Architecture for Networked Sensor Integration as an Enabler for Future Multi-Sensor Multi-Platform Operation

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Agenda

1. Introduction and Motivation
2. Multi-Platform Sensors
3. Multi-Platform Architecture Principles
4. Use Case Example
5. Conclusion

Introduction and Motivation

Our Future Operational Environment

- Modern warfare has been evolved into an overwhelming complexity in the usage of EMS (electro-magnetic spectrum).
- It comprises e.g.:
  - RF-Domain (Radar, COMMs, GPS)
  - EO/IR-Domain (Imaging, COMMs)
- EMS Operations are THAT means to transmit information between assets on the battlefield.
- Each transmitted information is related to a specific capability needed for operational success.

→ **Therefore, EMS Superiority will be a corner stone for all future warfare operations.**

How can EMS Superiority be achieved?

- EMS Operations (EMSO) utilize the capabilities:
    - Access / Protect
    - Attack / Deny
    - Sense / Exploit
- Proper use of these capabilities requires a suitable Electromagnetic Battle Management (EMBM).
- But to gain EMS Superiority the EMBM has to cope with an overwhelming complexity as mentioned before.

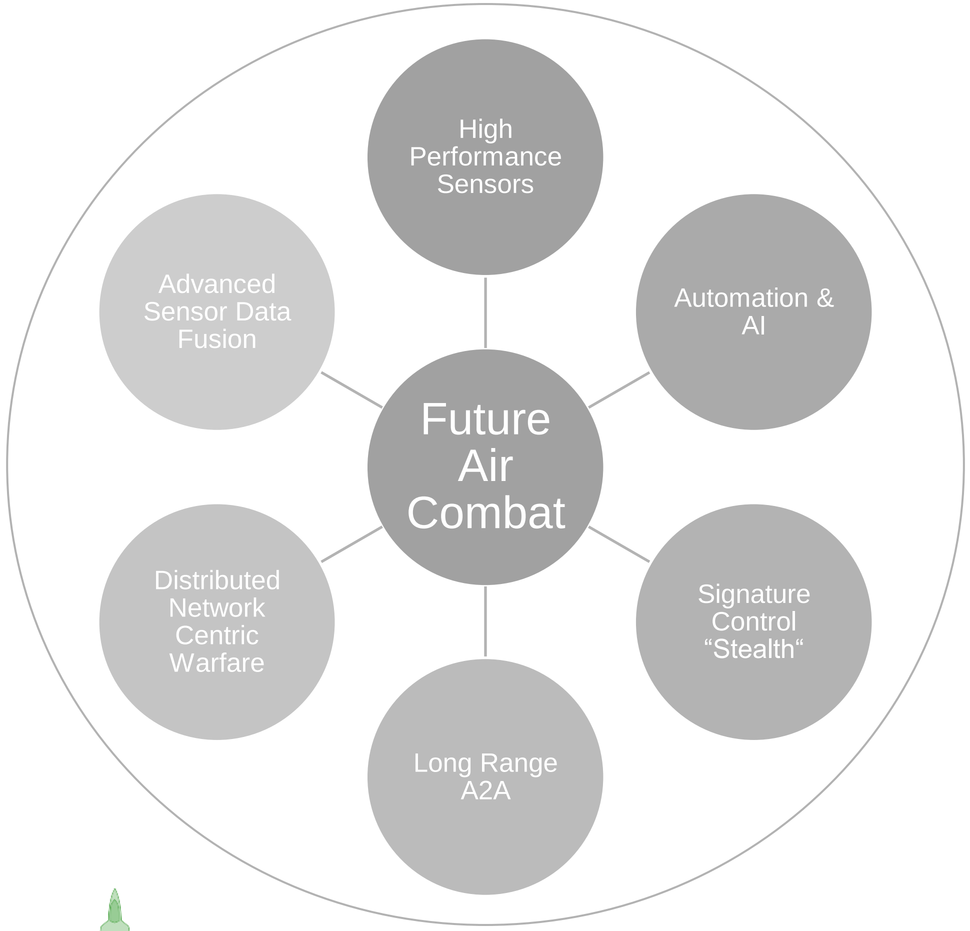
→ **Due to the fast heterogeneity and time critical dynamics of future EMSO the EMS Superiority can only by achieved by a Network Centric Approach.**

Future Challenges for the Sensor Suite

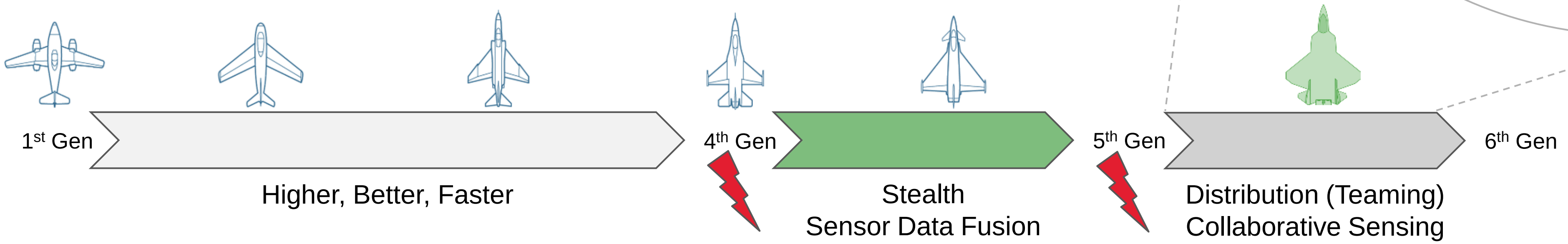
- Future 6th Gen. Fighters will face a new paradigm on future battlefields.
- Upcoming enemy systems will rely on networked and collaborative operation capabilities trying to establish EMS Superiority & Spectrum Dominance.

