Data Fusion and Resources Management

A warm welcome to the IEEE AESS / ISIF Symposium *Sensor Data Fusion – Trends, Solutions, Applications*!

University Club BONN, October 10 – 12, 2017

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Fraunhofer FKIE

Aerospace & Electronic Systems Society

- IEEE Aerospace & Electronic Systems Society (AESS) www.ieee-aess.org
- The AESS is the professional society dealing with the organization, systems engineering, design, development, integration, and operation of complex systems for space, air, ocean, or ground environments. These systems include radar, navigation, avionics, sonar, telemetry, military, automatic test, simulators, and command and control.

Teresa Pace,
AESS President

Reasons to Join AESS

- **Publications and communications** that advance knowledge and connect colleagues in the aerospace, electronics, and defense sectors, including peer-reviewed publications, a digital library of AES conferences, and regular electronic communication designed to serve members
- **AESS Professional Networking** and Mentoring Program is a new initiative started in 2017. This structured program is specifically designed to connect students and young professionals with experienced leaders in AESS fields of interest.
- **Leading international conferences** that connect members from industry, academia and research centers to share and collaborate with peers to advance knowledge and learn best practices while interacting with distinguished experts in our fields of interest.
- **Technical panels** that influence future technical advancements and worldwide standards across the 9 major technical focus areas.
- **Educational activities** that share and bring expert knowledge in our areas world wide, including distinguished lectures and tutorials
- **Collaboration opportunities with four IEEE councils** (Systems, Sensors, Biometrics, and Nanotechnology), other IEEE societies and geographic partners, including IEEE-USA, and work with student members
- **Awards and recognition** for achievements and contributions in AESS fields, publications, and conferences, including the newly established Robert T. Hill Dissertation Award.

AESS Publications

IEEE TRANSACTIONS ON AEROSPACE & ELECTRONIC SYSTEMS

Editor in Chief, Lance Kaplan

- Ranks #2 out of all aerospace engineering journals

Novel contributions with strong scientific underpinning, focusing on organization, design, development, integration of complex systems for space air, land, or sea environment

IEEE Aerospace and Electronic SYSTEMS magazine

Editor in Chief, Maria Sabrina Greco

- Informs on technology applications, research activities, state of the art, future trends and special tutorials.

IEEE AESS

AESS Conferences

Leading international conferences that connect members from industry, academia and research centers to share and collaborate with peers to advance knowledge and learn best practices while interacting with distinguished experts in our fields of interest.

- **IEEE Aerospace Conference (AeroConf)**
- **IEEE International Radar Conference**
- **IEEE AUTOTESTCON**
- **International Conference on Information Fusion (FUSION)**
- **IEEE Sensor Data Fusion – Trends, Solutions, Applications**
- **IEEE Radar Conference (RadarConf)**
- **And many more…**

DASC

IEEE AESS

AESS Conferences – cont'd

- IEEE/ION Position, Location and Navigation Symposium (PLANS)
- IEEE Metrology for Aerospace (MetroAeroSpace)
- IEEE International Carnahan Conference on Security Technology
- Integrated Communications Navigation Surveillance (ICNS)
- Inertial Sensors and Systems Symposium Gyro Technology
- And still more technically co-sponsored conferences
- Many of these conferences are in the AES Conferences Digital Library

IEEE INTERNATIONAL CARNAHAN CONFERENCE ON SECURITY TECHNOLOGY
★ ★ ★ ★ ★ 50th ANNIVERSARY ★ ★ ★ ★ ★

IEEE International Workshop on
Metrology for AeroSpace

ICNS

Inertial Sensors and Systems
Symposium Gyro Technology

IEEE AESS

AESS Technical Panels

Technical panels influence future technical advancements and worldwide standards across 9 major technical focus areas. Often they meet at AESS conferences relevant to their interests.

