SEARCHING LOST PEOPLE WITH UAVs:
SYSTEM & RESULTS OF THE CLOSE-SEARCH PROJECT

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AGENDA

- The CLOSE-SEARCH project
  - Motivation & concept

- The CLOSE-SEARCH prototype
  - Air, ground and communication
  - Thermal/optical sensors
  - Navigation subsystem

- Ultra-safe navigation for UAVs:
  - Integrity as a safety measure
  - Geodetic quality control

- Results

- Lessons learned and future work

THE PROJECT

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SUMMER ’94: A TRAGEDY & A 15 YEARS DREAM

CHARACTERISTICS OF SEARCH-AND-RESCUE MISSIONS

Item	Description	Requirements for aerial search
Target	Lost mountaineers, mushroom collectors, disaster survivors	Lives in danger → **High priority** → **Segregated airspace**
Scenario	• Remote, wild areas, • day & night, • bad weather conditions	SAR teams in danger → **unmanned** → **thermal/RGB vision** → **safe navigation**
Procedure	• Fast deployment, segregated areas • 1st phase: person is alive, searching paths, rivers… • 2nd phase: person might not be alive, full area scan	Rapid, effective response → **low weight & size** → **no setup dependency**

UAVs FOR DULL, DIRTY & DANGEROUS MISSIONS

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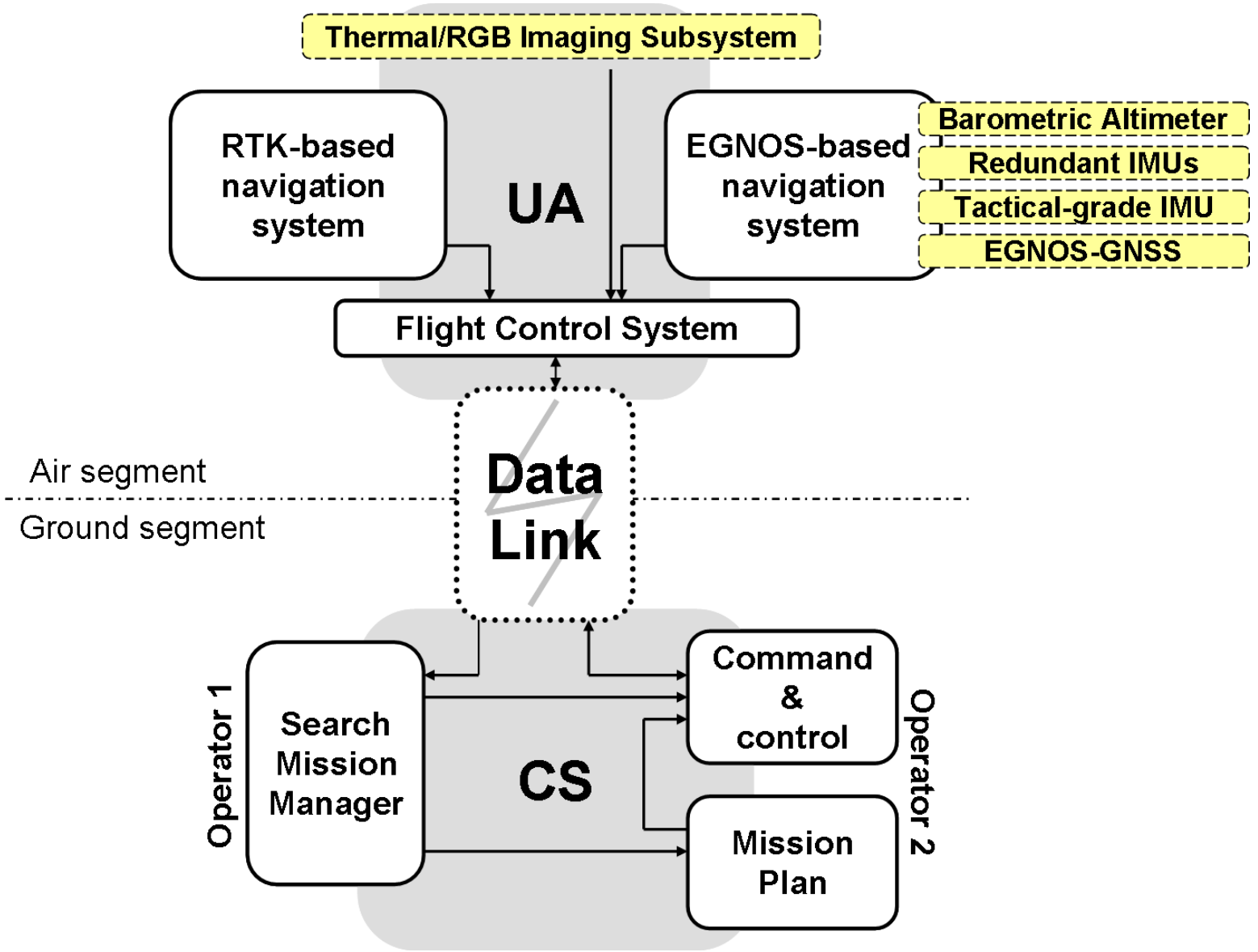
THE CLOSE-SEARCH PROTOTYPE: ARCHITECTURE



