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An Architecture for Seamless Integration of UAS-based Wildfire Monitoring Missions

UNIVERSITAT
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DE CATALUNYA

ICARUS Research Group
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Outline

- Presentation of ICARUS Research Group
- Motivation
- System Technologies and Architecture
- Application Scenario: Wildfire
- Conclusions

ICARUS Research Group

- Technical University of Catalonia at Barcelona
  - 15 schools: EPSC
  - 40 departments: DAC
  - 30.000 students
  - 2.500 PDI
- Castelldefels School of Tech.
  - Electrical Engineering
  - Aeronautic Engineering
  - 3.000 students
- Computer Architecture Dep.
  - 120 PDI
  - High Performance Computes (BSC)
  - Network Distributed Applications

ICARUS Research Group

- ICARUS
  - Intelligent Communications and Avionics for Robust Unmanned aerial Systems

- E.Pastor (Ph.D.),
- C.Barrado (Ph.D.),
- M.A. Peña(Ph.D.),
- J.López,
- X.Prats,
- J.Ramírez,
- P.Royo
- E.Santamaria

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- Computer Sciences
  - web services
  - embedded programming and compilers
  - GIS
  - formal methods and verification
- Electrical Engineering
  - WiFi, WiMax, RC, Satellite
  - Electronic board design
- Aeronautics Engineering
  - navigation
  - aeronavigation procedures
  - certification

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Shadow UAV 5,5m

AP04

Megastar RC 2,5m

Flir A320

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- Main resources

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Motivation

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- State of the Art in application of UAS:
  - Firebird 2001: Fire Fighting Management Support System
  - ERAST / FiRE: NASA Project Design
  - WRAP: NASA / US Forest Service Project
  - Fire detection by Szendro Fire Department, Hungary
  - NASA Dryden Flight Research Center

Firebird 2001

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- MALAT Division of Israel Aircraft Industries
  - Demonstrated a system capable of fire monitoring during 1996 based on the Firebird and Heron platforms:
  - Firebird:
    - Payload 25 kg, endurance 5 h cruise 60 KIAS, operating altitude 15,000ft.
  - Heron:
    - Payload 250 kg, endurance 40 h cruise 80 KIAS, operating altitude 35,000ft.

ERAST / FiRE NASA Project

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- ERAST (Environmental Research Aircraft and Sensor Technology) / FiRE
  - Develop and flight-demonstrate UAVs for cost-effective science missions
  - ALTUS-II
    - Payload 150 kg, endurance 12 h cruise 65 KIAS, operating altitude 30,000ft.
  - ALTAIR scientific variant of the PREDATOR-B
    - Payload 340 kg, endurance 32 h cruise 151 KIAS, operating altitude 50,000ft.

WRAP NASA Project

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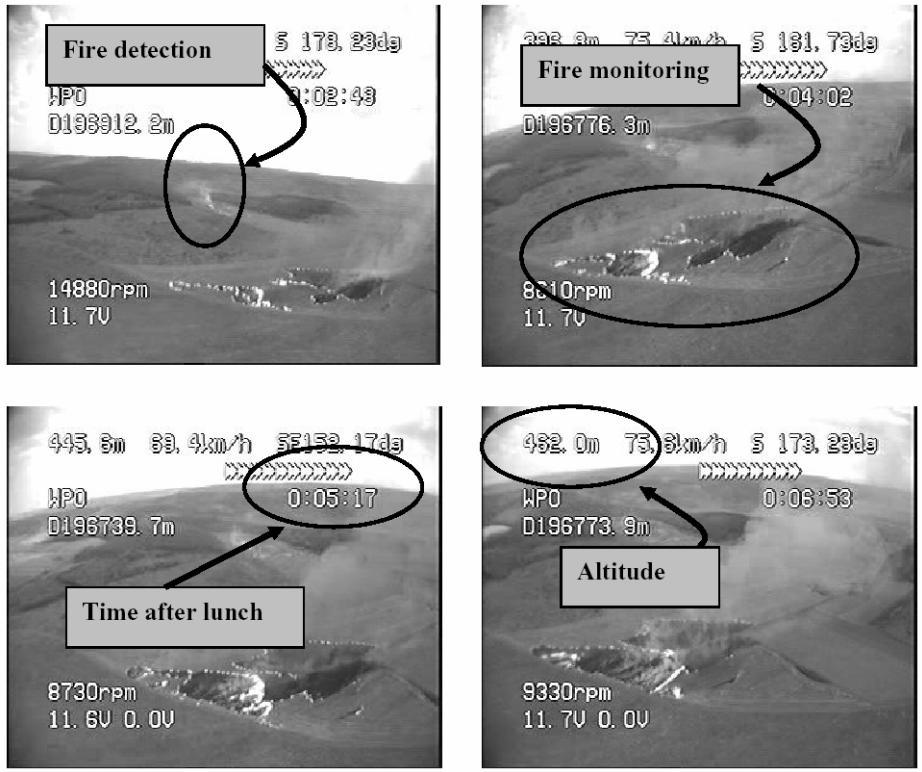
- WRAP (Wildfire Research and Applications Partnership)
  - Real fire monitoring missions over the USA west-coast
  - Airborne InfraRed System (AIRDAS)
  - Thermal scan bands:
    - 1 (0.61 - 0.68)
    - 2 (1.57 -1.70)
    - 3 (3.60 - 5.50)
    - 4 (5.50 - 13.0)
  - Calibration: IR +600 C. FOV: 108 degrees. Scan Rate: 4-23 scn / sec., Resolution: 8m at 10Kf

Szendro Fire Department, Hungary

- Small UAS used for early fire detection:
  - Low cost, simple approach
  - Fire department integrated UAV



Motivation

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"Market will be driven by the end user requirements and applications"

"Operational and acquisition costs when compared with an alternate method of completing the same mission will determine the level of success for civil applications"

"Access to NAS no expected until 2015"

- Earth Observation and the Role of UAVs, a Capability Assessment, NASA DFRC, Ago'06

Motivation

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"Market will be driven by the end user requirements and applications"

--> Requirements

"Operational and acquisition costs when compared with an alternate method of completing the same mission will determine the level of success for civil applications"

--> Small UAV and Open Architecture

"Access to NAS no expected until 2015"

--> Remote operations: Wildfire missions

--> and... collaboration with local firemen

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System Technologies

- Firemen requirements: GRAF
- System Architecture
- Communication Gateway
- Mission: HMI and End User Procedures

Geographical situation

- Fire extinction responsibility is decentralized by regions.
- Inter-region / central government cooperation available if necessary.