→ **Therefore, a new approach for the sensors & non-kinetic effector suite will be required to grant own success in future air combat operations.**

→ **That means, sensors cannot remain isolated elements that just collect measurement data. They should act in a coordinated and reactive way based on service requests from the Combat Management System (CMS) transforming measurement data via refined/improved information into reliable and consistent knowledge.**



Fighter Evolution



Multi-Platform Sensors

General Aspects for Multi-Platform Sensing

Coordinated Sensor Systems (combination of individual sensors on multiple platforms):

- Time synchronization in the order of milliseconds
- Geometric synchronization in the same range as the required target localization requirements
- Resource management on task level
- Data links between the platforms need typical performance (link capacity to transfer plot data with latencies in the order of 10ms)

Multi-Platform Sensors (one sensor that is distributed over multiple platforms)

- Time synchronization in the order of sub-microseconds
- Geometric synchronization in the same range as the required target localization requirements
- Resource management on job level
- Data links between the platforms need high performance (link capacity to transfer jobs, plot data with latencies in the order of 1ms)

Multi-Platform Radar

Operational benefits and challenges

Multi-platform radar offers multiple **operational benefits**:

- Detection of **low-observable targets**
- **Covert operation** of the receive platforms
- Increased number of **degrees of freedom**
- **Increased robustness**

Challenges for airborne multi-platform radar:

- **Localisation** of transmitter and receiver
- **Synchronisation** of common time and frequency
- **Coordination** of contributing sensors and platforms
- **Connectivity** between the platforms

Multi-Platform EW Operations

ESM Concepts can be divided into the following categories:

- **Expansion** of the reconnaissance area
- **Improvement** of data quality, e.g. by using specialized sensors in the same reconnaissance area
- **Overcoming physical limitations** of a single carrier, e.g. fine direction finding via large antenna base (TDOA)
- **Fast emitter localization** by triangulation, e.g. using the following techniques
  - **PET-technique:** localisation of emitters by calculation of intersections of hyperboloids
    only OD-antennas required; based on TDOA measurements; also FDOA-techniques can be applied
  - **Multi-lateration / triangulation technique:** localisation of emitters by calculation of intersections of bearings using DF antennas

ECM Operation with several cooperating EA platforms

- Multi-threat management
- Coordinated vs. cooperative/distributed jamming
- Different roles (ESM, ECM) for each platform
- Advanced ECM technique depends on type of jamming (radar vs. cover vs. deceptive jamming)

Multi-Platform ECM

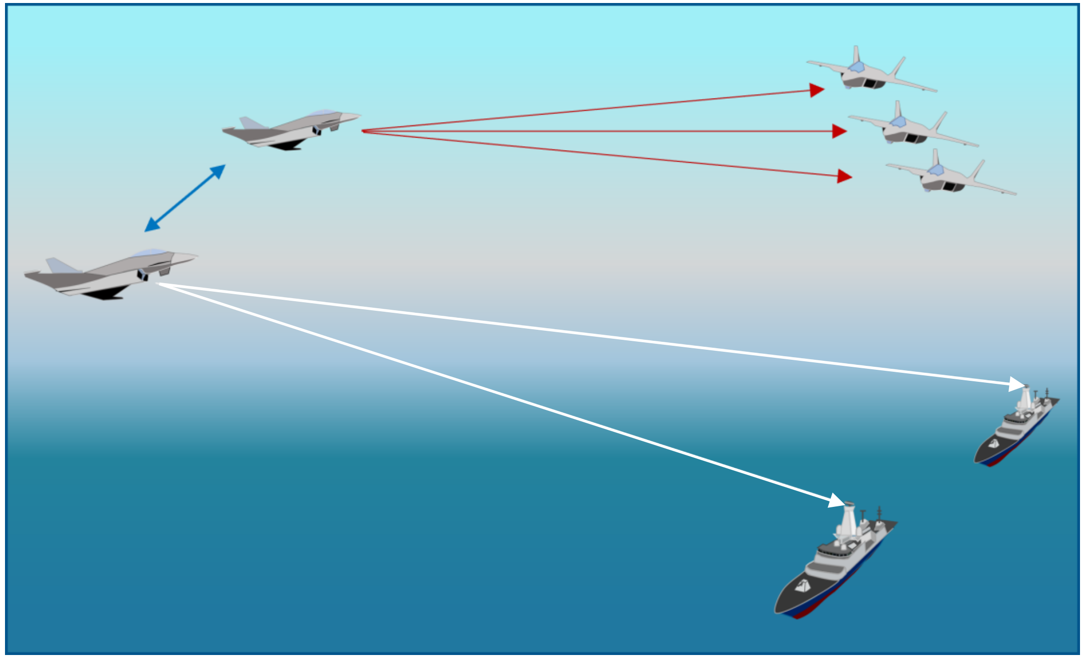
Realisation Concepts of Multi-Platform ECM Operations

