Unmanned Systems in Civilian Operations: Surveillance, Rescue and Forest Fire Prevention

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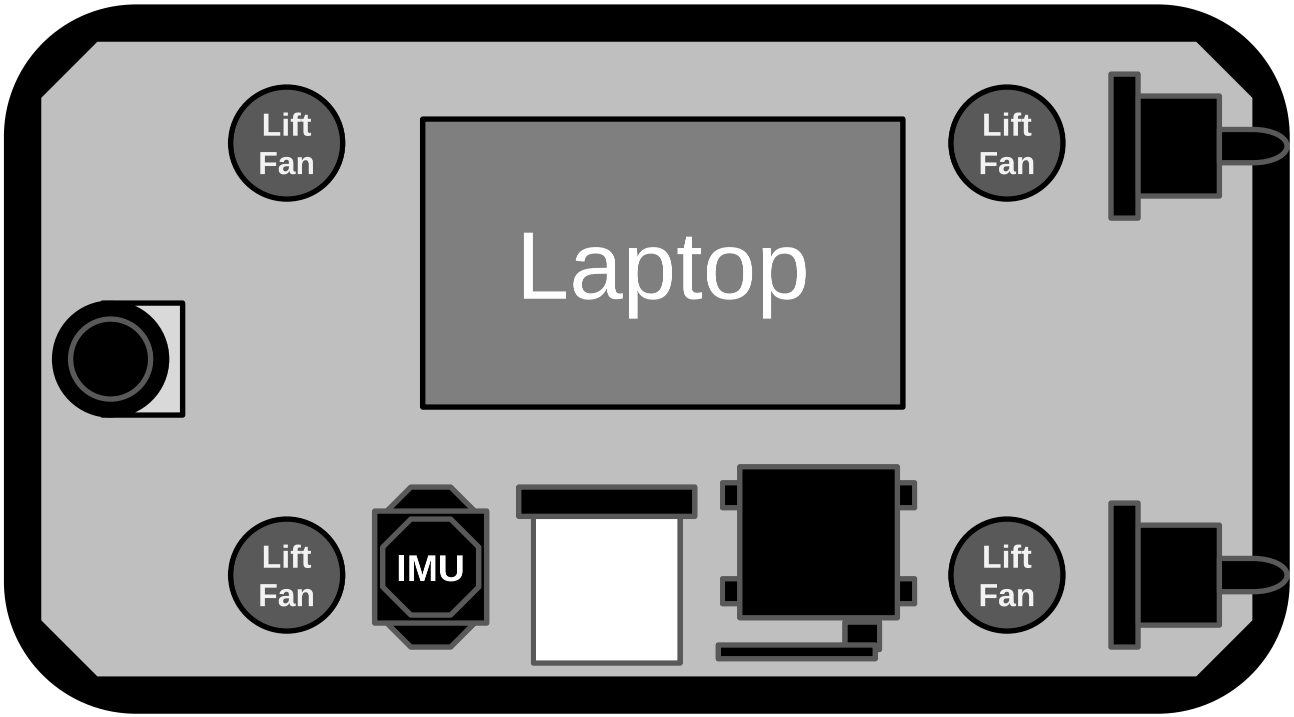
UAV/MAVs


Trimble GPS
Freewave Modem
12V/6V Batteries
Pitot
MicroPilot 2000
68332/Gyros/etc)
Static Port
Zenoah G23
Futaba Rx/Servos

Georgia Tech: New Autonomous Systems Developments

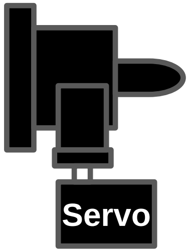
Hovercraft Layout

SICK LMS111
LIDAR



E-flite BL32
Brushless
Motor

E-Flite
Delta-V 15
Ducted Fan



Cooling Fan

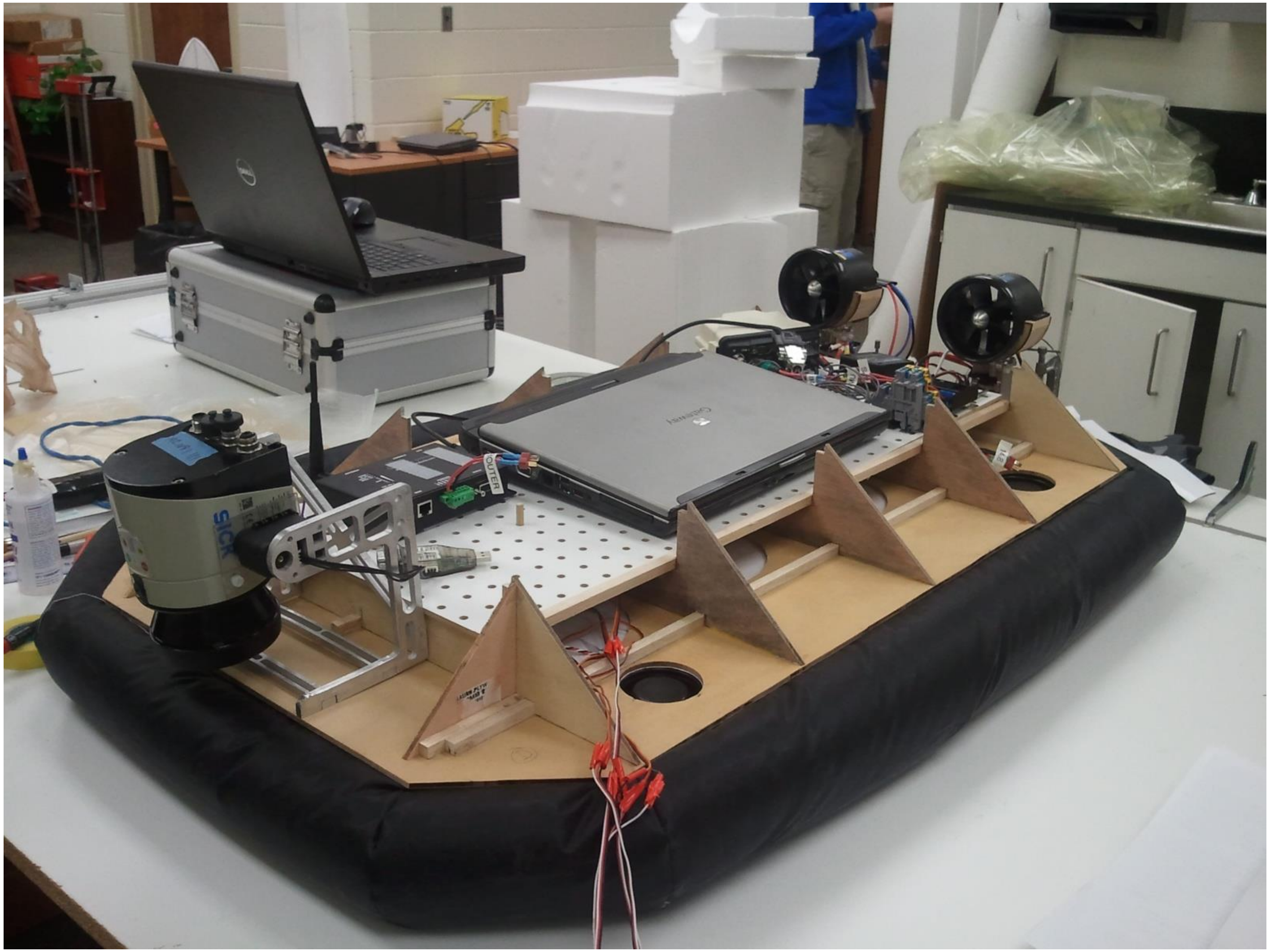
MicroStrain
3DM-GX1 IMU

Novatel
OEMStar

MicroHard
2.4GHz Router

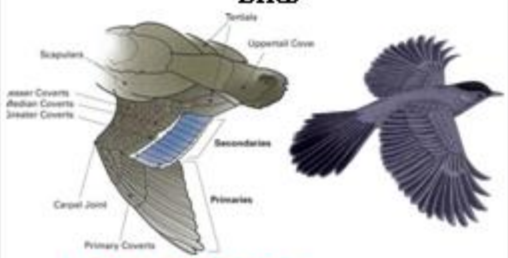
360° Servo

Hovercraft Layout – Front



Micro Air Vehicle Concept

BIRD



A. *Complex co-ordination*: Many muscles
B. *Larger wing-span* for long flight times
C. *Not recommended* for closed-quarter flight

HUMMINGBIRD

A. *Good Contender* for a design
B. *Not power efficient and short flight time*
C. *Complex Wing mechanisms* implementation

BUTTERFLY

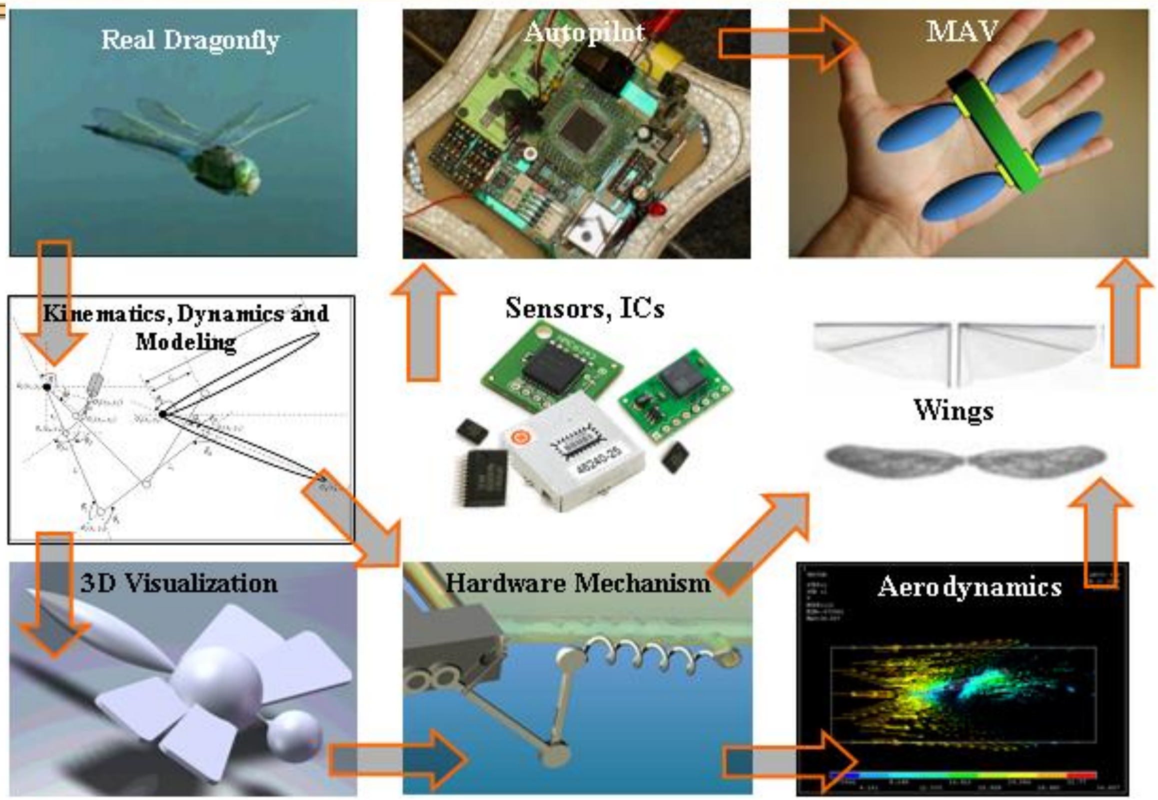
A. Excellent contender for a MAV
B. Long flight times
C. *Slow dynamics*, *low agility*
D. *Low controllability*

DRAGONFLY – THE DESIGN CHOICE

A. Four sets of wings provide *maximum Lifting power*
B. The Wings resonate synchronously, sustaining *super-long flight times*
C. Four wings give it unparalleled *agility and maneuverability*

D. Only *one actuator per wing*
E. *Simpler controls*
F. *Relatively less complex* parts - tolerance to damage

Program Objectives Dragonfly → MAV

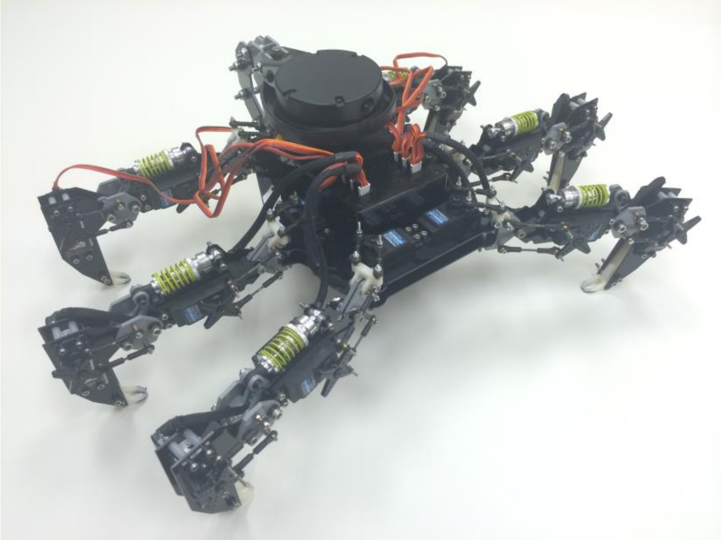


- Actuation Mechanism
  - Re-Use of Elastic Energy
  - Simple, Robust Construction
- Control Design Methodology
  - Wing Control
  - MAV Attitude Control
  - Simpler Control Methodology
- Modeling and Simulations
- Prototype Construction
  - Sensors, CPU, Communication
  - Wing Design
  - Hardware – In – Loop Sim

Ground Vehicles-The Hexapod

Test Platform for Rapidly Reconfigurable Subsystems

- Embedded electronics
- Autonomous behavior design
- LIDAR-based SLAM



Goal: Improve Hexapod endurance

- Reconfigured system states:
  - 4 wheeled vehicle (2 – 4 powered)
  - 6 wheeled vehicle (4 – 6 powered)
- **Measures of Effectiveness:** Time to complete the mission(t), “best” solution
- **Measures of Performance:** Velocity (m/s), Endurance (min), stability, robustness