Area: 31 932 km2

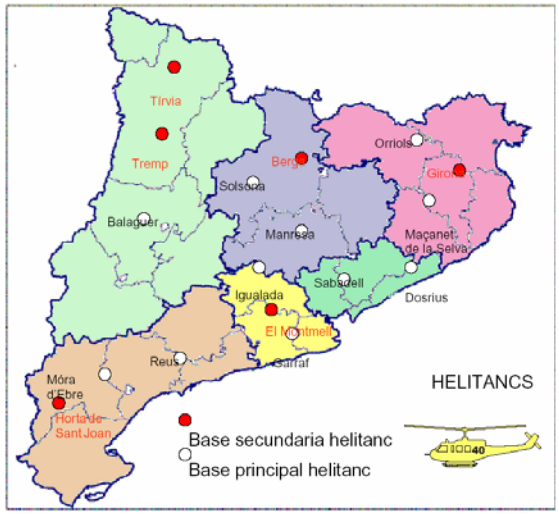
Population: 6.704.146

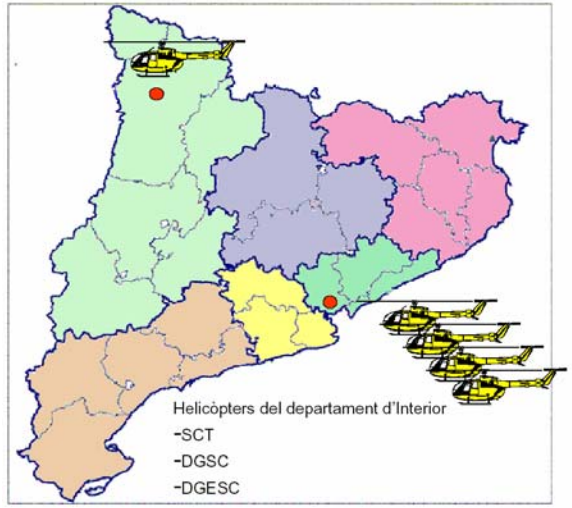
Fires during 2006: 629

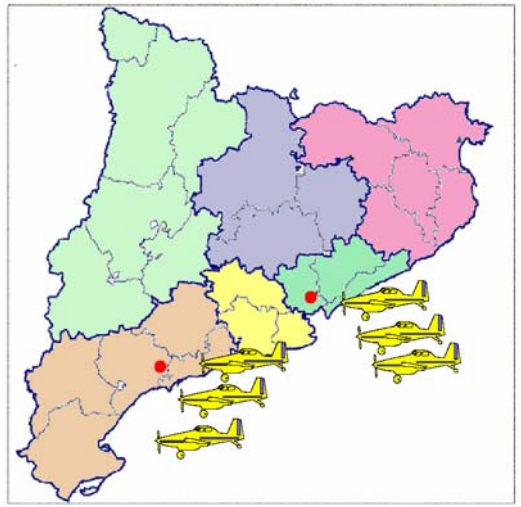
Burnt area: 3.404 ha

Worst year (1994): 76.125 ha

Available aerial resources

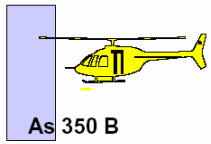






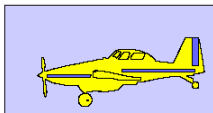
amfibis

5.500 x 2 = 11.000 l.



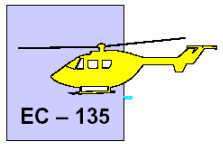
helicòpter suport HS

500 x 4 = 2.000 l.



avió vigilància i atac AVA

3.200 x 6 = 19.200 l.



H–03 H-05 (polivalent amb funcions d'helitanc)

900 x 2= 1.800 l.

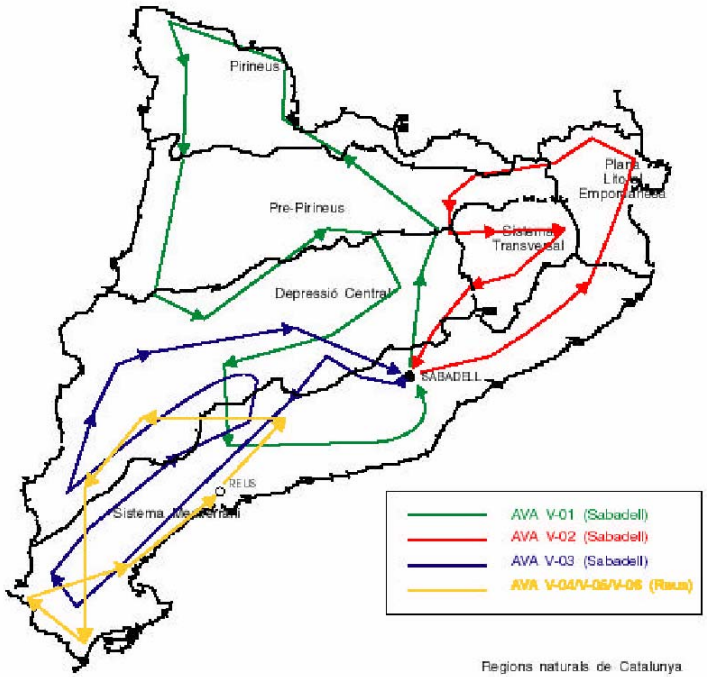
6 Bell 212 + tanc
4As 350 B3 + tanc

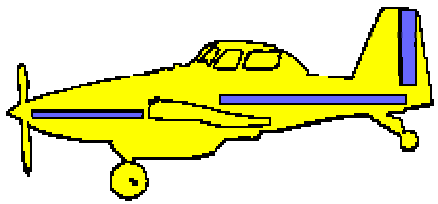
helitanc HLT

1.200 x 10 = 12.000 l.

H-02 helicòpter polivalent 600 x 1 = 600 l.

Aircraft operation schemes





- Surveillance and attack airplanes follow predefined routes around the clock during daytime.
- In case of detection first retardant attack is executed
- Rest of available units are used on demand.
- No flying during night time.

Conditionings

- Geographical application area:
  - Relatively small area; operations under responsibility of local government and therefore with limited budget.
  - Externalized aerial resources except C&C helicopters.
  - UAS to be operated by external providers.
- Integration with fire fighters own systems:
  - Aerial operators see opportunities but do not want to see a UAS mixed in their airspace!!
  - Ground firefighters are eager to receive any available technology innovation.
  - Even though existing legal limitations and pilots opposition, ground firefighters suggest several application scenarios with strict manned/unmanned separation.

Proposed lines of work

- Identify effective application scenarios
  - Contacts with many fire fighter organizations
  - Application scenarios change depending on user capabilities and geographical conditions
  - Human-Machine Interface critical for non-IT users
- Identify operational and information flow and implement the technology to support
  - Highly dependent on the selected autopilot
  - Information flow – management – exploitation: key points to create an usable system for non-IT users

Proposed system architecture

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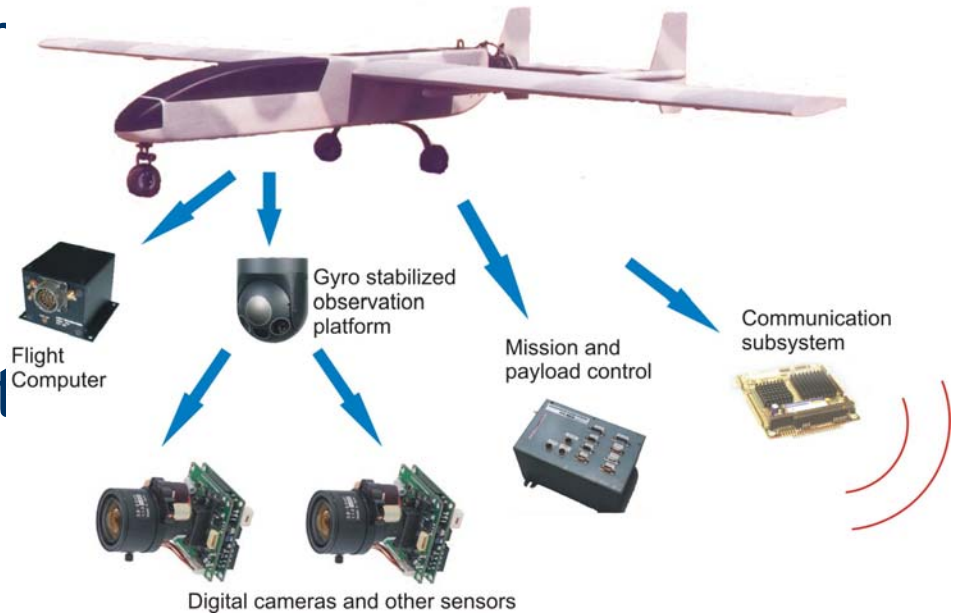
- Oriented to mission management and information flow.
- Real Time Data Acquired and Distribution
- System divided into four components:
  - **UAS**: designed for data acquisition and autonomous operation.
  - **Mobile Control Station**: responsible for UAS tactical control (flight operations), data gathering and processing.
  - **Squad Information Terminal**: provides information to the ground crew.
  - **Data Processing Center**: strategic control of multiple ongoing operations, data storage for post-fire analysis, high-level coordination and decision center.