- Radar Systems Panel
- Aerospace Control & Guidance Systems Panel
- Space Systems Panel
- Target Tracking Systems Panel
- Gyro and Accelerometer Panel
- Aerospace Systems Integration Engineering Technical Panel
- Cyber Security Panel
- Unmanned Aerospace Vehicles Panel
- Avionics Systems Panel
- Coming soon: Navigation Panel

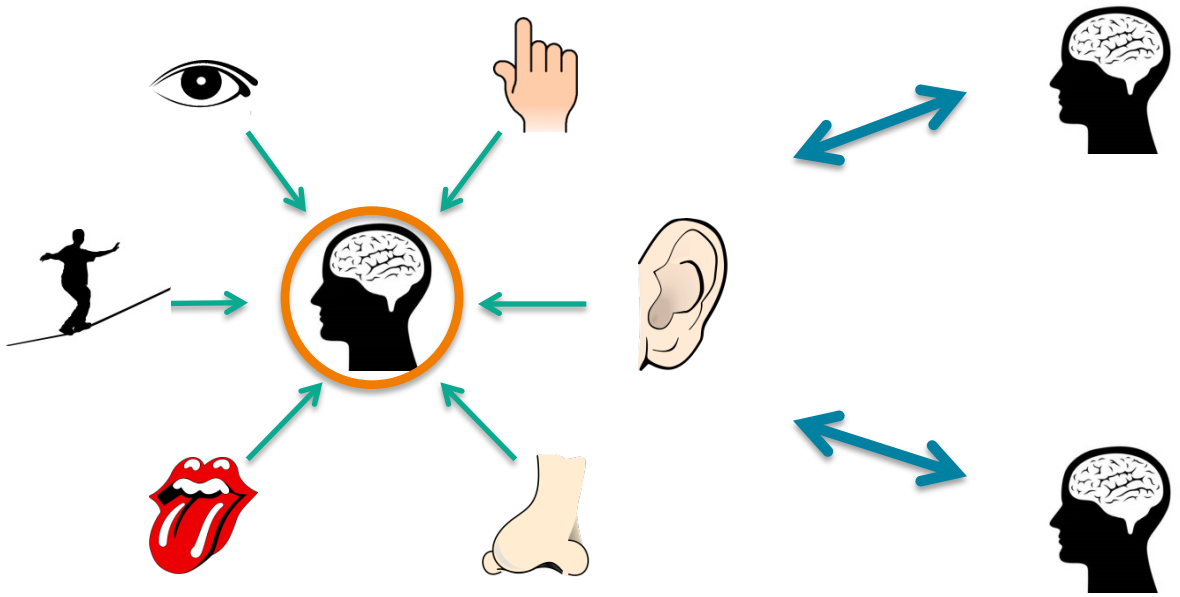
Contact **Walt Downing, AESS** VP Technical Operations (walt.downing@swri.org), Or see http://ieee-aess.org/technical-operations/home if you're interested in participating in the work of a technical panel.

Prior to any technical realization or scientific reflection,

situational awareness, evaluation options, reaching goals

is an omnipresent phenomenon.

All creatures "fuse" mutually complementary sense organs with prior information / communications: prerequisites for orientation, action, protection.



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Artificial Intelligence as a Branch of Informatics

Analyze, (at least party), automate, enhance.

Basic: heterogeneous data sources and platforms
Critical: data integrity, artefacts, blind spots, fake

→ Prerequisite of manned-unmanned teaming
→ Informational basis for acting responsibly

Artificial Intelligence with many degrees.