THE UNMANNED HELICOPTER

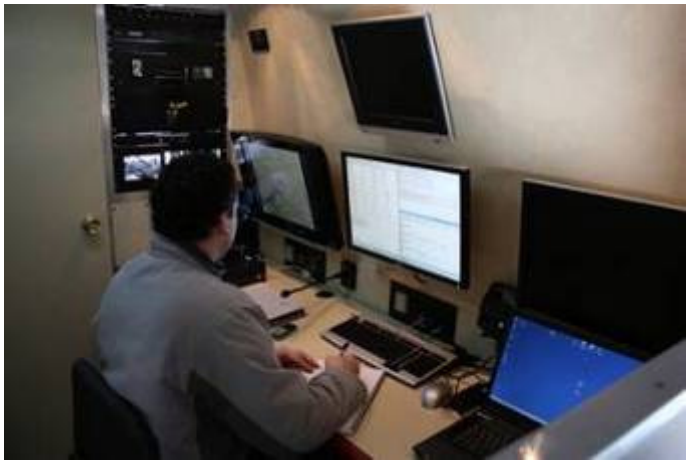
Fuselage	
Structural Material:	rectangular section aluminum frame
Total length:	3.9 m.
Length (w/o blades):	2.9 m.
Height:	1.3 m.
Width:	0.9 m.
Rotor diameter:	3.2 m.
Empty weight:	40 kg.
MTOW	
Structure:	75 kg
Power rating:	18 hp (13.42 kw)
Type:	1 engine, 1 cylinder, 2 stroke air-cooled, electric starter, gasoline (10l)
Performance	
Max speed tested -cruise speed:	50 km/h – 35 km/h
Endurance (10 l. fuel):	90’
Service ceiling tested:	ASL 1100 m
Wind speeds tested:	up to 40 km/h
Range	4 km (actual comm system)

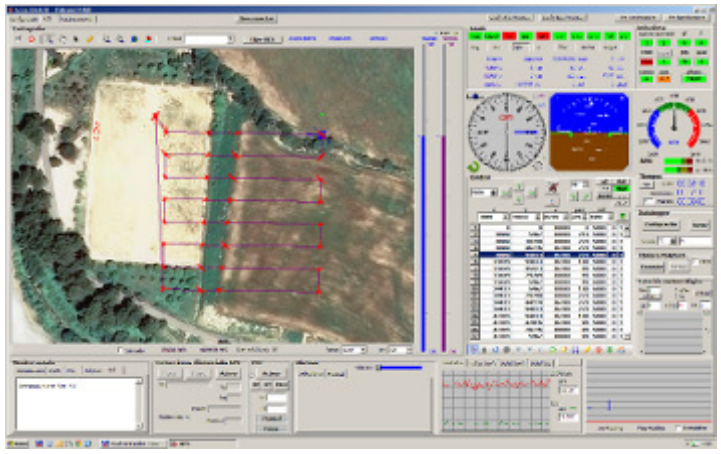
The UAR-35 is an in-house development by the Asociación de la Industria Navarra (AIN)

THE GROUND CONTROL STATION

The Ground Control Station (GCS) is also an in-house developement by AIN, mounted on a 4WD van, to perform:

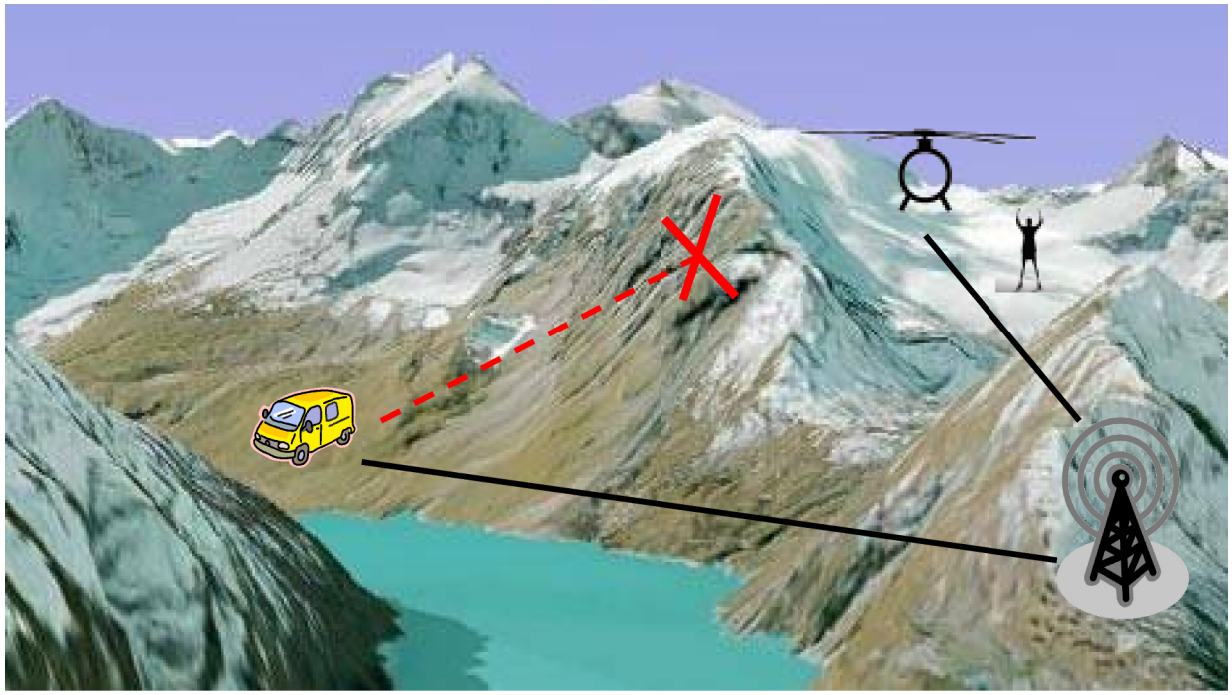
- [Off-line and/or on-site] mission planning,
- Modifications of the mission plan on-the-go, if needed,
- Telemetry and on-board imaging monitoring





LOS-&-BLOS COMMUNICATION: A SAR REQUIREMENT

Communication in CLOSE-SEARCH		
Architecture	Line-of-sight	Beyond-Line-of-sight
Technology	WiFi	WiMAX
Range	(tested up to) 4 km	> 50 km
Bit-rate	< 54 Mbit / s	30 – 40 Mbit / s
Obstacle dependency	Yes	Yes/No (tower locations)



THERMAL & OPTICAL IMAGING: SEEING IN THE COLD DARK

Why thermal and optical sensors?