Coordinated ECM

⇔ Coordinated Mono-static Radar Operation

Multiple jammers coordinate their activities towards common targets

➔ Higher-level threat management necessary

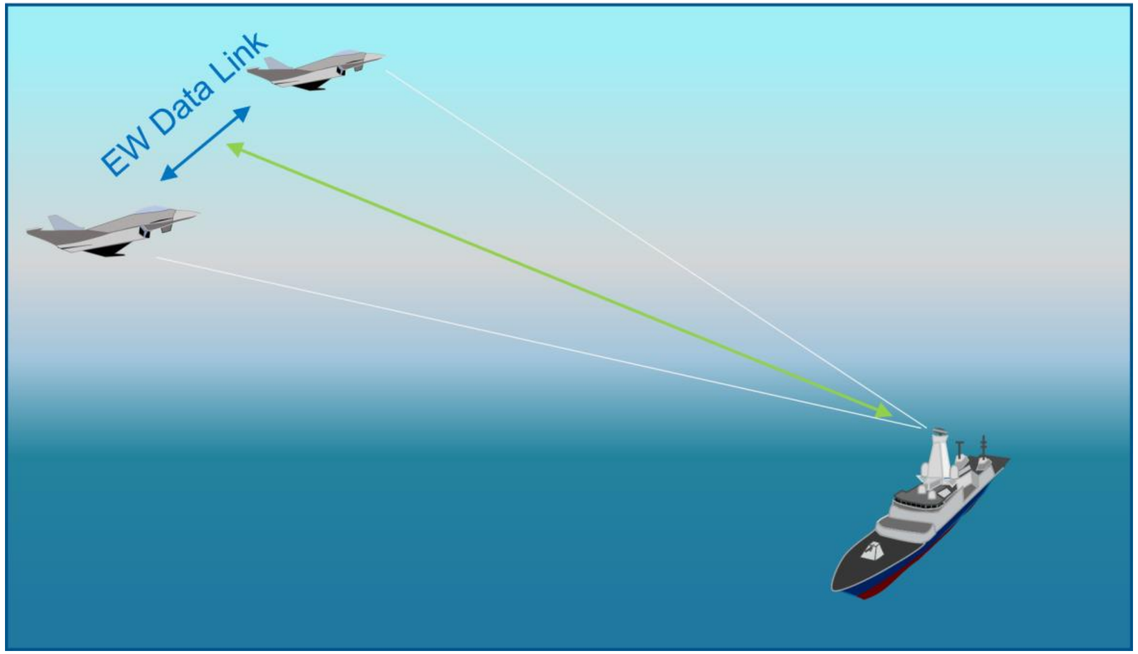


Cooperative/Distributed ECM techniques

⇔ Multi-static Radar Operation

Multiple jammers apply collaborative jamming techniques

➔ Challenging implementation



Multi-Platform EO/IR

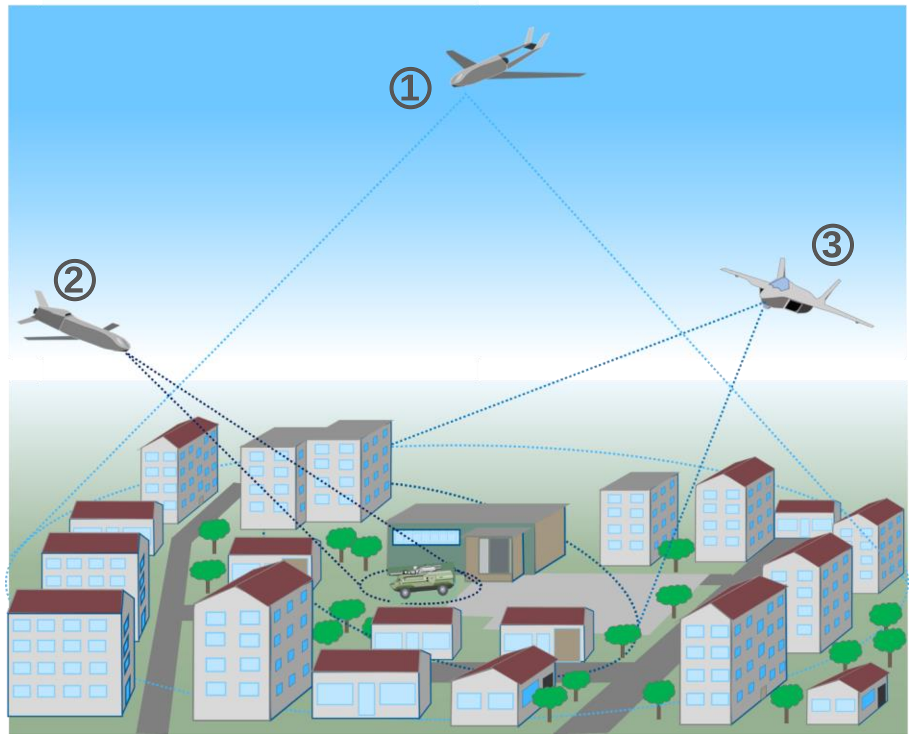
Operational benefits and challenges

Multi-platform EO/IR offers multiple **operational benefits**:

- **Reduce** scenario- /atmospheric **limitations**
- **Passive Range-Finding and Geo-Localization** of targets
- **Passive 3D Reconstruction**
- Combine specialized EO/IR sensors for **information increase**
- **Increased robustness**

Challenges for airborne multi-platform EO/IR

- **Synchronisation** of common time and frequency
- **Coordination** of contributing sensors and platforms
- **Location accuracy** of the involved platforms
- **Connectivity** between the platforms
- **Aspect angle independent object detection** algorithms



Example: Multi platform combined EO/IR sensor during attack scenario

① *Wide Area Motion Imagery (WAMI)* → *Common Global Picture Generation*

② *Target Identification (RECCE / EOTS)* → *Identification*

(① and ②: **Observe, Orient**)

③ *Attack (Radar / EOTS)* → *Scenario Adaptive Attack Optimization* — **Decide, Act**

Networked Multi-Sensor Architecture

Benefits of a Network Centric Approach

- EMS Operations (EMSO) are tightly coupled with Information Operations (IO).
- The intrinsic character of the Network Centric Approach is its decentralization based on the principle of subsidiarity.
- Decentralization means:
    - hold IO up & running in contested EMS environment
    - fight the enemy without lowering own EMSO capabilities
    - enable & maintain scalability of EMSO
    - ensure reliable stability of EMSO
    - allow full-spectrum dominance
- Full-spectrum dominance will be enabled by Information Superiority which in turn is enabled by EMS Superiority.

→ **Therefore, future warfare will not see units fighting units but networks fighting networks.**

First Cornerstone: The Principle of Subsidiarity for Future Architectures

The underlying general concept of the proposed **Network Centric Architecture** is the principle of **Subsidiarity** with its well-known key characteristics:

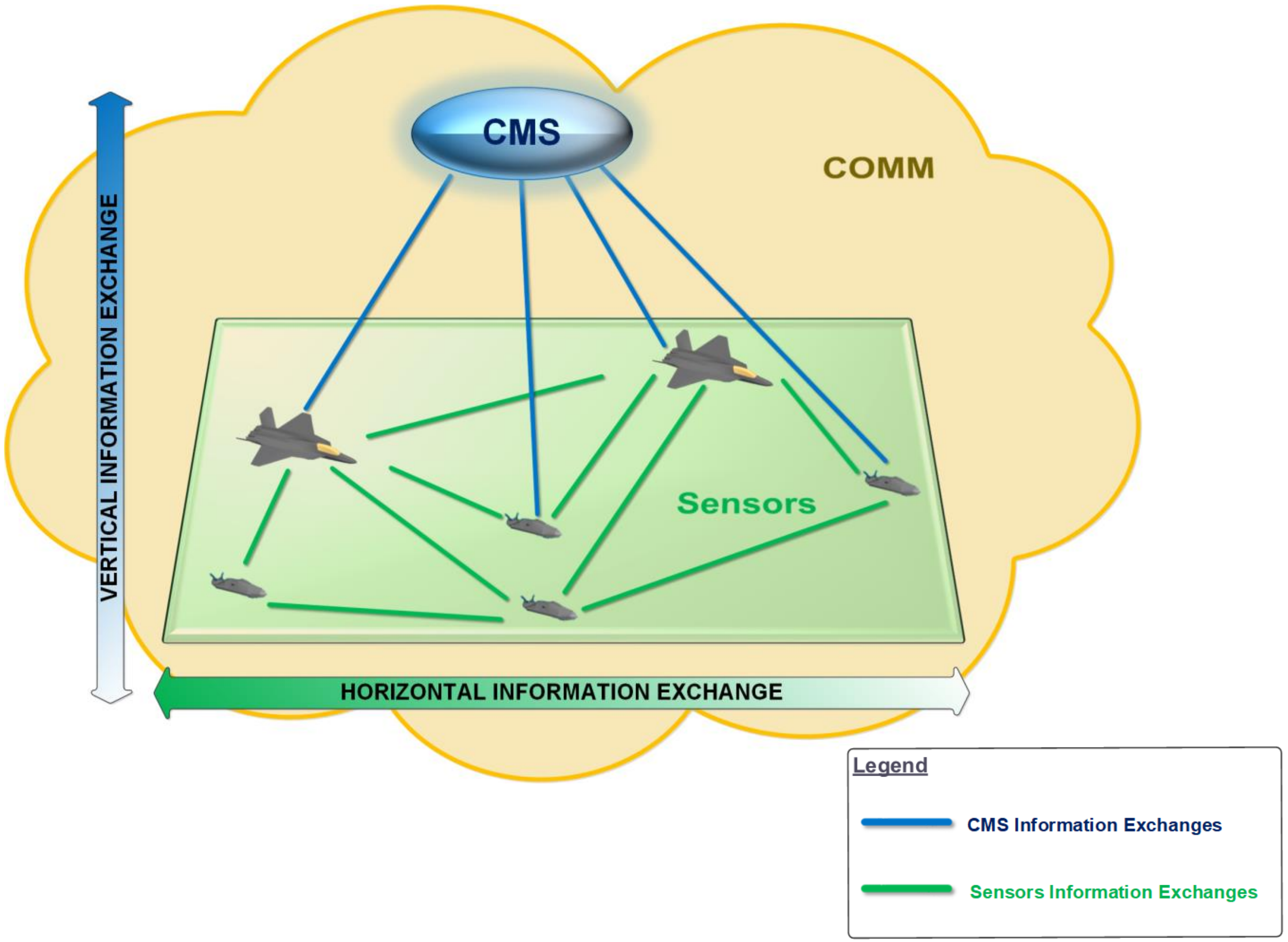
(a) the level of decision-making authority is always as low as possible and as high as necessary,

(b) flexible formation building of autonomous groups and

(c) an efficient self-organization.

The Oxford English Dictionary defines subsidiarity as:

"The principle that a central authority should only control those tasks which cannot be performed at a more local level".



Football Match as Example of a “Subsidiary De-centralized Architecture”

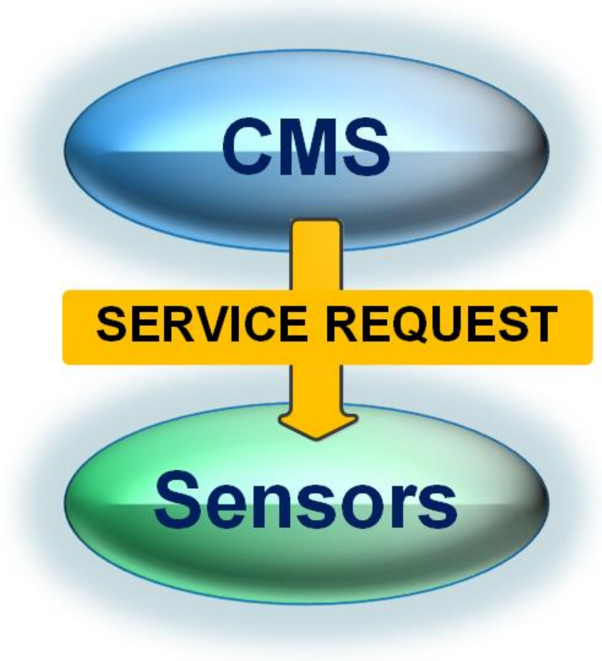
- Distributed/Emergent decision making

- Mission/play starts with
  - Predefined plan
  - Different roles and corresponding tasks are defined

- During execution of play
  - Quick reaction on actions of the opponent is needed
  - Group members must have awareness of overall situation on the pitch
  - Constant re-adjustment of predefined plan with dynamic allocation of roles and tasks

Second Cornerstone: Service Oriented Architecture as Control Structure

- This real-life example of a system architecture (football match) which follows the principles of subsidiarity brings just another very important aspect in to play: **Service requests as a control structure.**
- To master the overall complexity and maintain consistency of the overarching architecture during design, development, operational use, and upgrade cycles, the underlaying architecture principles should promote low-coupling, ease of integration, interoperability, and reuse.
- This can be achieved by the principle of **Service-oriented Architecture** (SoA).
- Designing defense systems, services are the cornerstone of interoperability and capability development supported by the NATO Architecture Framework (NAF) and others architecture methods.
- Service-oriented Architecture (SoA) is centered on the services provided by system components.



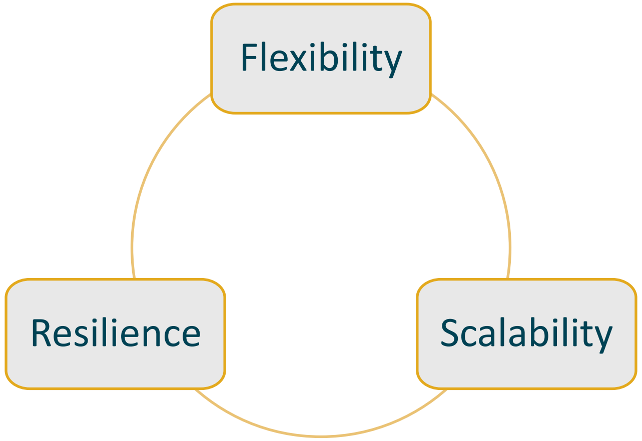
Third Cornerstone: Establishment of Architecture Design Drivers

The purpose of the Architectural Design Drivers is to establish a set of properties which shall drive the architectural system design and provide guidance for decision making during the actual systems engineering activity of architecture creation.