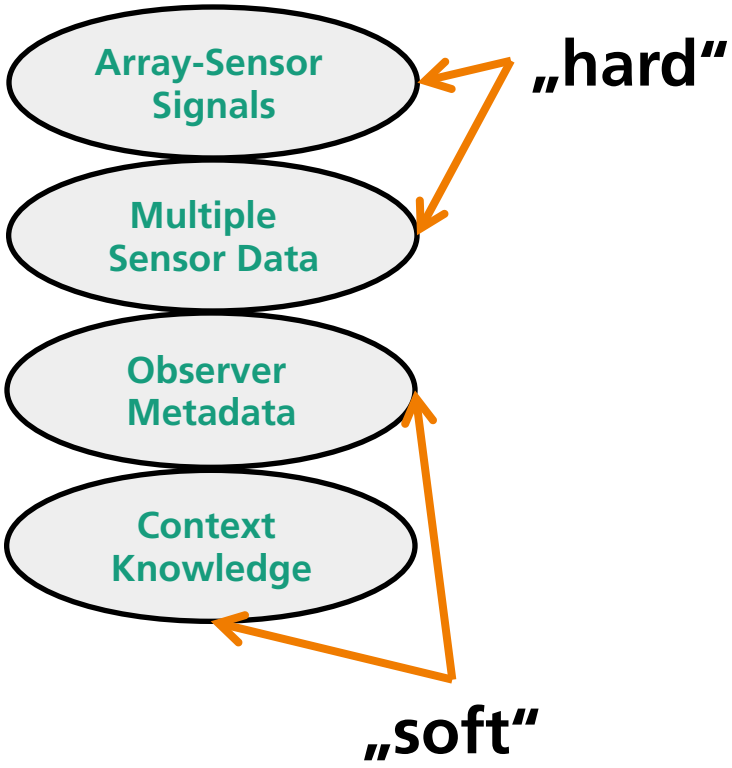
Weak AI: Automation of particular mental capabilities:

mature mathematical basis
ITC Enabling Technologies

Strong AI: "real", human-type Intelligence with consciousness and judgement – an utopic program, a myth.