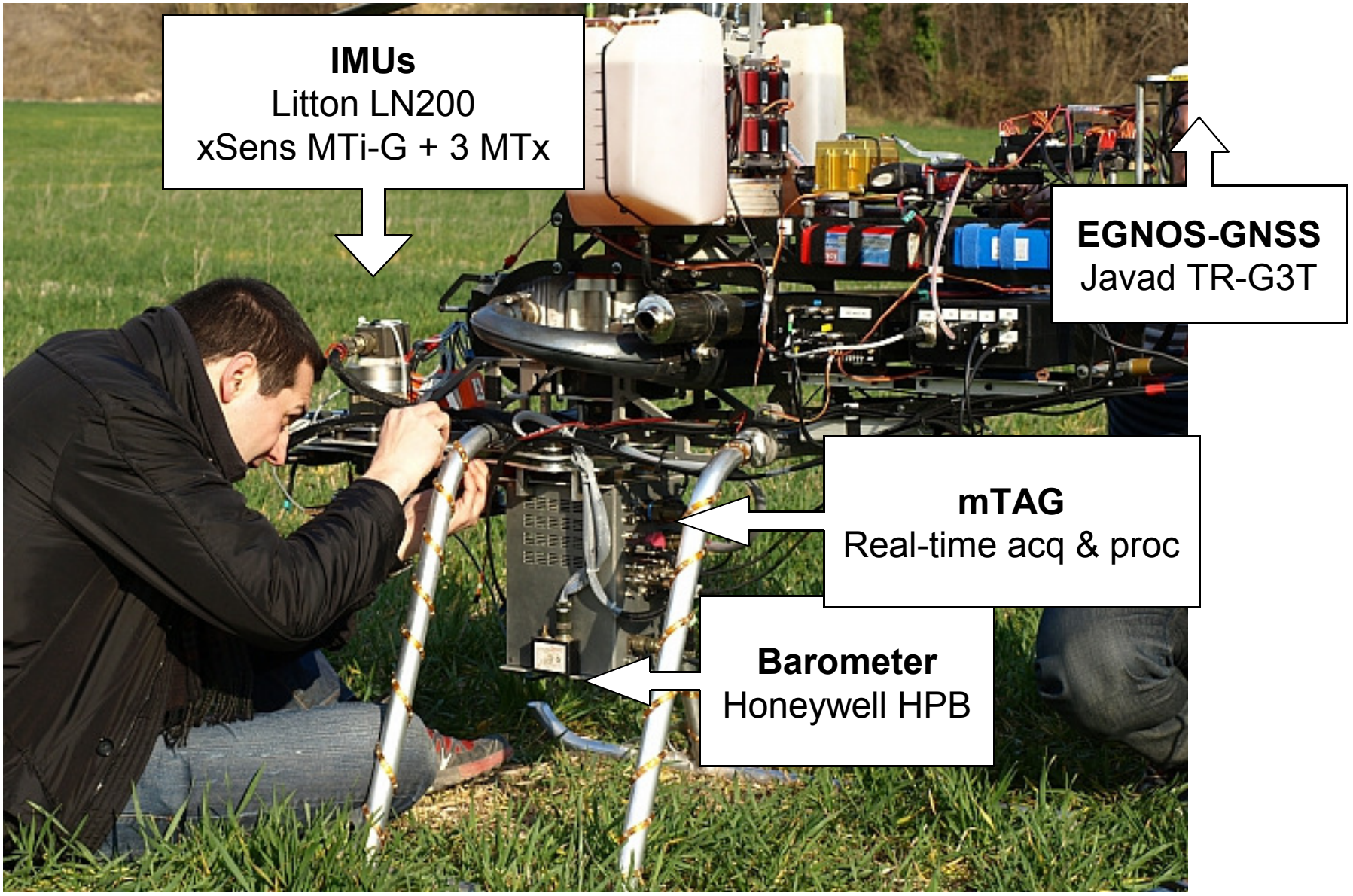
-Cold nights are common SAR scenarios:
- Specially dangerous for humans
- Manned platforms do not usually operate at night

-RGB complements thermal vision:
- Discard false alerts
- Clothes, etc... might be useful hints