Unmanned Systems for The Civilian Domain: Target Applications

- Windmill
- Accident & Crime Scene Investigation
- Crowd control
- Fire Fighting
- Search & Rescue (SAR)
- Surveillance
- Geomorphology
- Mapping
- Crop Science
- Live Stock Control
- Creative
- High voltage
- Infrastructure
- Anti-Poaching
- Drug & Gas Detection
- SWAT
- Traffic Monitoring

Challenges

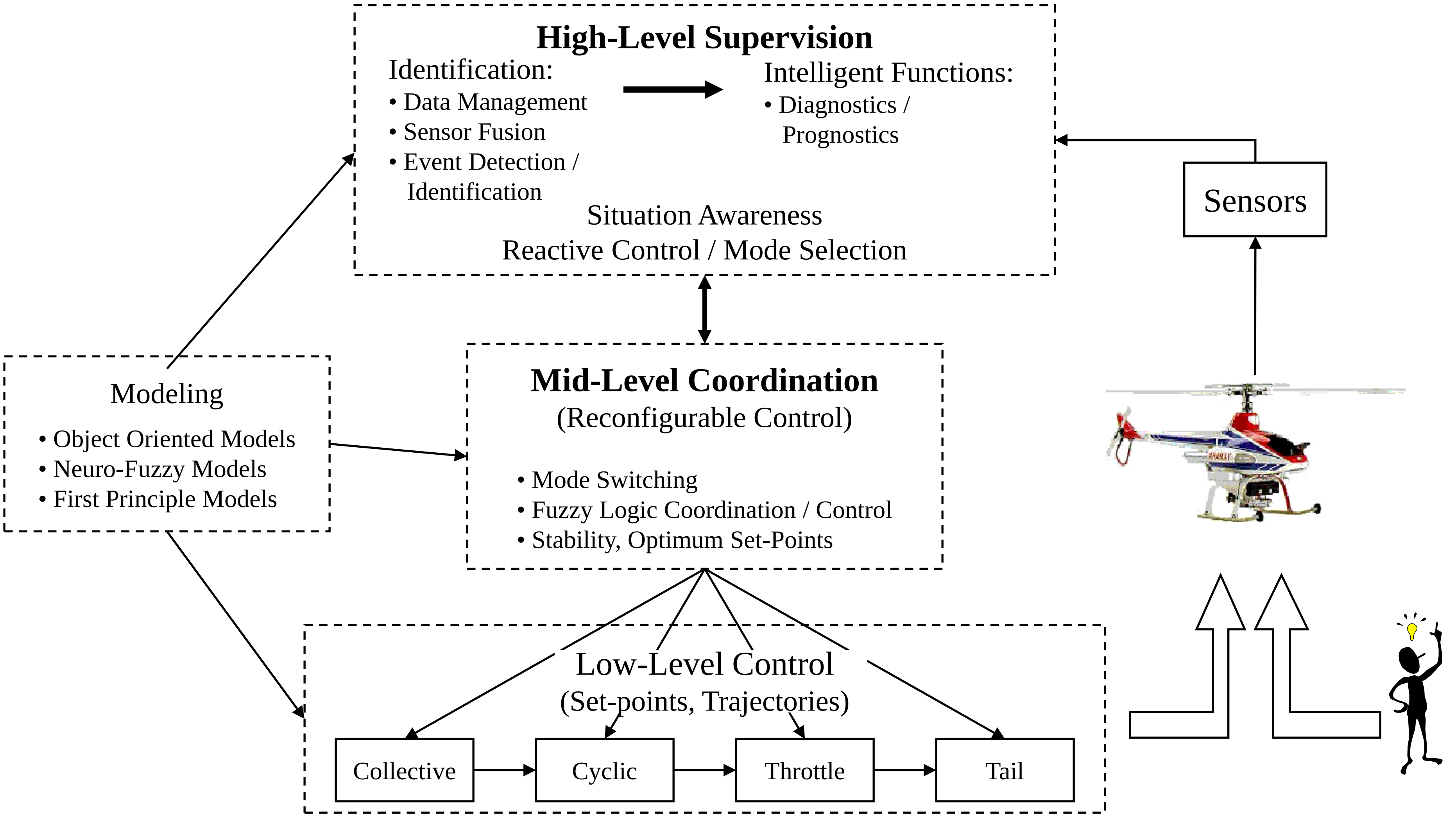
- Regulatory Restrictions
- Improved Autonomy
- Reliability and Robustness in Uncertain Environments
- Reduced Operator Workload

Mission Planning and Control of Autonomous Systems

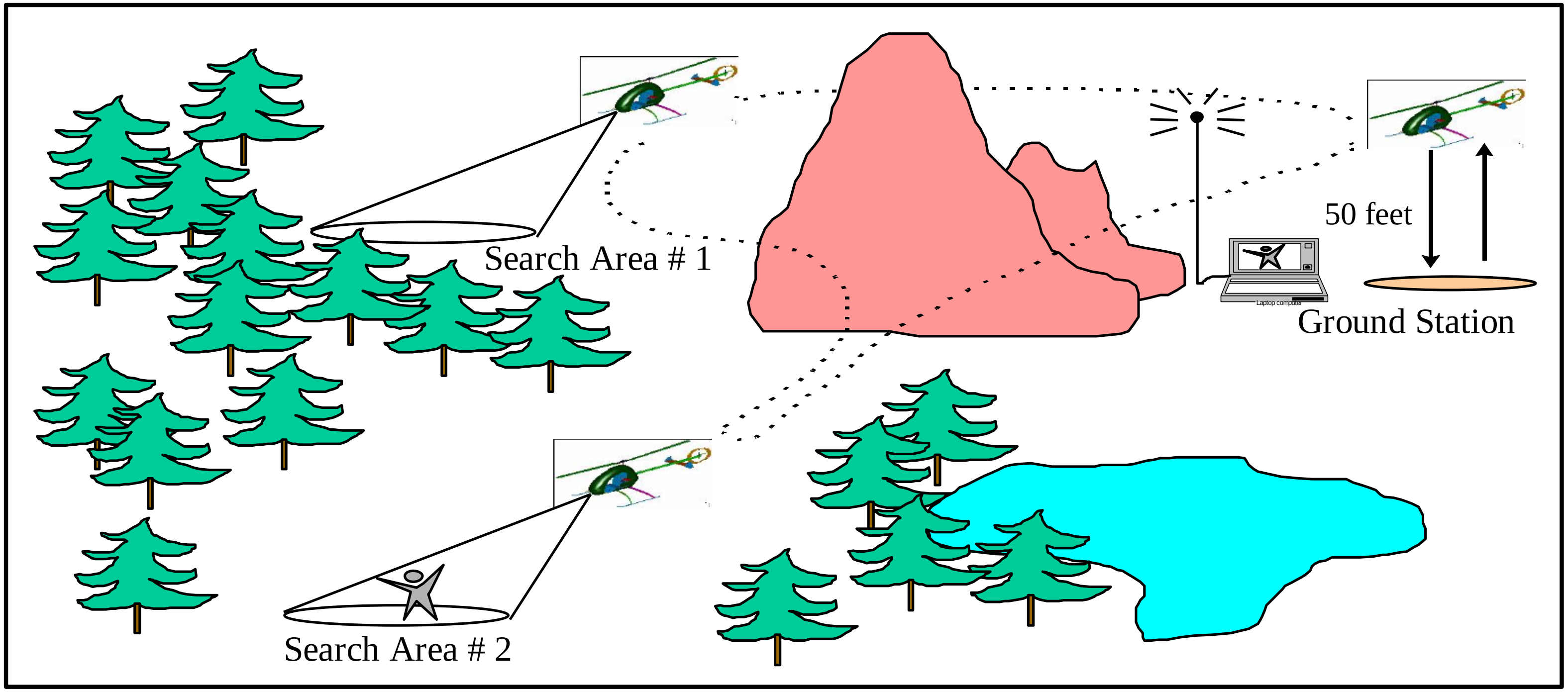
Control of autonomous systems presents major challenges to the designer:

- Autonomy attributes require complex adaptive, robust, nonlinear and fault-tolerant control strategies
- Mission planning and execution is a difficult task requiring coordinated tools and methods

Hierarchical Intelligent Control Architecture – Single UAV



Typical UAV Mission in Natural Terrain



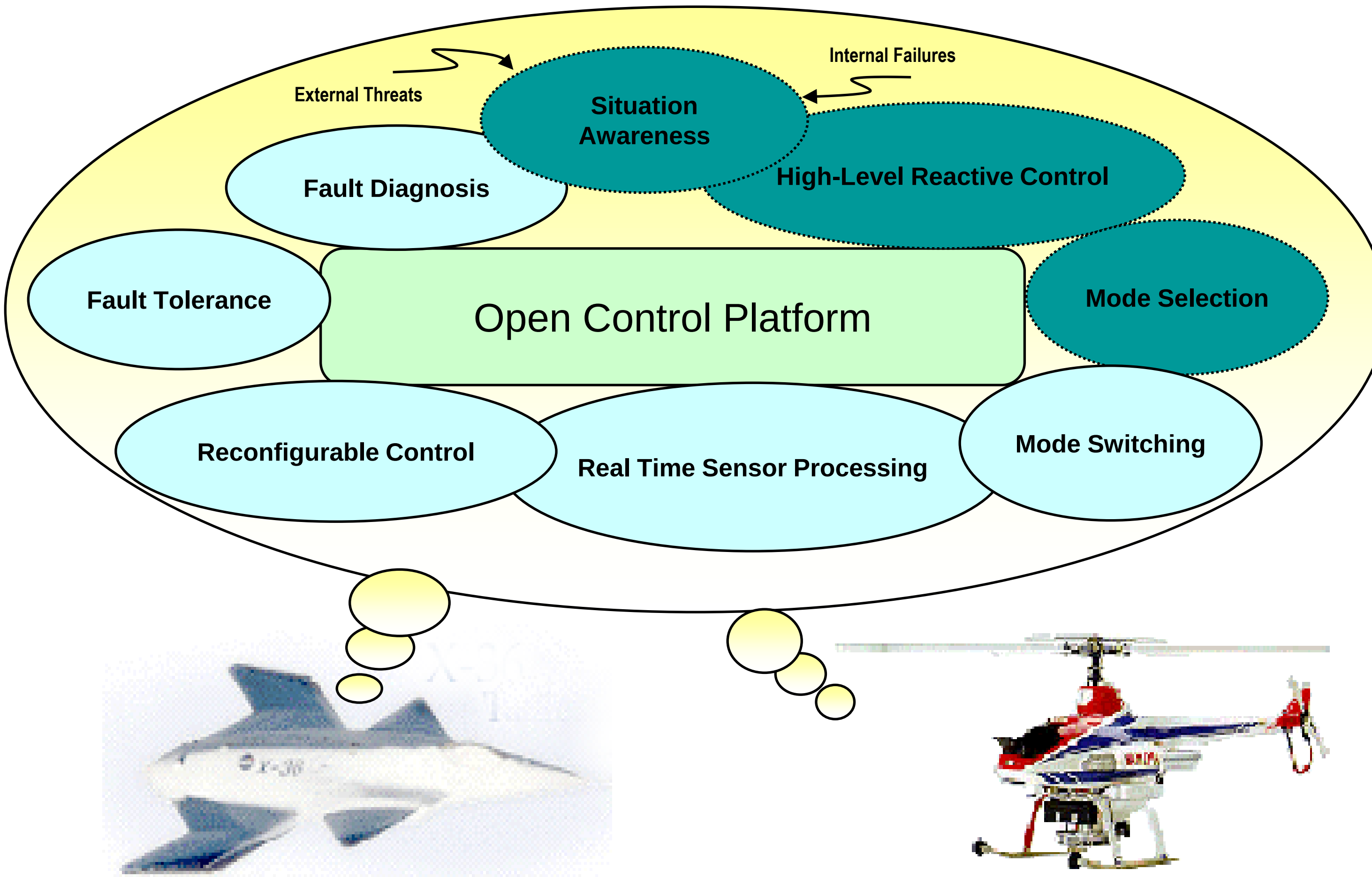
Mission Planning

From One Vehicle to Many

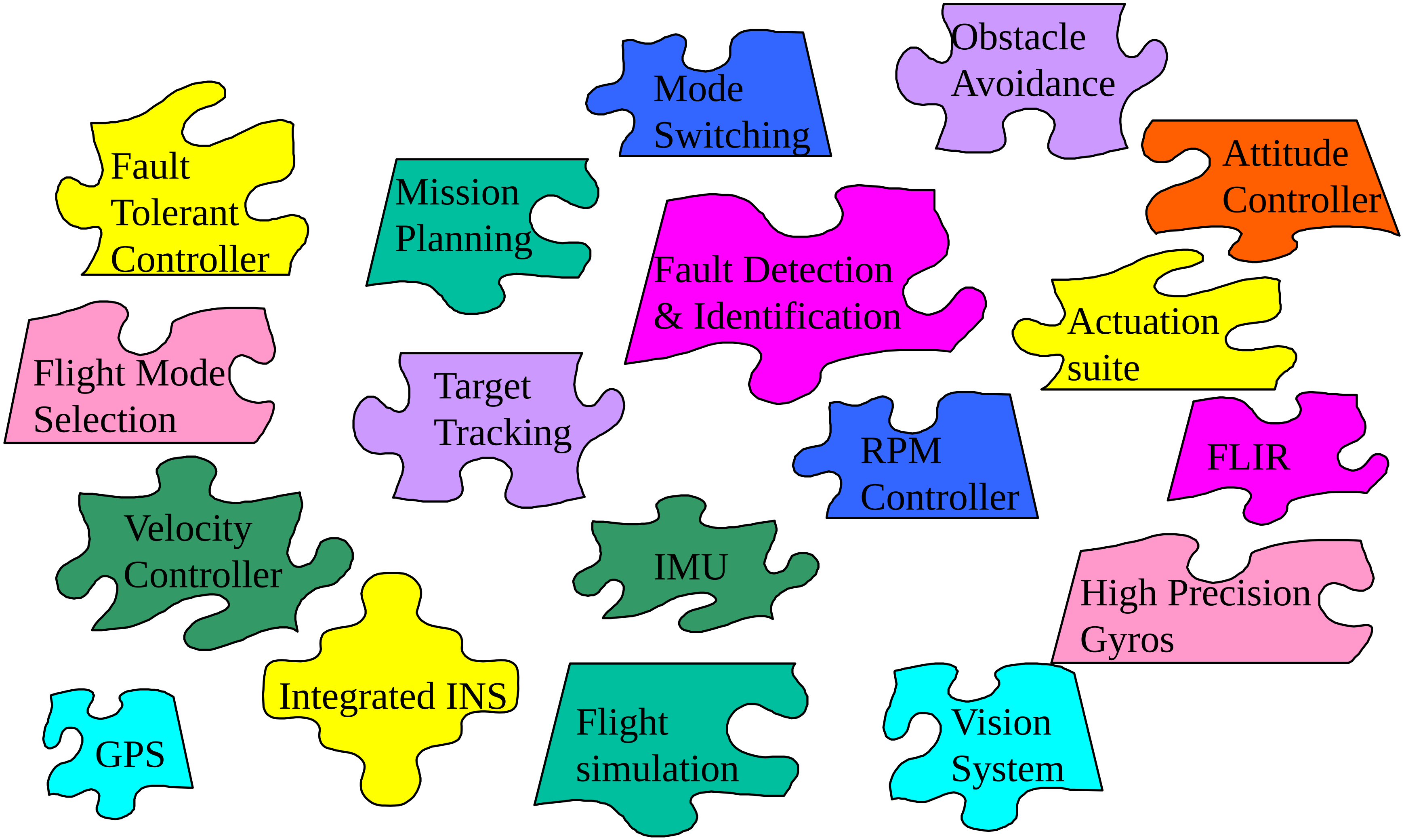
The Software Infrastructure

On-platform and on the ground station an open software architecture is built to allow for rapid reconfiguration, control changes, etc.

