NATO SCIENCE AND TECHNOLOGY ORGANISATION – RSM SET-262

Artificial Intelligence for Military ISR and EW Problems and Applications

Wolfgang Koch
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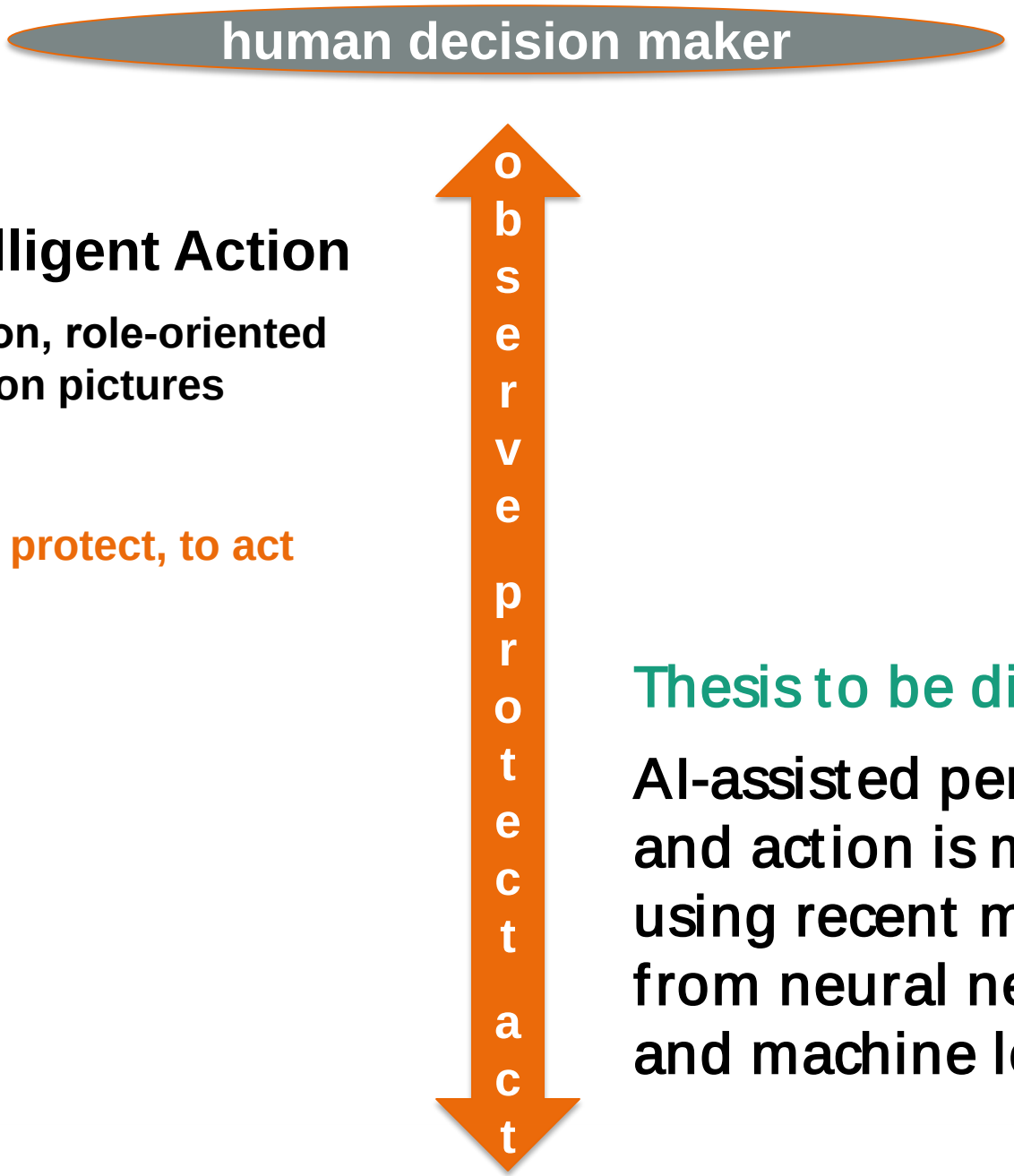
Fraunhofer FKIE



AI for Intelligent Action

→ common, role-oriented situation pictures

Prerequisite

to lead, to protect, to act

Thesis to be discussed:

AI-assisted perception and action is more than using recent methods from neural networks and machine learning!

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human decision maker

AI for Intelligent Action

→ **common, role-oriented situation pictures**

Prerequisite

to lead, to protect, to act

observe protect act

Integrating Deep Learning and Model-based Reasoning for Robust Sensor Data Fusion.
Chee Chong (USA)

AI / ML for Multi-Domain Battle.
Tien Pham (USA)

Sensemaking in Cyber Social Spaces.
Geeth de Mel (GBR)

AI Methodology and Robustness
Chair: Tien Pham (USA)

AI in Detection and Classification I
Chair: Tibor Buzási (HUN)

AI in Detection and Classification II
Chair: Chee Chong (USA)

AI for Management and Action
Chair: Geeth de Mel (GBR)

AI for Situational Understanding
Chair: Wolfgang Koch (DEU)

AI for Internet of Military Things
Chair: Roy Streit, Metron (USA)

mission, environment

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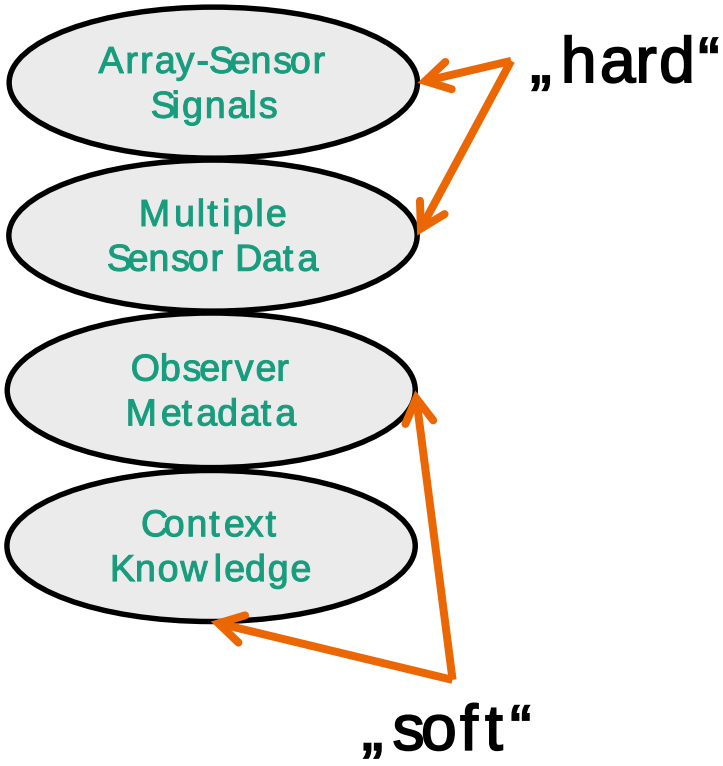
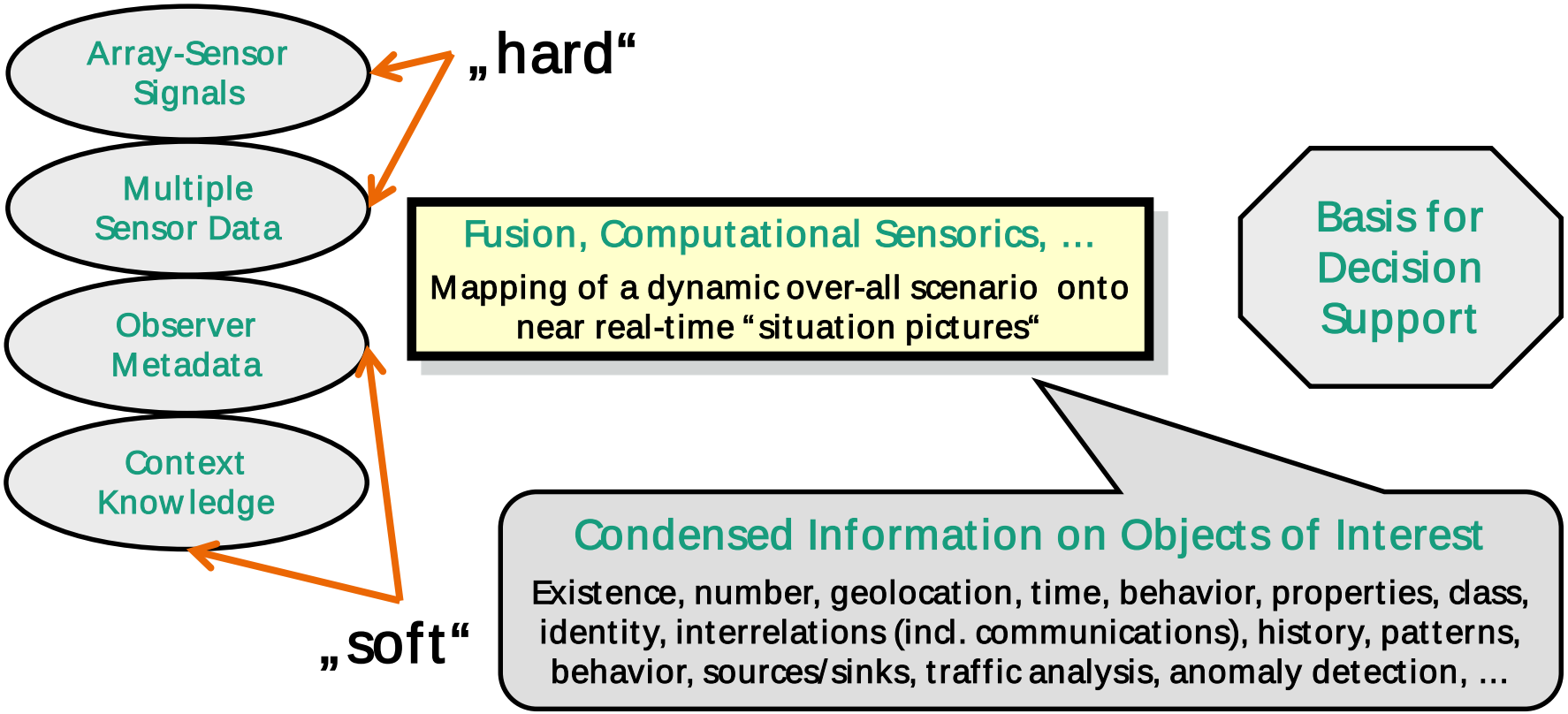
Situational Awareness for Intelligent Action



Basis for Decision Support

Data to be fused: imprecise, incomplete, ambiguous, unresolved, false, deceptive, hard-to-be-formalized, contradictory, ...