Proposed system architecture

- UAS components:
  - Airframe
  - Flight Control Syster
  - Payload
  - Payload/Mission Control System
  - Communication Syst



UAS Architecture

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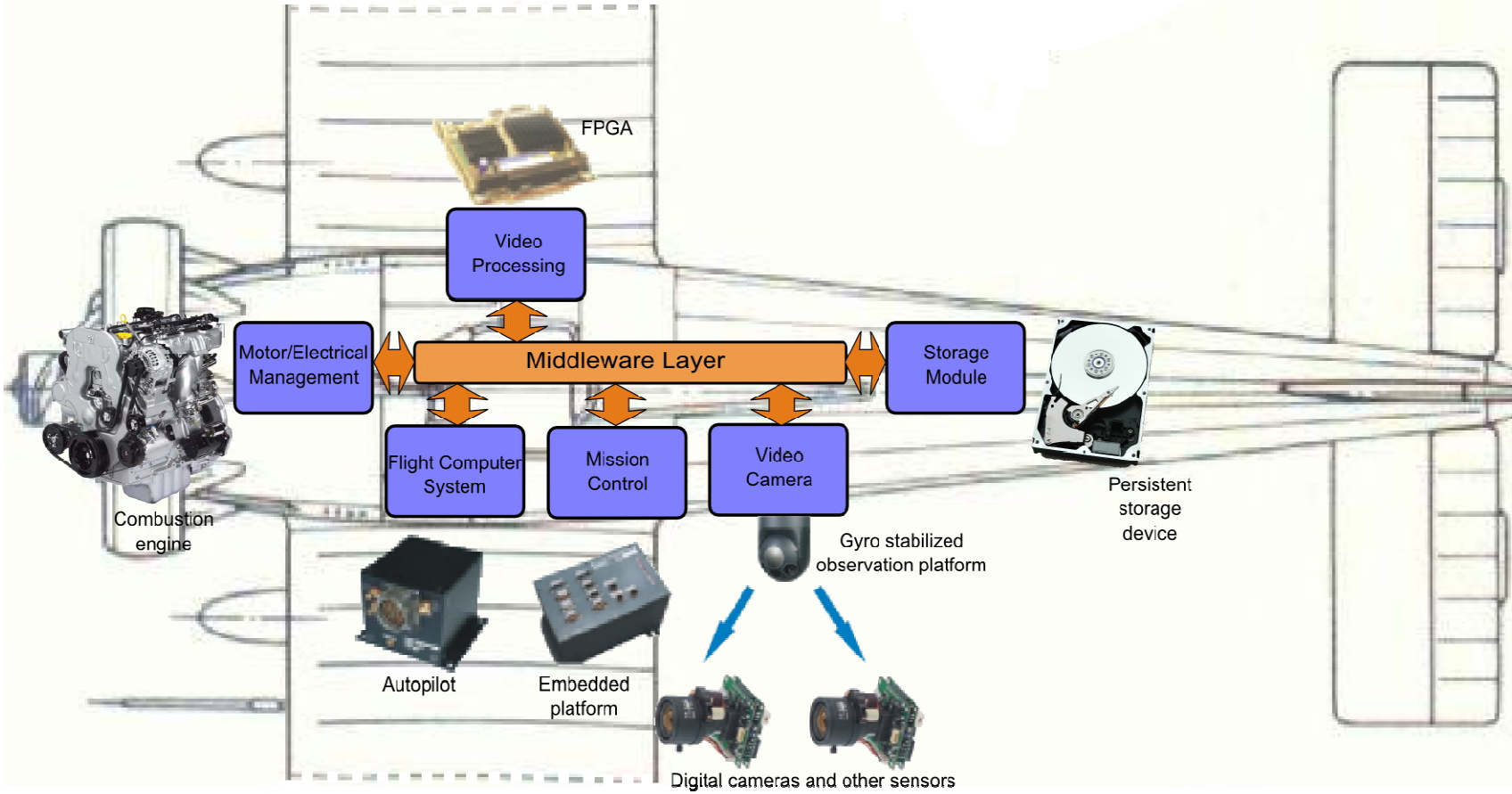
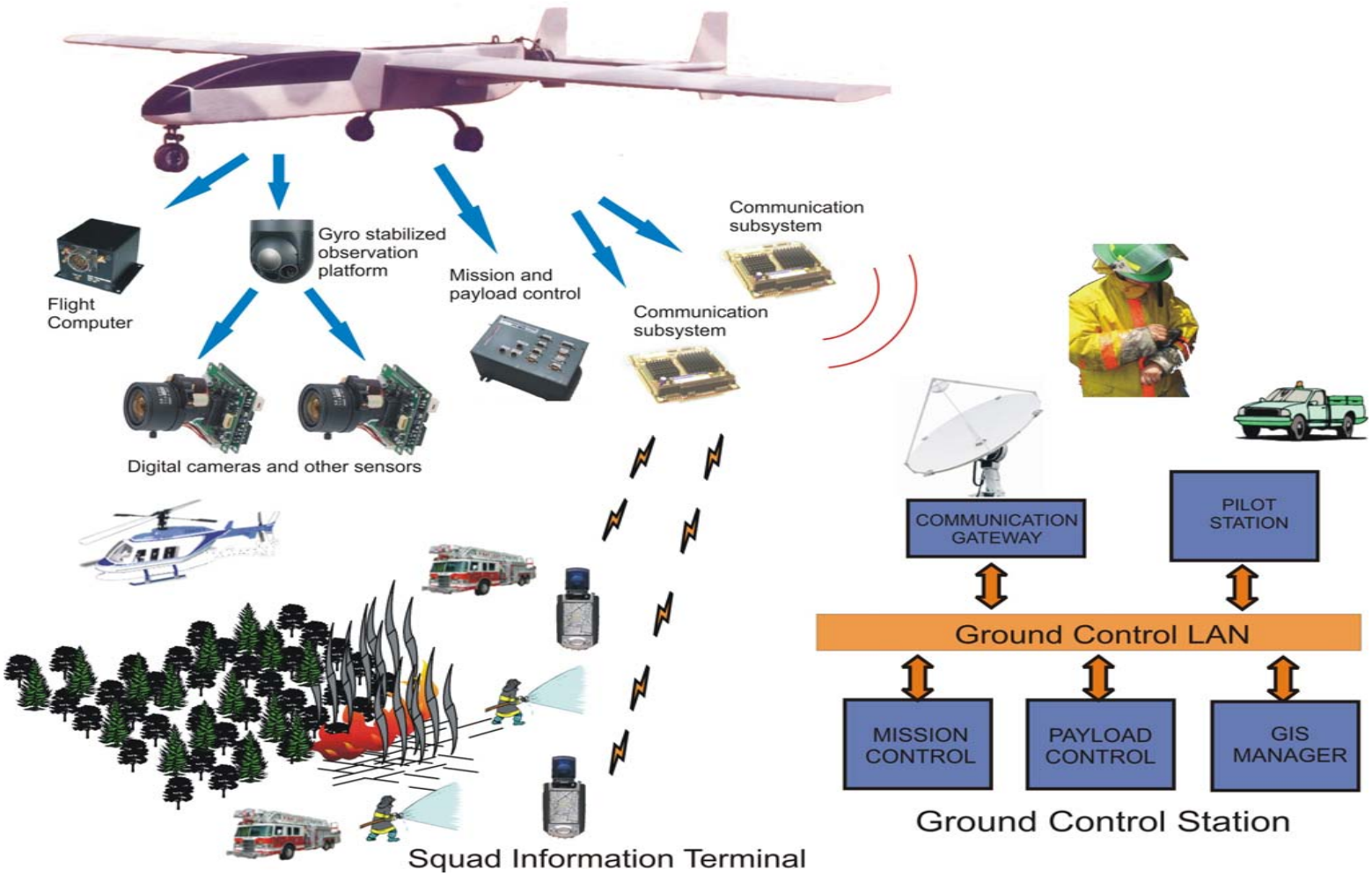
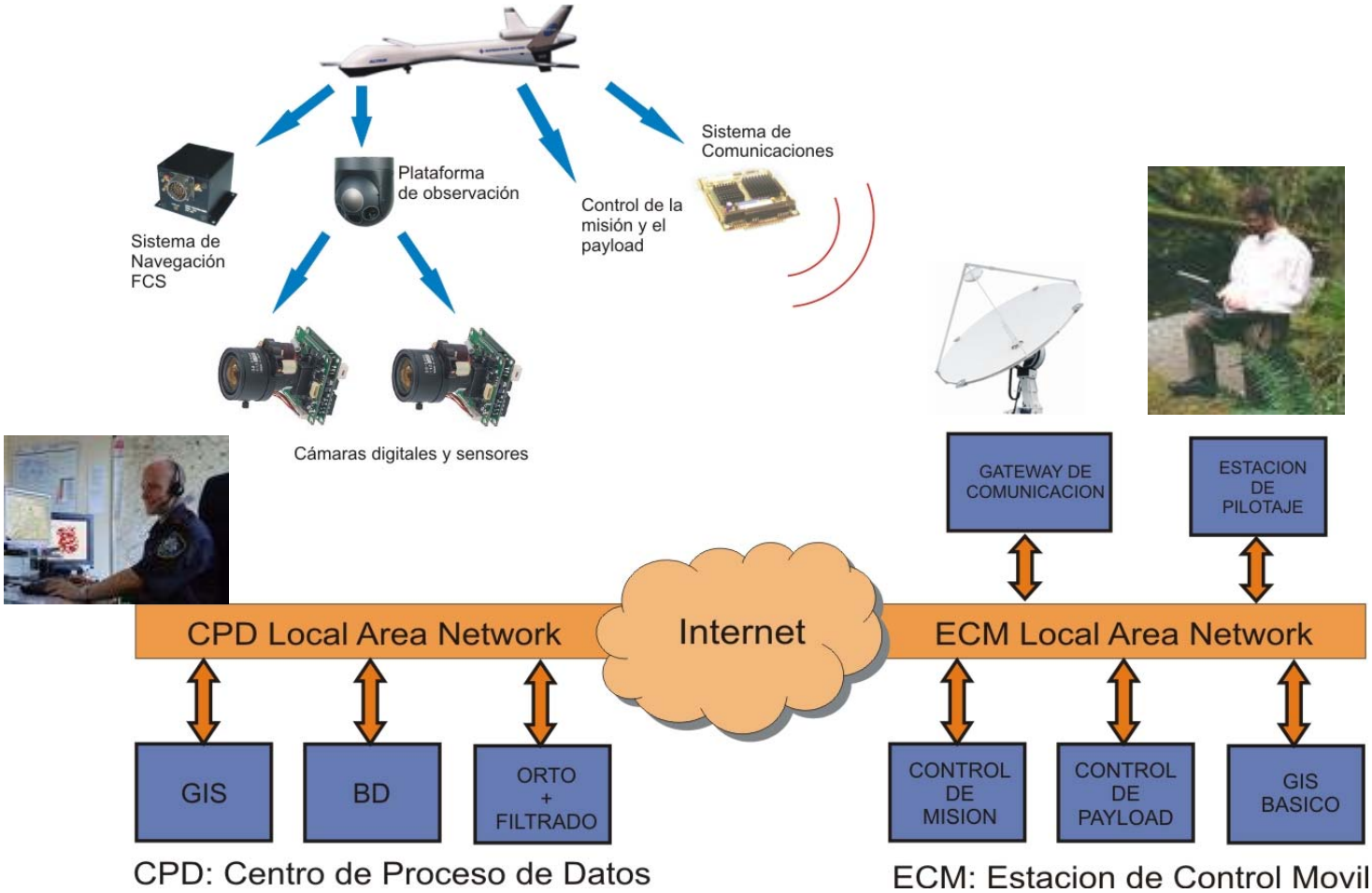
- Network Centric with data Publish/Subscribe
- Services may be producers and/or consumers