Open Control Platform

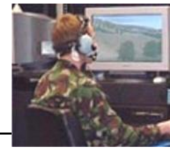


OCP Integrates Components



Hierarchical Multi-agent (Multi-UAV) System Architecture

Command and Control



Manned Vehicles

Global Knowledge

Team Mission Planning, Global Situation Awareness, Knowledge Fusion
Global Performance Measurement, QoS Assessment

Local Knowledge

Formation Control, Obstacle Avoidance, Local Situation Awareness
Local Mission Planning, FDI/Reconfigurable Flight Control

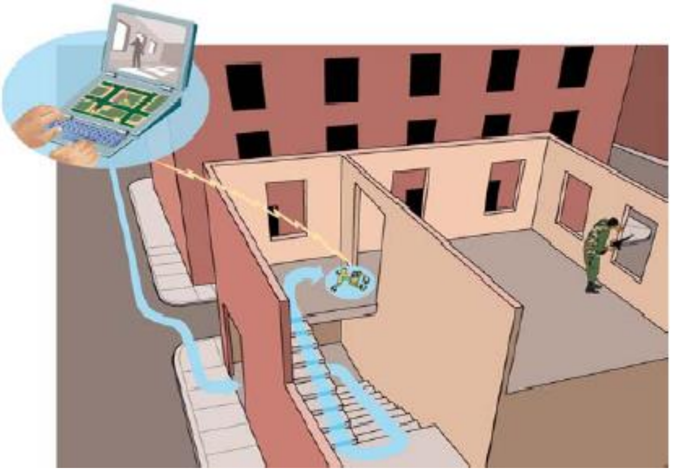
Behavioral Knowledge

Vehicle Control, Weapons, Communications, Sensing

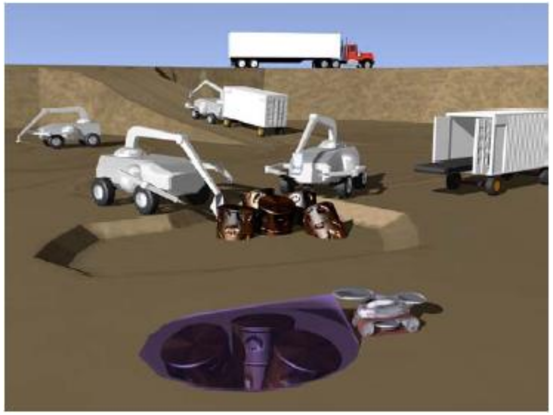
Many Potential Application Domains for Multi-UAV/agent Systems

Space Exploration

Mining



Surveillance and Reconnaissance



Hazard Waste Cleanup

Traffic Monitoring

Real-time traffic planning and control

Model Simulation

Data Collection by UAV Mounted Video Cameras

Data Collection by Infra-red detectors, other sources

Real-time update of simulation parameters

Image Analysis

Obtain Observed Parameters (Vehicle type, density, flow, etc)

Historical Data

Interface

The Need for Traffic Monitoring

The continuous increase of vehicles on roadways forces transportation managers to look for more effective ways to reduce the traffic congestion problem. Traffic monitoring can:

- Reduce the traffic congestion on highways

- Reduce the road accidents.

- Identifying suspicious vehicles.

Traffic Monitoring System (source: ibulwork)

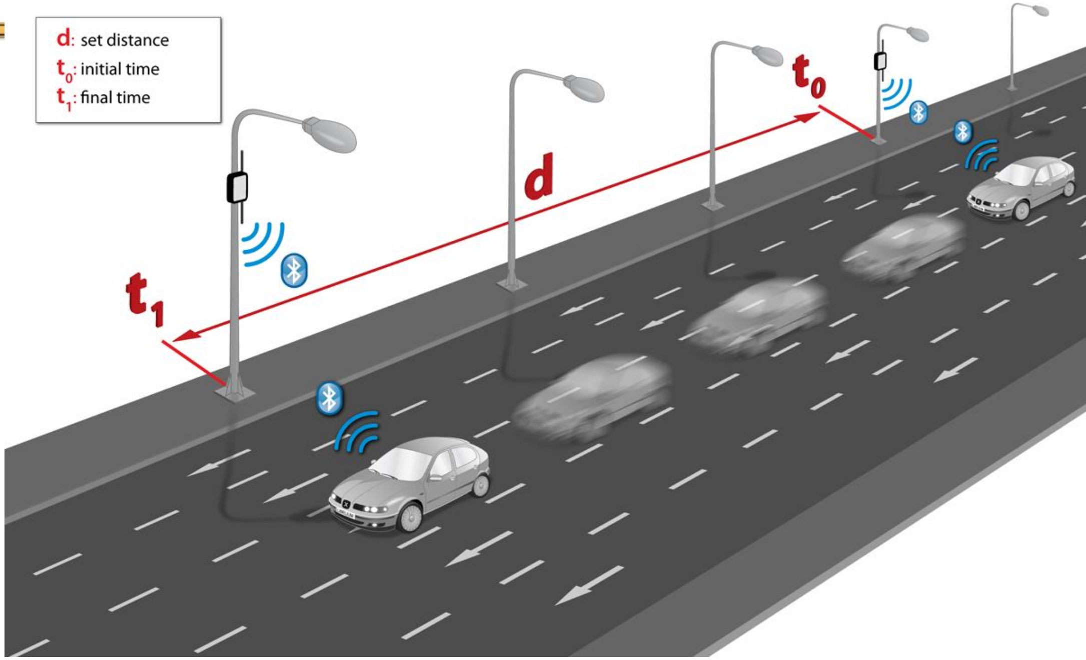
Traditional Technologies

- Inductive loop detectors

- Video

- Radar

•Ultra-Sound Technologies etc.)

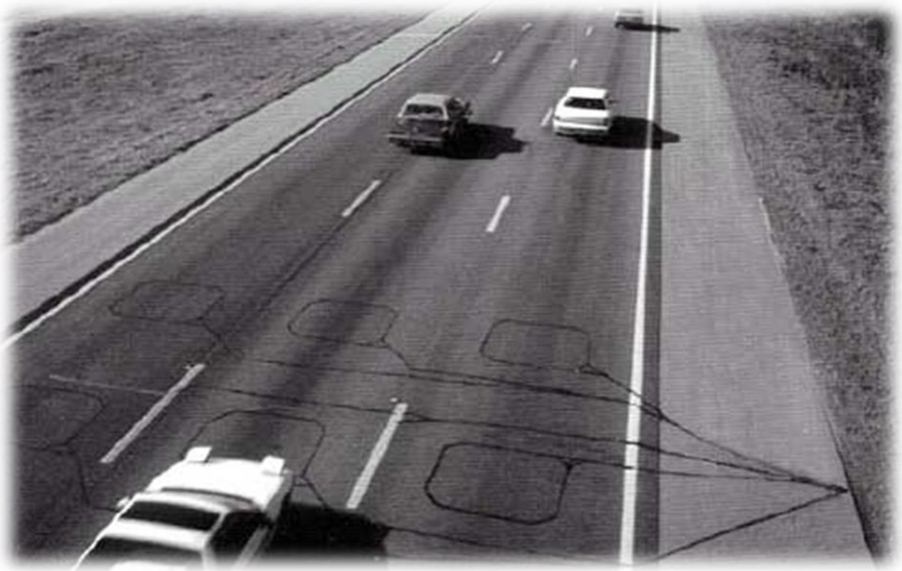


A Vehicle Traffic Monitoring Platform (Source Libelium)

- Traffic monitoring software_(1:57)_ http://www.youtube.com/watch?v=gs4Q_IBq-r0
- Inductive loop traffic detector_(3:13)_ http://www.youtube.com/watch?v=V0x7AFfzX6A

Why UAS?

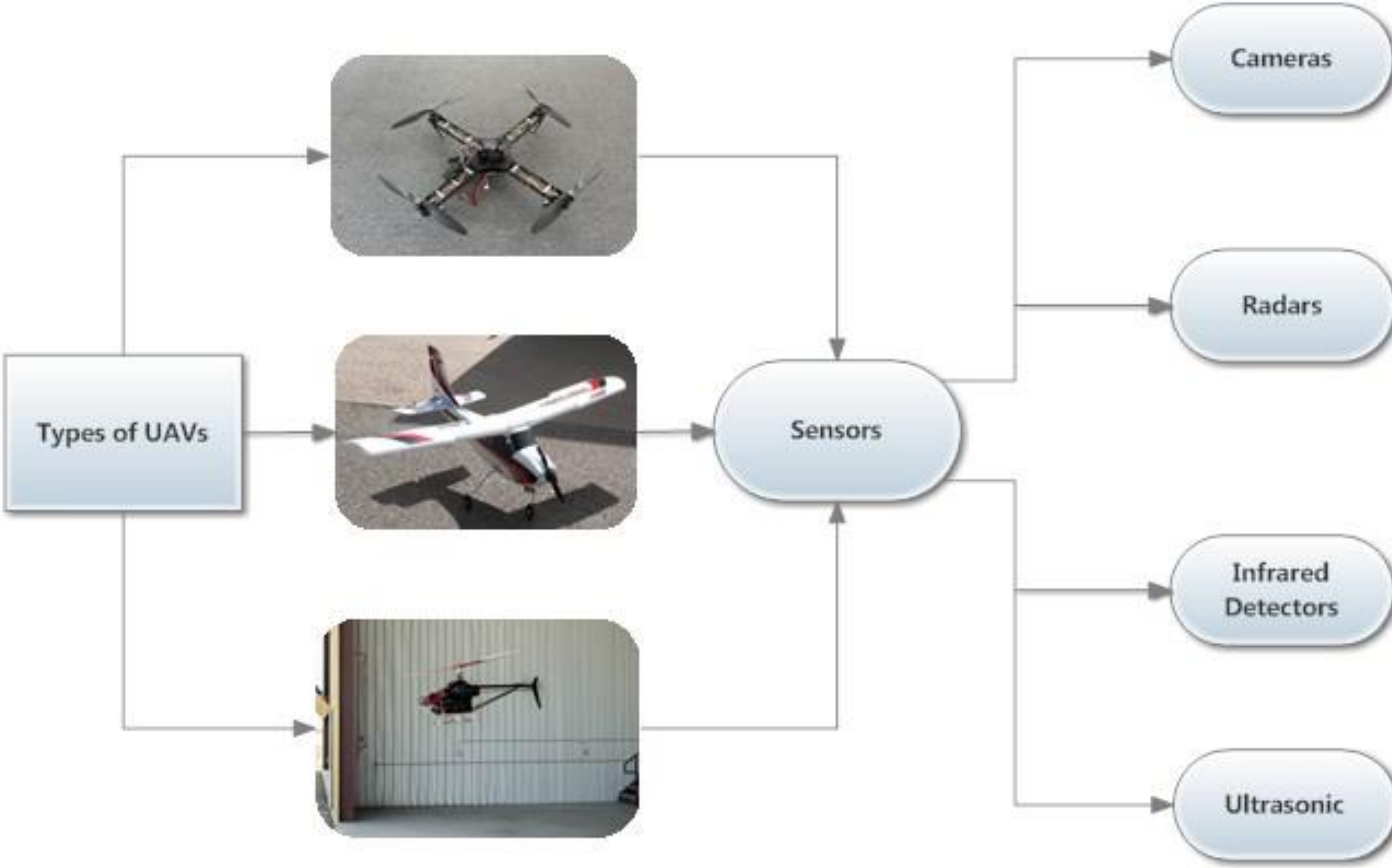
"Moving" eye-in-the Sky sensor. Preferred over traditional technologies (inductive loop detectors, video, radar, ultra-sound technologies, etc.) because of ***mobility*** and ***cost-effectiveness***.



Inductive Loop Detector System. **[1]**

Aerial image from a custom-made Unmanned Helicopter.**[2]**

Types of UAS & Sensors For Traffic Monitoring



System Requirements for Traffic Monitoring

UAVs capable of carrying sensors and communications hardware to relay data to the ground are becoming available on the commercial market today. The ability of extracting useful information from images sampled from a UAV for both off-line planning and real-time management is a requirement in traffic monitoring.

On-board:

- A system able to follow a path considered as the surveillance area and defined by a set of ordered GPS points.

- A (vision/ radar) system treated in real time to be able to detect, track and count fast moving objects (vehicles).

Off-board :

- A server to guarantee the consistency of data flow and high throughput of the communication channel.

- Image processing.