Situational Awareness for Intelligent Action



Data to be fused: imprecise, incomplete, ambiguous, unresolved, false, deceptive, hard-to-be-formalized, contradictory, ...

What is the methodological essence of *Multiple Source Data Fusion Engines?*

Learn classified tracks of multiple time-varying objects from uncertain data!

Which object properties are of interest?

Define an *object state* at varying time instants.

Which information is to be fused?

Time series of report data, context information

How to describe imprecise information?

E.g. functions of the state: pdfs, PHDs, intensities

What does "learning" from reports mean?

Iteratively calculate these functions (Bayes!)

What is required for the learning process?

Source and evolution models, data association

How to initiate/terminate object tracks?

Sequential decision making (implicitly, explicitly)

“hard” data
- physical sensors
- to be interpreted
- focus on algorithms

“soft” data
- observers, context
- directly understandable
- focus on HMI, linguistics

→ Evolution of two different research communities / mentalities

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- focus on algorithms

“soft” data
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→ Evolution of two different research communities / mentalities

- vast amounts of hard and soft data to be exploited
- enormous potential gain by fusing hard & soft data

Beware: situational awareness, understanding, only by human beings!

At least partial automation: cognitive assistance, “computational” ISR

Very general prerequisites of algorithmic processing:

Formal representation of the data

- Qualitatively
  - Which object / phenomenon?
  - Interrelation between objects
  - Strength of human reports
- Quantitatively
  - Which properties are reported?
  - Data on details, aspects
  - Strength of physical sensors

Reliability measures for the data

- Validity
  - Is it a plausible report at all?
- Accuracy
  - How good is the message?

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  - Data on details, aspects
  - Strength of physical sensors

On this level of abstraction:

no fundamental difference between "hard" and "soft" data.

Context information is crucial for "hard" and "soft" fusion equally!

Reliability measures for the data

- Validity
  - Is it a plausible report at all?
- Accuracy
  - How good is the message?

A reasonable distinction: “hard” & “soft”?

- Close-to-object-evolution data (short time-scale)
  - real-time sensor measurements (really “hard”?)
  - human observer reports (really “soft”?)
- Slowly-changing context data (long time-scale)
  - environmental context, typically determined in operation
  - partially known context, often given by statistical models
  - language-encoded context, background information

A reasonable distinction: “hard” & “soft”?

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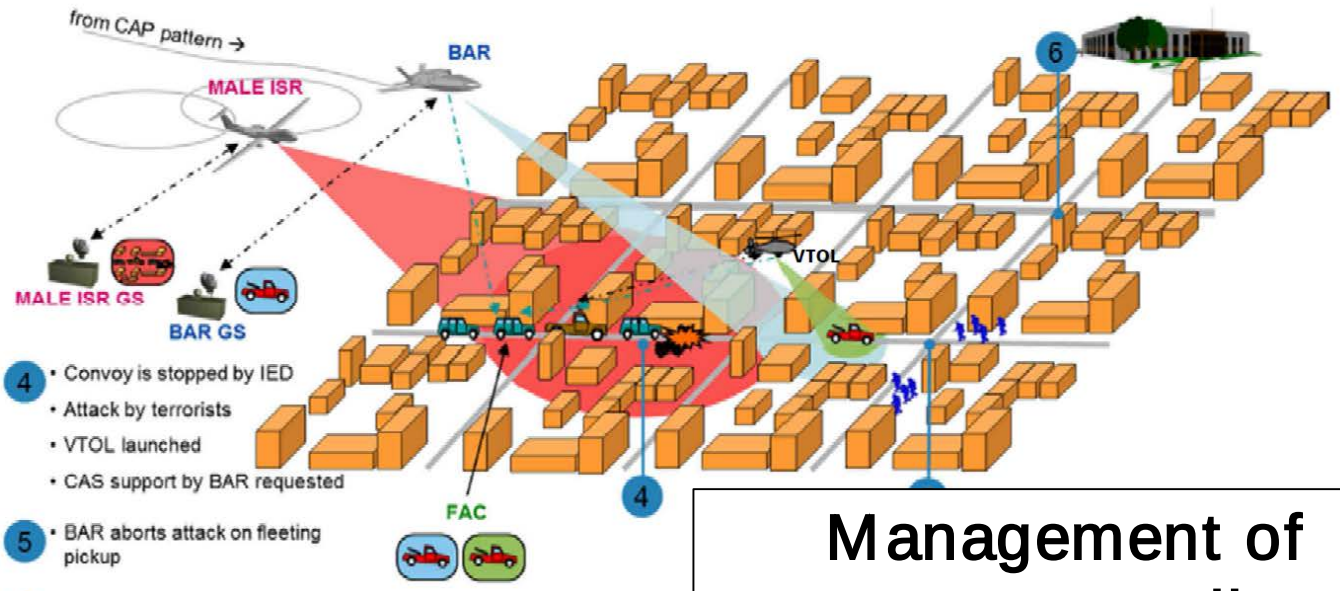
Apparently, there is “hard” and “soft” context information.

Often, the categories of context information are not isolated from each other. A sensor model, for example, combines physical and partially known context for describing an imprecise measurement with environmental context, e.g. when a clutter background has to be estimated online.

Military Convoy under attack: Urban Close Air Support

An example of Situational Awareness for Intelligent Mobility



1. Convoy leaves Camp "Pluto"
   - BAR in CAP orbit
   - ISR MALE in holding
2. Convoy requests air support with estd. arrival time at "3"
   - ISR MALE leaves Holding
3. Convoy enters urban area
   - ISR MALE joins convoy
4. Convoy is stopped by IED
   - Attack by terrorists
   - VTOL launched
   - CAS support by BAR requested
5. BAR aborts attack on fleeting pickup
6. BAR attacks and destroys fleeting pickup

Management of resources according to Rules of Engagement.

Bundesministerium der Verteidigung

Gefördert durch

A II.6

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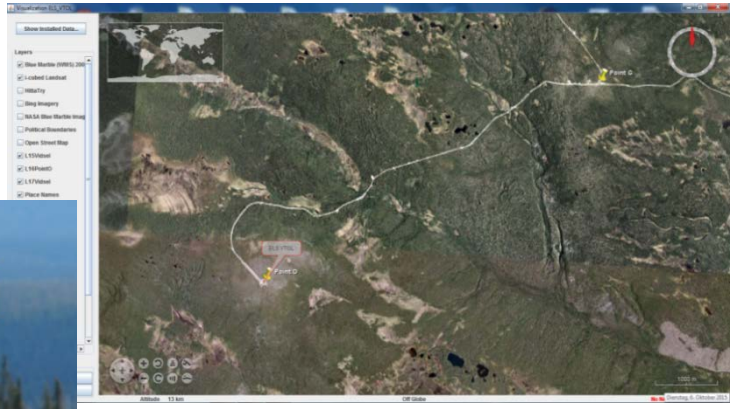
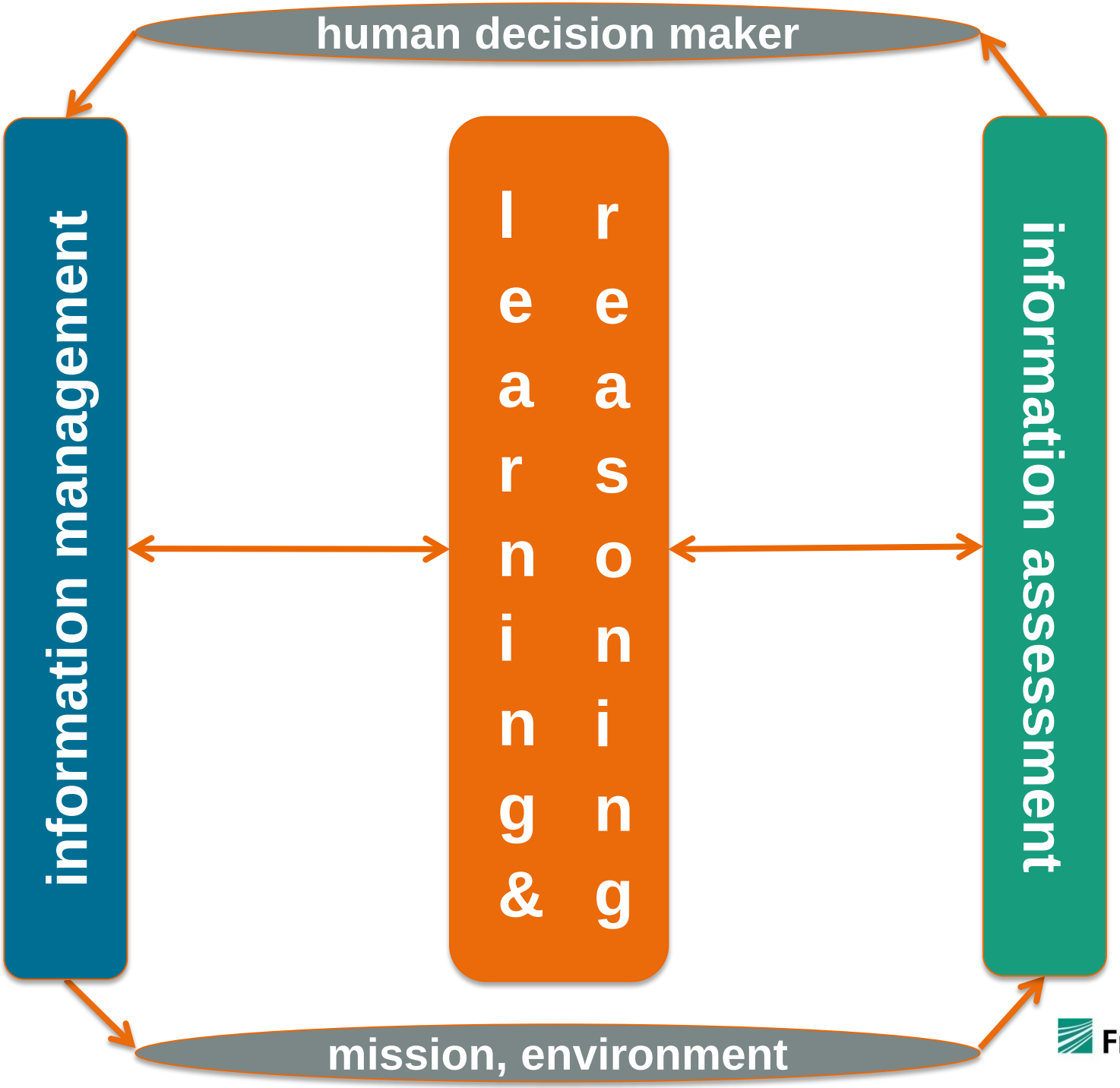
Vidsel Campaign: VTOL Sensor Payload Ground Control Station