Unfulfillable expectation by Hollywood movies: → disillusionment after hype

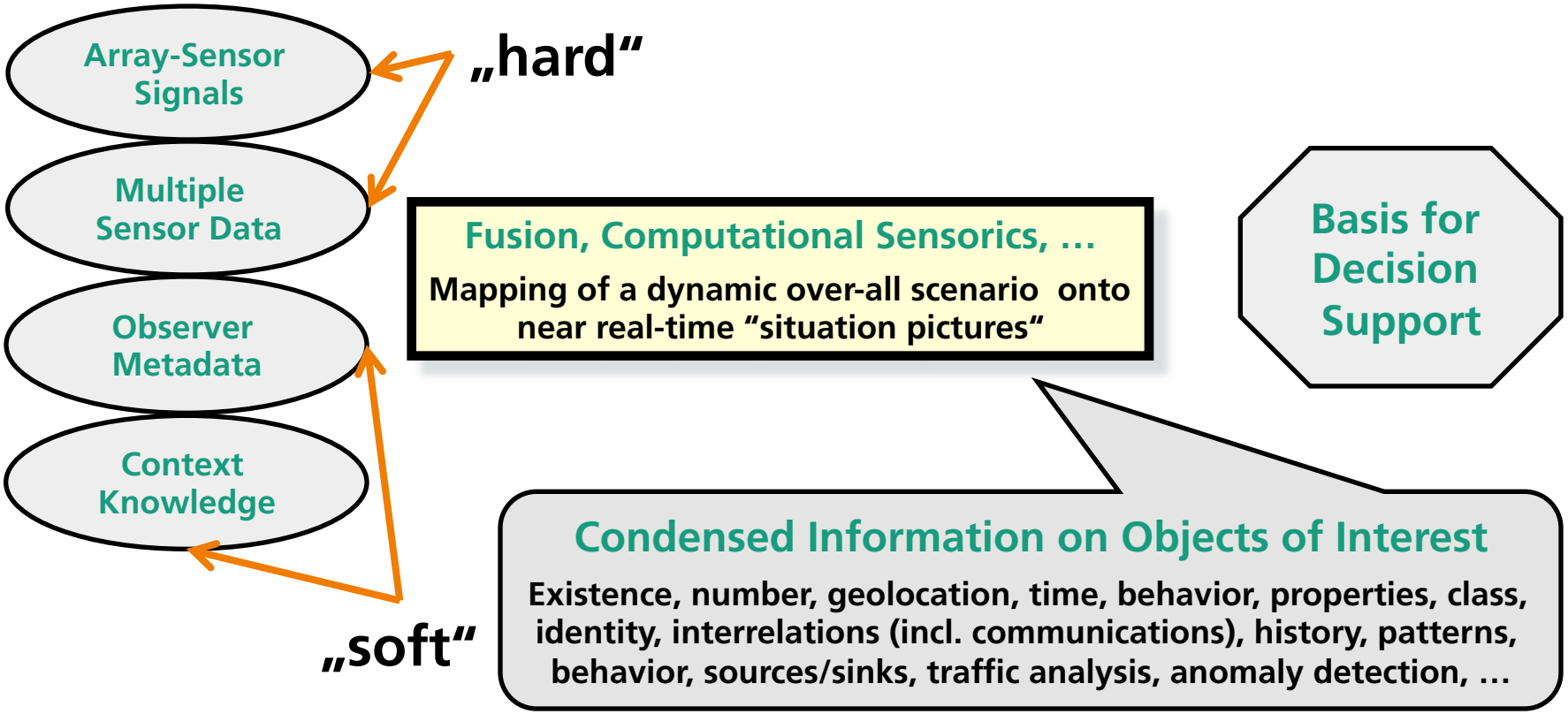
AI-assisted Systems: Mission Statement



Basis for Decision Support

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

AI-assisted Systems: Mission Statement



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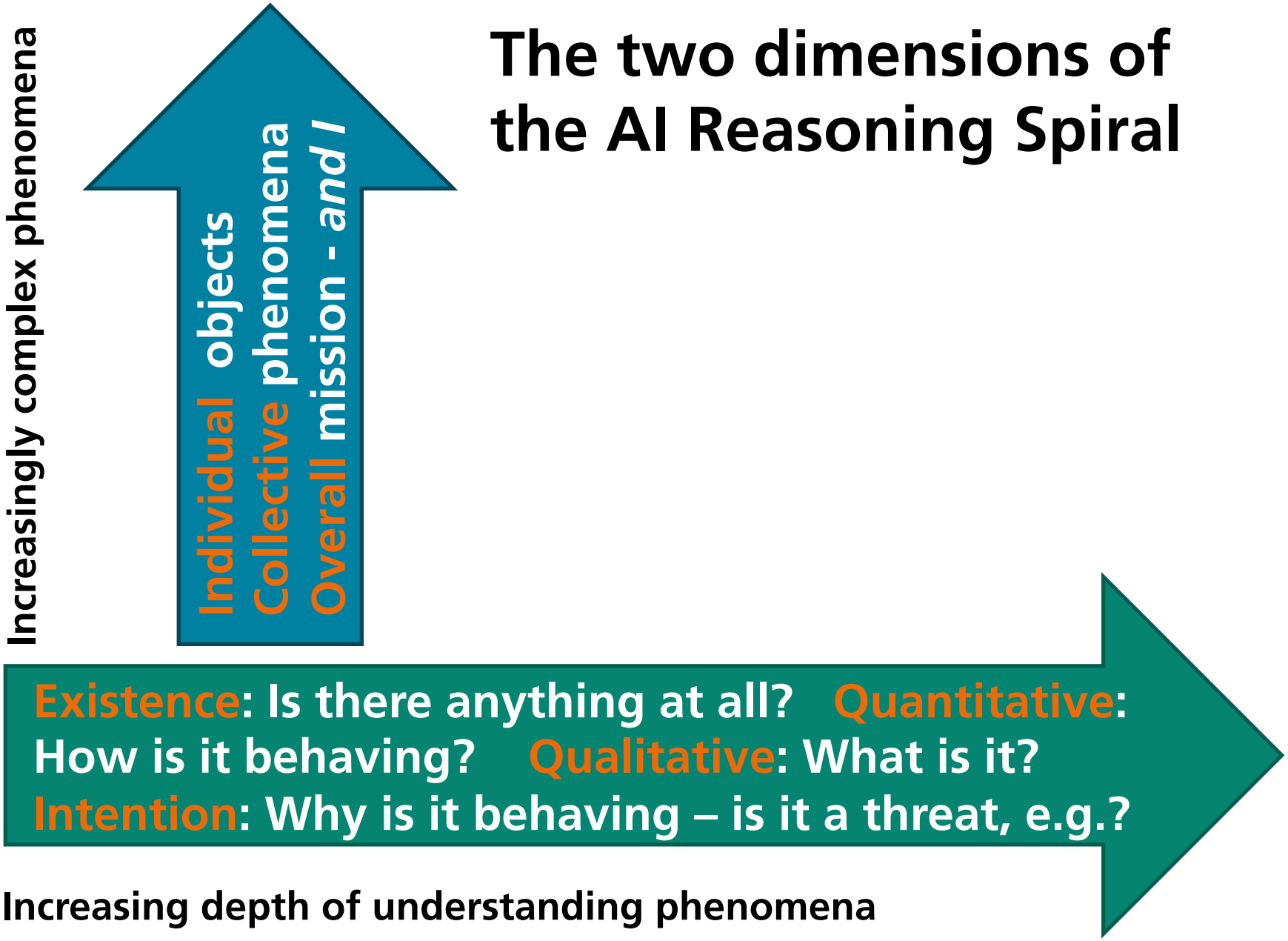
The Four Columns of Artificial Intelligence

