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# Persistent Surveillance with a Team of Robotic Drones – Basic Concept and Practical Results

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# Outline

1. Context
2. DRDC Valcartier indoor laboratory facility
3. Persistent surveillance
4. Experiments

# 1. Context

**Collective:** a collective body : **group** (Merriam-Webster)

… **of drones** (UAVs)

A collective as a drone **formation**

V-shape squadron

String formation

A collective as a **dispersed group** of drones

# 1. Context

**Navigation, control, decision making for collectives →How?**

One to Many

Everyone: t
25 degrees to the right!

*"Intelligence" on the ground*

VS

Team: Search area #1, find the target, then send info to ground station. Limit your comms. You have 10 minutes.

*Intelligence partly aloft…*

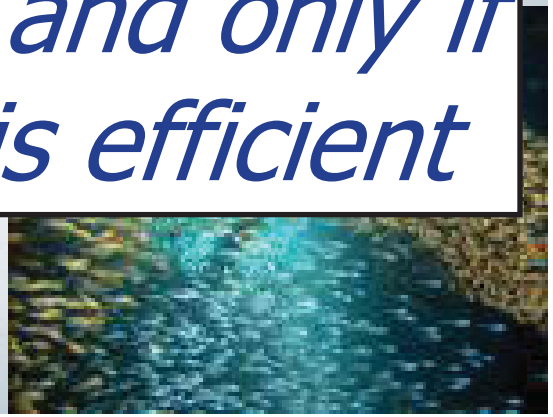
# 1. Context

**A collective, isn't it more efficient than a single individual?**

Cooperative or Collaborative Control:
The ability for two or more robots to plan, coordinate, and execute a mission or a set of tasks.

Unmanned systems
1. Remove human from danger
2. Are force multipliers – *if and only if coordination/collaboration is efficient*

- new capabilities (e.g. RT intelligence, defense)



# 1. Context

## Some envisaged applications (CFAWC, USAF documents)

Networked Robotic Drones

- Persistent Surveillance (24/7)
- ISTAR
- Search and Rescue
- Airlift (slung load)
- Air Refueling
- Coordinated bombing
- Protection of an area
- …

Airlift

Surveillance


Air refueling

# 1. Context

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## Rationale for part of our work