GCS Payload DL Anten-na System

ELS Display



Video Display



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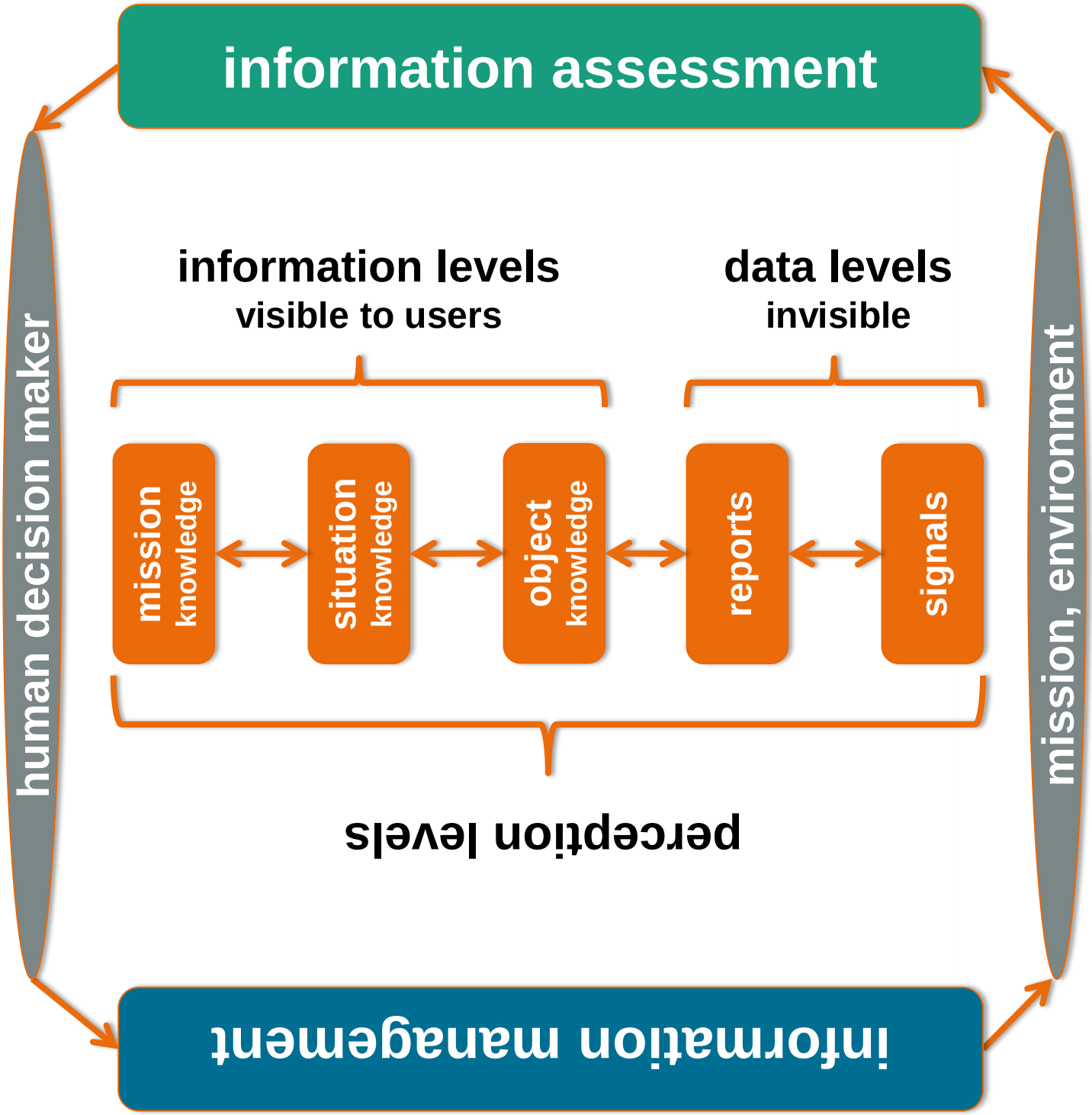
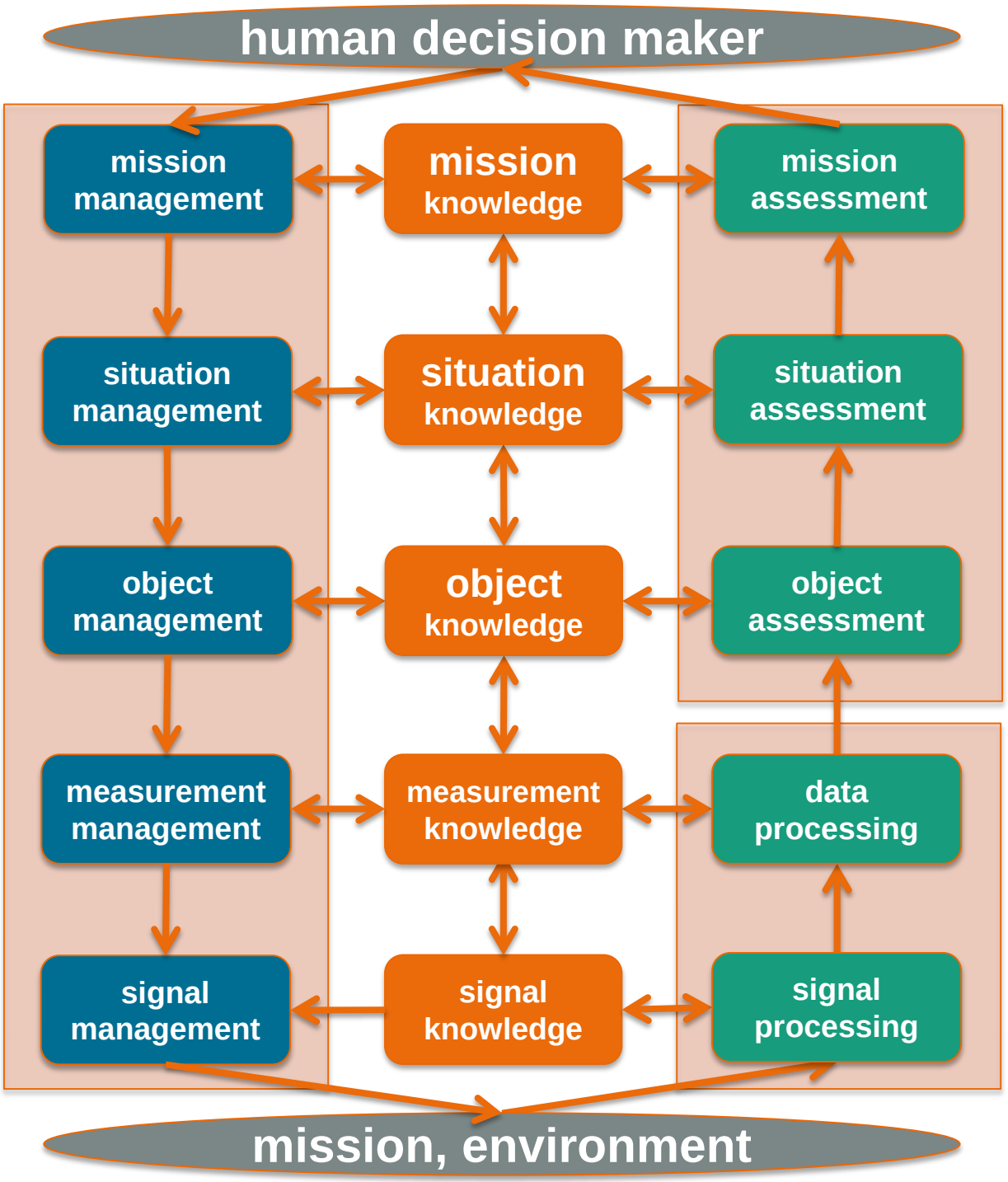

information assessment
information levels
visible to users
data levels
invisible
mission knowledge
situation knowledge
object knowledge
reports
signals
perception levels
information management
human decision maker
mission, environment



Resources Manage-ment Chain

Classical Tracking & Data Fusion

Classical Signal / Image Processing

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Paradigm *Deep Learning*

- Neuronal networks: long been known
- Boost: massive data, GPUs, tensor flow
- Correlation only: no *Tell me why?*
- Purely phenomenological approach
- Problem: prior knowledge only via data