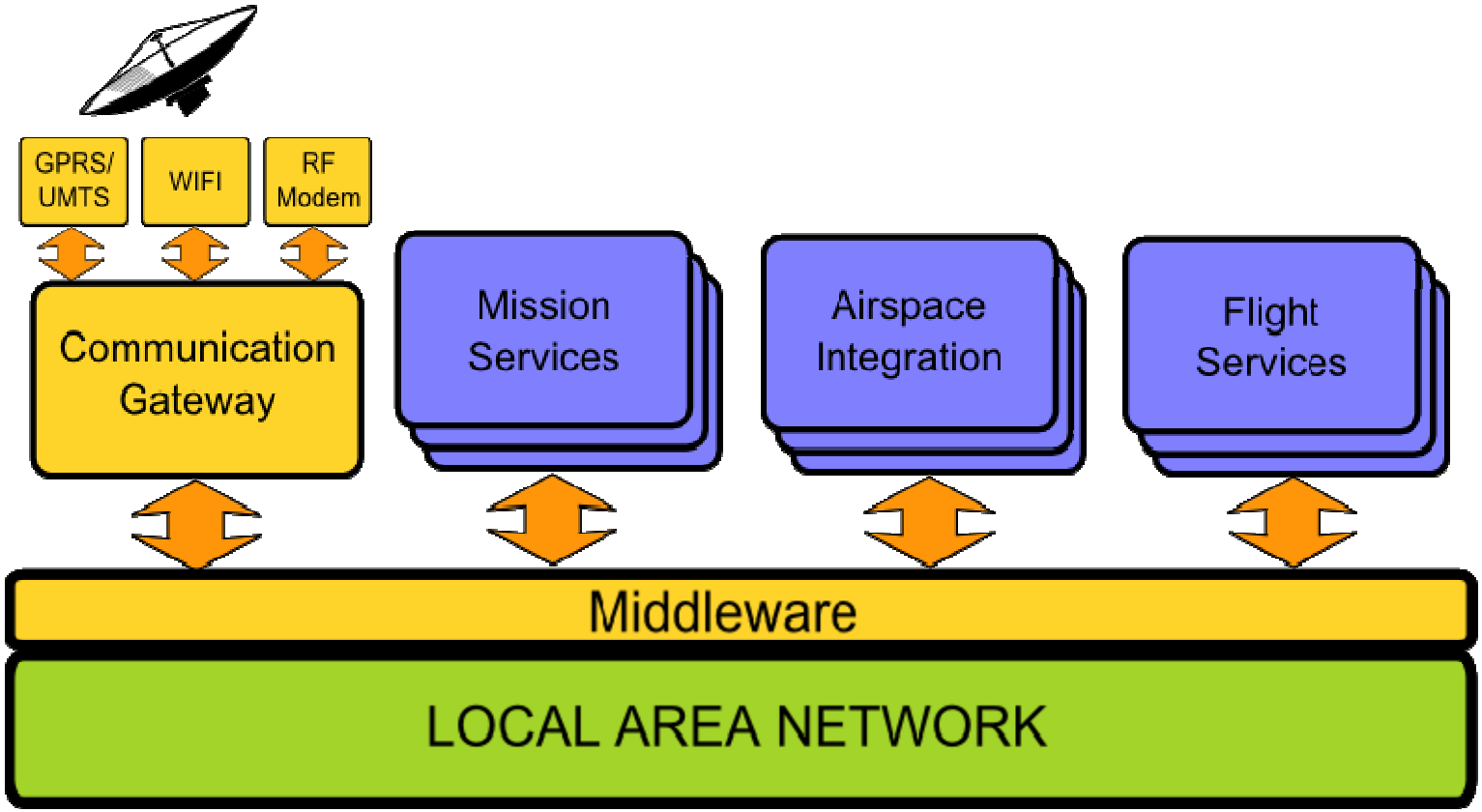
GCS and Squad Systems



CPD System

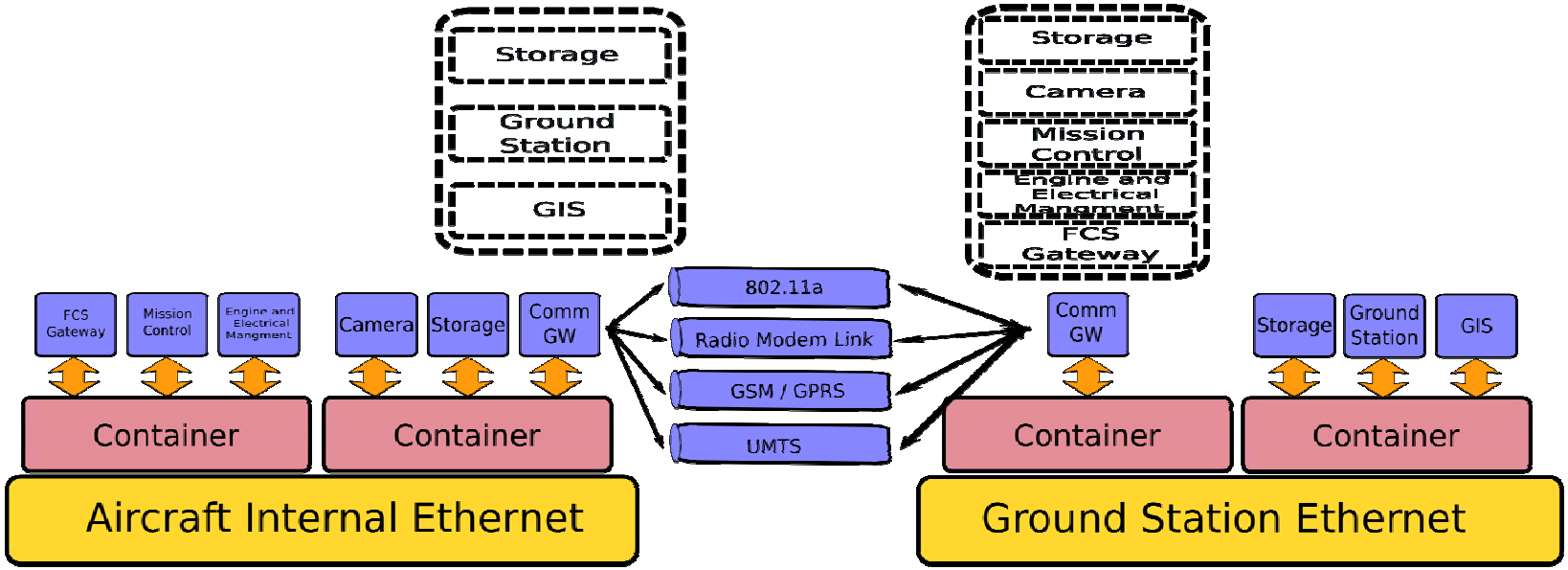

Sistema de Navegación FCS
Plataforma de observación
Sistema de Comunicaciones
Control de la misión y el payload
Cámaras digitales y sensores
GATEWAY DE COMUNICACION
ESTACION DE PILOTAJE
CPD Local Area Network
Internet
ECM Local Area Network
GIS
BD
ORTO + FILTRADO
CONTROL DE MISION
CONTROL DE PAYLOAD
GIS BASICO
CPD: Centro de Proceso de Datos
ECM: Estacion de Control Movil