**Loss of altitude**

## Challenges

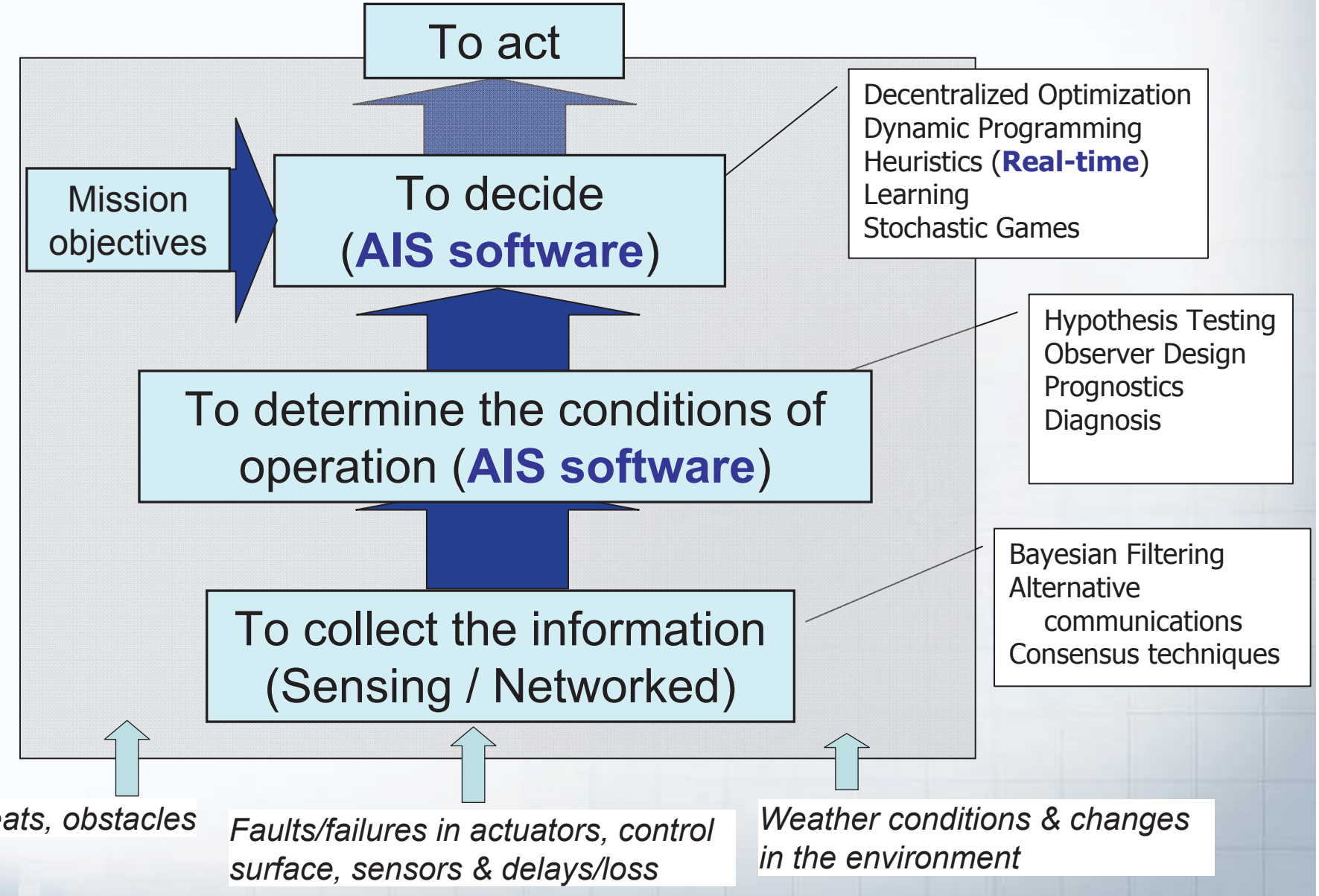
1. Complexity: number of variables, changes
2. Hard comp/comm constraints, real-time
3. Safe, reliable, trusted?
4. Integration and experimental validation needed