Flexibility: The architecture should support modifications (e.g. internal sensor modifications, new sensors addition, service modifications, etc.). Innovations in equipment should be integrated quickly and easily by using well defined interfaces.

Scalability: Is the property of the architecture to cope with a large number of sensors and functions and the ability to compensate for a greater data load by using distributed resources to return the most beneficial information according to the related service request.

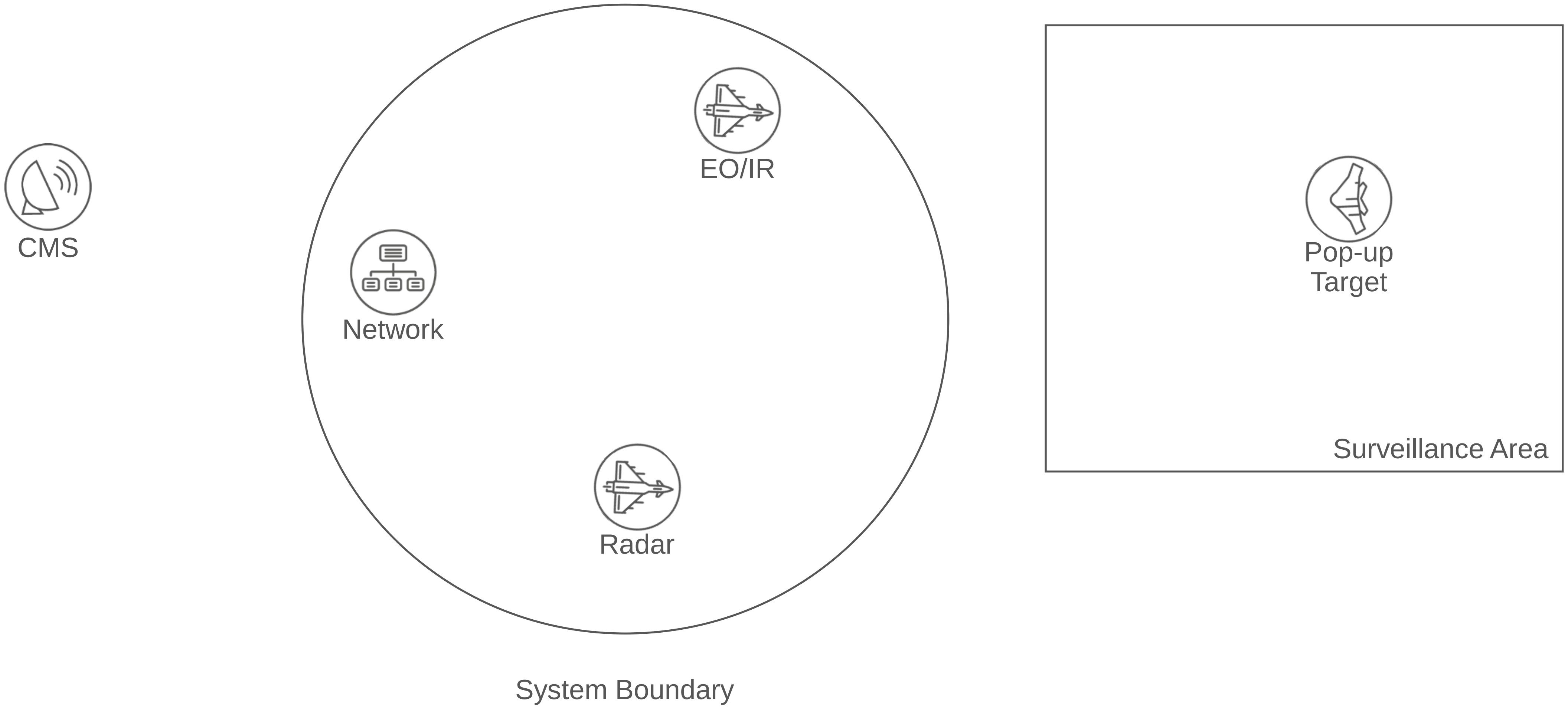
Resilience: The architecture should be adaptable to unexpected events, failures, or communications issues (e.g. jamming, etc.) by re-scheduling tasks, resources and services if necessary.



Use Case Example

Application Example/Use Case

Exemplary Scenario Elements (Logical View)