Thermal camera
→ Raytheon 2000B, 320 x 240 pixels

Optical camera
→ Sony CM-3120CDM, 582 x 500 pixels

EGNOS-BASED REDUNDANT NAVIGATION: FLYING SAFELY



SAFE NAVIGATION

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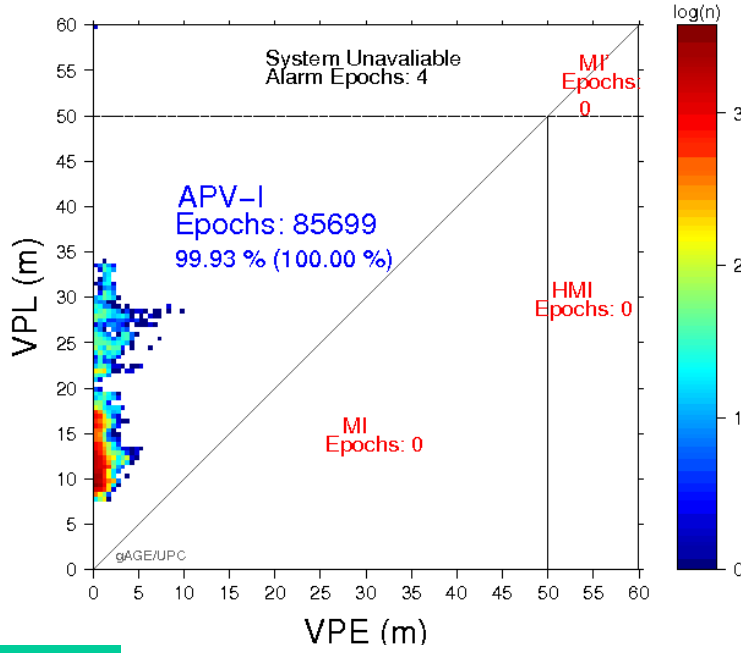
INTEGRITY: FROM CIVIL AVIATION TO UAV MISSIONS

Approach	HAL, VAL (m)	TTA (s)	IR (-/s)	
APVI	40, 50	10	10^{-7}/150	EGNOS certification (2010)
CATI	40, 10-15	6	10^{-7}/150	

Our thoughts for UAVs

- large Alert Limits (ALs)
- low Integrity Risk (IR)
- long Time-To-Alarm (TTA)