They will sort it out…

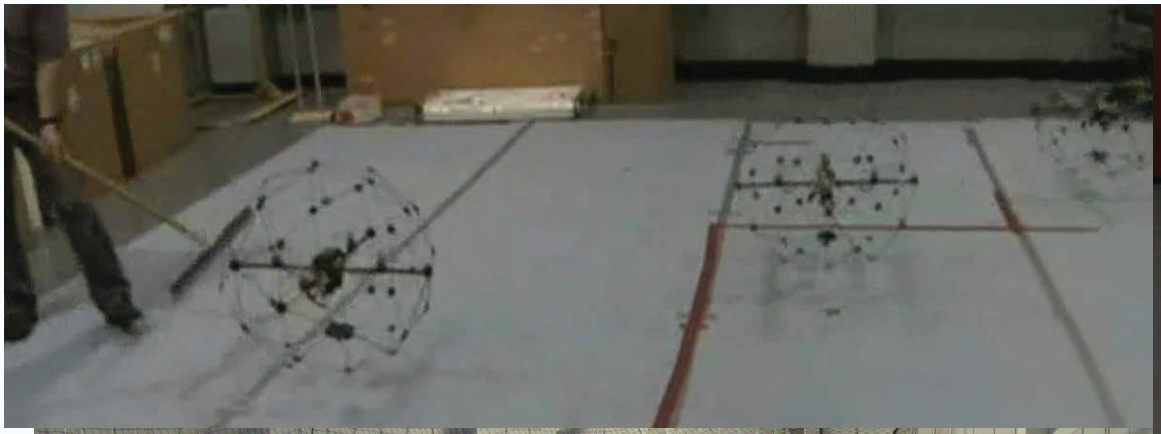
**Detection of new threats & targets**

# 1. Context

→ Increased drone autonomy



# 2. DRDC Valcartier Indoor Laboratory



# 2. DRDC Valcartier indoor laboratory

VTOL

VTOL

*UDP*

UGV

# 2. DRDC Valcartier indoor laboratory

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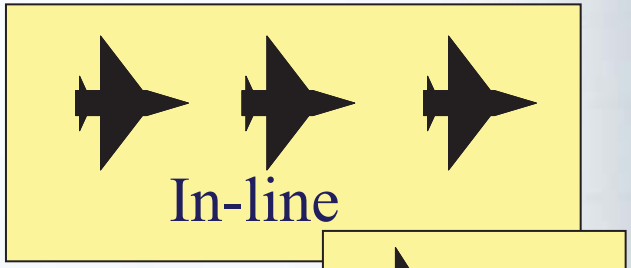
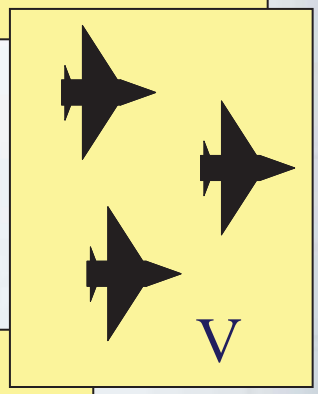
* Our AI design allows for **scalability**

From 2-vehicle squadron to 100s-vehicle **SWARM**

* Formation maintains prescribed **geometries** in flight





The commander DOES NOT pilot the drones

AIS adjusts to damage, motor problems, adverse weather, crash of a drone, drone takeover …

* Formation complies to **high-level** commander's commands without continuous human supervision