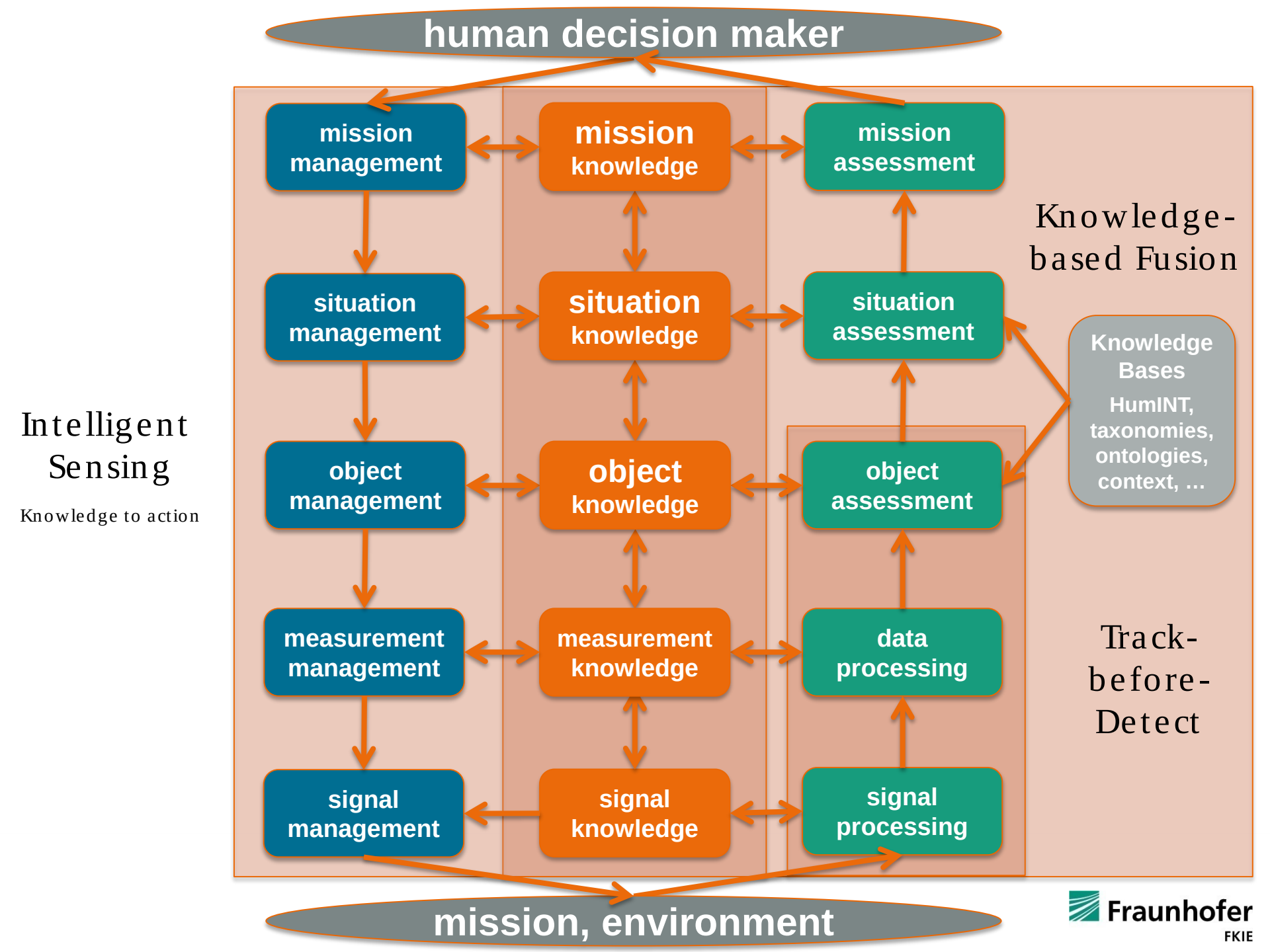
Paradigm *Bayesian Reasoning*

- Logical reasoning under uncertainty
- Probable causal chain structures
- Systematic algorithm design
- Physical, context, expert knowledge
- Not yet a "perfect" hardware

Currently under research:

Bayesian Deep Learning

- Represent uncertainty
- Use of stochastic methods
- Incorporate context data
- Probabilistic MoP, MoE
- Origins in the 1990ies
- Problems: scalable, big data


human decision maker
mission management
mission knowledge
mission assessment
situation management
situation knowledge
situation assessment
object management
object knowledge
object assessment
measurement management
measurement knowledge
data processing
signal management
signal knowledge
signal processing
Knowledge-based Fusion
Knowledge Bases
HumINT, taxonomies, ontologies, context, …
Track-before-Detect
Intelligent Sensing
Knowledge to action
mission, environment
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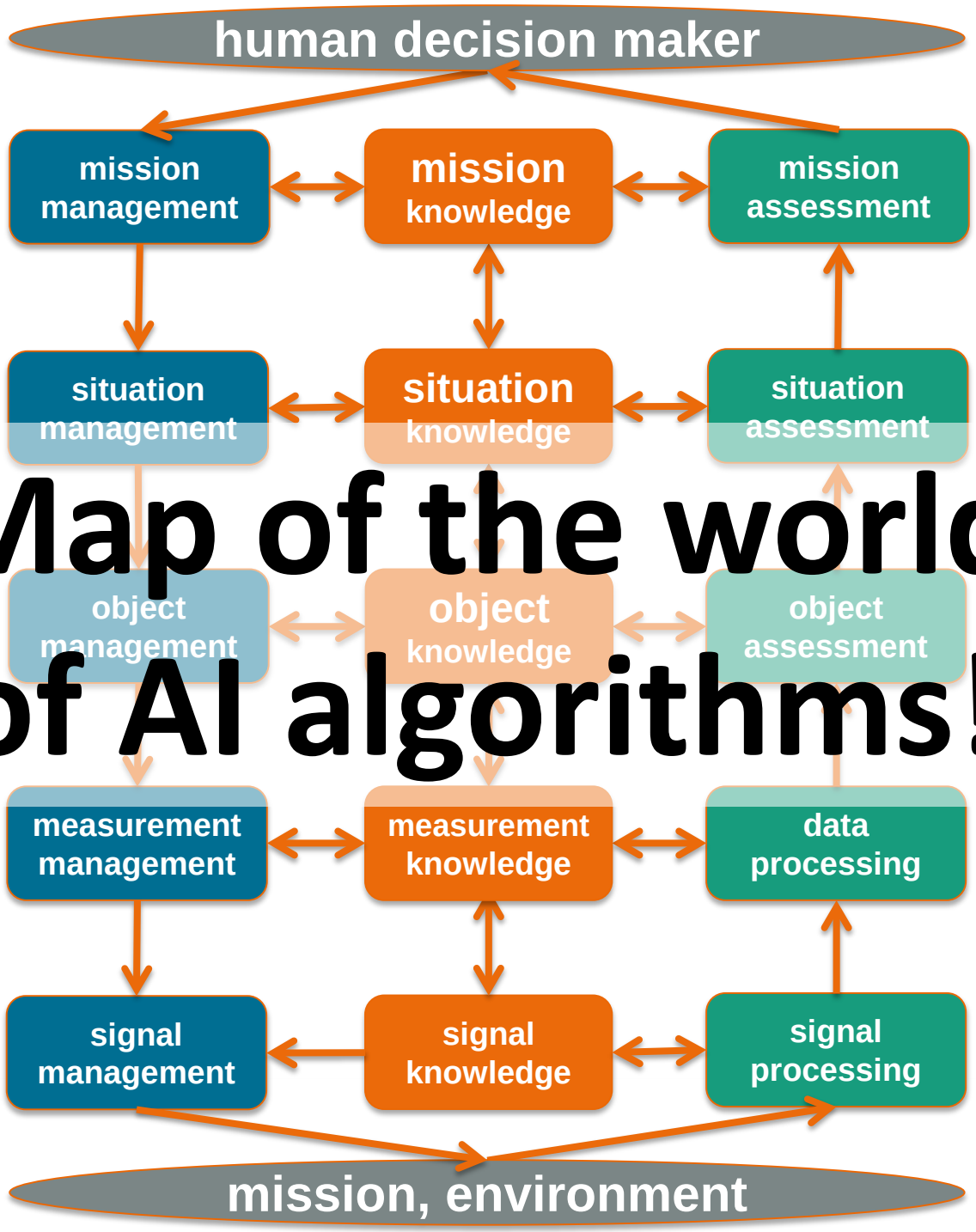

Map of the world of AI algorithms!

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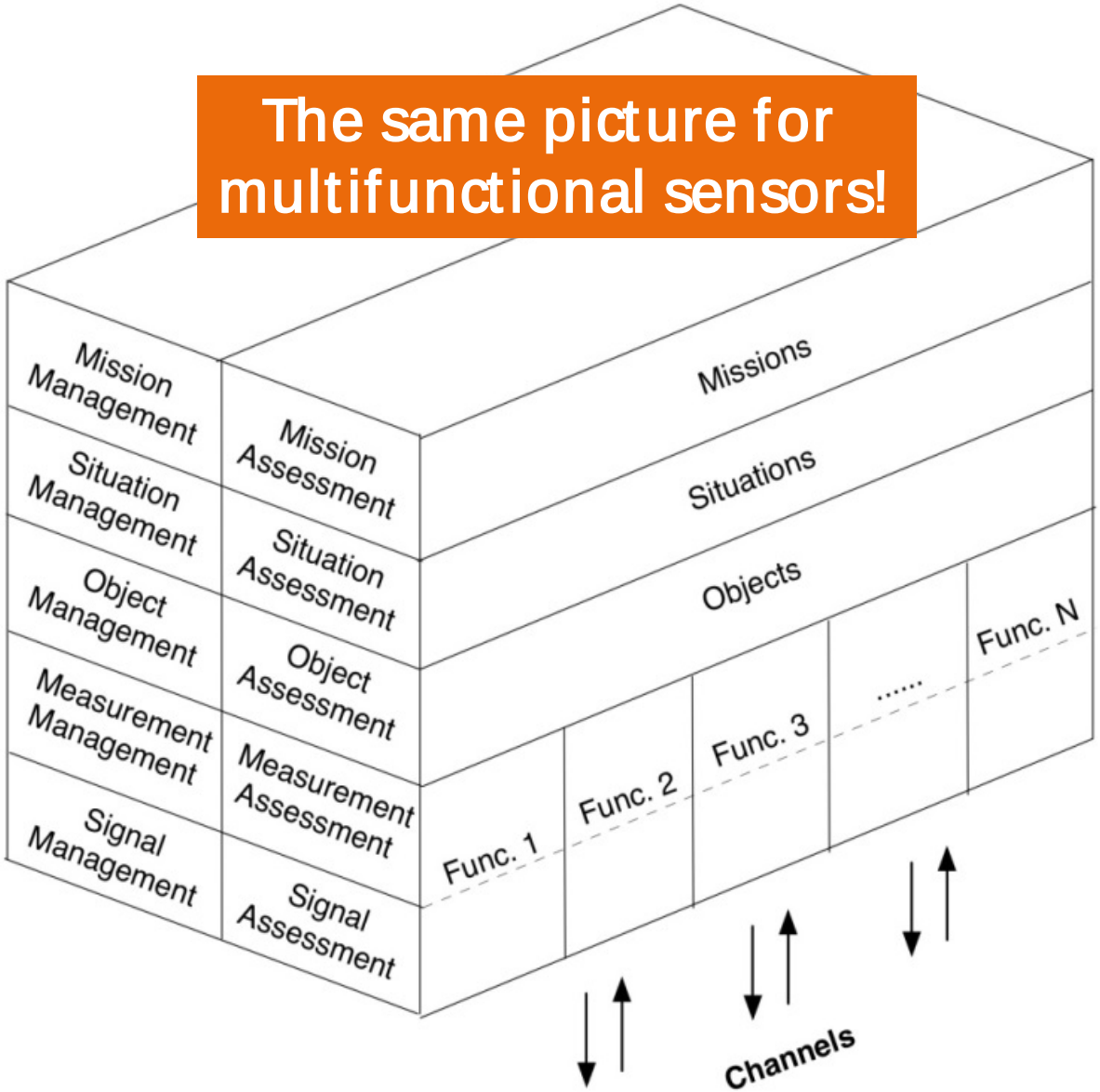
human decision maker