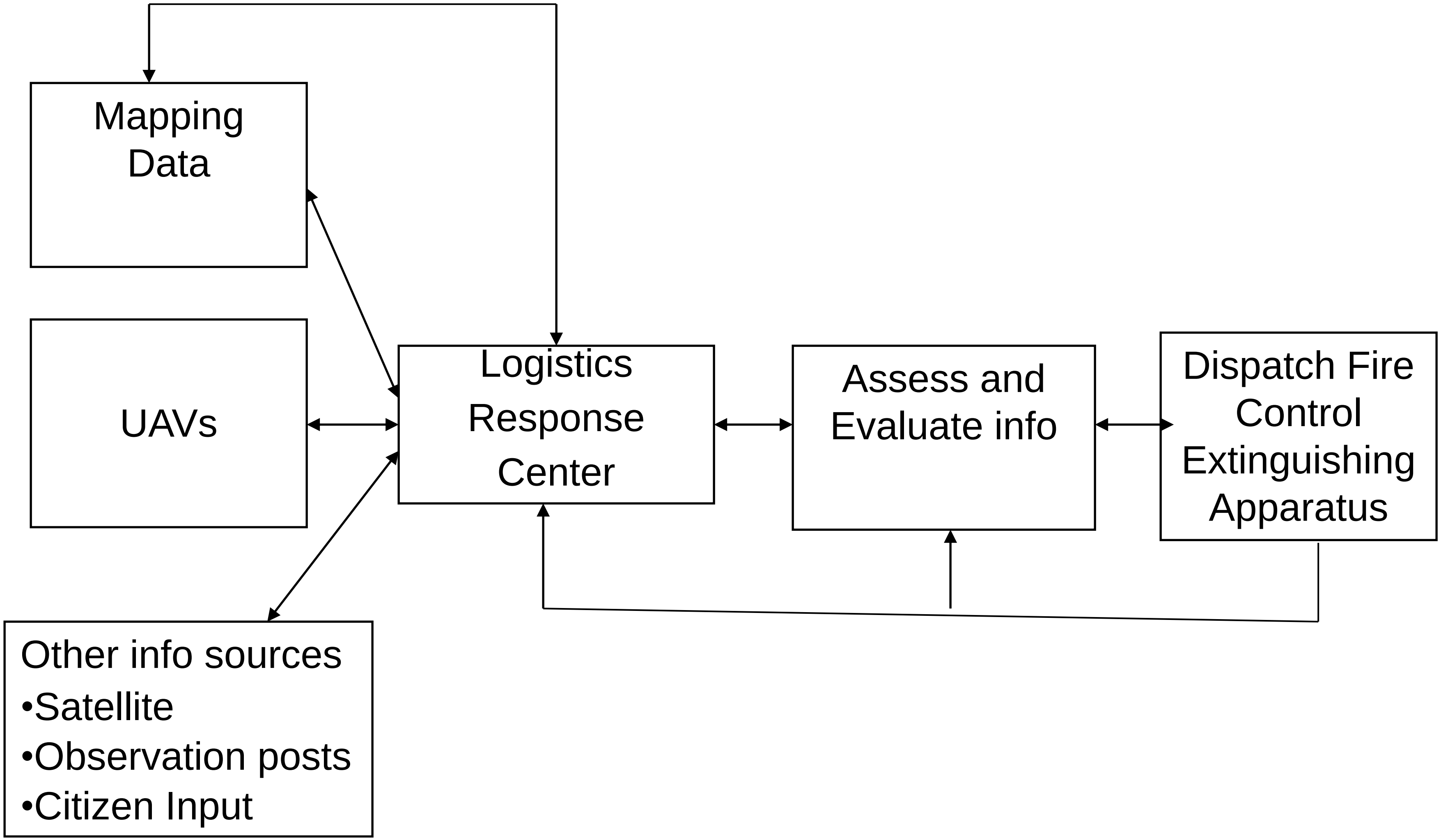
Forest Fire Prevention

- Emergency Response Center (ERC) – An integrated real-time mapping, detection, and logistics approach to forest fire prevention

Inputs:

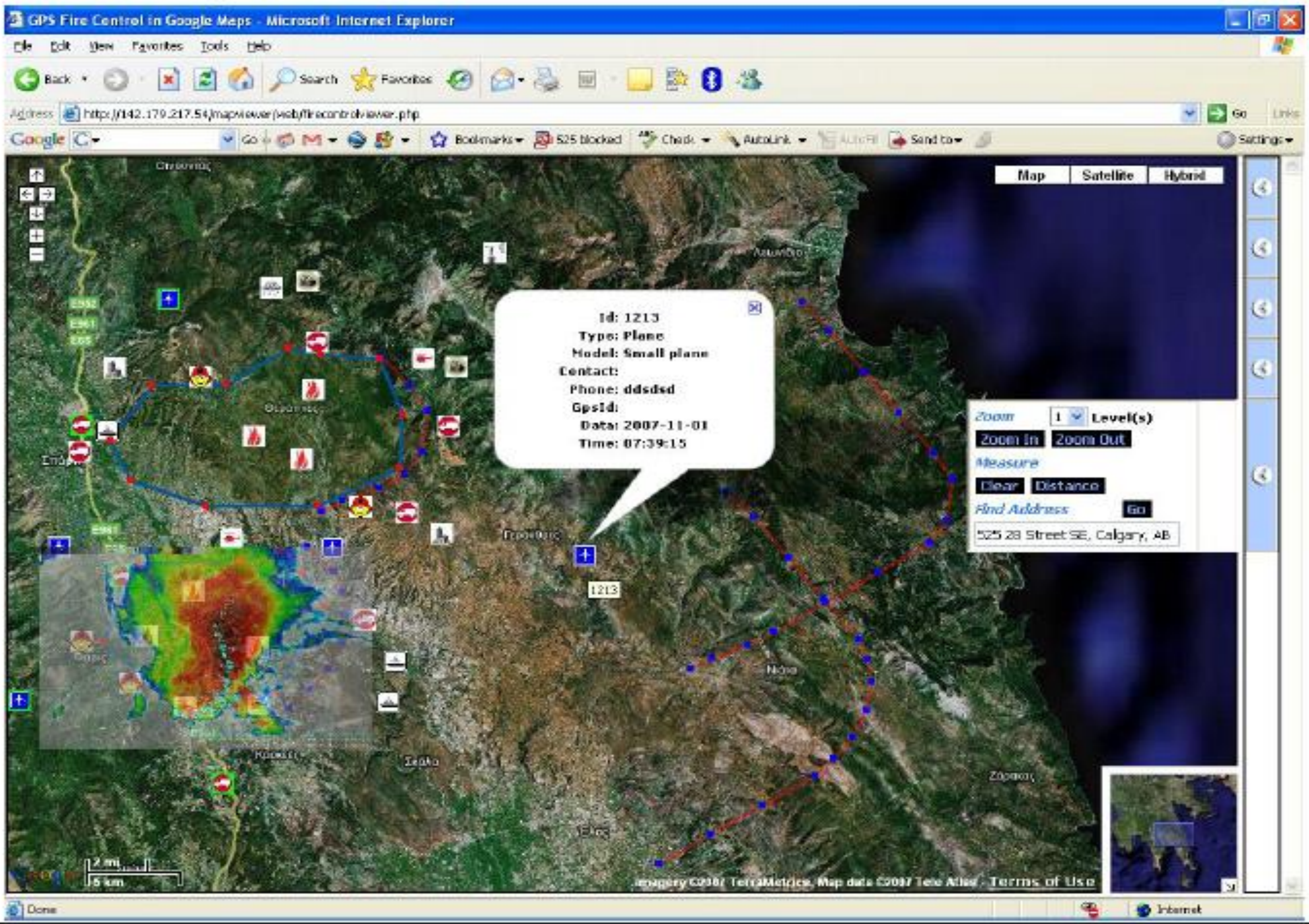
- Logistics Response Center – Command and Control

Emergency Response Center Overview



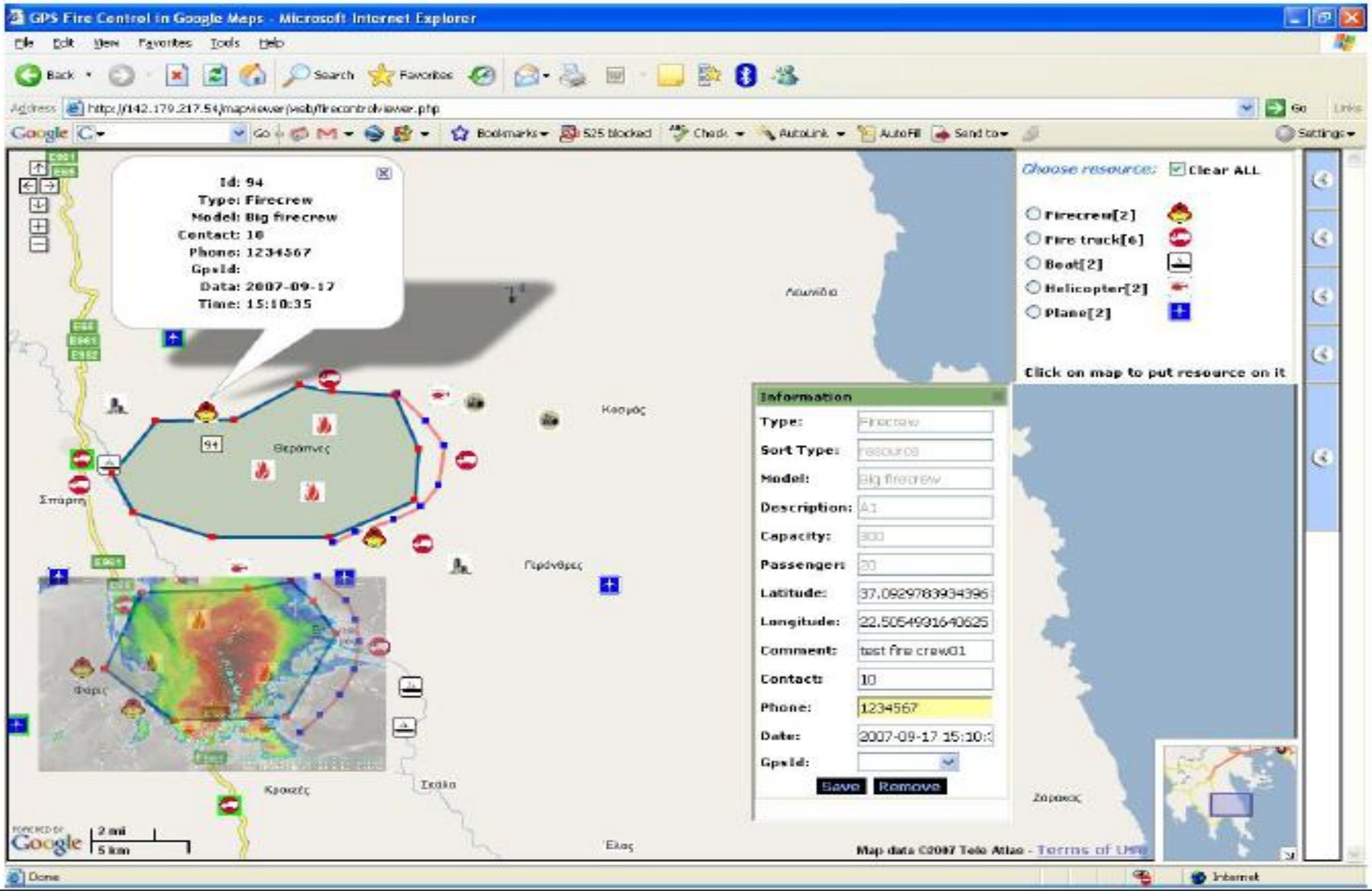
Mapping

Fire Control System



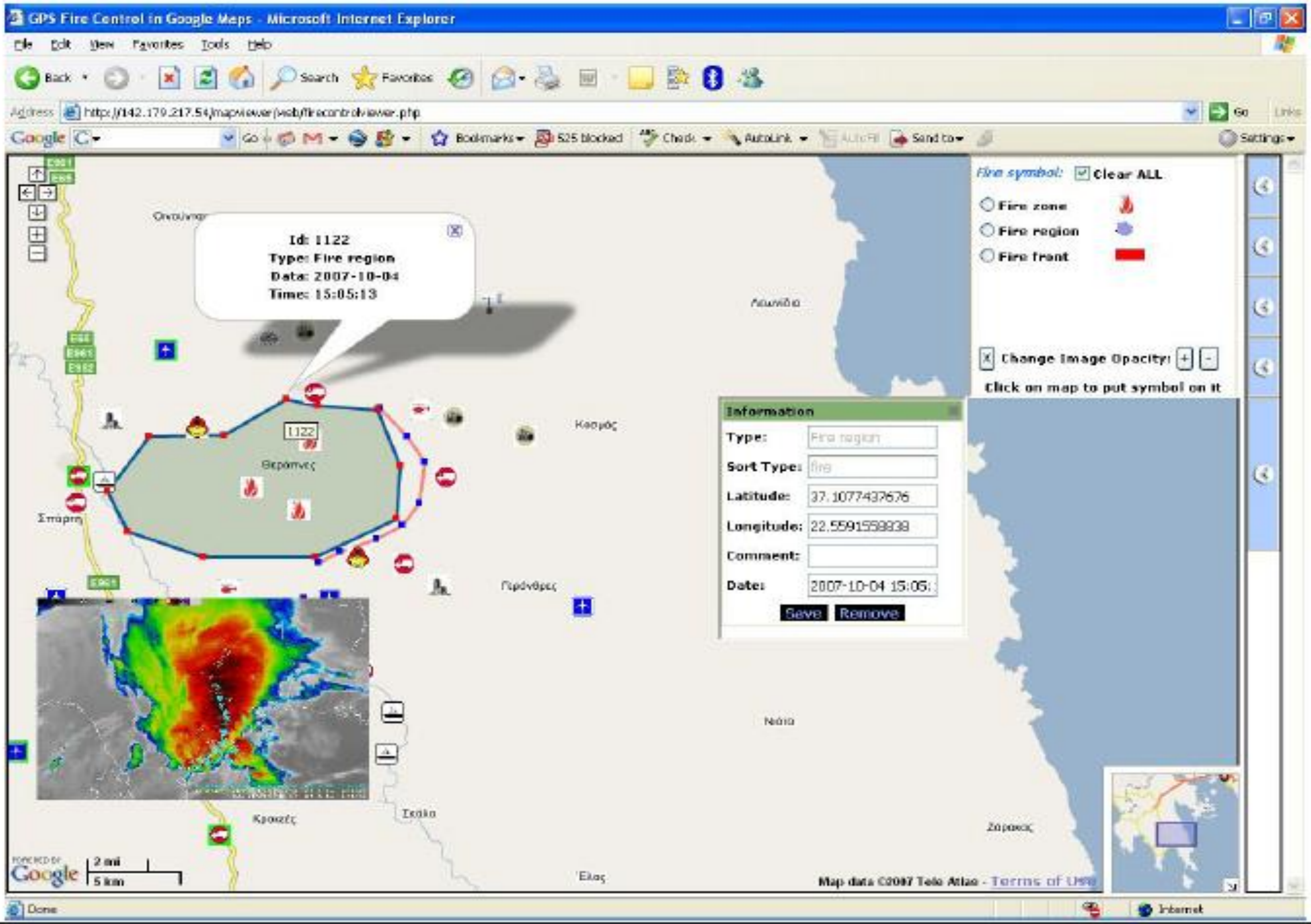
Mapping (cont'd)