UAV Service Abstraction Layer



Communication Gateway

- makes service location is irrelevant
- monitors links to provide cost effective QoS



Example of Mission Services

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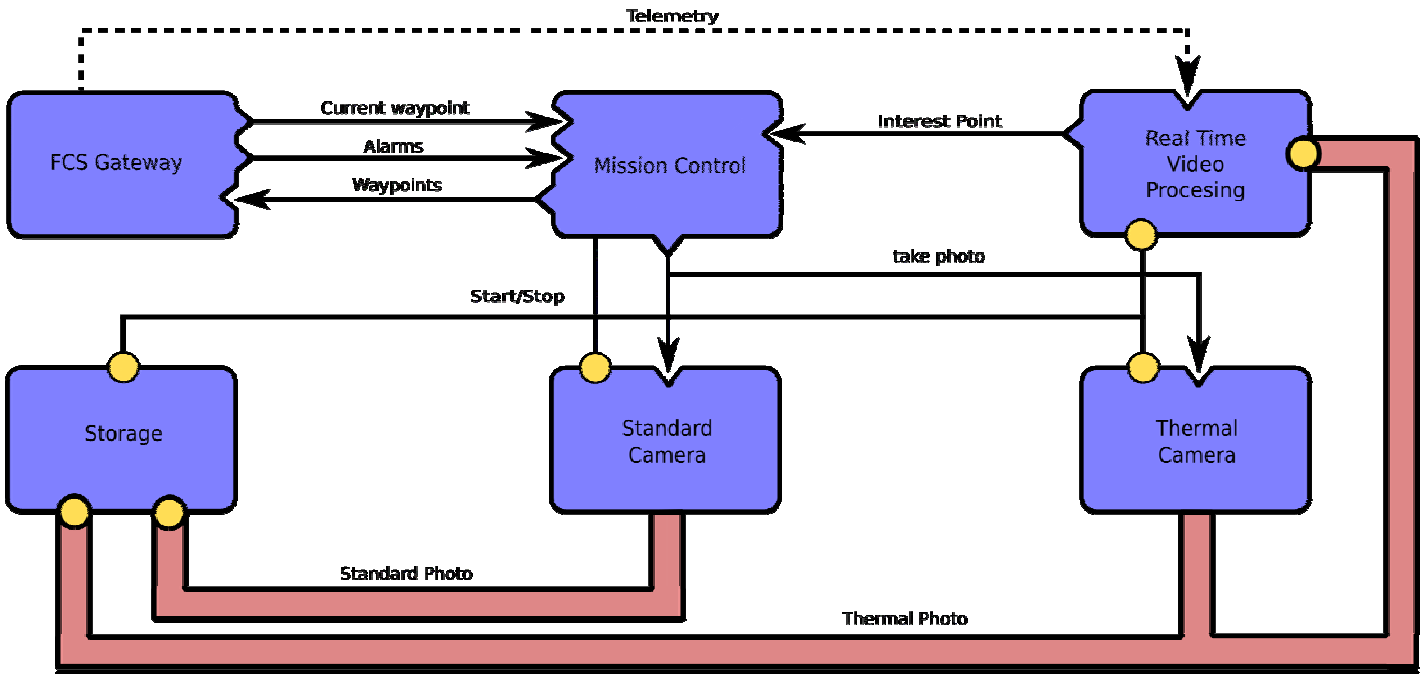
- Mission is formally specified through visual tools:
  - Relations between services are specified by flow diagrams
  - Dynamic activities through event-based systems.



Benefits of network centric / SOA

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- Dynamic service discover
  - Services can be identified when the system goes online or later during operation.
- Remote execution
  - Consumer simply sends a service request and its parameters. Later on it will get results.
- Self-description
  - Each module provides a description of the services that it can provide. Services may shut down or be set up dynamically. Multiple equivalent services may be available adding a level of redundancy.
- **Data streaming**
  - Semantic publish/subscription mechanisms for high change rate data

Mission

- The mission is a set of services that orchestrate the whole operation of the UAS.
- Link the flight plan that the UAS follows and the operation executed by the payload.
- Mission may dynamically change as fire evolves, therefore updated flight plans should be computed.
- Given that operational requirements change from mission to mission, additional or improved quality payload can be added just by including new or inherited services.

Mission procedures

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- Previous to flight: mission definition
- During flight (in parallel):
  - Exploration (flight area redefinition)
  - Data processing
  - Data Presentation
  - Data Storage
- After flight: Data post-processing

Mission procedures

- Previous to flight: mission definition
- During flight (in parallel):
  - Exploration (flight area redefinition)
  - Data processing
  - Data Presentation
  - Data Storage

tactical

scientific

- After flight: Data post-processing

Man in the loop: HMI functionalities

Mission Roles

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- Responsible: Decision maker
  - Data Presentation
- Mission Operator
  - Definition
  - Exploration
- Others
  - Pilot-in-command
  - Maintenance

Parametric Flight Plan Definition

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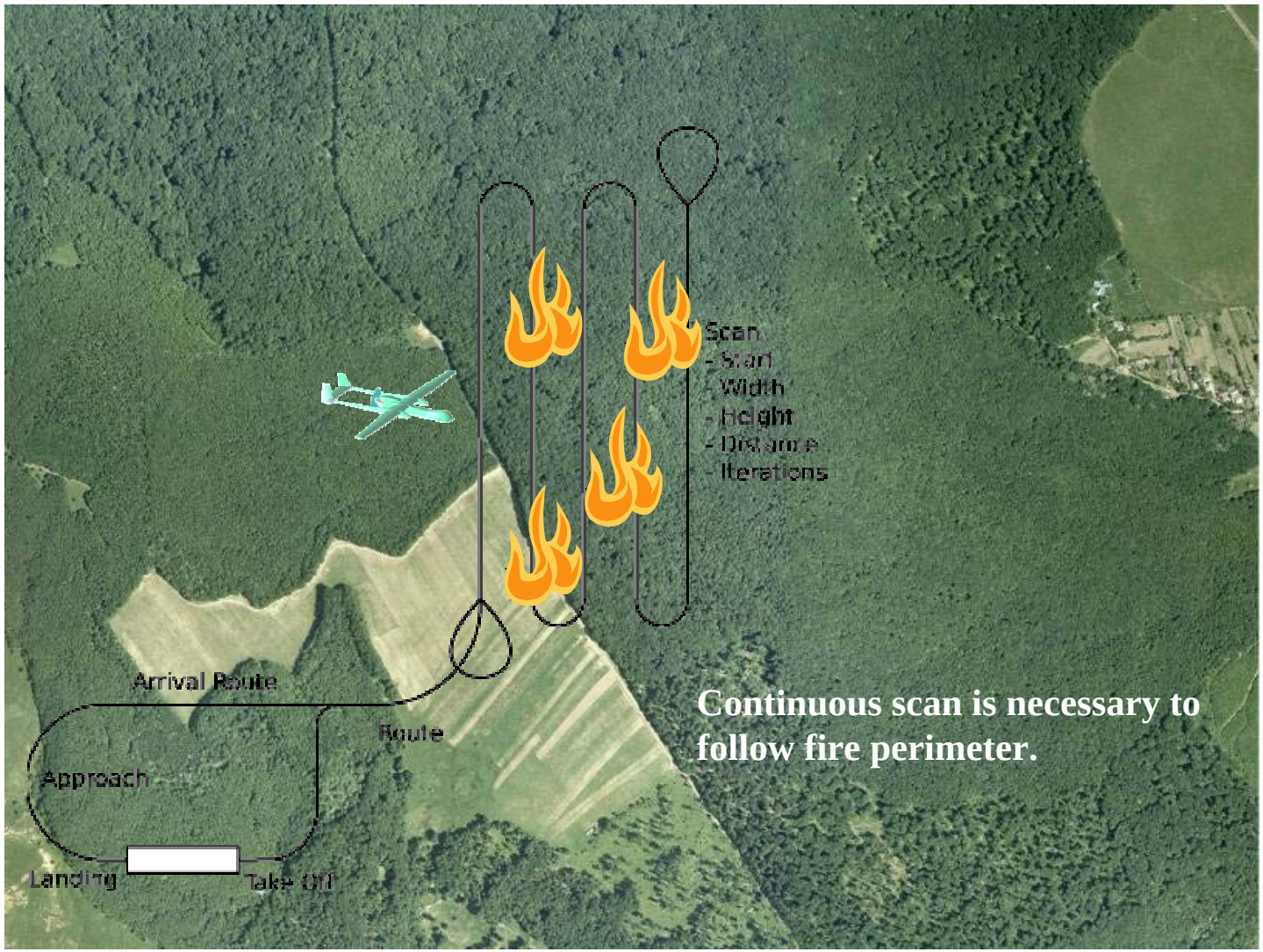