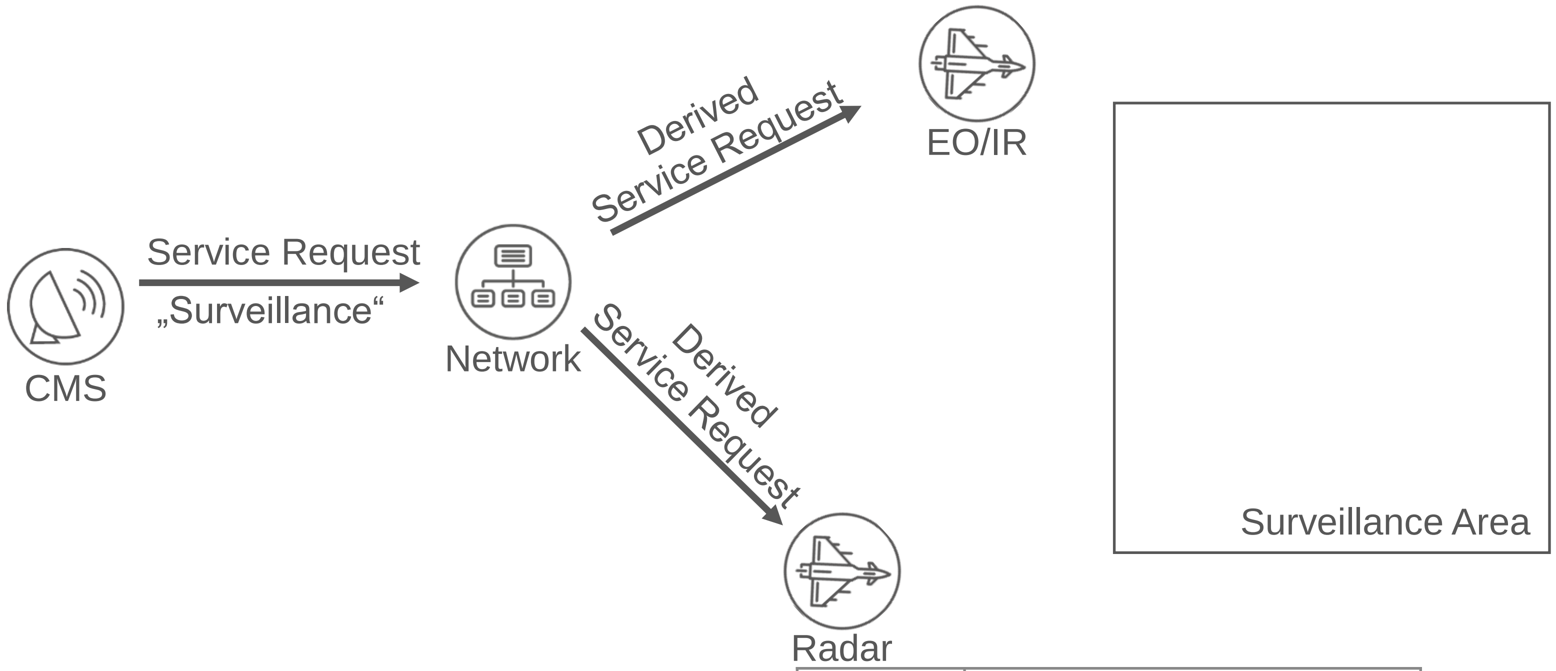


Application Example/Use Case

Step 1: Service Request “Surveillance” is Received

1. Service request from CMS is received on network level
2. Derived service requests are distributed to the platforms and sensors
3. Technical tasks are generated on sensor level:
   T1: scan the area/volume
   T2: guide targets
   T3: classify targets
4. As service quality requirements are fulfilled, sensor managers reduce the priority of Task 1 to Low

T1	**Prio L, Active**
T2	Prio M, Inactive
T3	Prio M, Inactive

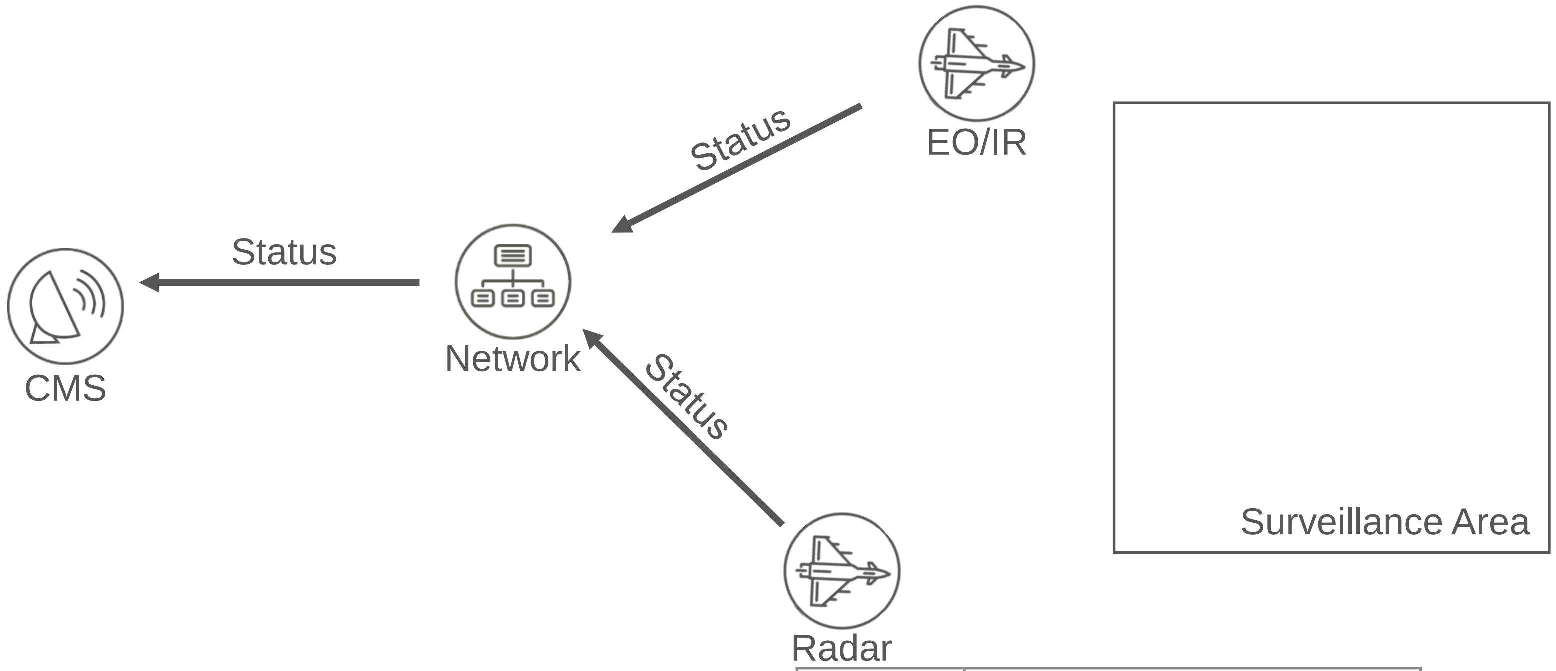


T1	**Prio L, Active**
T2	Prio M, Inactive
T3	Prio M, Inactive

Application Example/Use Case

Step 2: Perform “Surveillance”