Fire Control System

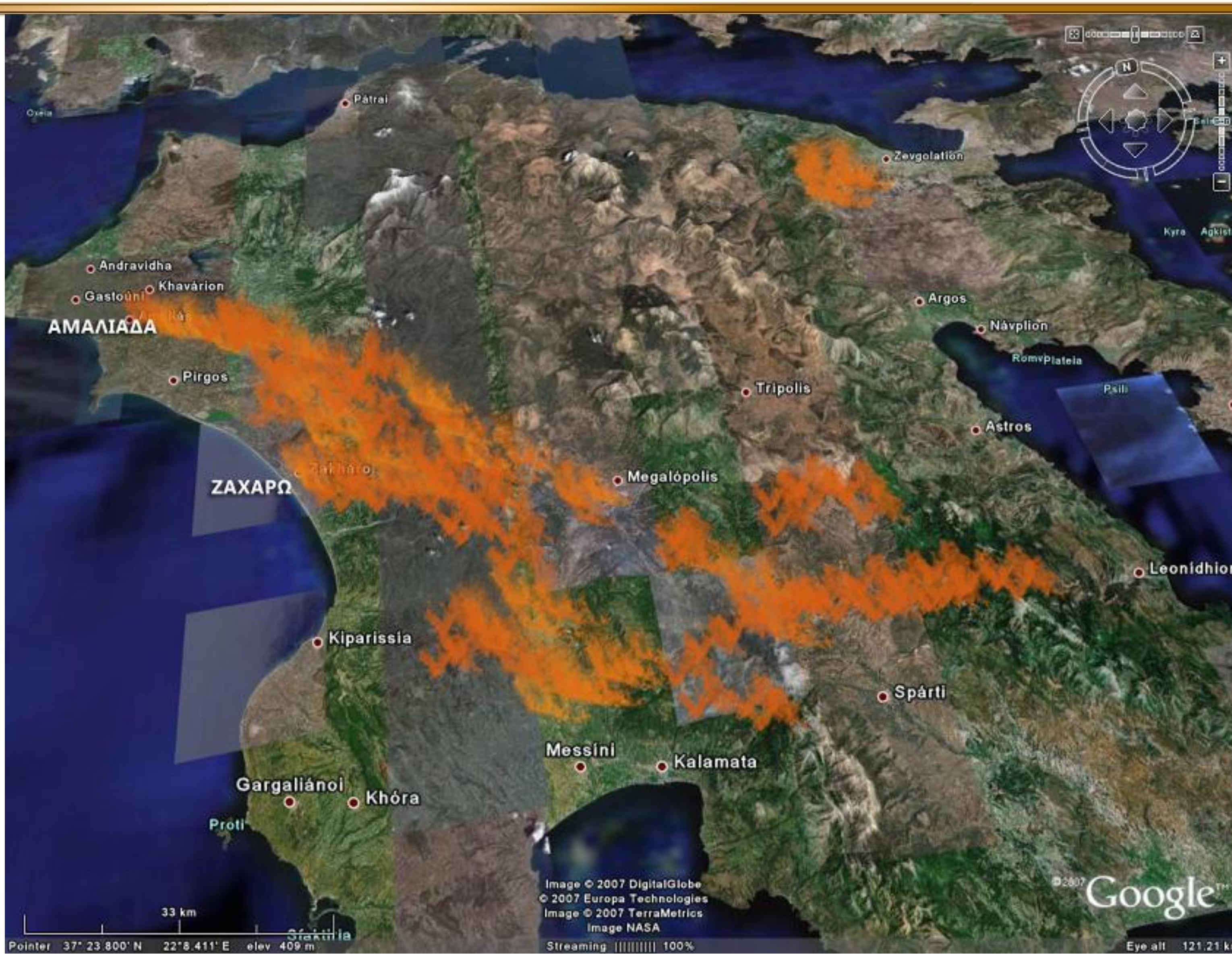


Mapping (cont'd)

Fire Control System



Google imaging



Catastrophic forest fires of 2007 in Greece

UAVs in fire detection

ALTAIR FiRE

Mission Plan with ALTAIR UAV:

- Fly +24 Hr Mission over Western US
- Collect AIRDAS data over multiple fires
- Telemeter via Ku-band to ground
- Real-time image rectification
- Distribute information to web and ICC's

ALTAIR Specifications:

Wing Span: 84 ft.; Length: 36.2 ft.; Height: 11.8 ft.

Weight: Max GTOW 7700 lbs.; Payload: 750 lbs.

Max Altitude: 55K feet

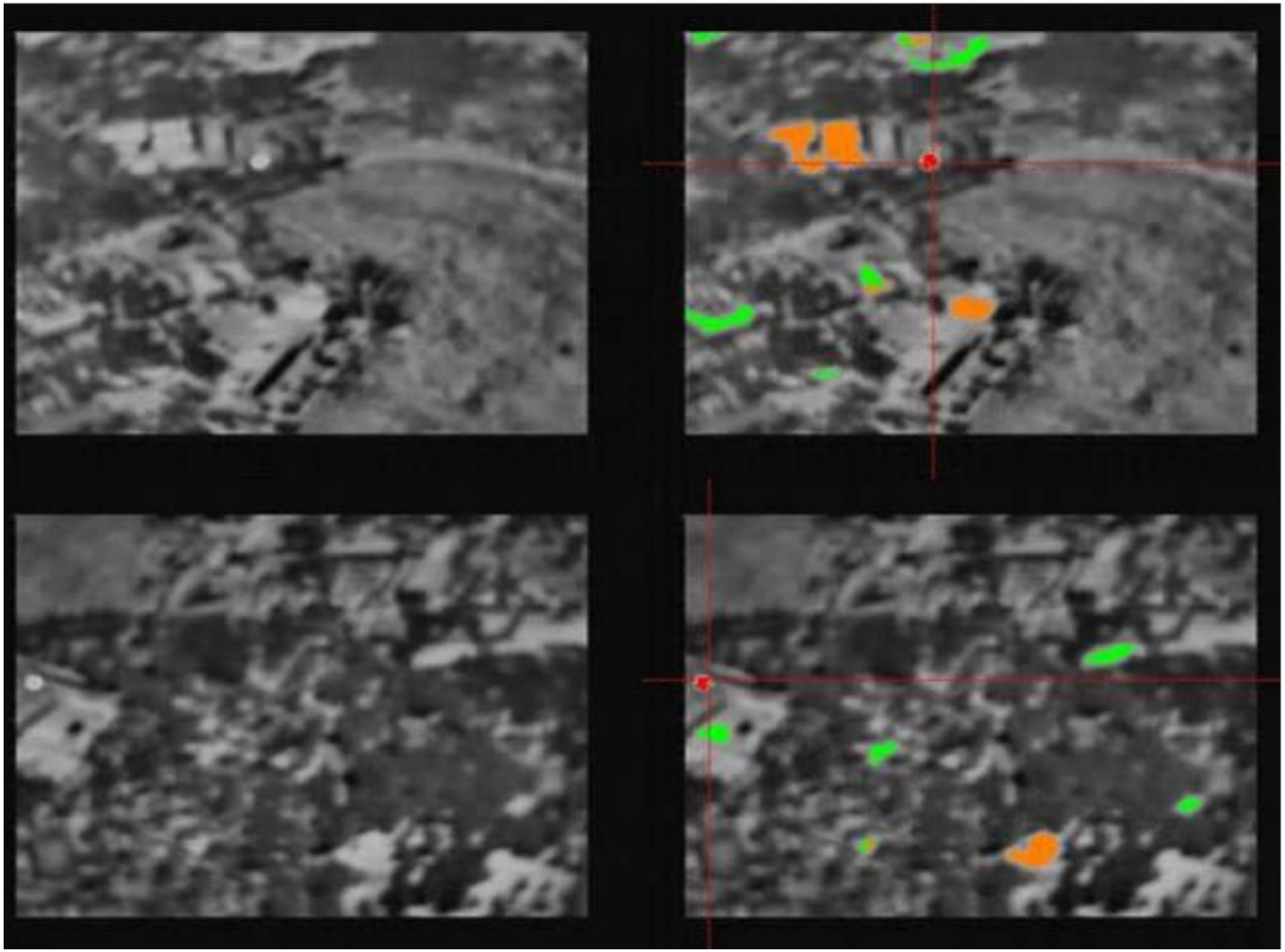
Endurance: 32 hrs w/ 700 lb payload

Cruise / Loiter Speed: 144 KIAS; **Range:** 4500 nm

C-Band LOS Range: 100 nm; 500 Kbs Ku-band OTH Operations; Autonomous flight capable

Navigation: 3 integrated IMU's & 3 D-GPS

Infrared Imaging



Inputs

- Fleet of Unmanned Aerial Systems (UAS), ground vehicles and ground support
- The Human Factor – trained team of technologists, operators and responders

Outputs:

- Detection of forest fire precursors/possible arsonists
- Immediate notification to response center
- Optimum dispatch of fire fighting personnel/equipment

⇨ A confluence of technologies, technologists and trained personnel to prevent forest fire catastrophes

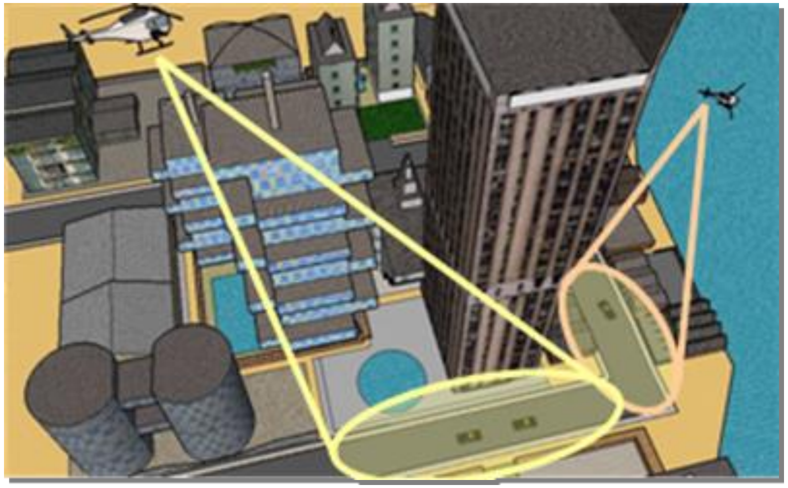
Localization of Potential Target Areas

Small UAVs equipped with EO/IR cameras must be capable of locating precisely potential targets.

Localization

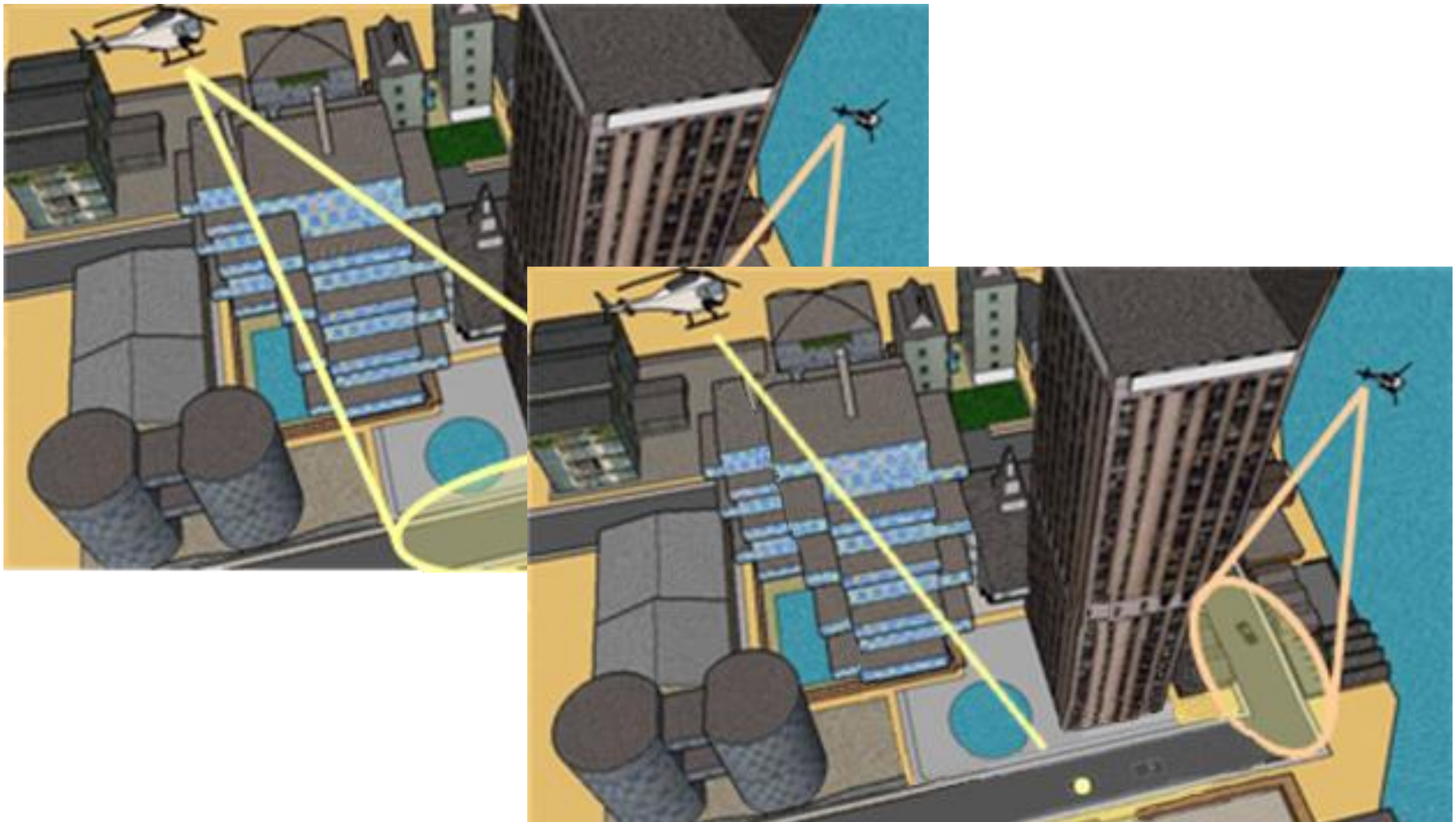
Definition

: determination of something's position.

