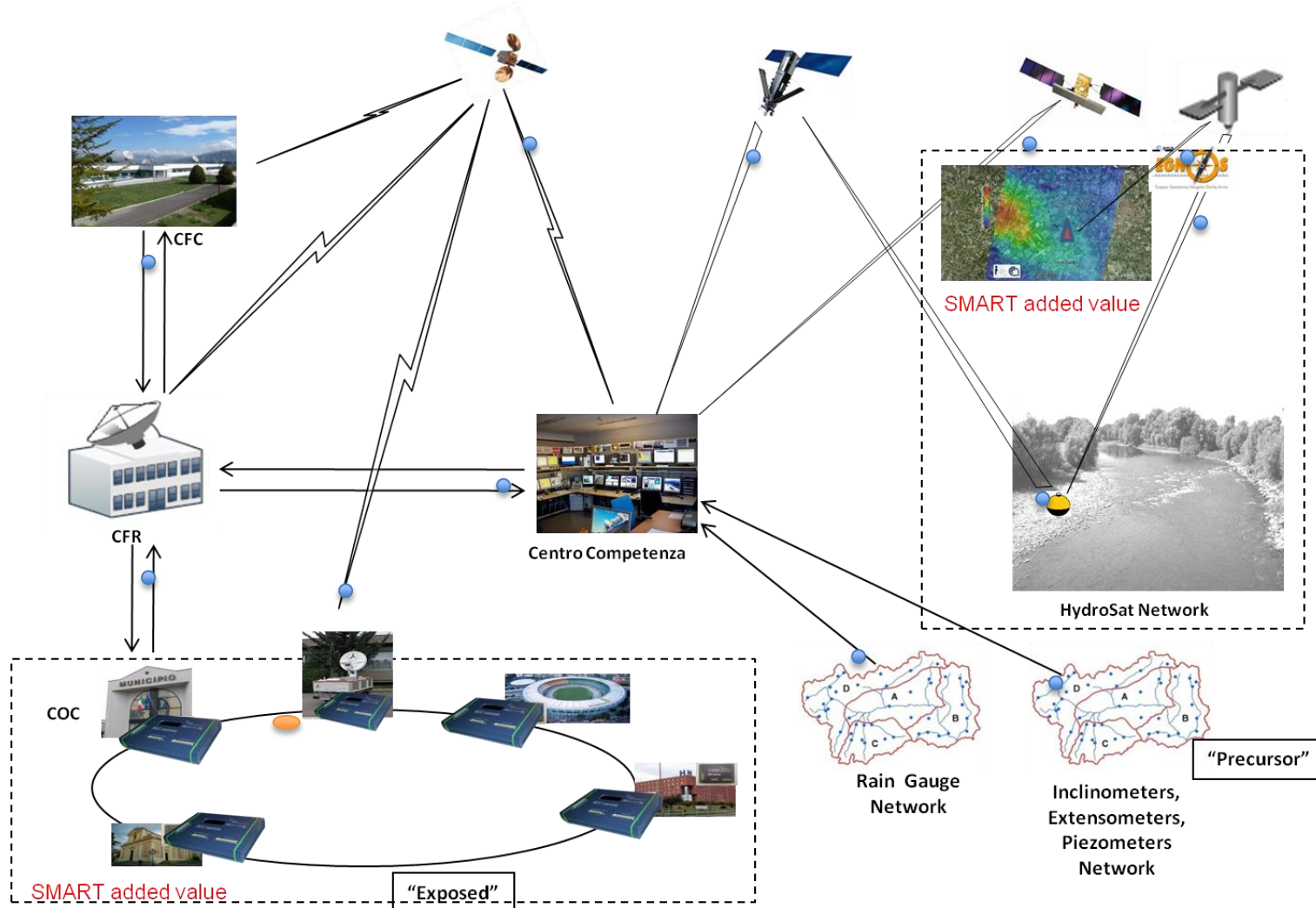
*The system takes advantage of the collaboration with Civil Protection at both central and regional level, which represents the end user identified up to now.*

## SMART: innovation

- SMART is a system based on data distribution by **integrating satellite information** (location via EGNOS, telecommunications and Earth observation via COSMO – SkyMed) and data from *in situ sensors* according to the innovative *Swarm Intelligence model*. SMART can be of valuable support in case of critical situations that require dual use (military & civil).
- The Swarm model architecture is an innovative solution that is well suited to the design of complex systems, such as security of the territory, based on concepts of **cooperation and adaptability** to changes of scenery.
- The SMART system is based on cooperative agents, or specialized heterogeneous entities (men, sensors, software agents, smart devices) which are able to **self-organize** and **cooperate adapting** to environmental changes .