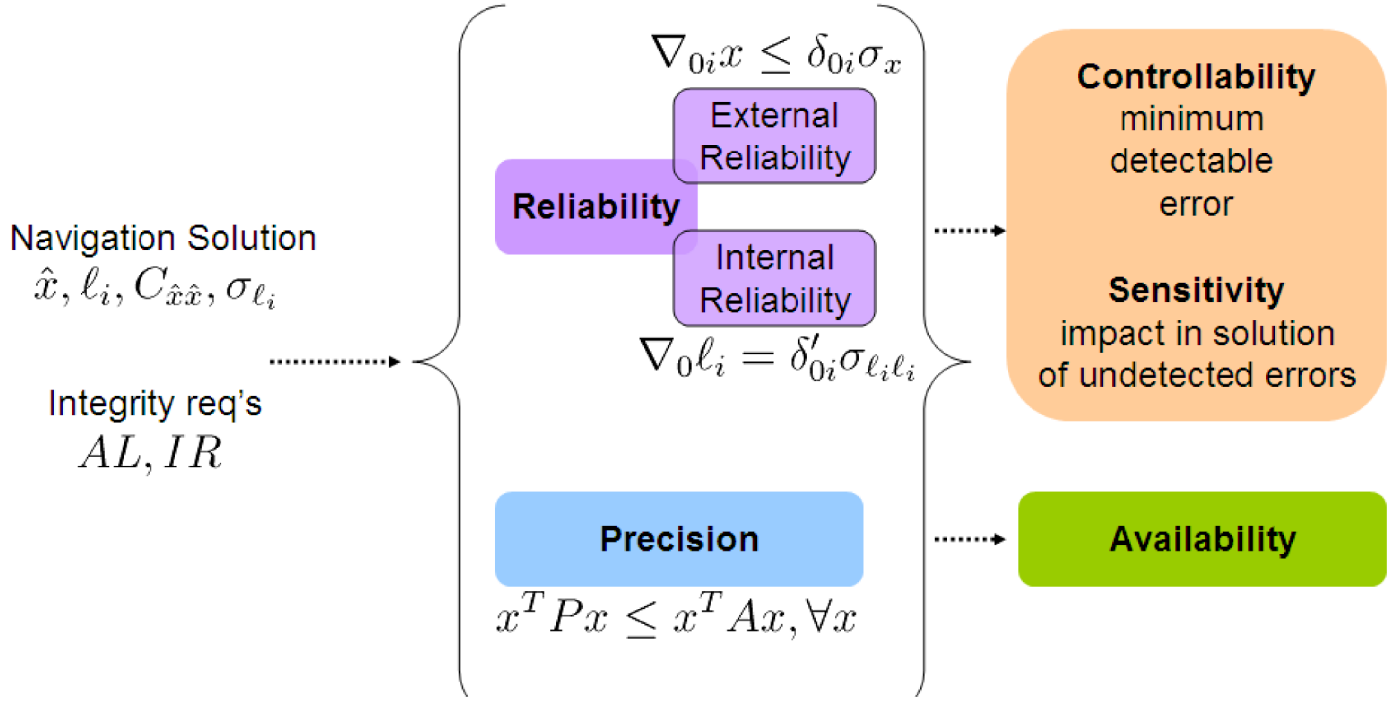


Approach	HAL,VAL (m)	TTA (s)	IR (-/s)
W2W	4, 7.5	<<10	$1 \cdot 10^{-6}$/150
GA/S	2.5, 4	<<10	$1 \cdot 10^{-6}$/150

Molina et al., "*INTEGRITY ASPECTS OF HYBRID EGNOS-BASED NAVIGATION ON SUPPORT OF SEARCH-AND-RESCUE MISSIONS WITH UAVs*", ION GNSS 2011, 2011-09-21/23, Portland, OR.

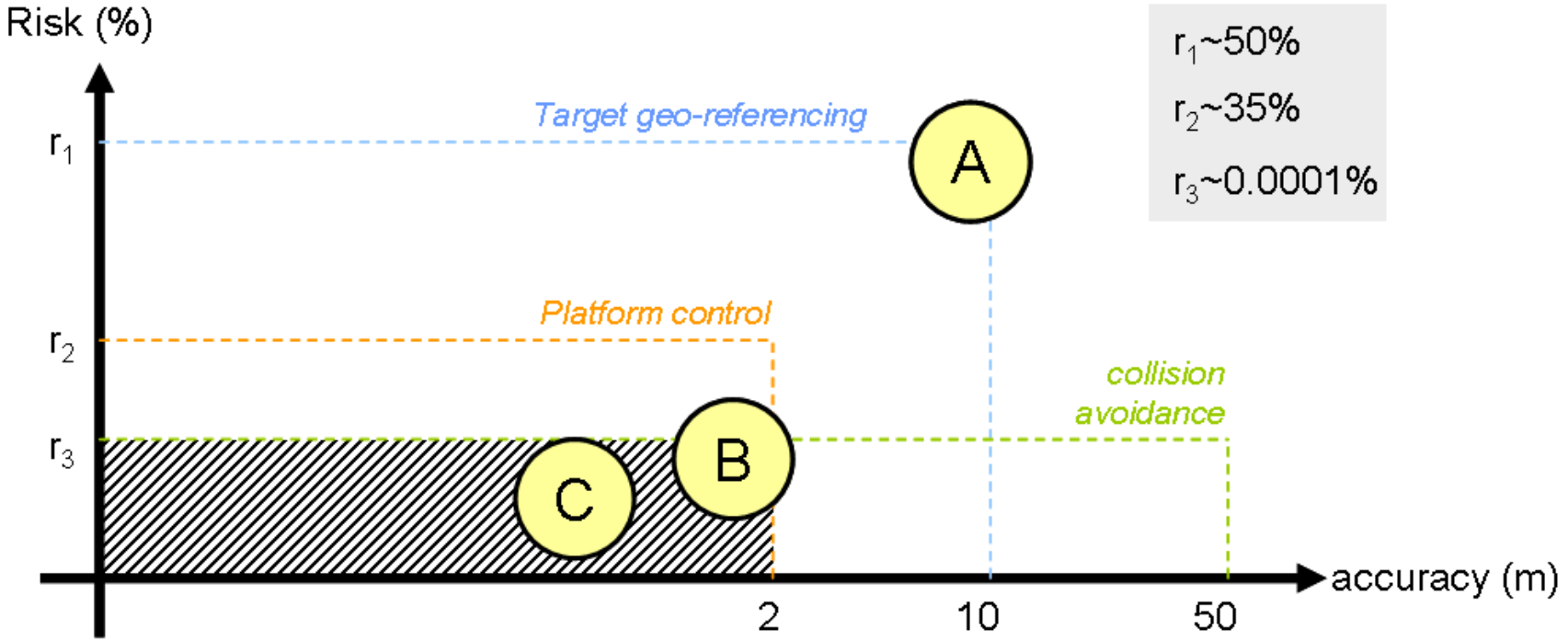
INTEGRITY: GEODETIC QUALITY CONTROL

In presence of **outliers** in measurement, precision-based integrity is not sufficient → **geodetic quality control** (Baarda, 60's, 70's): consistent, rigorous and systematic framework to the quality of geodetic networks (least-squares)