The same picture for multifunctional sensors!



mission, environment

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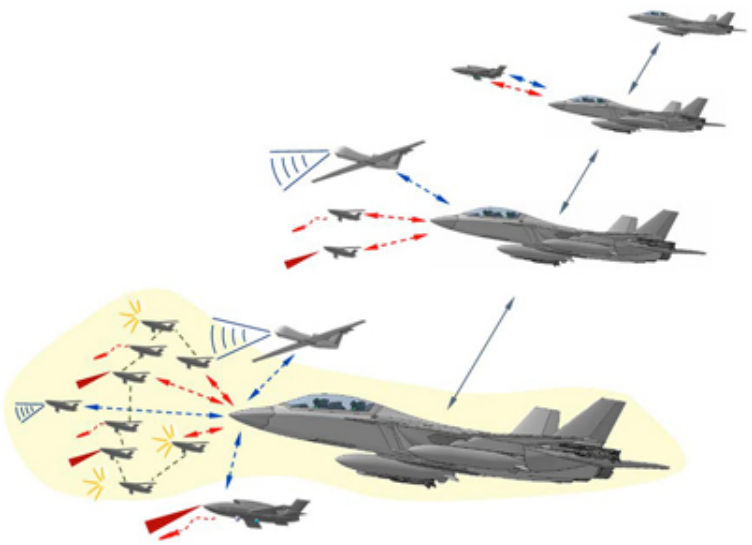
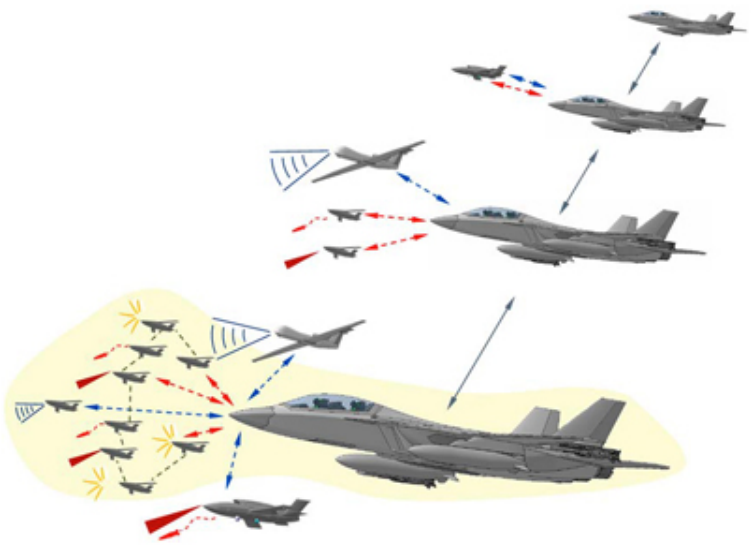


Distributed, modular, scalable actionable system of systems with UAS components

Example: UAS for self protection

not necessarily to be provided by a manned platform!

- UAS as sensor- /jammer /deception platforms
- Covert surveillance: UAS as illuminators
- Multiple aspect geometries support NCI
- Redundancy: high system survivability
- Dynamic and specific role assignment
- Reduced interference, optimized processes
- False / deceptive targets: counter targeting



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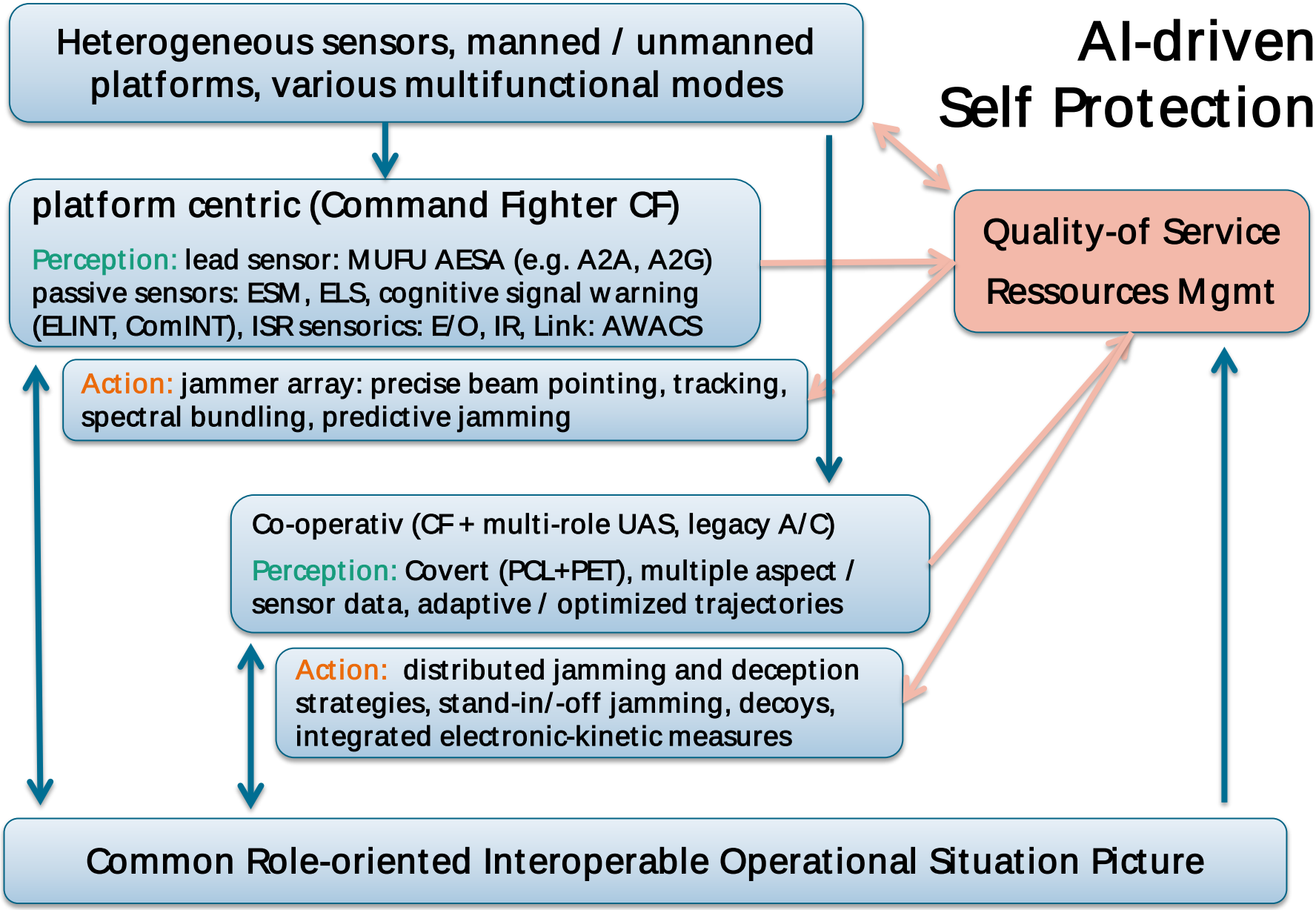
AI-enabled / AI-enhanced technlogies:

- highly efficient multisensor data fusion
- multifunctional RF sensors: AESA-enabled
- Quality-of-Service resources management
- adaptive multi-UAS trajectory optimization
- cognitive ESM sensors, predictive ECM
- interference, deception, cyber-robustness