* Formation efficiently handles **degraded** conditions and unexpected events **on its own**

# 3. Persistent surveillance

A team of VTOL UAVs with **limited sensing capabilities** must **maintain information** about a region for an **extended period of time**.

**Limited sensing capabilities**: A single sensor (drone) cannot cover the whole area. Need: network of sensors with precise positioning.

**Maintaining information**: To sense the whole region and network the information to the ground control station (GCS). Need: A robust network.

**Persistence**: Monitoring must be maintained for extended periods of time, despite degraded capabilities, presence of intruders/threats. Need: Autonomy & AIS.

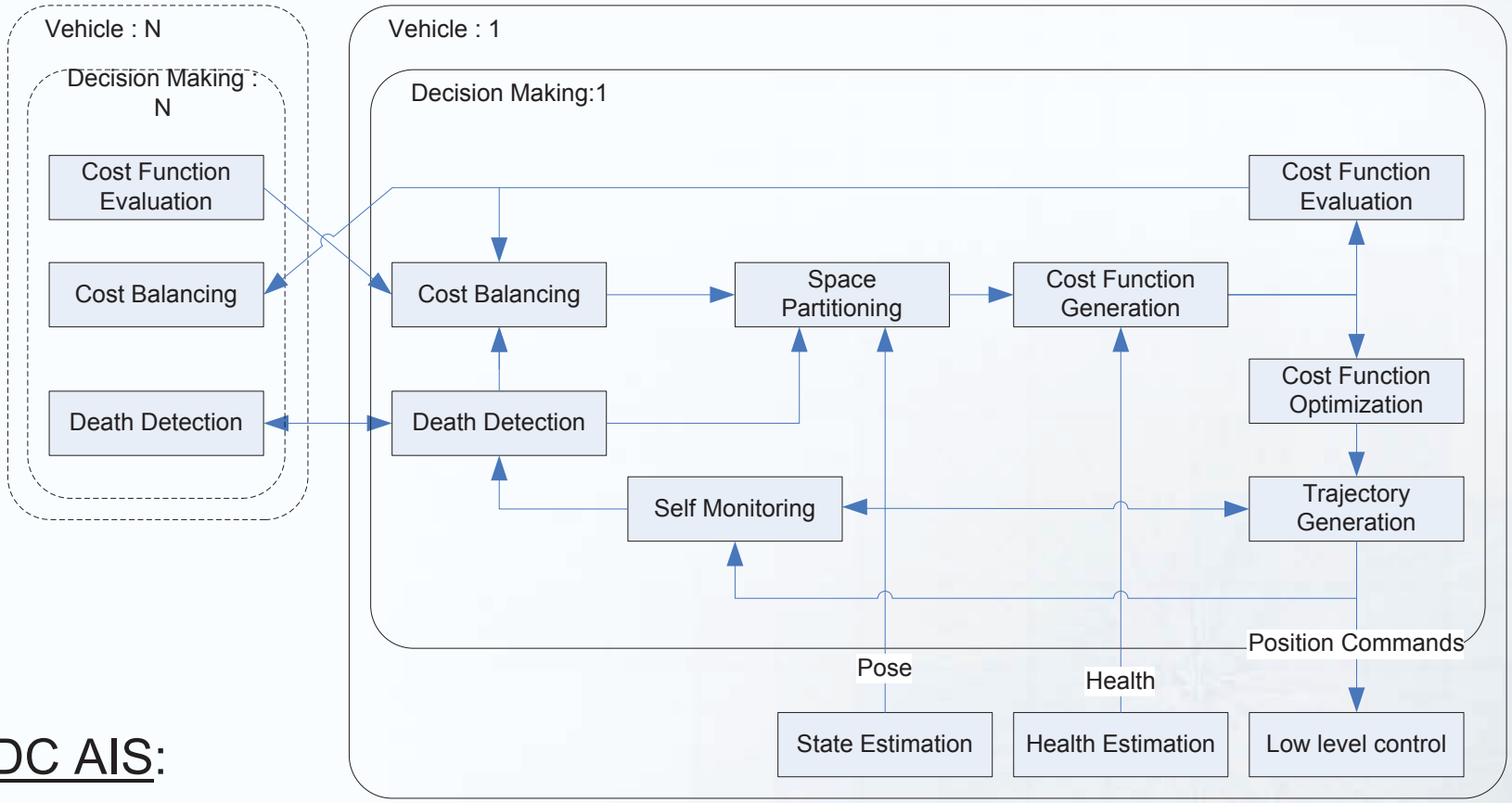
**Examples of degraded capabilities**:

- Sensor loss of effectiveness or malfunction,
- Control effector problems (e.g. damage, wear),
- Inter-vehicle communication failure,
- Loss of one or more robots (e.g. collision, hit, system shutdown).

**Our autonomous intelligent system (AIS) manages & positions the drones.**

# 3. Persistent surveillance

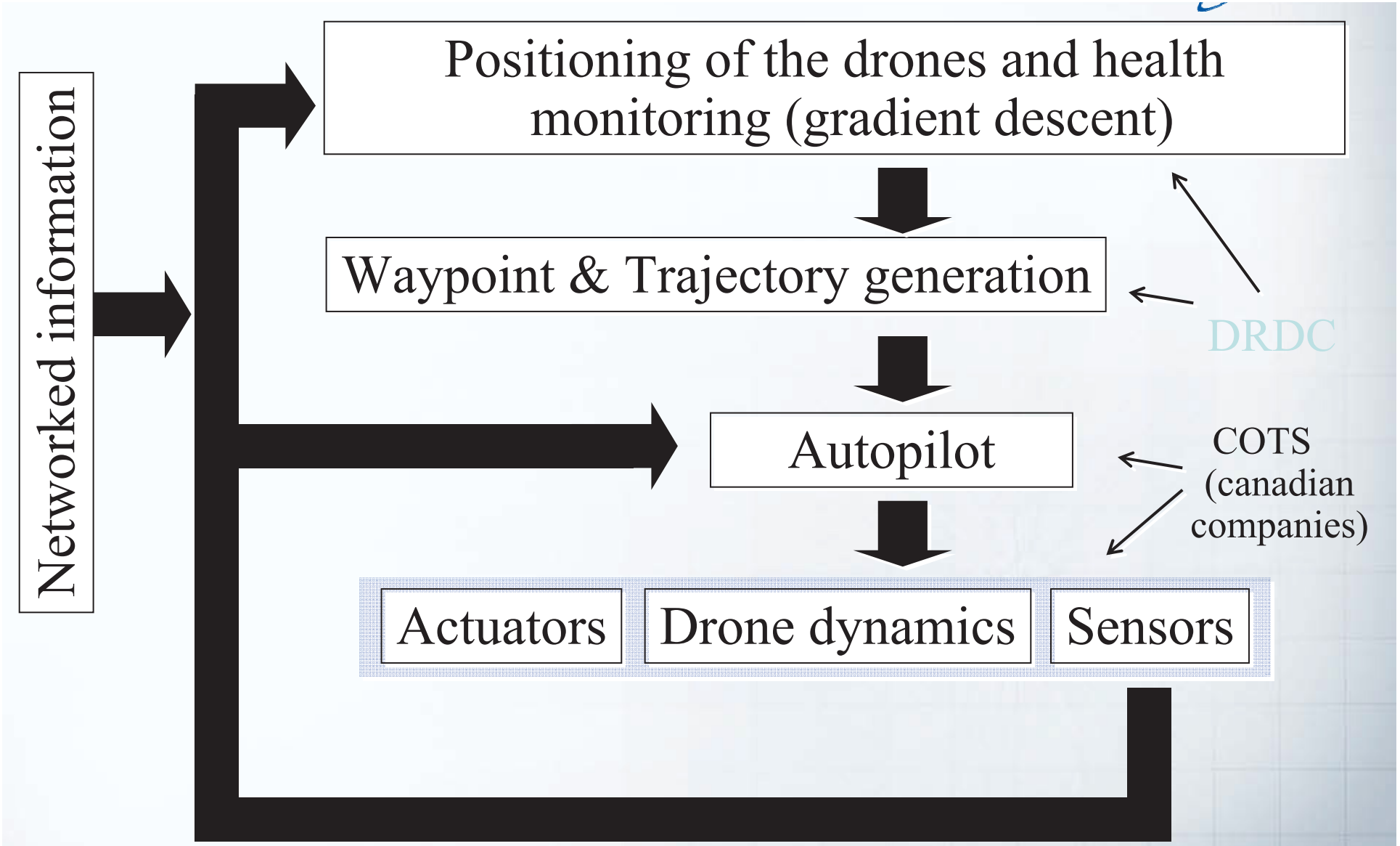
S/W algorithm implemented onboard the drones




DRDC AIS:

- A geometric location optimization problem is solved online via a gradient descent method (***real-time optimization*** of the position of the drones)
- Consensus seeking among the robots for ***coordinated group positioning***
- Trajectory generation/tracking to avoid collisions
- ***Integration*** with low-level COTS autopilots on the drone electronics

# 3. Persistent surveillance - High-level AIS loops



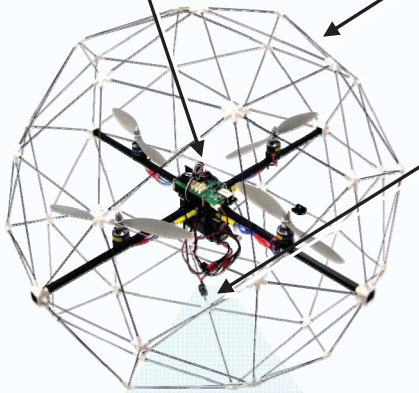

Updated at every 0.1 second (in real time)

# 4. Experiments

## Assumptions

COTS VTOL UAV (quadrotor with protective cage)

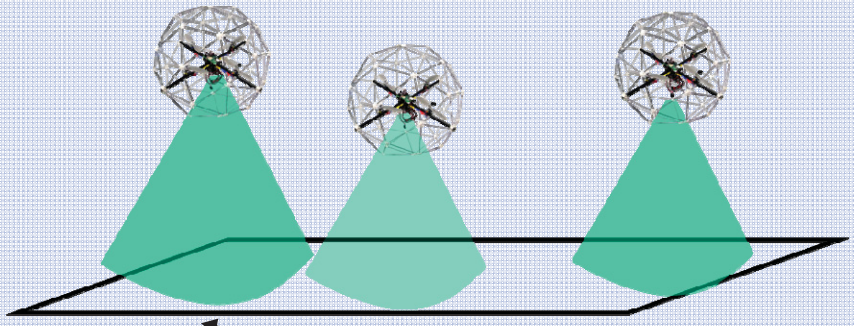
Onboard AIS software



On-board visual sensor (to observe ground)