Full safe-navigation approach for UAV missions:
-warn the user in case safety margins are overcome (*availability*),
-provide the minimum detectable error (*controllability*),
-what is the impact in the navigation solution of undetected errors (*sensitivity*)

NON-METRIC RISK VS ACCURACY



A = standard IMU/GPS integration

- improvable accuracy, no risk measure

B = CLOSE-SEARCH system (EGNOS-GPS/IMU/BA);

- on the edge of accuracy and risk requirements

C = future EGNOS-GPS + GLONASS + Galileo + Compass/redundant IMU/BA/++

- highly accurate, redundant, safe navigation

RESULTS AND LESSONS

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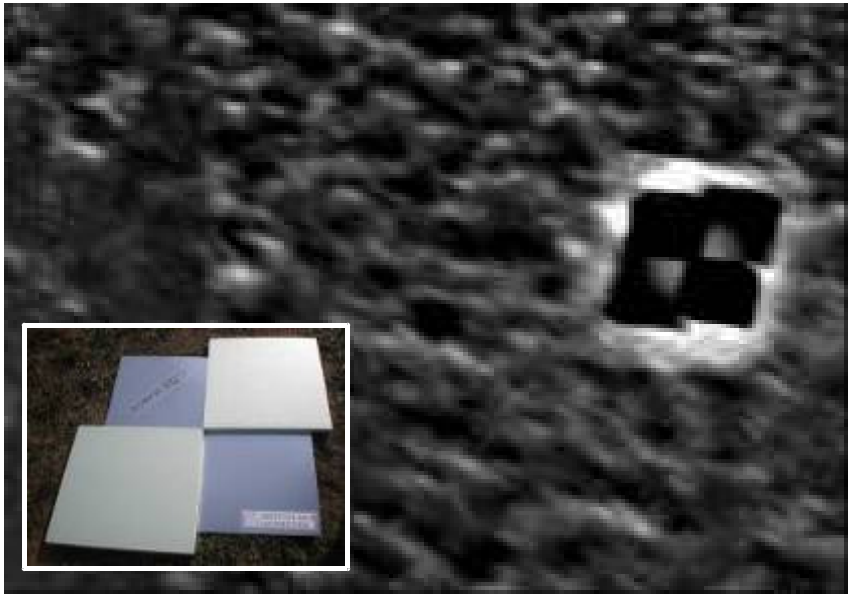
RESULTS ON PROJECT TEST CAMPAIGNS: IMAGING



Non-human targets (2m x 2m)
Investigate thermal response
Image GSD: 2 cm x 2 cm

Human targets (sitting and lying)
Assess detection & identification
Images GSD: 5.5 cm x 5.5 cm

RESULTS ON PROJECT TEST CAMPAIGNS: IMAGING

Combined RGB and thermal

- GSD = 7.4cm x 7.4cm (both sensors), person standing and waving hands.