Parametric Flight Plan Definition

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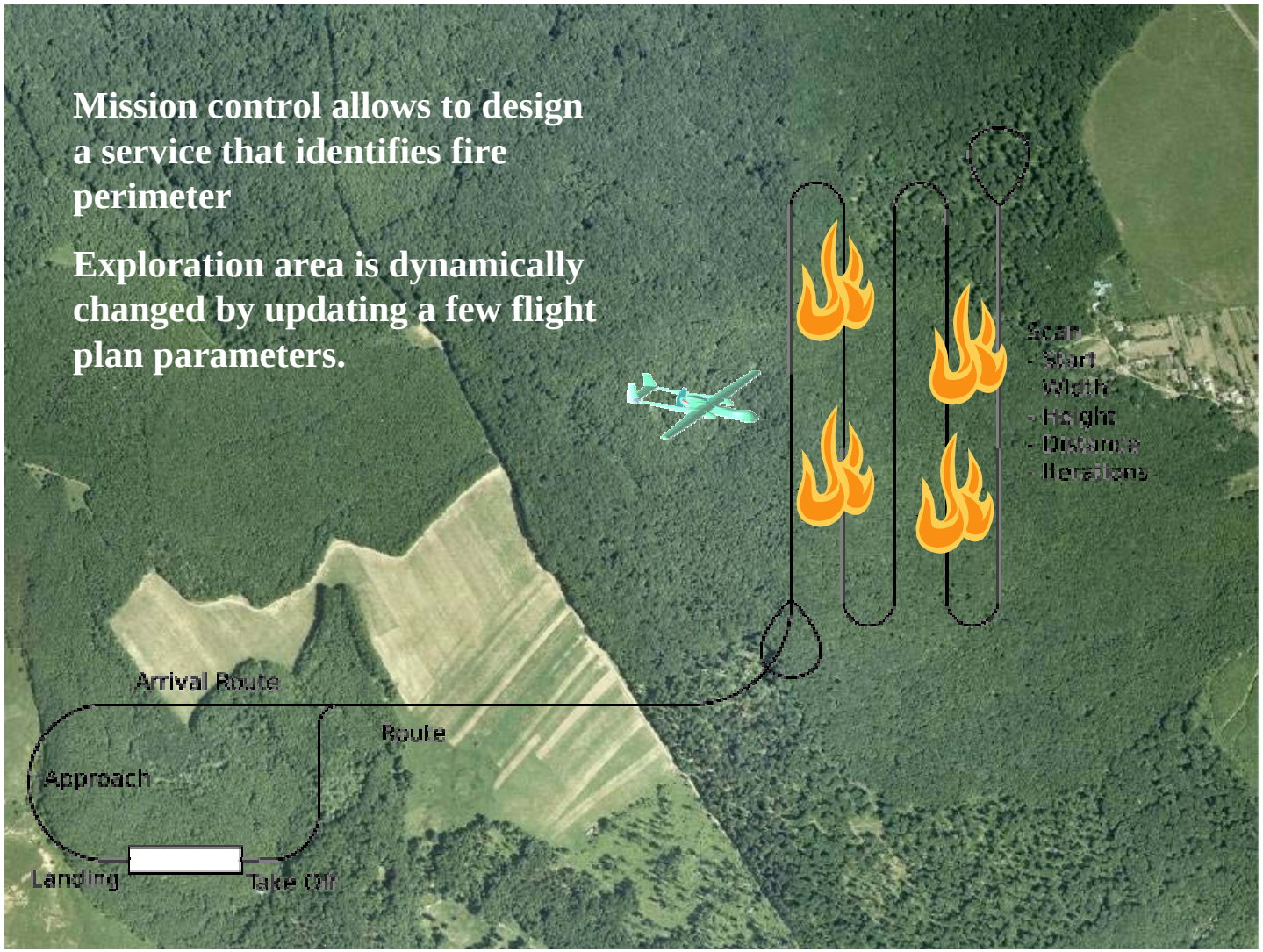

HMI Flight Plan Definition

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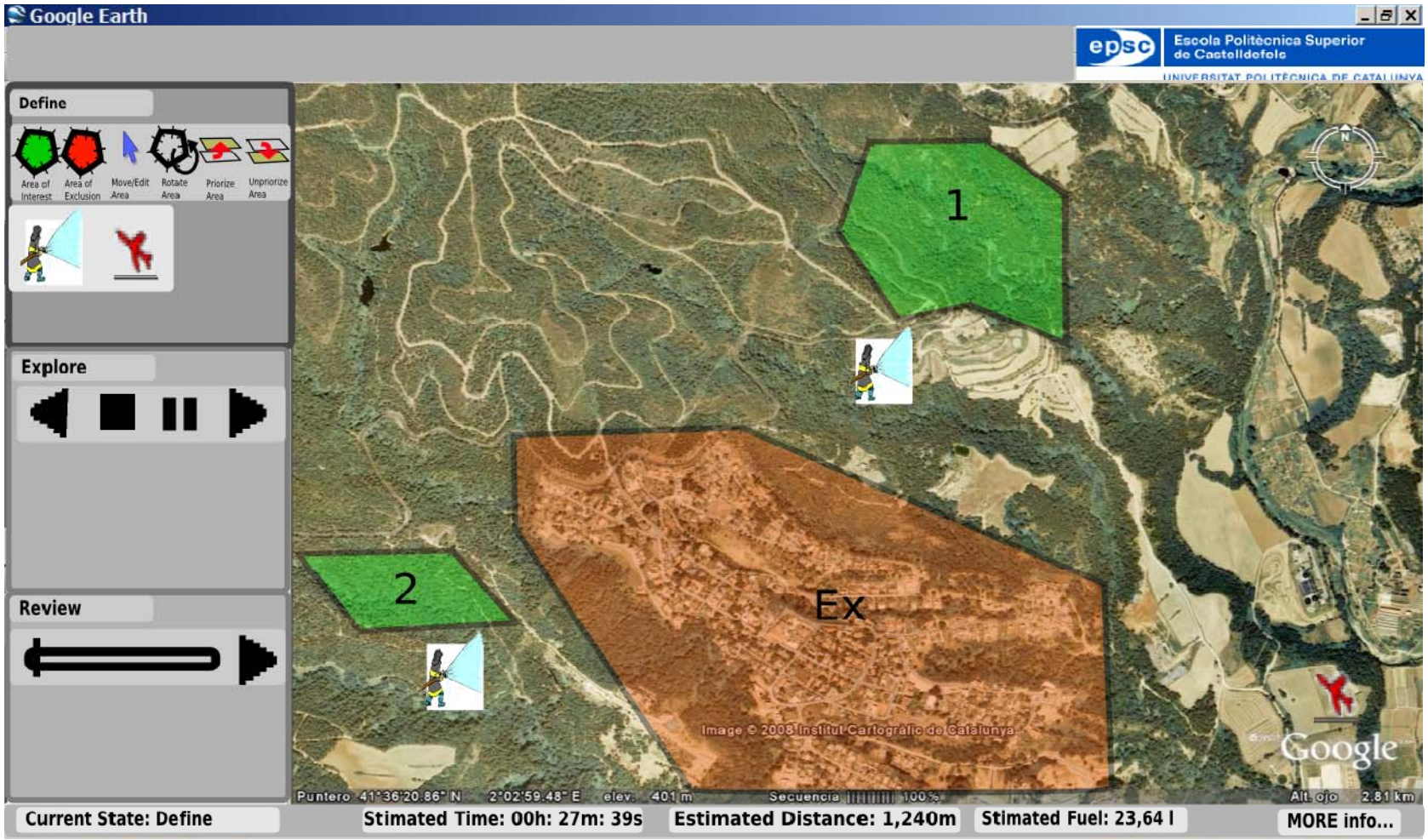