Conic sensor FOV

3 drones conducting PS mission

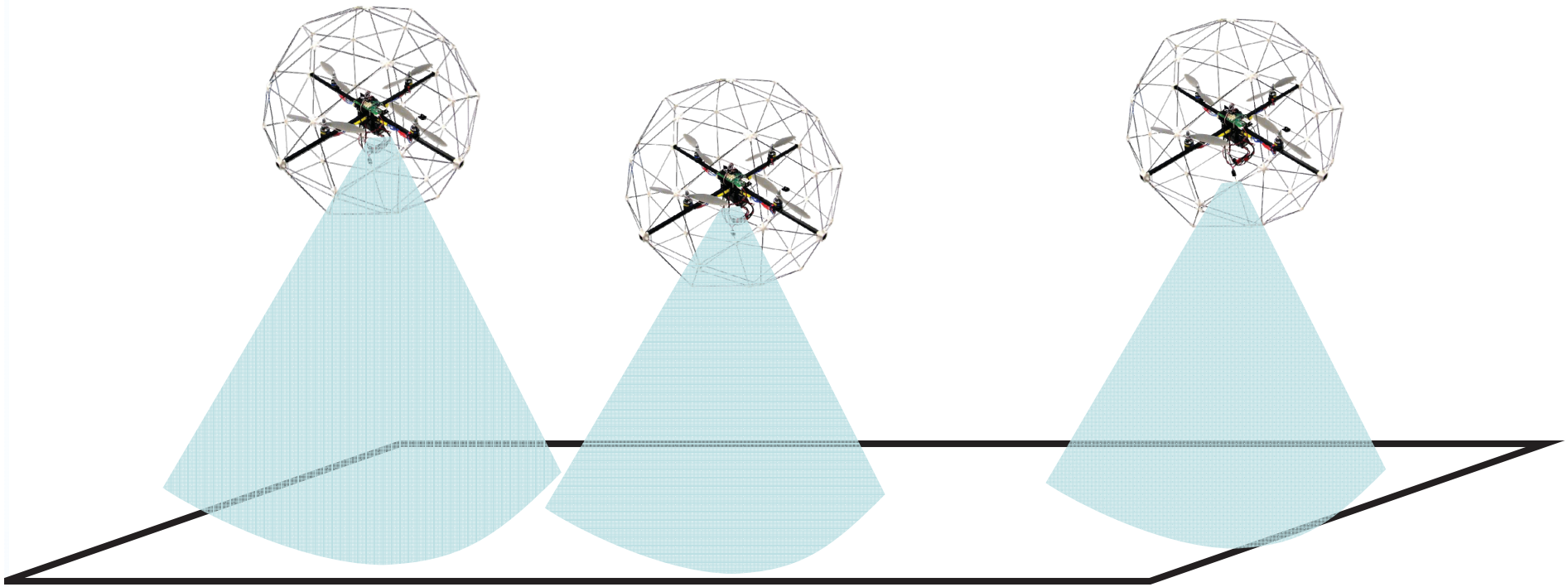



Healthy sensor FOV | Degraded sensor FOV

Degradation implies reduced ground coverage

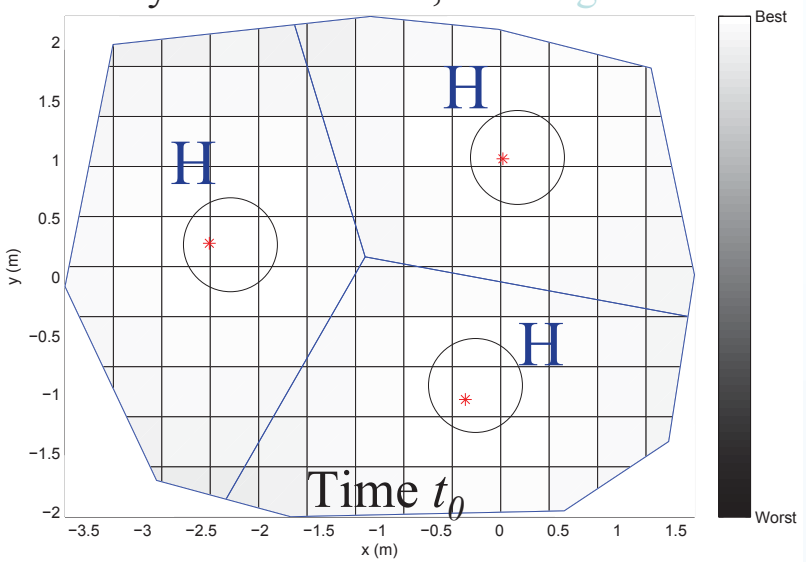
# 4. Experiments

The team adapts in the event of a loss.