- **Statistical Estimation**
  - Classified object states (Bayesian or machine learning)
- **Combinatorial Optimization**
  - Which measurements belong to which objects?
- **Optimal Decision Making**
  - Track initiation, cancelling, classification, anomaly detection
- **Resources Management**
  - Optimal use of sensor modes, platforms, links, …

Many fusion systems make use of these distinctions. Innovative approaches develop a unified methodology. Room for “soft” data!

The two dimensions of the AI Reasoning Spiral



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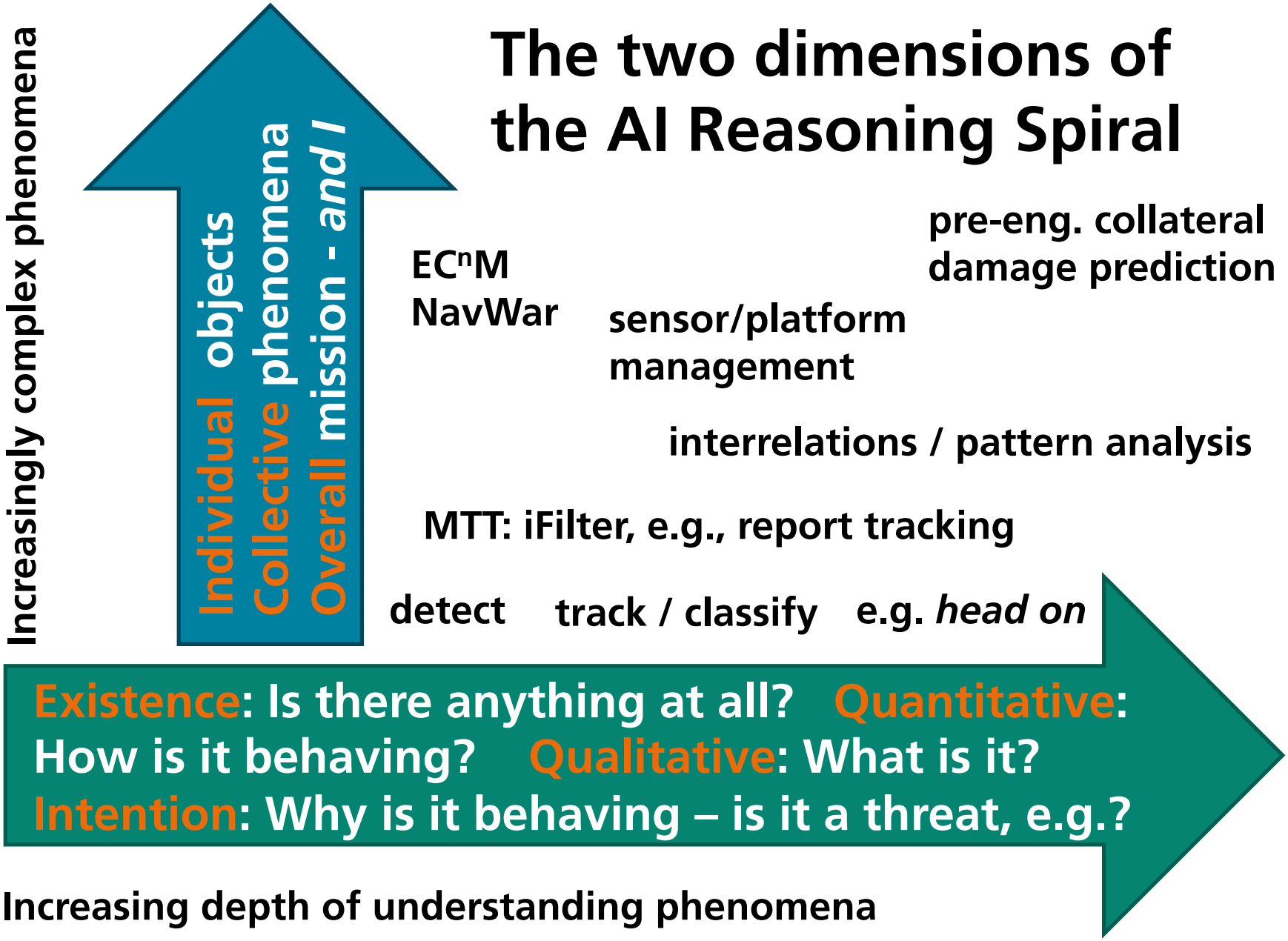
The two dimensions of the AI Reasoning Spiral