AI-driven Self Protection



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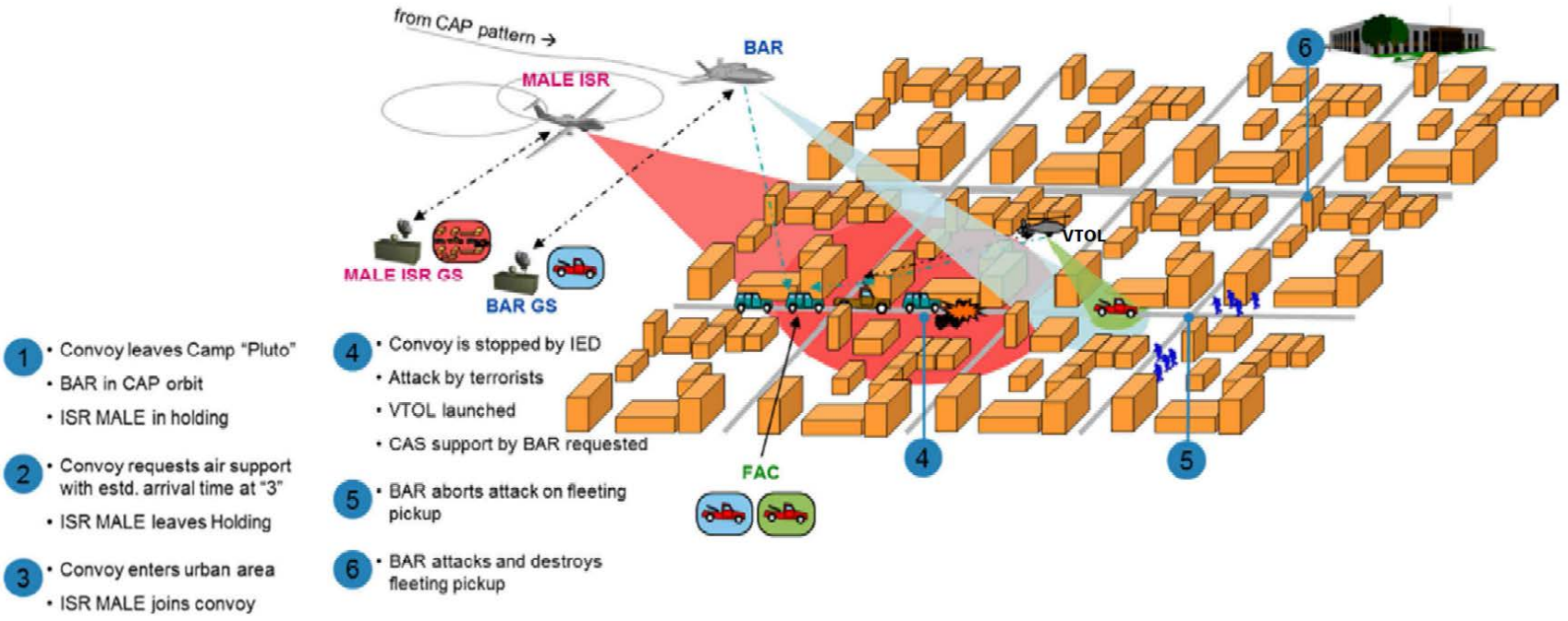
Example: Convoy under attack - Urban Close Air Support

→ directly related to controversial political discussions in Germany



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Example: Responsibly in Urban Close Air Support

Rules-of-Engagement (RoE) ***ius in bello:* mission-specific frame of action**

Discrimination: Engage only when continuously aware

- **no perception gaps, no misclassifications, ambiguities**

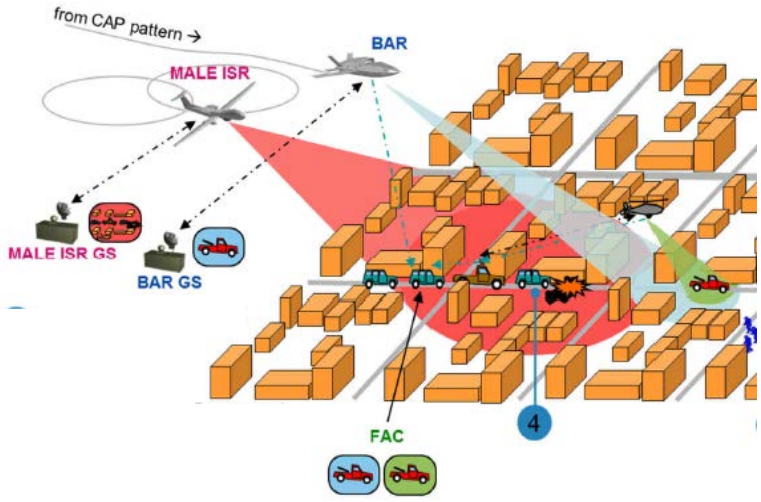
Proportionality: threat-appropriate effectors

- **urban environment: multiple sensor UAS copter**
- ***pre-engagement collateral damage prediction***

Responsibility: Forward Air Controller, documentation

Wanted: RoE Compliance by Design

Management of re-sources according to rules of engagement.



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acting human beings

perceive achieve

A fundamental ethical notion: responsibility

Literal meaning: Being requested to respond to questions on the effects of own actions at court.

First associations:

What is the duty, who is judging and accusing according to which law?

What about resulting praise or punishment?

Elements of thought:

Only free beings can take over any responsibility:

Readiness of interior acceptance of rules / laws.

Behaving well also when external rules are missing or mutually conflicting.

Good: Overarching notion?

“In the end, everybody is alone with his freedom …”