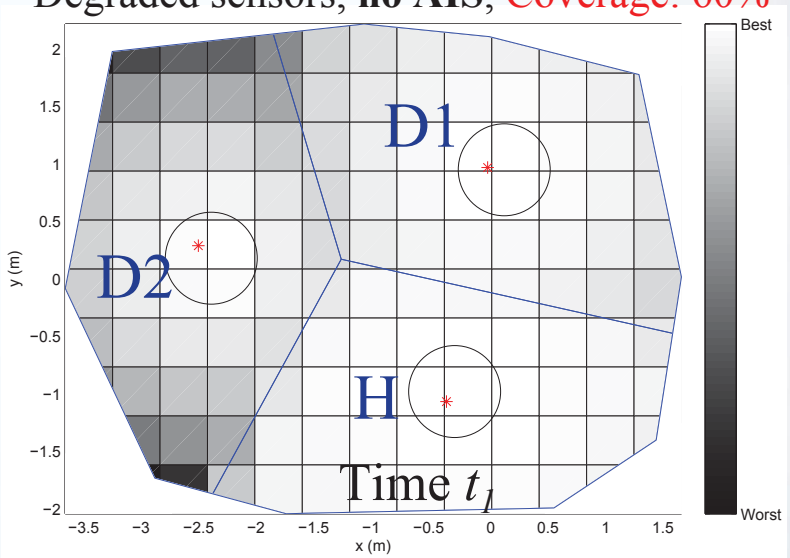


# Typical results: from healthy to degraded sensors

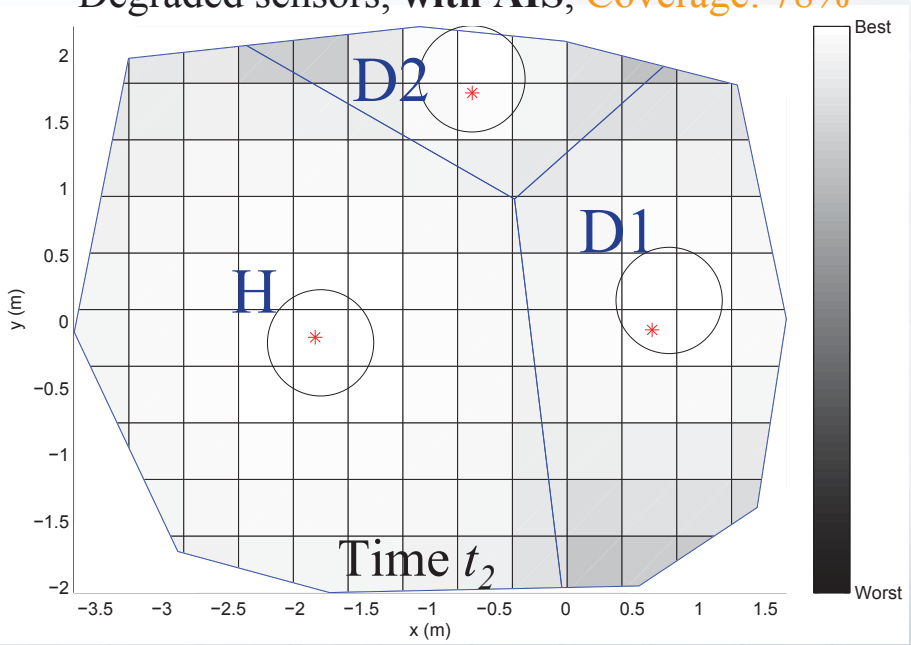
3 healthy drones/sensors, Coverage: 99%




Degraded sensors, **no AIS**, Coverage: 60%




Degraded sensors, **with AIS**, Coverage: 78%




$t_0 < t_1 < t_2$

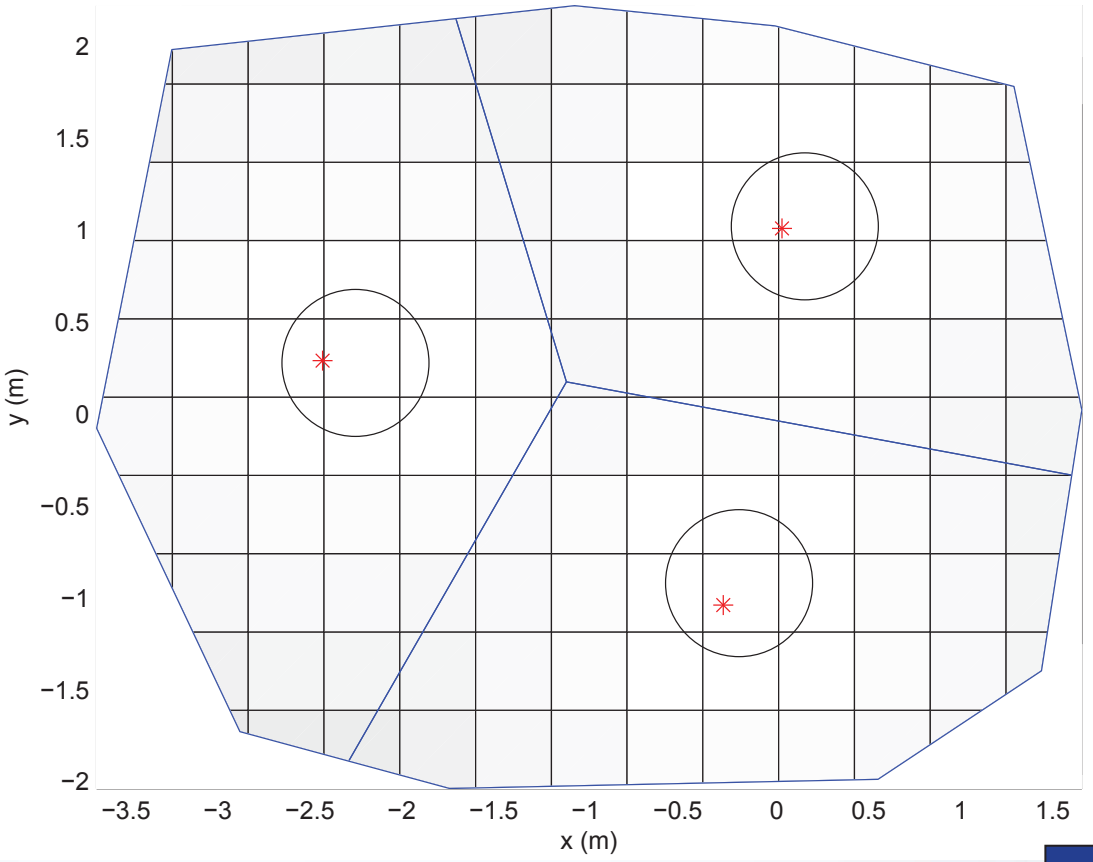
H: Healthy

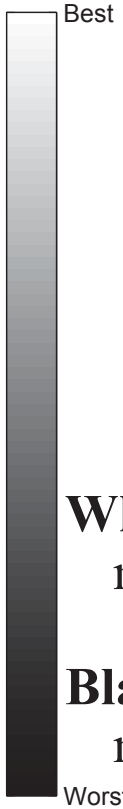
D1: Slightly degraded

D2: Severely degraded

# 4. Experiments

Top view – ground area to monitor




persistent-surveillance-3dronesDRDCV.wmv

persistent-surveillance-4dronesDRDCV.wmv

DEMOs

**White**: "good" sensor measurement

**Black**: sensor does not measure anything

Team of 3 drones

* = Commanded drone position

◯ = Actual drone position

**Coverage %** = Percentage of the zone which is measured by the sensors with a minimum level of "quality"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