Some preliminary distinctions and relations

Hard Data
physical sensors
focus on algorithms

"hard" when formalized

often imperfect, false …

Soft Data
language encoded
Focus on HMI, linguistics

Report Data
close to evolution time
measurements
observer reports

processing prerequisite

extract, check validity

Context Data
stationary, slowly changing
sensor/target/env. models
taxonomies, ontologies

Content Data
measurements, tracks
Context information
HumINT, ontologies

processing prerequisite

content of metadata

Metadata
data on content data / comms
space-time stamps, addresses,
sources, formats, context

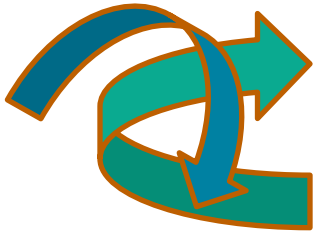
Raw Data
to be interpreted
physical signals
spoken/written

input for next level

extraction of information

Processed Data
interpretable data
measurements, target tracks
formatted observer reports

Low-level Data
signals, spoken/written text
meas., metadata, reports
classified tracks, interrelations
vignette/situation pictures



Data Fusion Spiral

High-level Data
meas., metadata, reports
classified tracks, interrelations
vignette/situation pictures
patterns, intent, anomalies

Examples for context data (representation, reliability)

Sensor context: *What and how do sensors see?* **Likelihood functions**.

Observer context: *Why not likelihood functions for observer reports?*

Geographical context: roads, constraints, visibility, signal propagation

→ **algorithmically calculated likelihood fctns** (e.g. ray tracer)

Knowledge context: *Which features can tell what about objects / phenomena* → **taxonomy-based likelihood fcts** (→ Snidaro).

Planning context: often detailed information: **motion constraints**.

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Sometimes **context information can be extracted** from sensor / report data, e.g. road map generation from ground moving target tracks.

Validity of **context information can be tested** by processing sensor / report data assuming its validity / non-validity: anomaly detection

human decision maker

AI in complex missions:

→ common, role-oriented situation pictures

Prerequisite

to lead, to protect, to act

C5JISR based on:

multifunctional sensors
mobile sensor platforms
comprehensive networking

Key role:

system-secure multiple sensor / platform / effector networks

observe protect act

mission, environment

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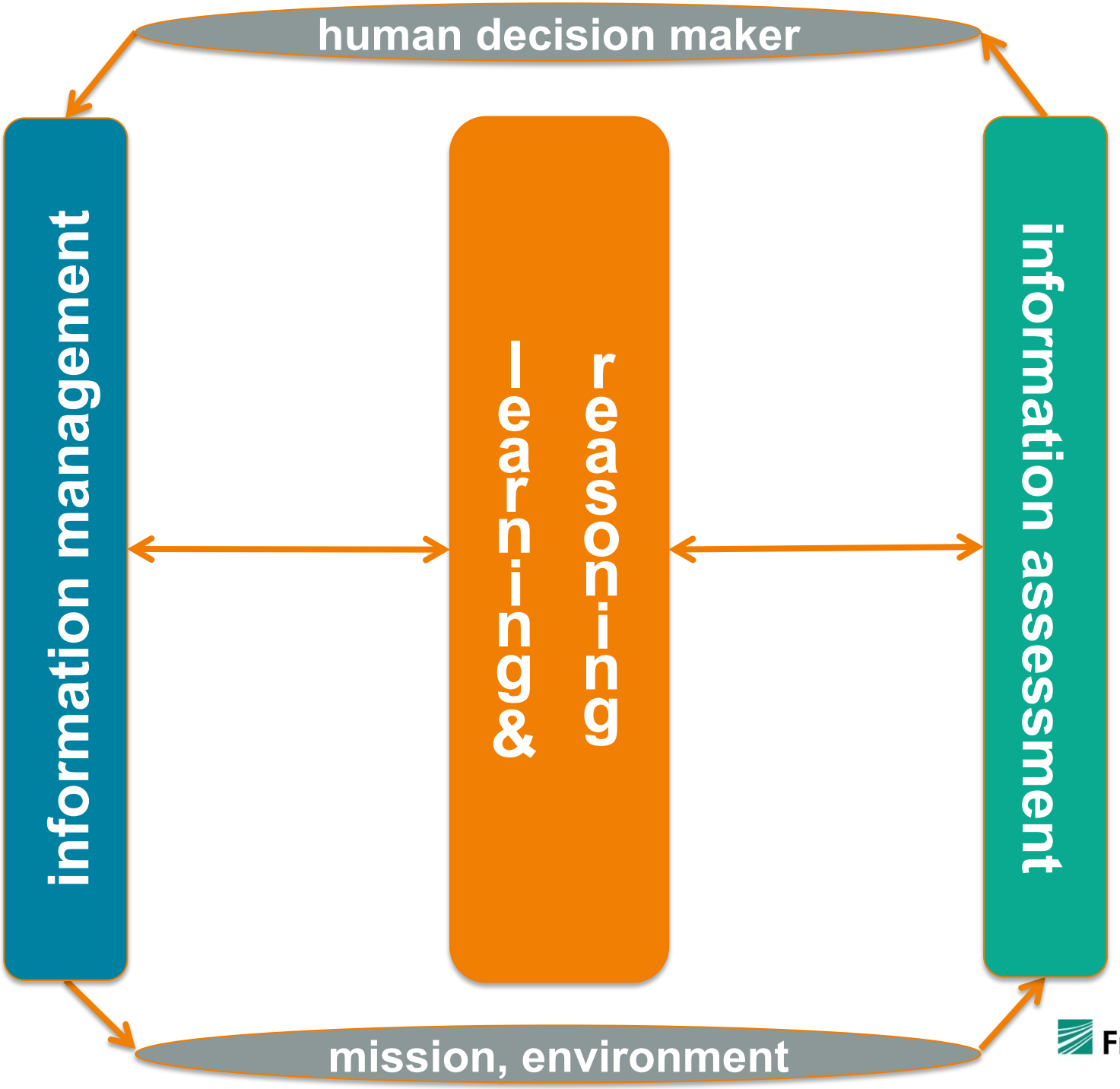