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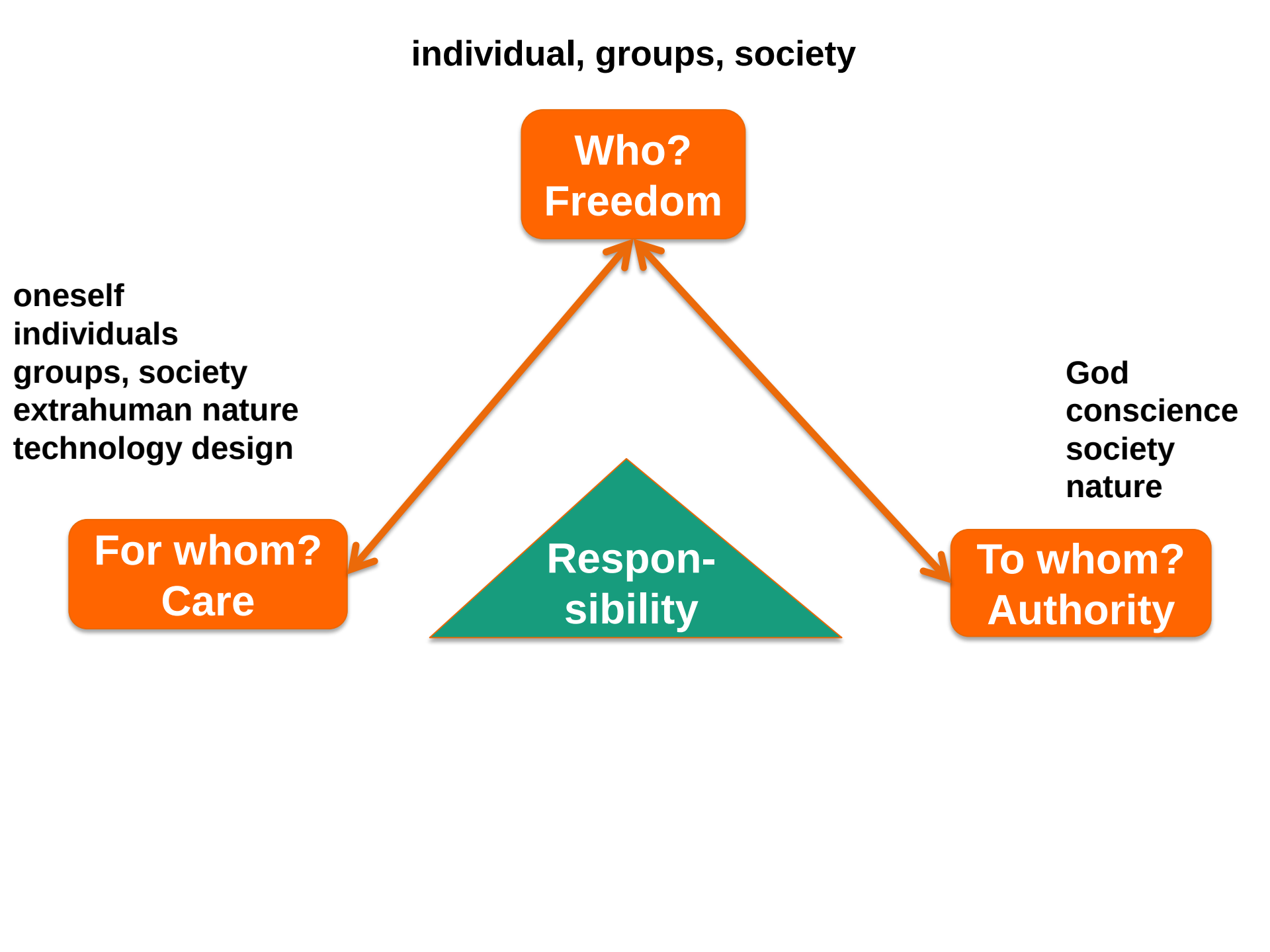
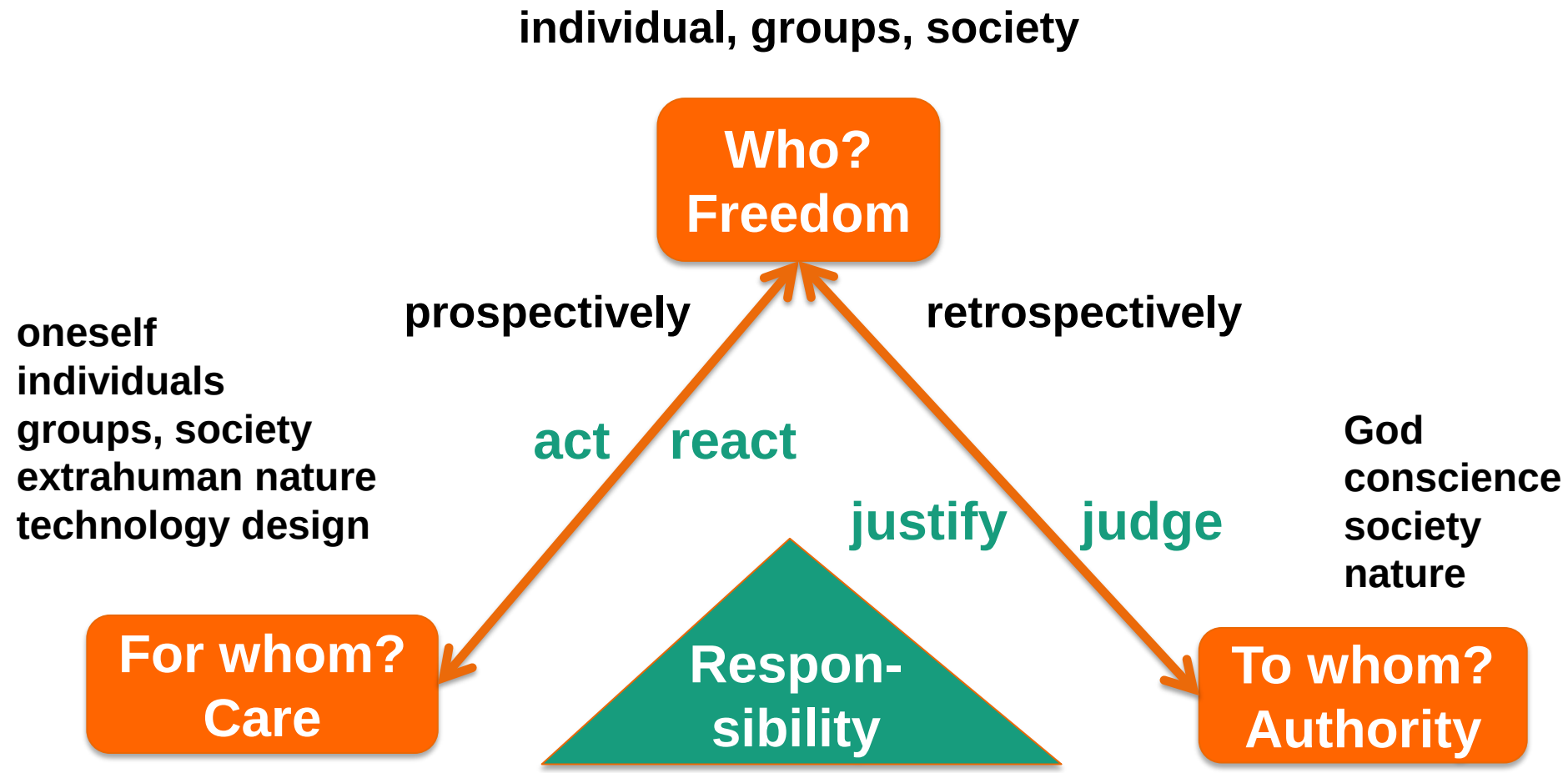
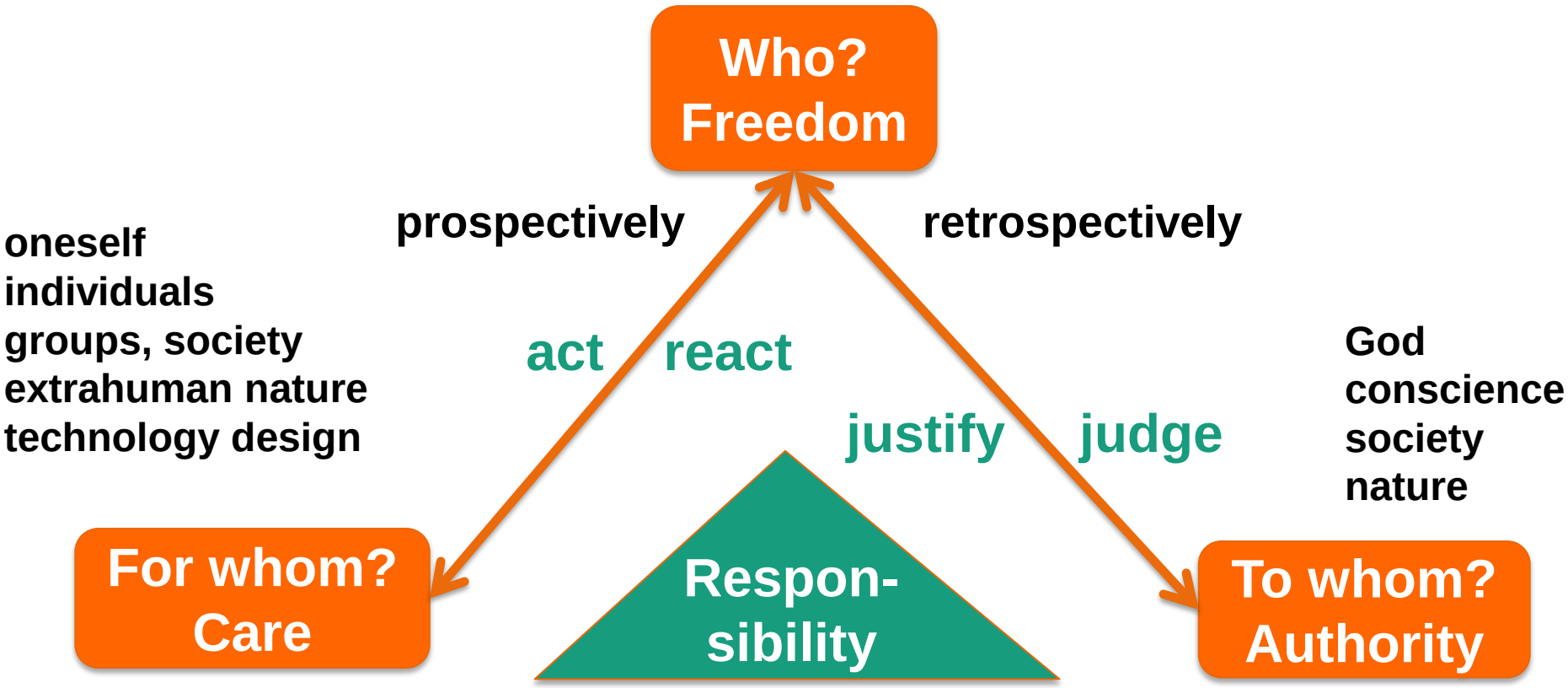

individual, groups, society
Who?
Freedom
oneself
individuals
groups, society
extrahuman nature
technology design
God
conscience
society
nature
For whom?
Care
Respon-
sibility
To whom?
Authority


individual, groups, society
Who?
Freedom
prospectively
retrospectively
oneself
individuals
groups, society
extrahuman nature
technology design
act
react
justify
judge
God
conscience
society
nature
For whom?
Care
Respon-
sibility
To whom?
Authority

individual, groups, society

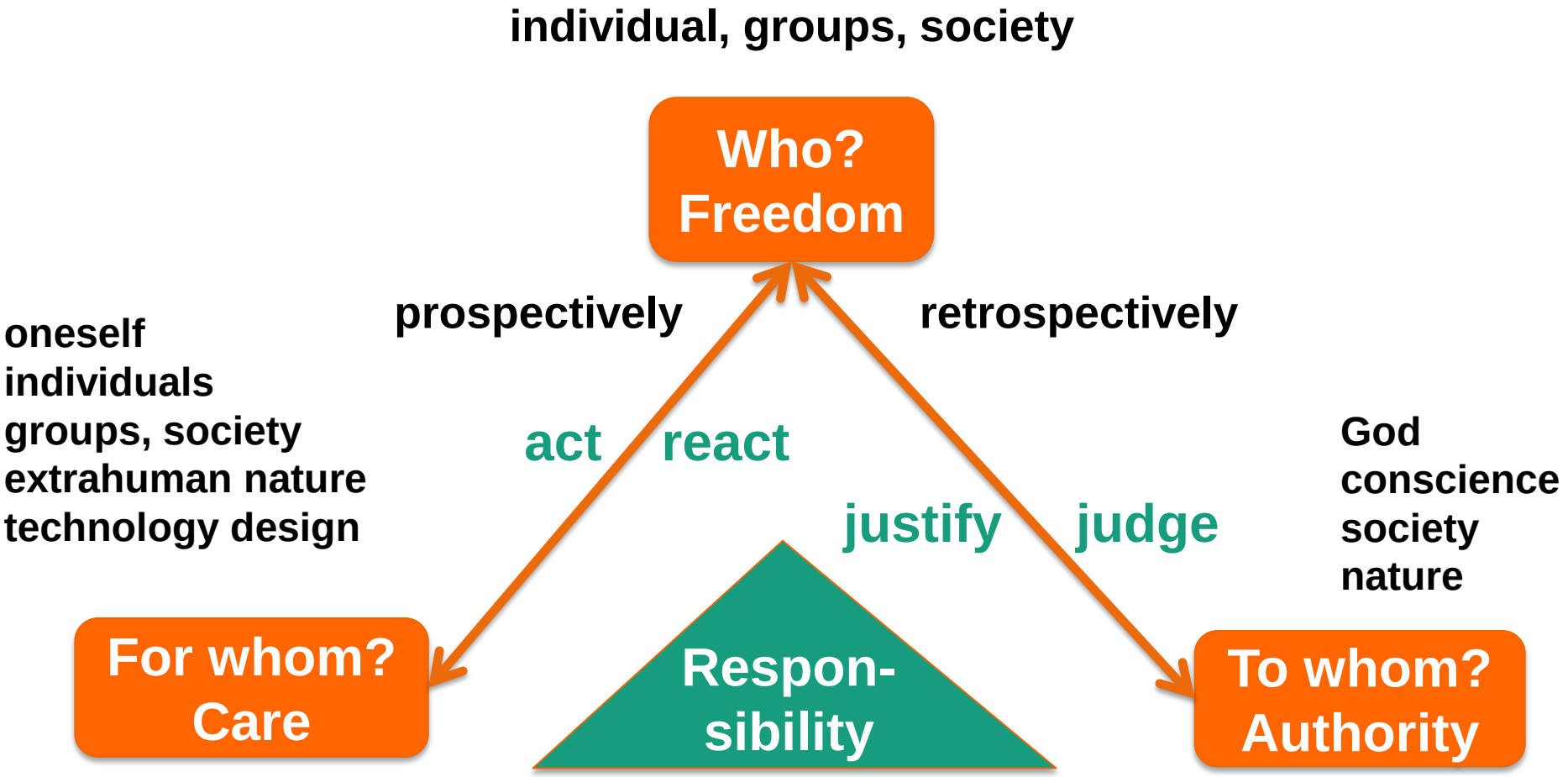


Notions of keeping a society balanced: Responsibility versus Liability:

elements of insight, personal commitment, comprehensive care

Insight, freedom, self-reflectivity, dialog, merit / guilt, carelessness:

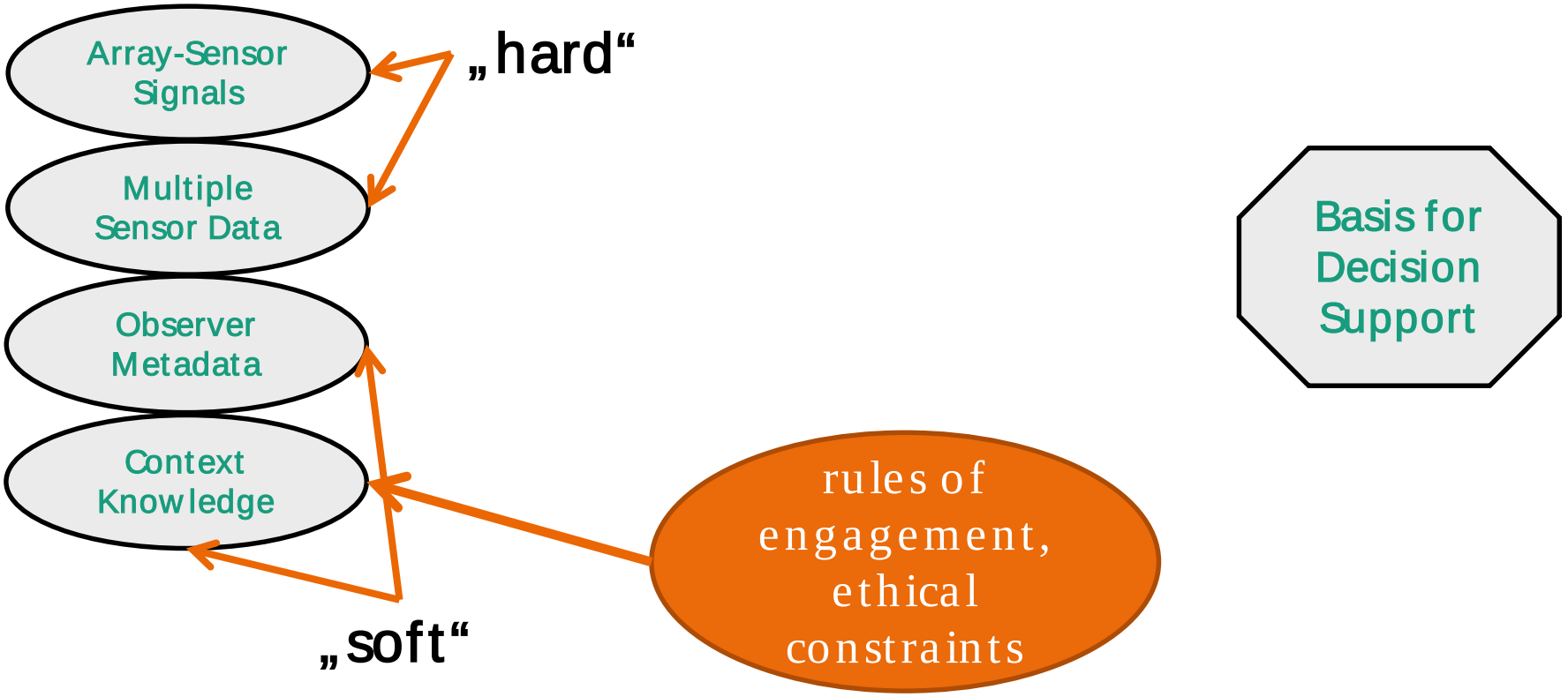
Only human are capable of acting responsibly / irresponsibly.



Design principle for *Cognitive Systems Engineering*?

AI-assisted awareness may encourage responsible action.
Cognitive may present ethically acceptable options of action.
Required: plausibility check of the situation and the options.
“artificially intelligent” evaluation of data integrity, artefakts.

Sensor Data Fusion: Mission Statement

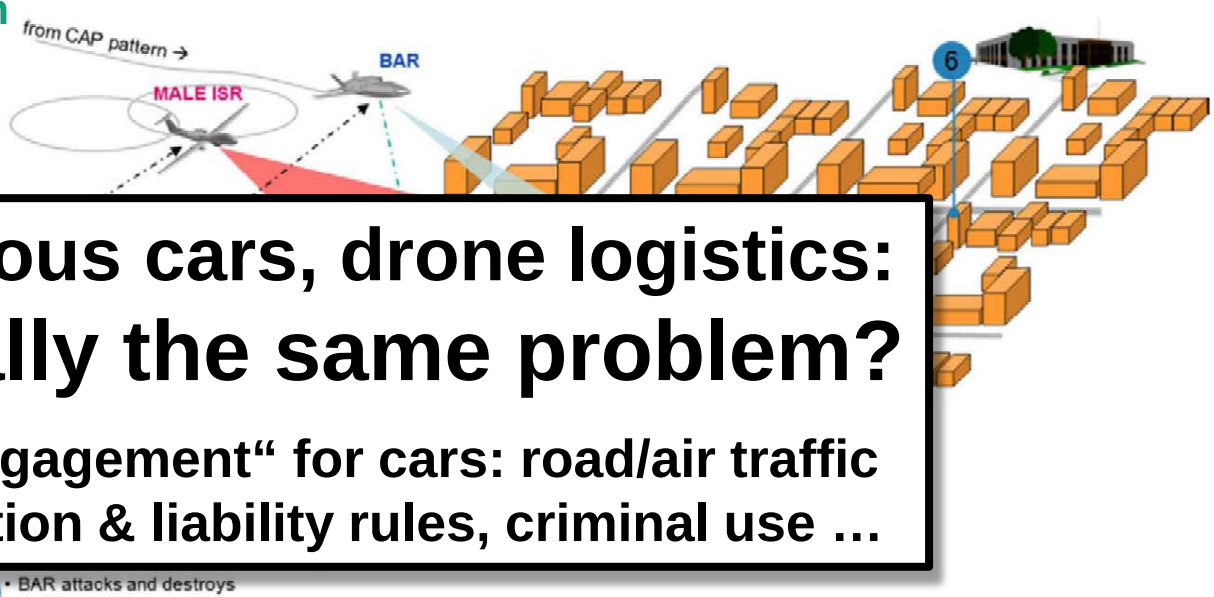


Data to be fused: imprecise, incomplete, ambiguous, unresolved, false, deceptive, hard-to-be-formalized, contradictory, ...

Urban Close Air Support (convoy under attack)

Rules of Engagement (RoE) = *ius in bello:* scenario-specific framework for actions

- **Discrimination**: engagement only when seamlessly observed without gaps
- **Proportionality**: Choose weapons that adequately correspond to threat
  - Challenging in urban environments: lacking line of sight
  - UAS copter: signal and image collection, context data
  - *Pre-engagement collateral damage prediction*
- **Responsibility**: decisions made only by *Forward Air Controller* – Situation picture
- Future systems: *RoE Compliance by Design*
- **Mission Documentation**
  - Transparency
  - Legal conformity



Autonomous cars, drone logistics:
Essentially the same problem?

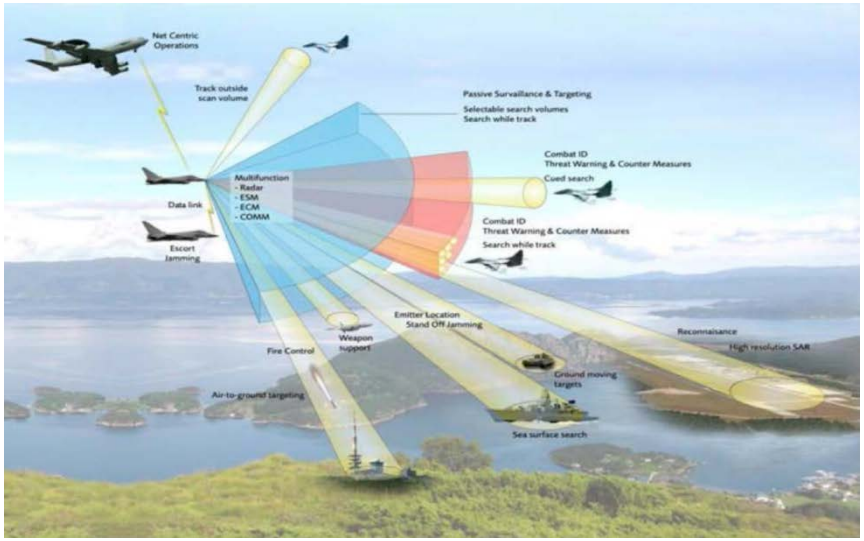
"Rules of Engagement" for cars: road/air traffic act, certification & liability rules, criminal use …

AI-enabled assistance systems versus autonomously operating systems:

- **Human being must be in control of action: only he or she is capable of responsibility.**
- **Assistance systems: Enable human action-ability even in highly challenging situations.**

Example:

Massive need for assistance whenever multifunctional multiple sensors on multiple platforms are to be used.



HENSOLDT
Detect and Protect

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AI-enabled assistance systems versus autonomously operating systems:

Simpler, faster, more precisely, comprehensively, reliably, persistently, risklessly …

- **Command, guide, act, protect oneself / others**
- **Plan, execute, act / react, behave responsibly.**

Strongly enhance “natural” capabilities:

- **Perception by *sensor* assistance**
- **Awareness by *cognitive* assistance**
- **Presence by *physical* assistance.**

- **Action: system design will be dominated by artificially ‘intelligent’ data exploitation in comparison to classical hardware.**
- **Individual sensors: embedded into multiple sensor systems of mutually complementary and heterogeneous sensors.**
- **Multifunctionality: predominant factor, i.e. the shared use of the same sensing hardware to achieve several specialized goals.**
- **Place emphasis on data integrity aspects! Pressing in civil application as well, comprising navigation and cyber security.**
- **Emerging Sensor Fusion Engines: “cognitive” w.r.t. scenario and mission requirements, massive external knowledge bases**
- **Situational awareness: reach the goals of military action more efficiently AND in an ethically acceptable and responsible way.**

Contact

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