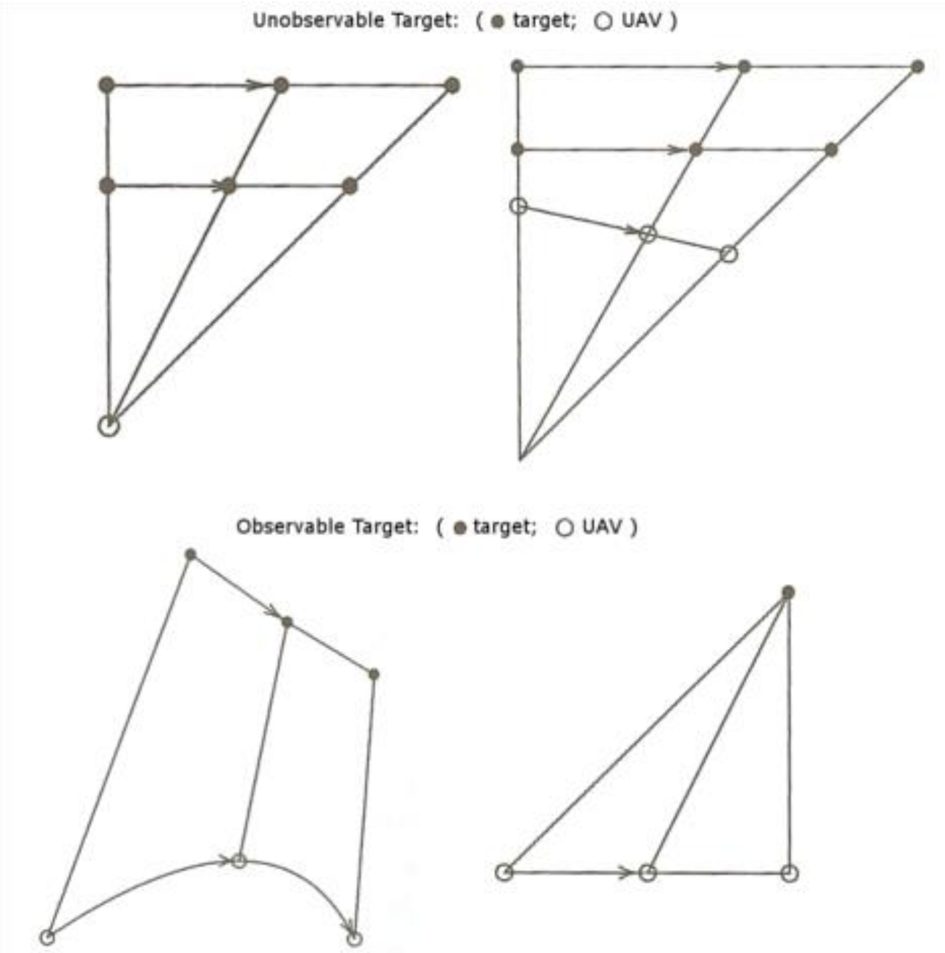


- Given a target in a known space, determine its position within that space using measurements from one or more observers.

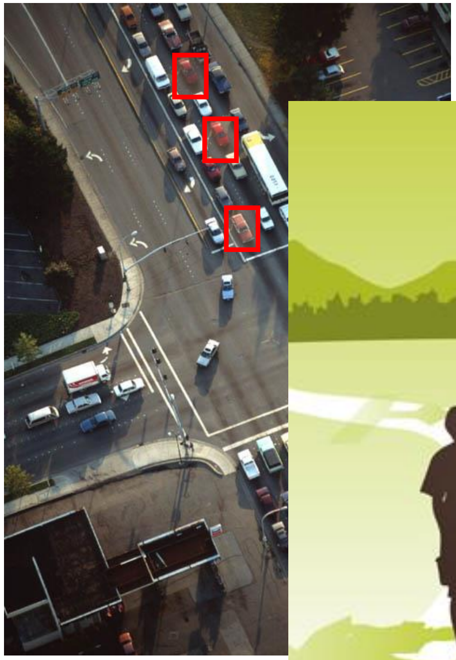
Why Geo-locate? (motivation)



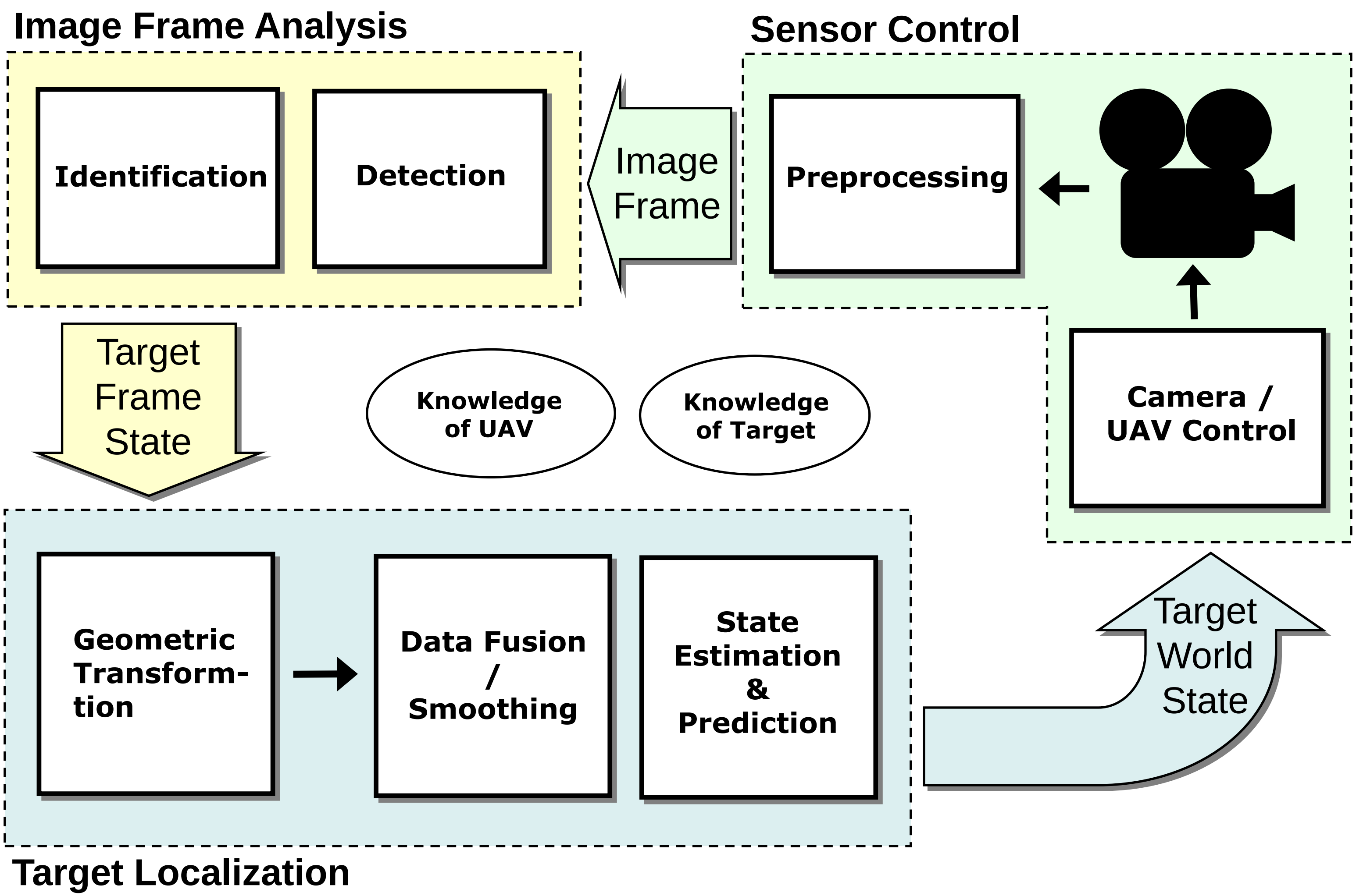
Benefits of Localization



- Target Observability
- Image Clutter
- Model Uncertainty



Localization System Architecture



Wildfire Monitoring

Uncontrolled wildfires have a big impact on both human population and the environment. Fires, whether of human or natural origin, have profound effects on land cover, land use, production, local economies, global trace gas emissions, and health.

Wildfires in western US (source: Boston)

Traditional Methods

Satellite images:

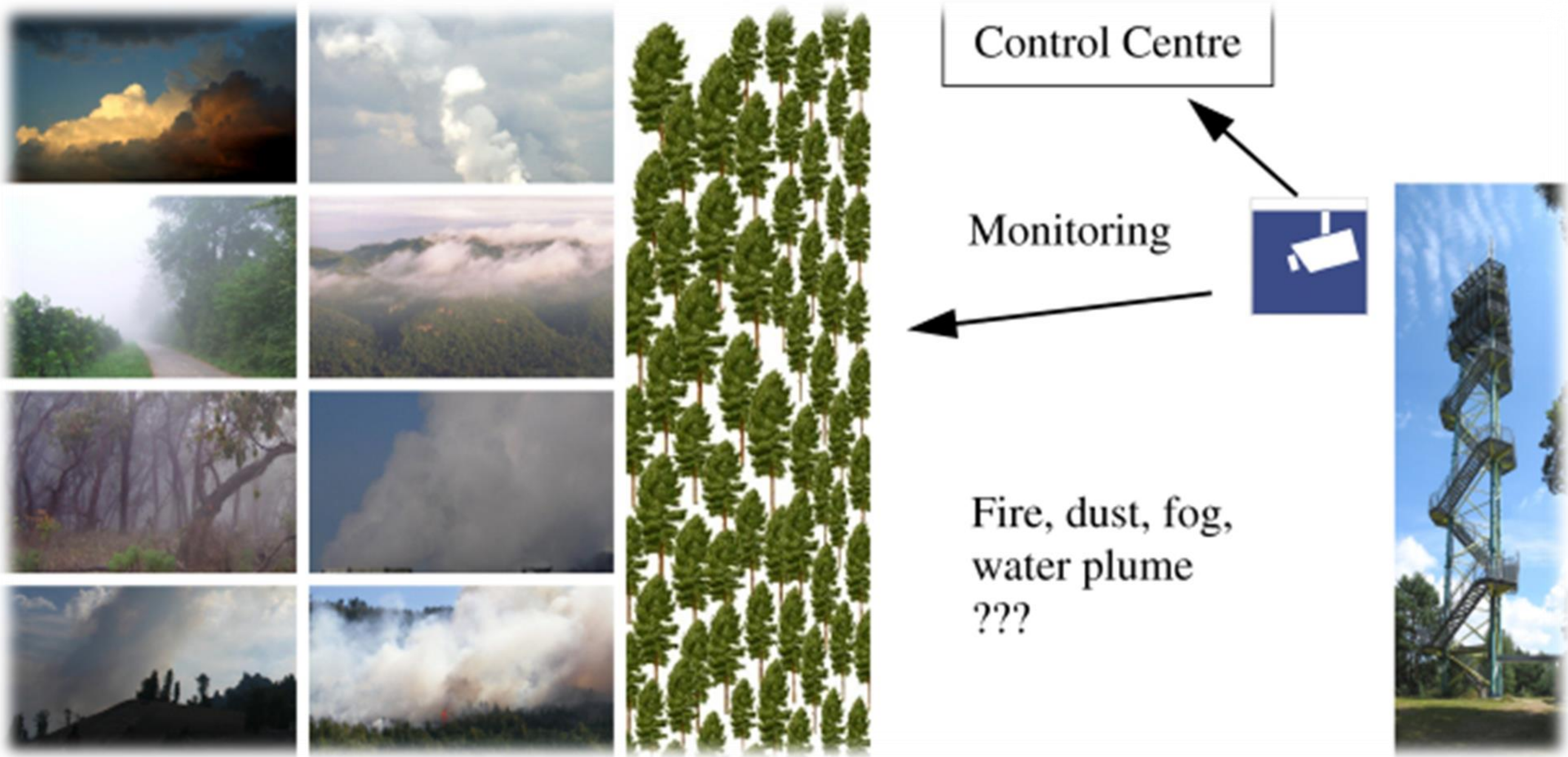
are still costly and the availability, ordering and delivery process is time consuming. Another fundamental problem with most satellite-based fire detection is that observation is limited to relatively cloud-free areas **[9]**.

Patrol Units:

costly, a lot of human recourses to cover wide areas, not fast response.

Upper Figure:Unique View of Wildfire Smoke
source (Earth Observatory). Lower figure: Firemen patrol(source: inciweb)

Problems with Traditional Methods



Scenes with alarm and false alarm situations (source: University of Duisburg-Essen)

Satellite Capabilities

Satellites are not so used to support direct detection of fires. They provide excellent wide area coverage. Revisiting time of the existing satellites is too coarse and not adequate as a primary source for making field decisions **[9]**.

Satellite	Spatial resolution	Revisiting cycle
GOES, USA http://www.goes.noaa.gov/	1000 – 4000 m	30 min
Meteosat, Europe http://www.esrin.esa.it/msg/pag0.html	2500 – 5000 m	30 min
NOAA/AVHRR, USA http://edc.usgs.gov/glis/hyper/guide/avhrr#avhrr1	1000m	12 hours
Defense Meteorological Satellite Program /OLS, USA http://www.laafb.af.mil/SMC/CI	600 – 2700m	12 hours
Landsat, USA http://landsat.gsfc.nasa.gov/	15- 30m	16 days
MODIS (EOS), USA http://modis.gsfc.nasa.gov/	250,500,1000m	12 hours
Spot, HRVIR, France http://www.spotimage.fr/home/system/earth/welcome.htm	10 – 20m	Daily
ERS/ATSR, Europe http://www.esa.int/	1000 m	17 – 18 days
Indian Remote Sensing Satellite (IRS), India http://www.isro.org/	23.5 m	24 days
ADEOS-II (Global Imager), Japan-USA http://asterweb.jpl.nasa.gov/	250 – 1000m	4 days
Ikonos, Private http://www.spaceimaging.com	1 – 4 m	1 – 3 days

Space-borne Fire Detection Platforms **[9]**

The Need for Technological Solution

Especially in populated areas a rapid response is required and the following actions need to be taken:

•Real-time data input for wild land fire spread models needed.