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Information Assessment

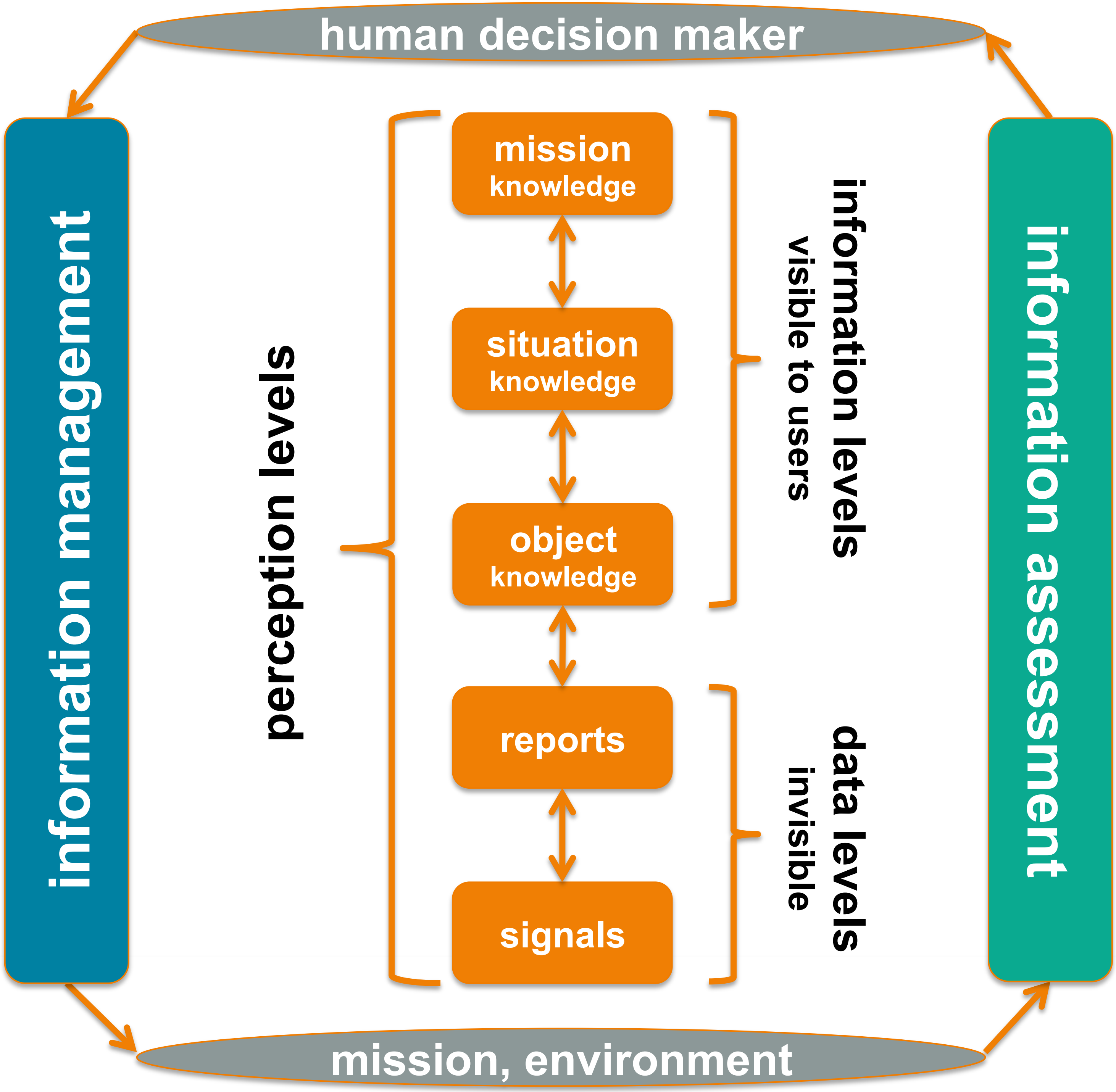
- information extraction from reported data
- computer linguistics, statistics, combinatorics
- starting point: signals / HUMINT → higher levels

Learning & Reasoning

- adaptively learn elements of the observed environment
- situation: What belongs where when how to what?
- predict effect of potential data acquisition decision

Information Management:

- control of sensor data / report collection: decisions
- statistical decision theory, mathematical game theory
- goal-oriented: mission → signals, report requests


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


human decision maker
mission management
e.g. capability selection, adaptive platform control, source selection
mission knowledge
mission assessment
e.g. pre-engagement / impact collateral damage prediction
situation management
e.g. priority / utility assignment, communications analysis
situation knowledge
situation assessment
e.g. multiple target tracking, interrelation/anomaly detection
object management
e.g. task management, parameter optimization, data base requests
object knowledge
object assessment
e.g. tracking & classification, ontology-based inference
data collection
e.g. scheduling, adaptive tracking, local search, reporting requests
reports
data processing
e.g. detection, parameter estimation, computer linguistics
signal collection
e.g. select / adapt waveforms / beams, message requests
signals
signal processing
e.g. matched filtering, STAP, speech / text recognition
mission, environment

Contact

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