1. The current status of the service execution is continuously reported to higher levels



T1	Prio L, Active
T2	Prio M, Inactive
T3	Prio M, Inactive

T1	Prio L, Active
T2	Prio M, Inactive
T3	Prio M, Inactive

Application Example/Use Case

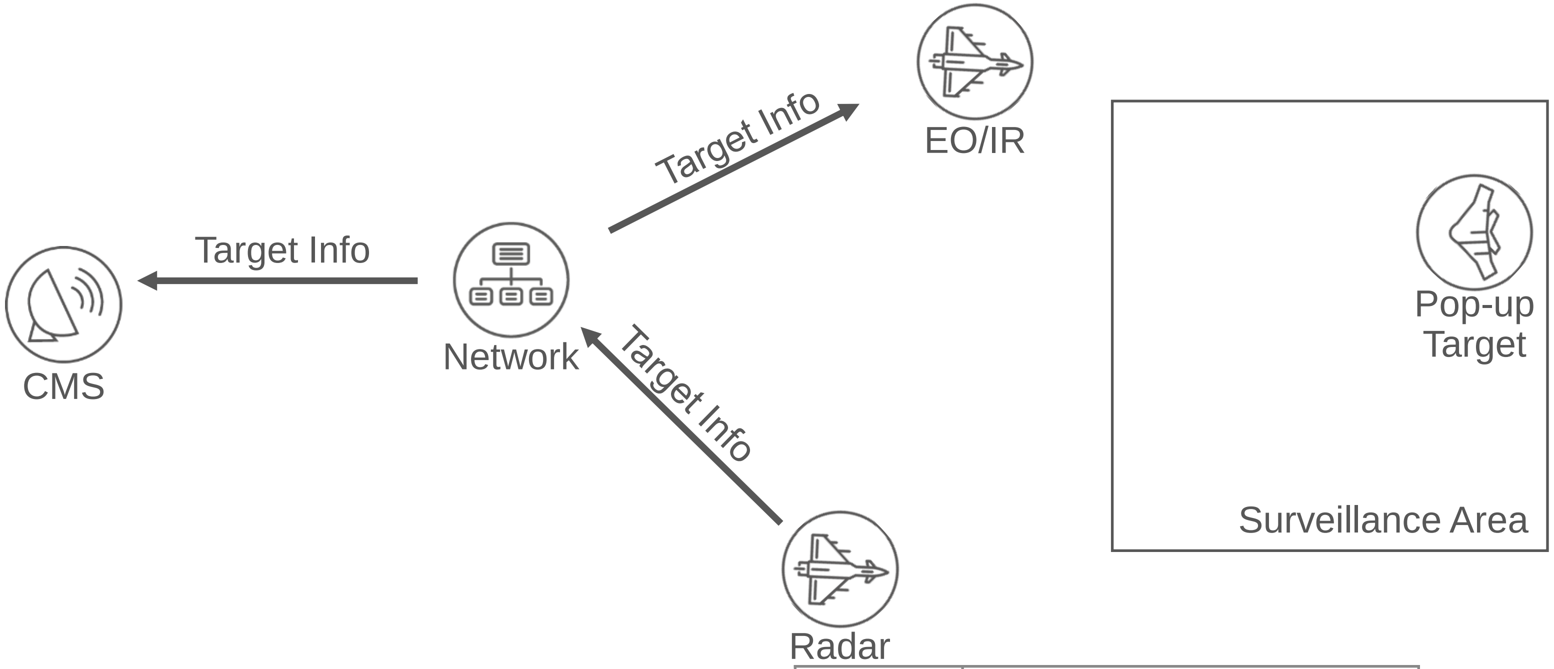
Step 3: Pop-up Target is Detected by Radar

1. The target is detected and reported by radar Target related tasks are activated for the radar based on local decision

2. The target information is distributed to the EO/IR platform/sensor

3. Target related tasks for EO/IR are activated based on local decision

T1	**Prio L, Active**
T2	**Prio M, Active**
T3	**Prio M, Active**



T1	**Prio L, Active**
T2	**Prio M, Active**
T3	**Prio M, Active**

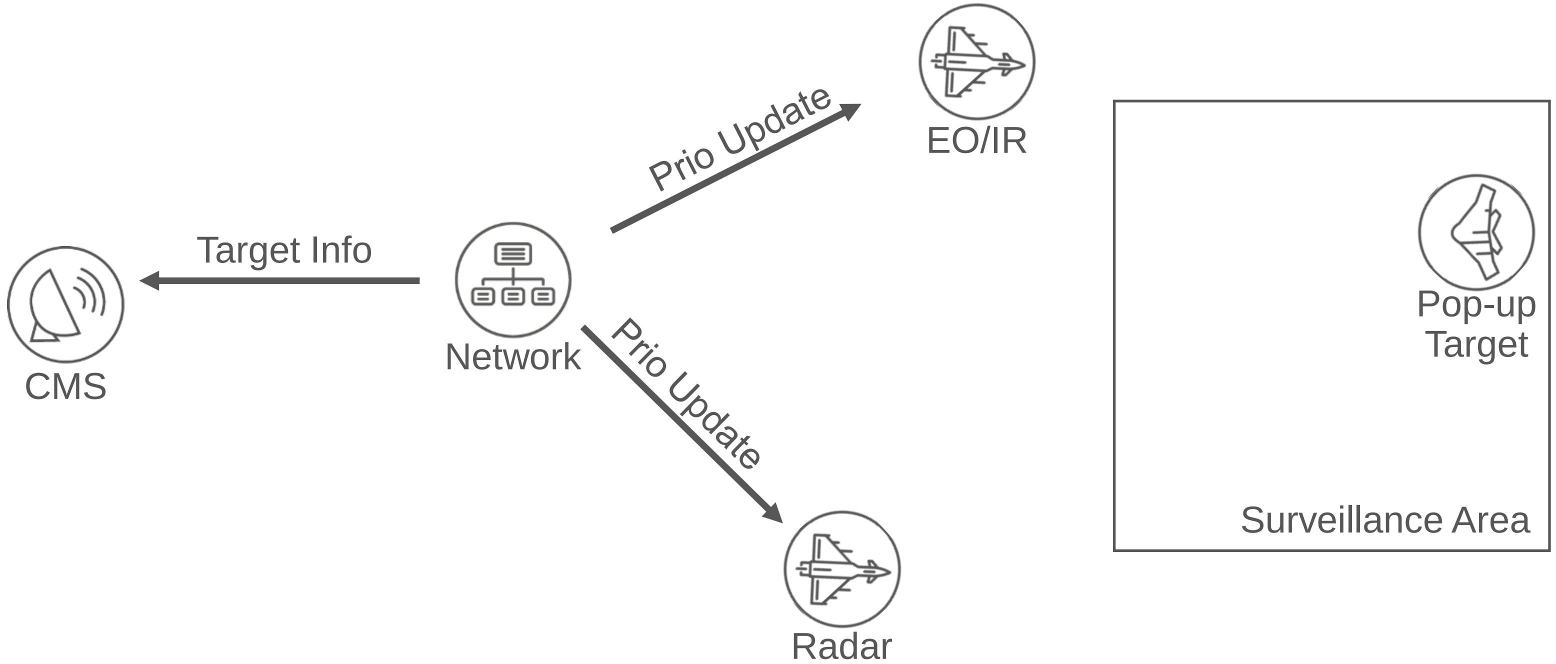
Application Example/Use Case

Step 4: Priority Update

1. Joint evaluation of classification data on network level shows quality is not achieved

2. Updated priorities for Task 3 (classify targets) and T2 (guide targets) are distributed from network level management to platforms/sensors