Integrated space-aided and *in situ*  
autonomous sensor system

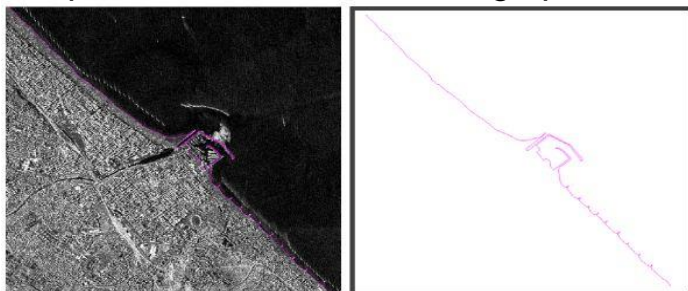
# SMART: System Architecture



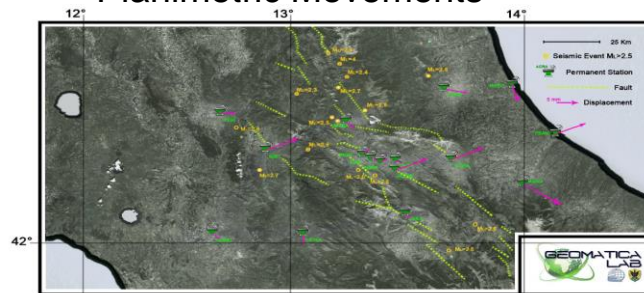
# SMART for hydrogeological disaster management

- **Landslide Information Services (precursors):** methods for detecting precursor events based on SAR data from COSMO-SkyMed satellite system; geo-referencing of SAR images using scatterers whose position is determined by EGNOS.
- **Flooding Information Services (precursors):** HydroSat, a sensor hosted by a floating buoy, which provides data for detecting river flow high waters making use of EGNOS and satellite communication.
- **Field Information Services (exposed):** support both operator in the field and the tactical and strategic planners, to manage disaster events, especially in first responder operations. It is based on a data-centric architectural paradigm and delivers data from sensors and actuators via the Data Distribution Services (DDS), a standard real-time middleware specified by Object Management Group (OMG).