Intelligent Flight Plan Service

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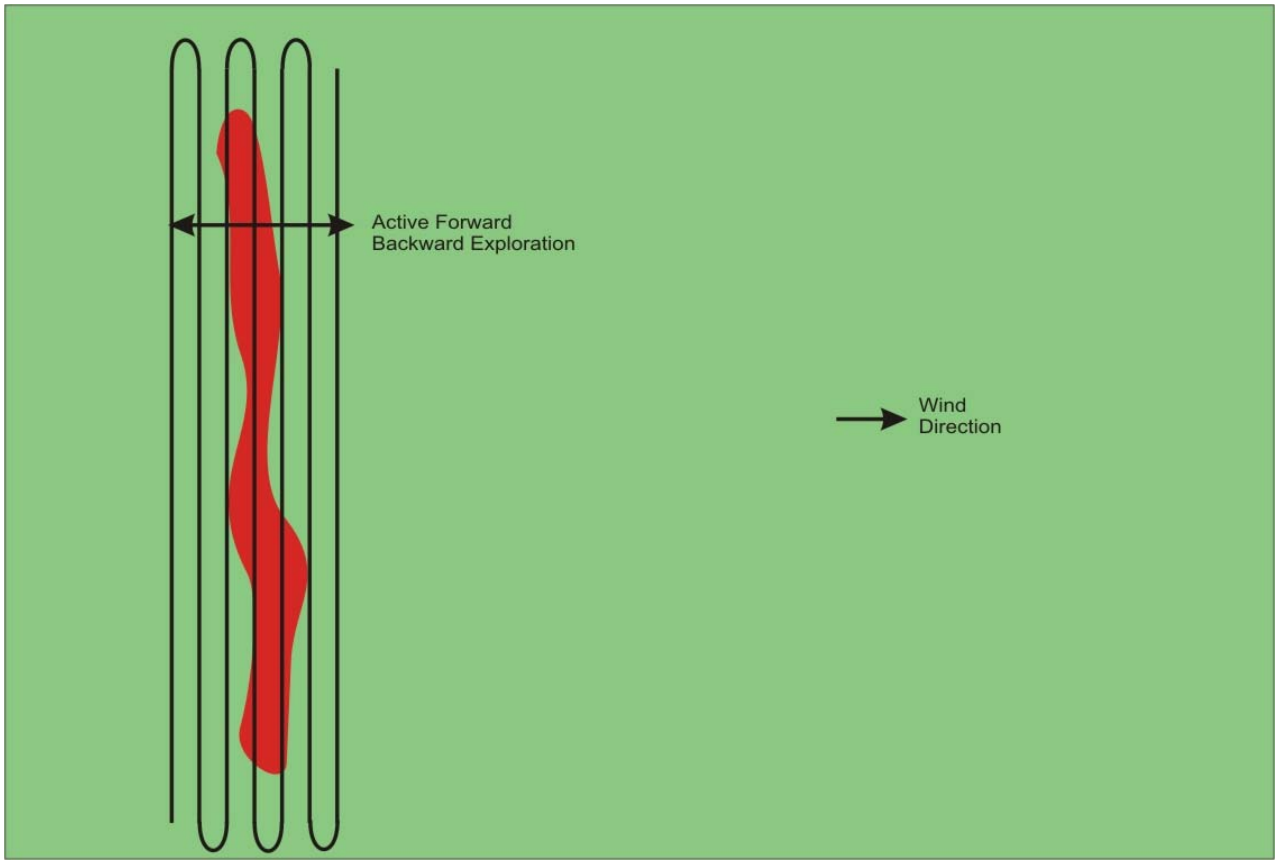
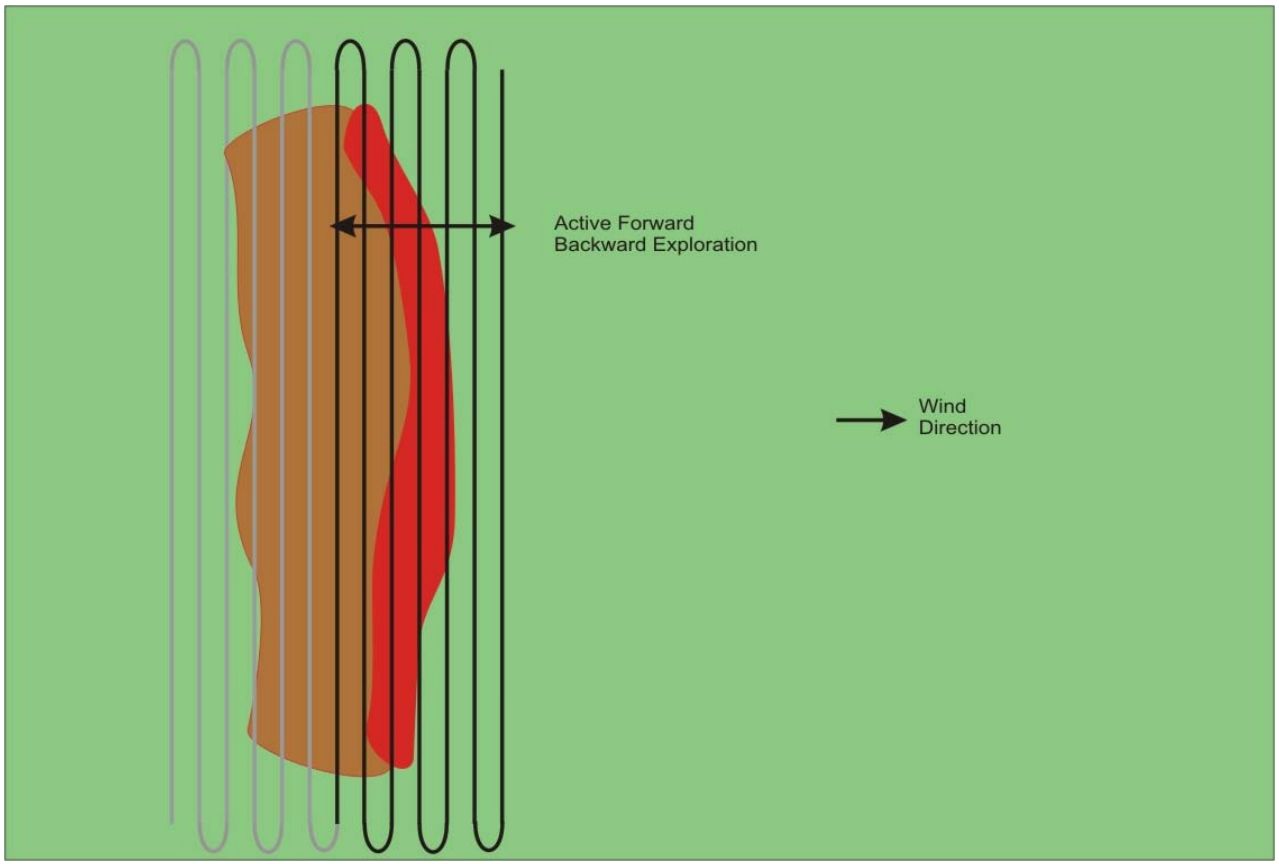
- Dynamic adaptation