T1	**Prio L, Active**
T2	**Prio L, Active**
T3	**Prio H, Active**



T1	**Prio L, Active**
T2	**Prio L, Active**
T3	**Prio H, Active**

Application Example/Use Case

Step 5: Priority Update Effect

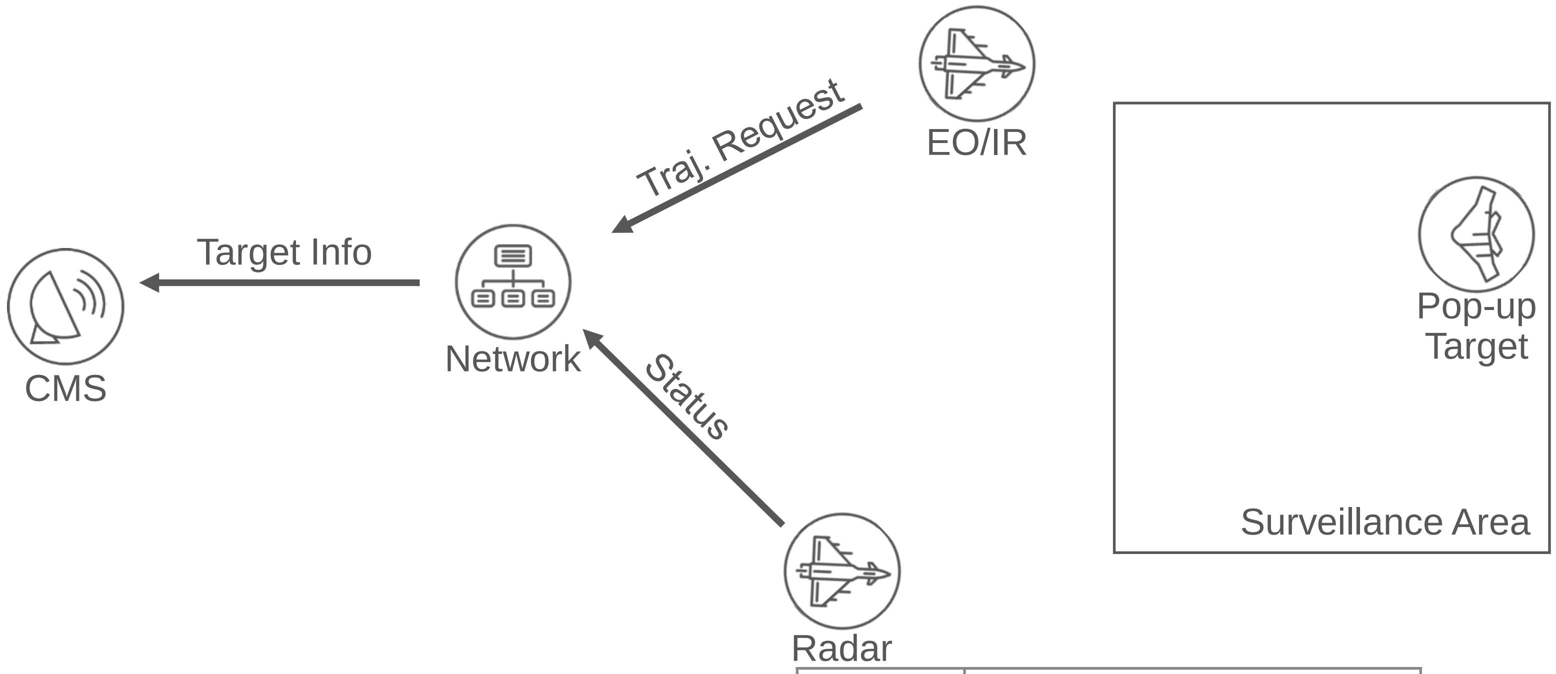
1. EO/IR sensor cannot fulfil requirements with current trajectory
   A request for a suitable trajectory is issued

2. Radar sensor cannot fulfill requirements with current mode
   A dedicated classification mode with high resource demand is selected
   T1 is temporarily deactivated to fulfill classification task

3. Trajectory request is denied on network level to wait for radar classification results

…to be continued

T1	**Prio L, Active**
T2	**Prio L, Active**
T3	**Prio H, Active**



T1	Prio L, Inactive
T2	**Prio L, Active**
T3	**Prio H, Active**

Key Technology Requirements

Technology Domain 1: Enabling Technologies

- Robust communications for data and information exchange between platforms
- Reliable, robust and precise PNT (positioning, navigation, timing), including synchronization between platforms

Technology Domain 2: Robust Single Sensor Technologies

- Sensor RM must be flexible enough to perform single sensor tasks as well as incorporating multi-sensor tasks

Technology Domain 3: Robust Distributed Decision Making, Resource Management and Data and Information Fusion

- Distributed decision making and resource management without hierarchy and single points of failure
- Integration of the different sources in a distributed manner without introducing data incest

Technology Domain 4: Robust Distributed Data and Information Processing

- Having the required data and processing power on the right platform without moving large quantities of data.

Conclusion

Conclusion

- Future scenarios and environments require the capability for quick reaction and fast adaption to changing situations
- Current single platform sensor technologies and management paradigms are not suited for these future challenges
- Emerging multi-platform sensing and EW technologies will enhance the capabilities in these scenarios
- Networking between the contributing platforms enables the optimal use of these new capabilities
- Multiple technology advances need to be made in order to fully exploit the potential of these technologies

Thank you for your kind attention!