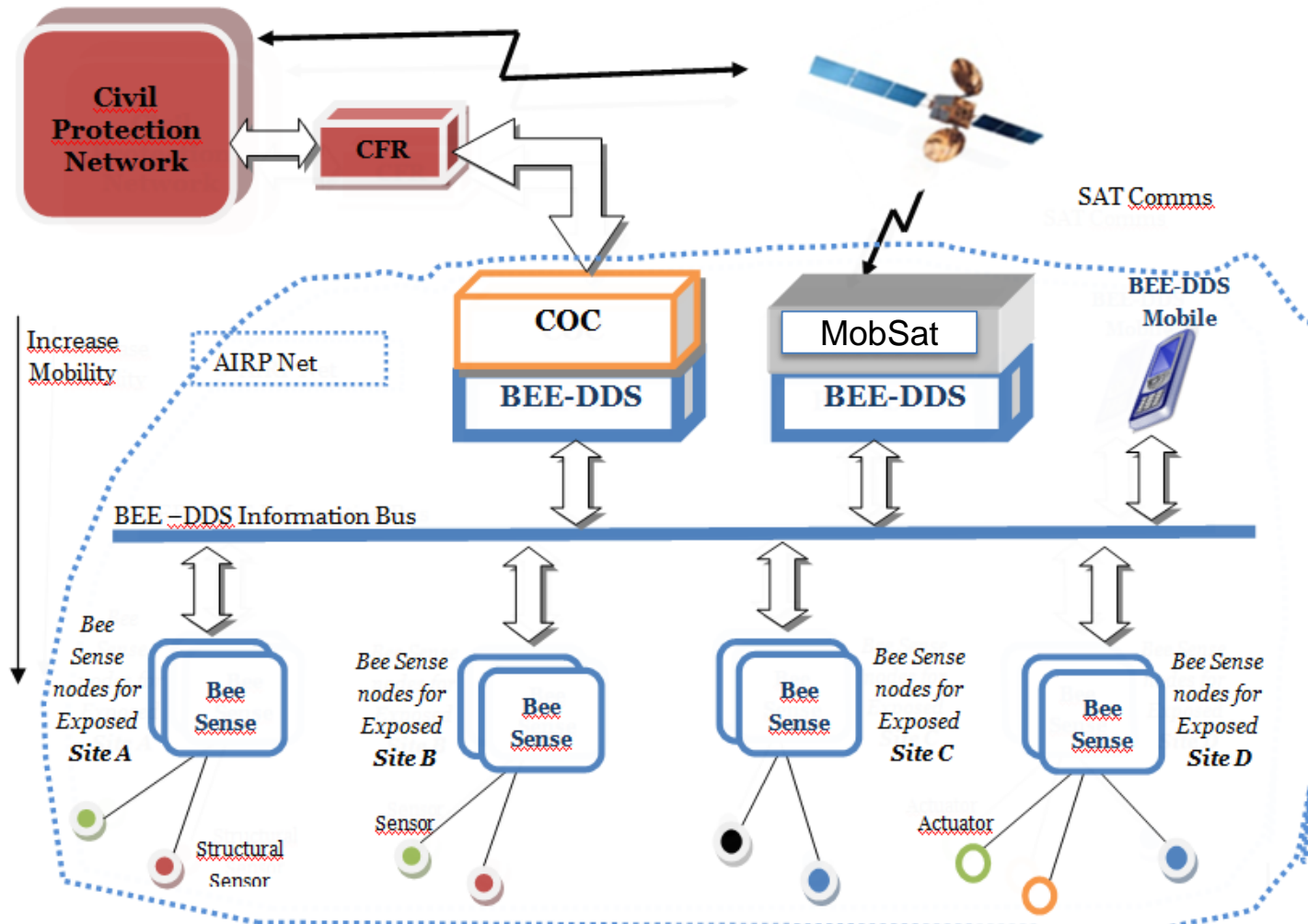
Example of COSMO-Coast image processing



Planimetric Movements



# Adaptive Information System for Prevention and First Response (Swarm Centric Solution)

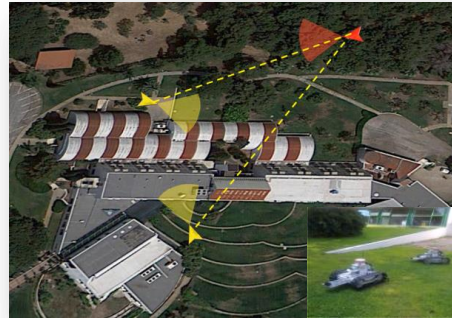




# Swarm-centric innovative solutions for **dual use** applications



**EMERGENCY/  
CRISIS MANAGEMENT**



**COOPERATIVE  
SURVEILLANCE**



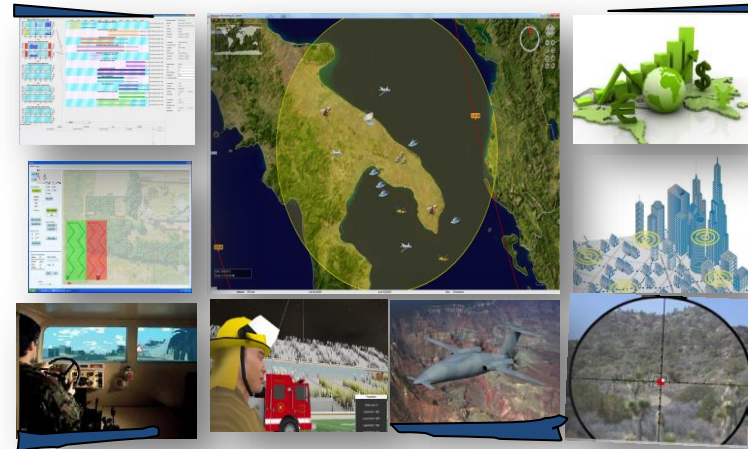
**INFORMATION SHARING &  
COOPERATION**

## **DUAL USE APPLICATIONS**

**NEXT GENERATION C4I**



**COOPERATIVE RESOURCE MANAGEMENT**



## Conclusions

- SMART provides an integrated, swarm/data-centric service/system architecture which allows to integrate very different kind of systems, due to a key focus on *interoperability capabilities*.
- The adoption of a **swarm-centric** architecture ensures higher Quality of Information/Quality of Service typical of real-time system/services:
  - *Robustness; Security*
  - *Scalability; Predictability*
  - *Adaptivity; Persistence*
- A metrological characterization of complex sensors could be further enhanced if provided data are annotated in a logic-based formalism and a deductive reasoning is performed on them. The resulting system should allow an improvement of performance and reliability with respect to competitor frameworks.



# SPECIALISTS' MEETING - SET- 222

## on Swarm Centric Solutions for Intelligent Sensor Networks



**Metrological Characterization & Semantic Annotation of Space-Aided Distributed Sensor System for Hydrogeological Disaster Management**

**THANK YOU FOR YOUR ATTENTION**



**Politecnico di Bari**