•The need for fire ground mapping to aid in resource allocation and deployment.

•The need for vector modeling to manage evacuations and relocations.

•The need to project or model possible impact on critical infrastructure components, including remotely located cellular communications facilities.

The need to automatically activate exterior structural defense systems (source: Fire Protection Engineering magazine.)

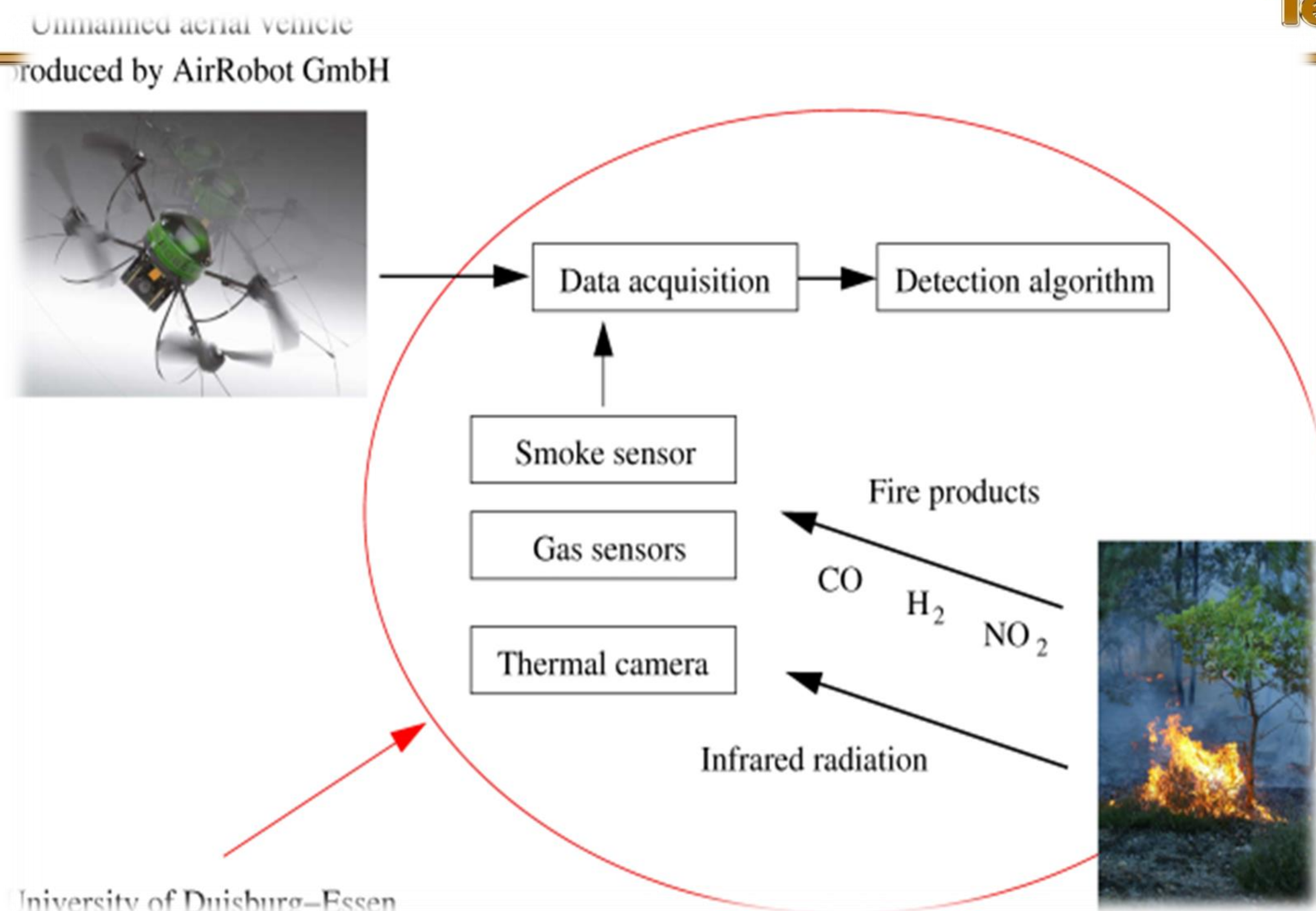
Fire monitoring constraints:

- Time is critical (delays can result in dramatic consequences as potentially human losses)
- Operational environments are unfriendly due to the strong winds

Using Unmanned Aerial Vehicles (UAVs) :

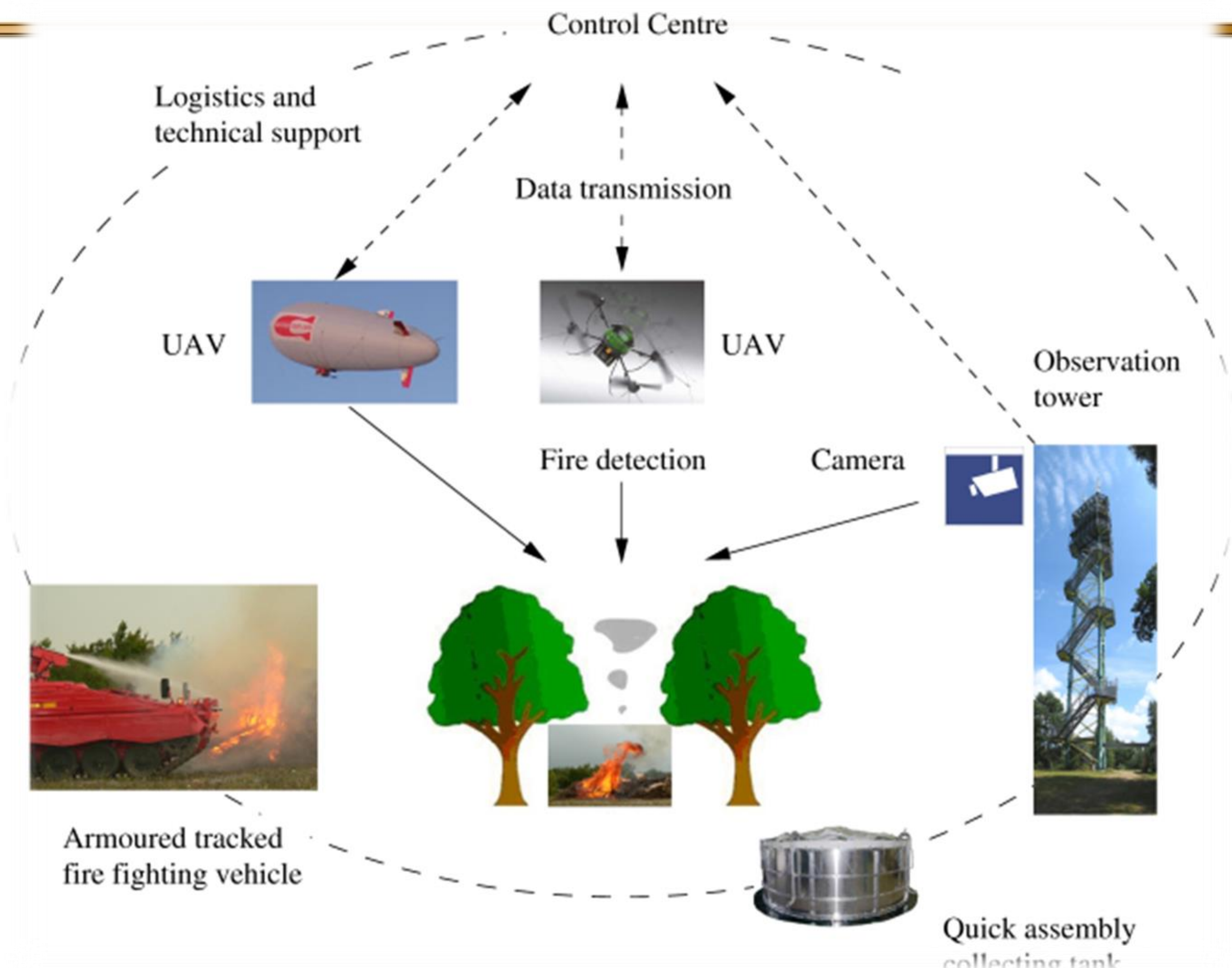
- UAVs are fast and can exhibit autonomous behaviors.
- Can perform operations hard to execute by human operators.
- Low operating costs.
- Many efforts to automate forest and wild land fire detection have focused on

UAS?



Gas and Smoke detection (source: University of Duisburg-Essen)

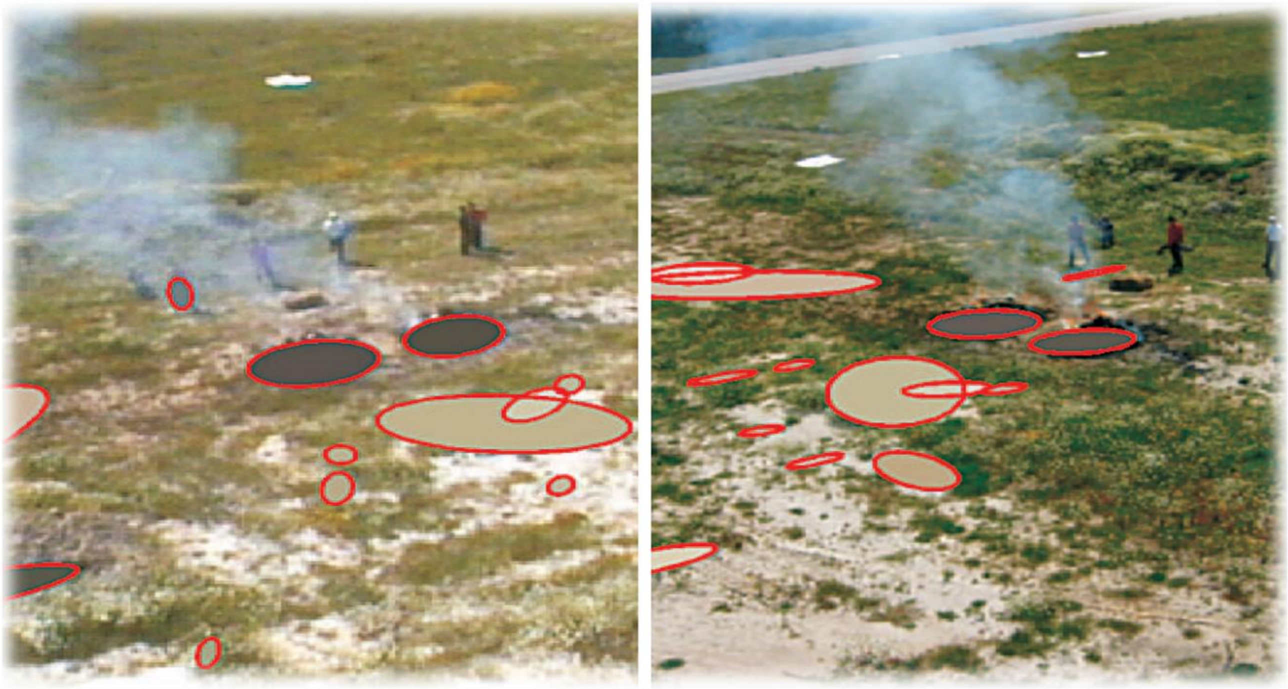
UAS?



Schematic structure of the integrated forest fire detection and fire fighting system(source: University of Duisburg-Essen)

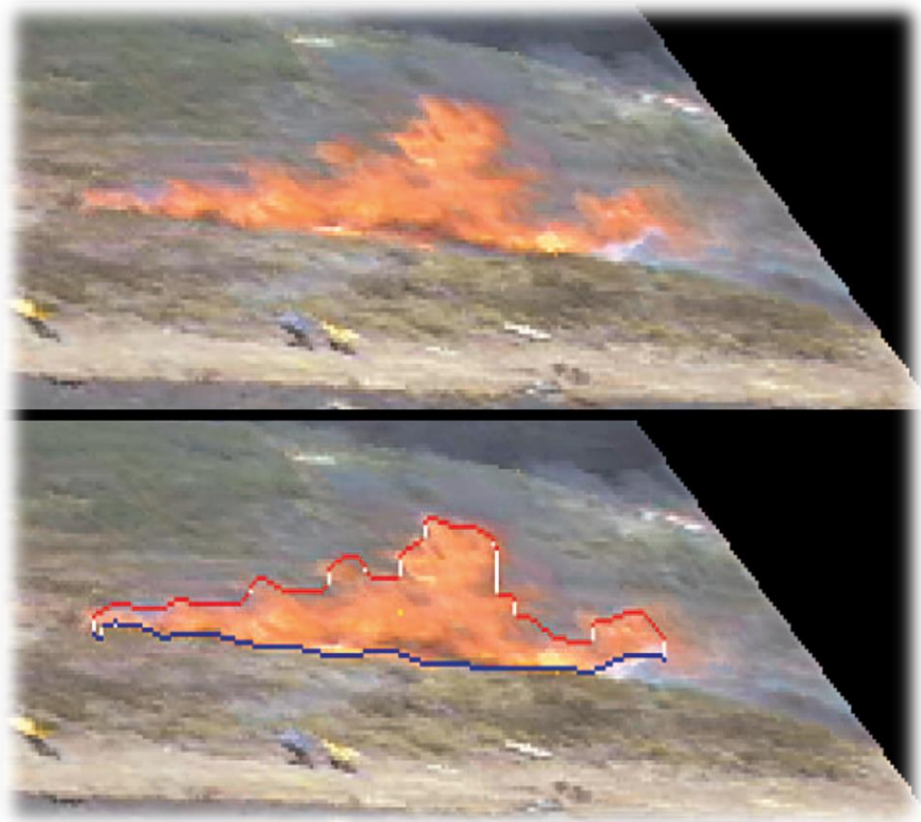
Fire Detection Using UAS

The UAVs are distributed around the object of interest. Each camera will provide measures of the object of interest. Procedures are employed to combine the results obtained from several cameras to derive the 3-D model of the fire.