Intelligent Flight Plan Service

ICARUS

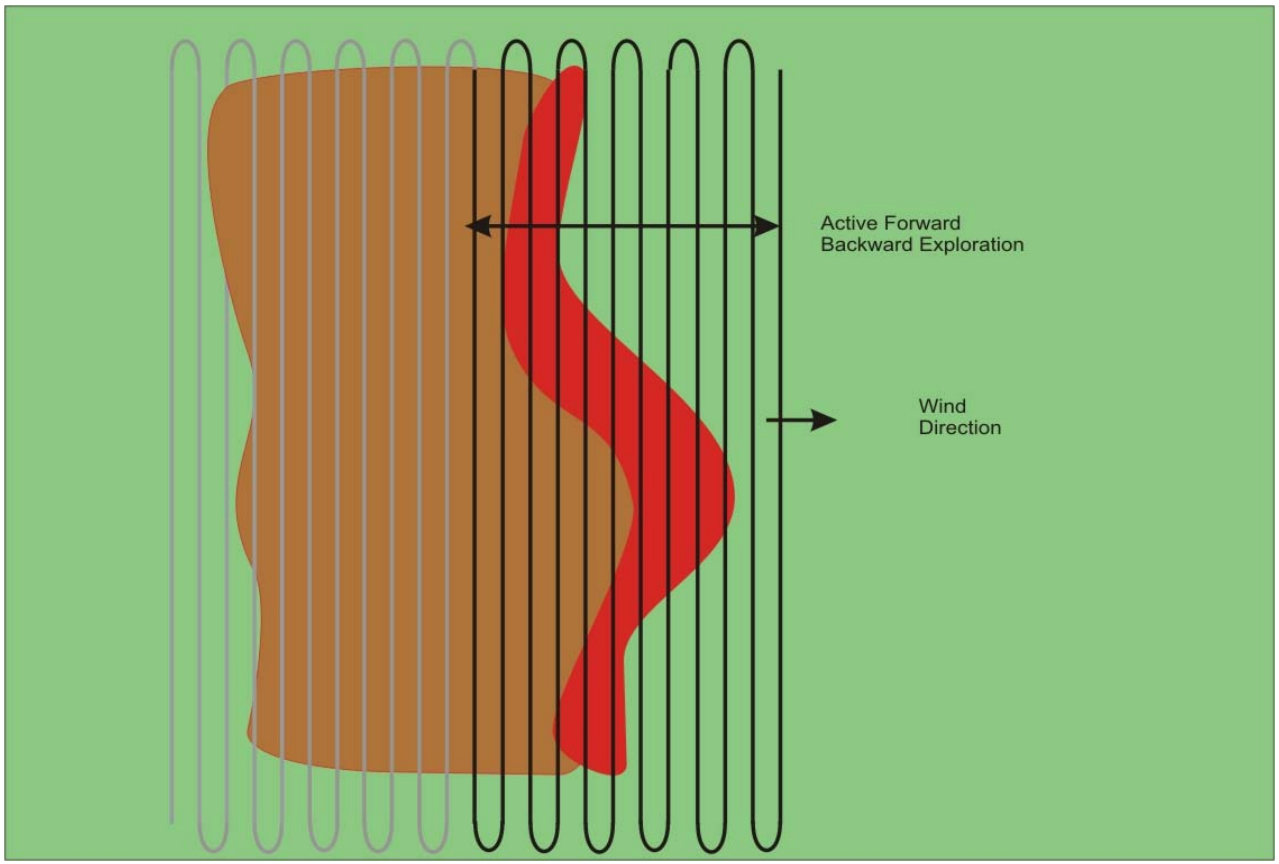
- Dynamic adaptation



Intelligent Flight Plan Service

ICARUS

- Dynamic adaptation



HMI Flight Plan Exploration / Presentation

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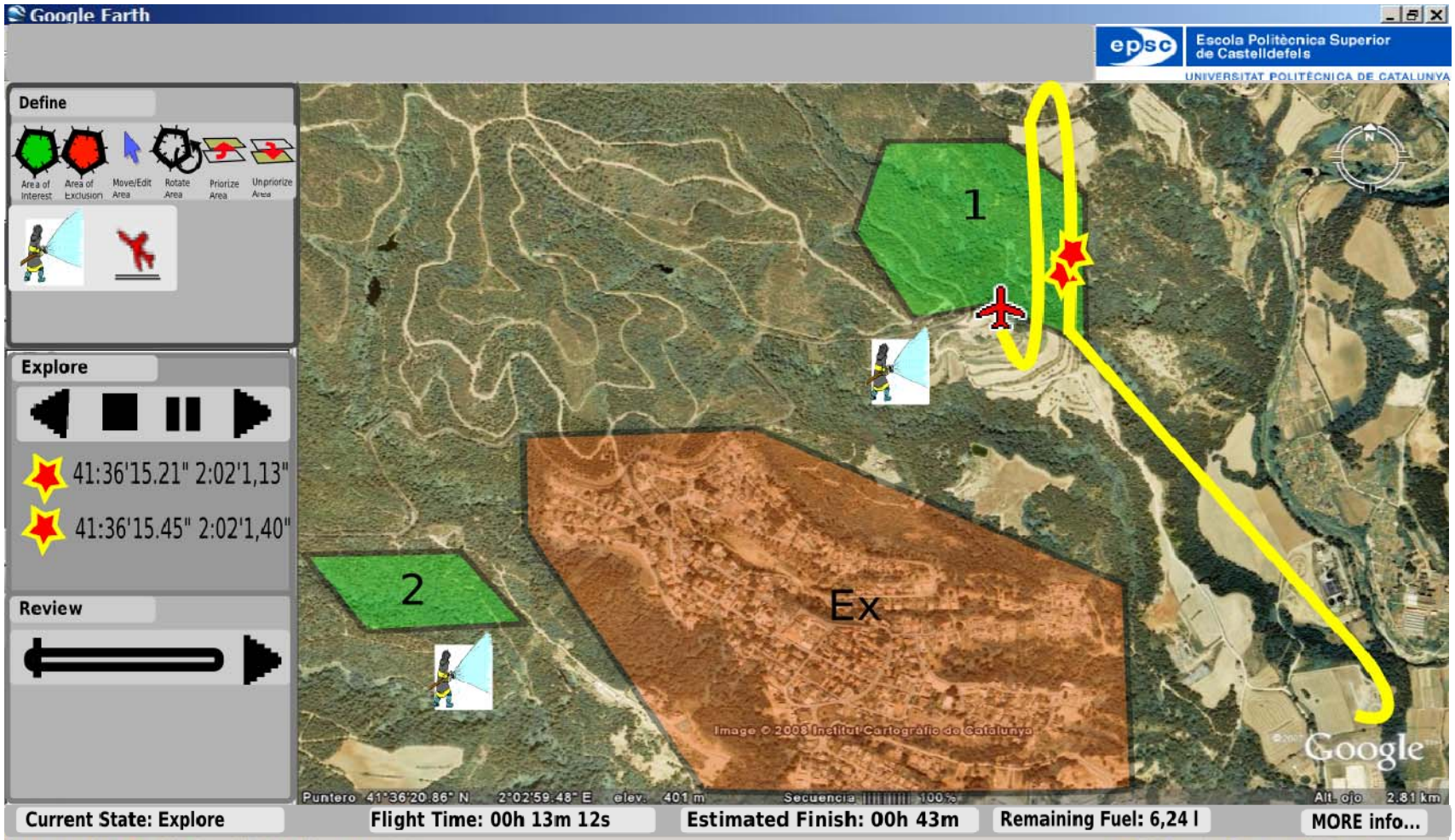

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Application Scenarios

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- GRAF identified three **viable fire missions**:
  - Monitoring of prescribed burnings for security and fire behaviour post analysis
  - Final fire mop-up with hot-spots detection
  - Fire monitoring during night
- Based on the following characteristics:
  - Detection is not a goal in populated areas
  - No interference with standard air-planes
  - High cost of alternate solutions
  - Progressive complexity

Some numbers

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- Mean of burned surface per wildfire is 6Ha
- FLIR A320 camera characteristics:
  - 320 x 200 pixels
  - At 100 AGL: image is 40 x 30 m
    ---> 1 pixel = 0.02 square meters
  - Frequency rate up to 9Hz
- UAV flight characteristics
  - 100 meters AGL
  - speed 60Km/h
    ---> Aprox. 3 minutes flight to scan 6Ha

Conclusions

- ICARUS group research topics and proposals for (small) UAS
  - Hardware/Software embedded architecture
  - Human-Machine Interfaces
  - End Users Requirements and Procedures
  - Integration of UAV in air space (future)
- Forest fire is an target civil application for:
  - Segregated airspace
  - UAS operation is cost effective
  - Commercially viable

Conclusions

- Not all geographical scenarios are equivalent; countries with large unpopulated areas may require emphasis in “detection”
- Other applications (fire perimeter detection, crop monitoring, rescue of lost people, ...) need a previous successful stories

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Muchas gracias