Correspondences for blobs in two images originating from two different UAVs with (left) a video sensor and (right) a high-resolution digital camera.

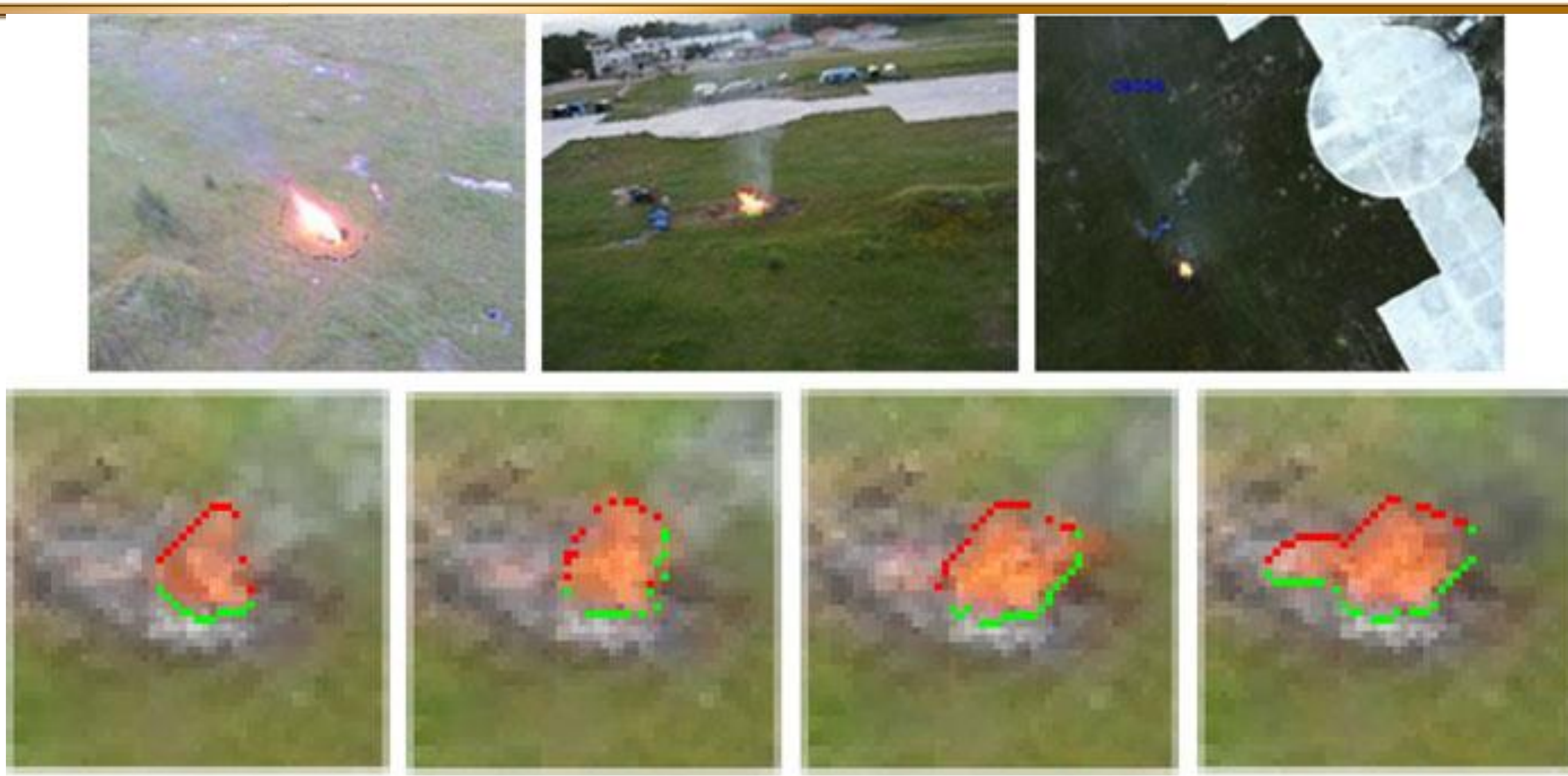
Fire Detection Using UAS



Teleoperation experiment: Visual and IR images and other information depicted in the teleoperation station**.**

Fire images: *(upper) stabilized image and (bottom) segmented fire: in blue, the pixels of the fire base; in red, the top of the flames.*

UAS for Automatic Forest Fire Monitoring



Top left: image from Heliv, after stabilization and feature extraction.
Middle: image from Marvin after stabilization and feature extraction.
Right: image from Karma
Bottom: details of the extracted contours.
Green: fire front. Red: top of the flames.

Search & Rescue (SAR)

Georgia Tech

Top left: Schiebel's Camcopter S-100 (UAV) (Source: Naval-technology).Top Right: Rescue scenario with UAVs . Bottom left: Haiti earthquake *(Source: Coroflot).* Bottom right: Fire rescue operation *(Source: DronesWork).*

SAR Hypothetical Scenarios

- Point-to-Point Communications – Chemical Leak Response
- Search for survivors in a building that is on fire.
- Search and rescue operation for survivors after an avalanche.
- Search and rescue operation for survivors after a shipwreck.
- Ad Hoc Communications Infrastructure – Earthquake Response.
- Point-to-Point Communications – Chemical Leak Response

TGR Helicorp Alpine Wasp poised to launch Everest rescue operations (Source Flightglobal)

Pars Aerial Rescue: (Source *RTS Labs*)

Ad Hoc Communications Infrastructure – Earthquake Response

Equipment:

- The specialized equipment necessary for this application includes a thermal camera that will be installed on all vehicles in order to locate civilians in the debris.
- To provide wireless communications the RN-XV Wifly communication will be used. This module allows a maximum transmission power of 32mW (approximately 100 meters line of sight)

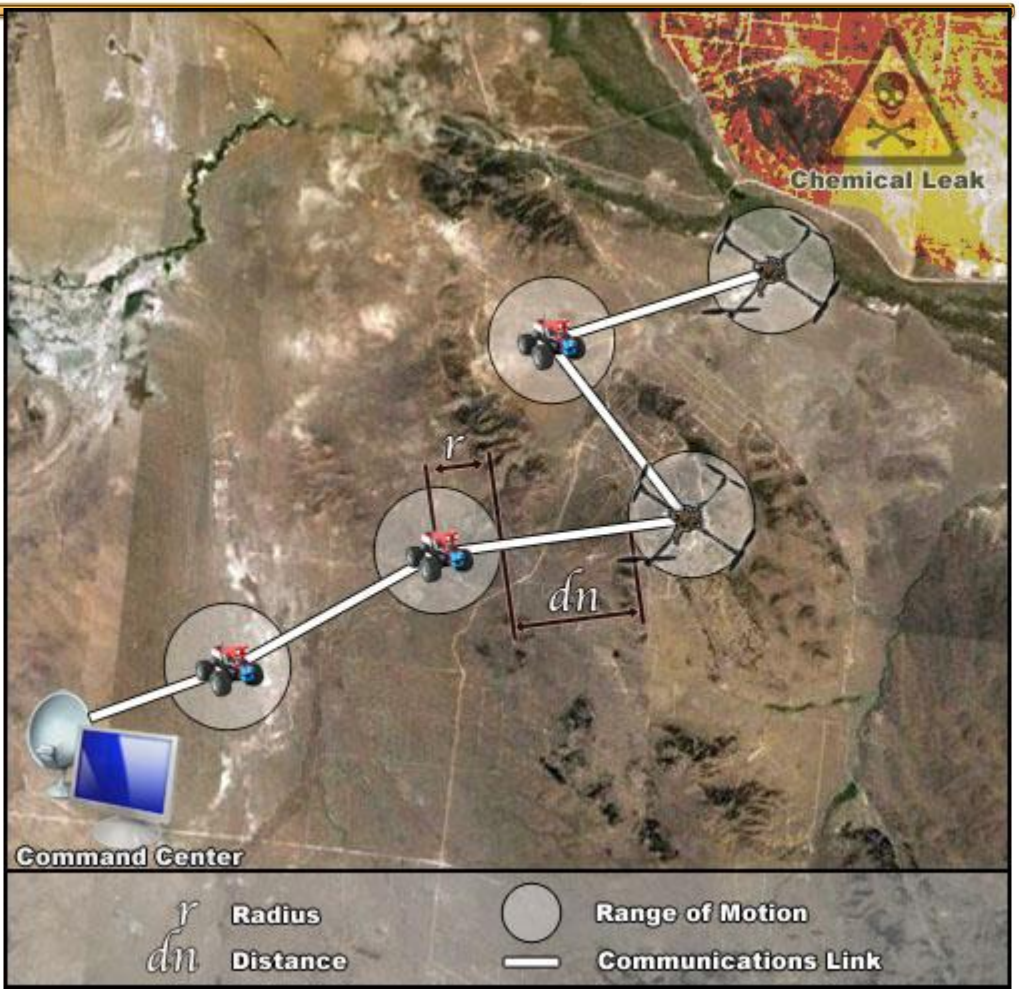
Establishment of a mobile ad hoc network to aide victims of a natural disaster.

Ad Hoc Communications Infrastructure – Earthquake Response

Equipment:

The specialized equipment necessary for this application includes a chemical sensor, that will be installed in all vehicles in order to perform the appropriate readings.

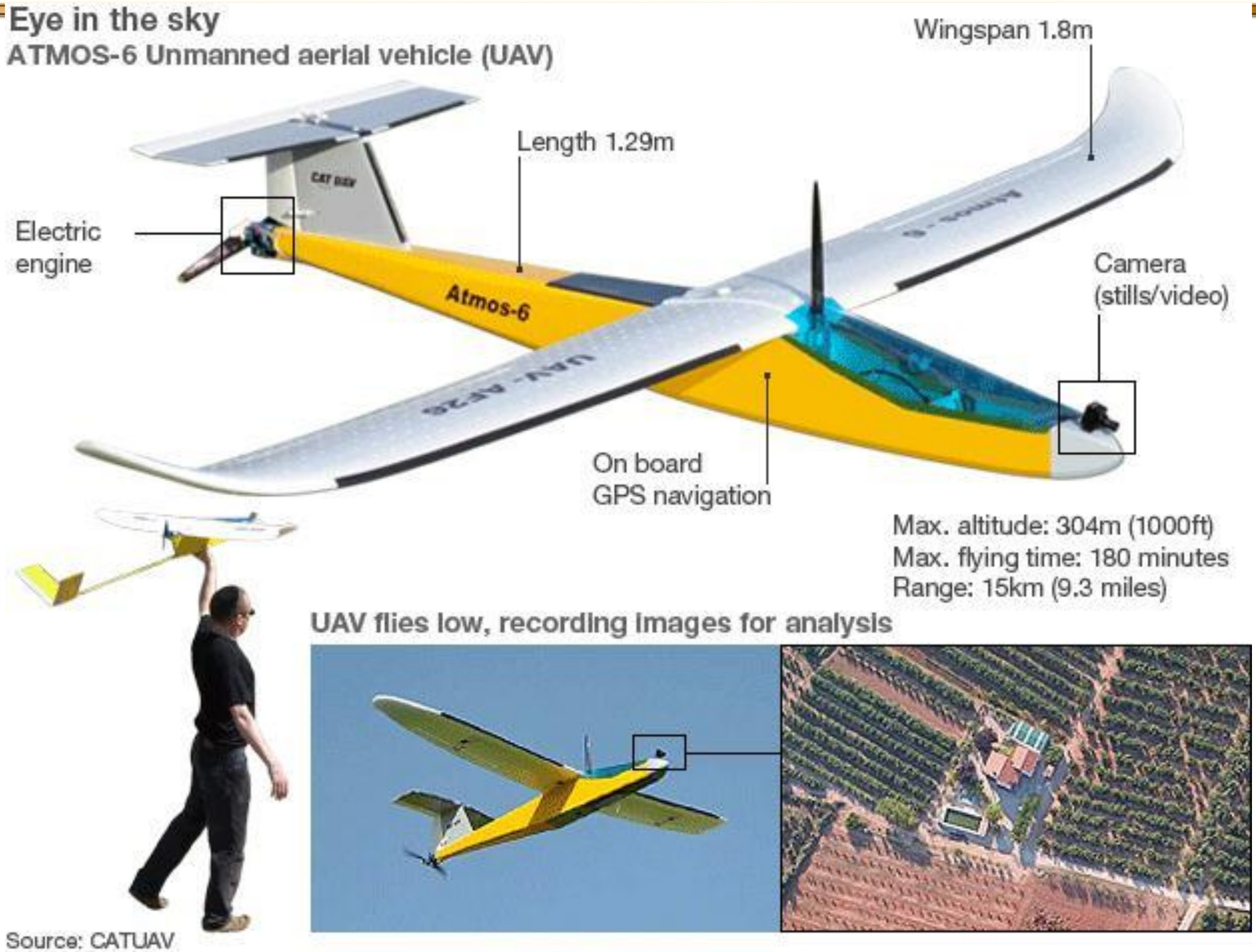
The communication module necessary for the link will be a WiFi module.



Observation of a chemical leak site via a chain of vehicles.

Agricultural Applications

UAS for Crop Applications



Earth Observation Technologies:

Videos: UAS for Crop Applications

- AG210 Spraying _(1:15)_ http://www.youtube.com/watch?v=aqYpEyEZ2jI

- Precise crop monitoring using UAVs _(1:24)_ http://www.youtube.com/watch?v=QvrRkXpeLec

- ZERO UAV-Pesticide Spraying UAV_(3:01)_ http://www.youtube.com/watch?v=hdSzGxjvwDs

Source: pbs

Videos: UAS for Crop Applications

Top left: Rmax spraing (source: microdrones) : Top Right: Rmax in a farm (source: DIY Drones) . Bottom left: UAV in a farm (source: futurespeaker). Bottom right: Farmer with a UAV (source: DIY Drones)

Flight Test

Tactical approach and landing

Tactical departure

eturn at 70 ft/s

backwards oval

Flight Test (Cont'd)

hover over fort benning

glider launch

fixed heading pirouette

Pirouette to landing

Conclusions

- UAVs can be exploited for a variety of rescue, reconnaissance, and forest fire prevention.
- UAVs already used in many countries for such purposes.
- An integrated system architecture is required to achieve optimum results.