Ground pic *UAV image*

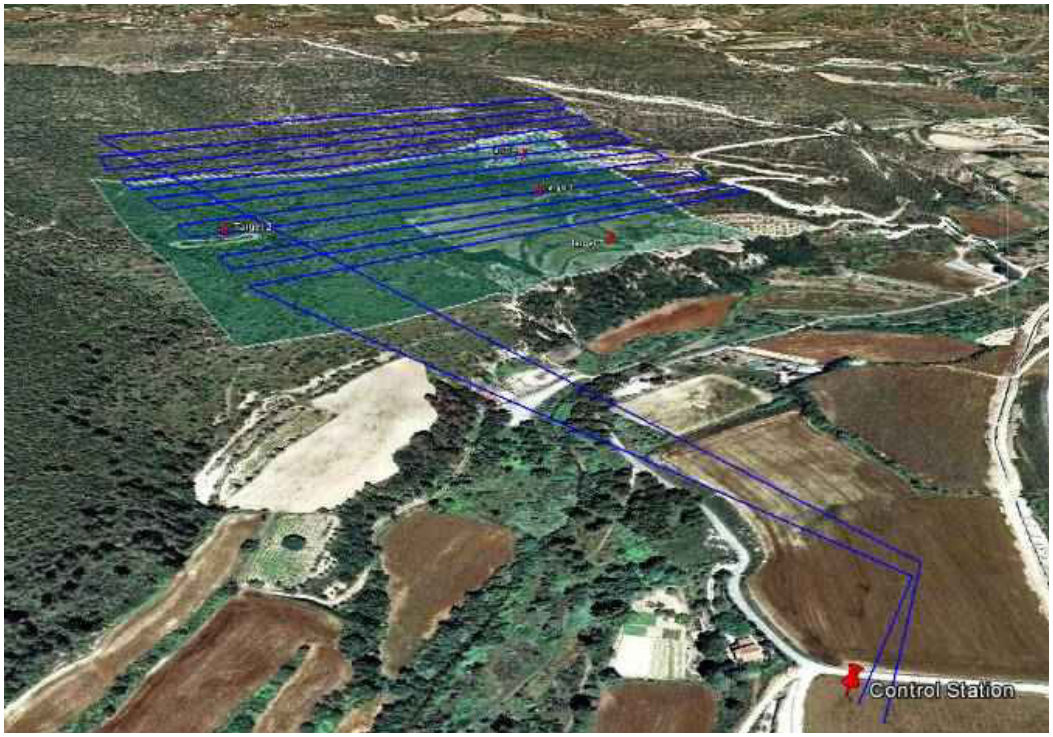
Geo-referencing ground targets

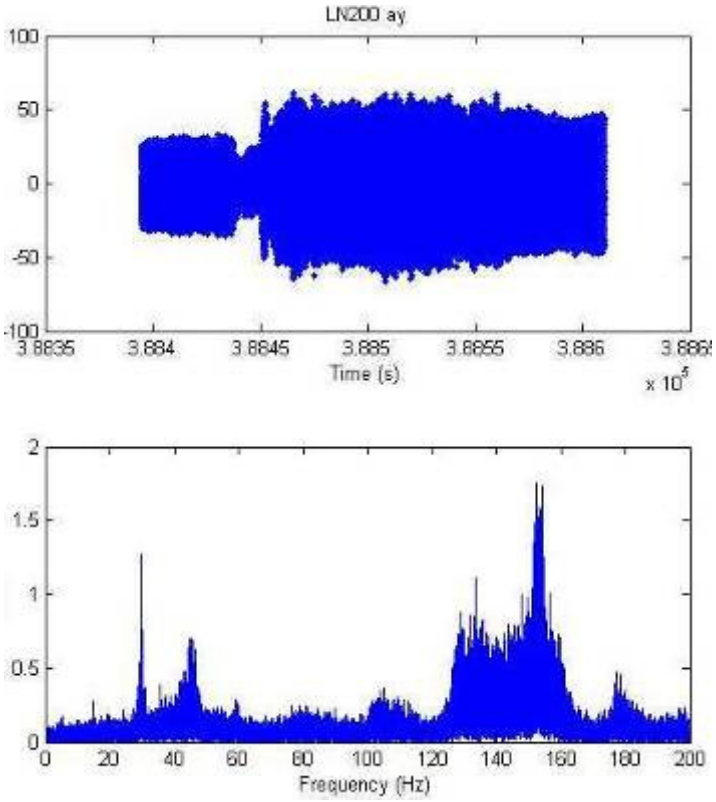
- The Flight Control System (FCS) yields UAV position and attitude at a high frequency

- Using a Digital Surface Model (DSM), the ground target coordinates are produced and provided to the rescue team.

- Results in Test Campaings showed georeferencing **accuracy around 10 m x 10m**

RESULTS ON PROJECT TEST CAMPAIGNS: NAVIGATION





	Test 1			Test 2		
	East	North	Height	East	North	Height
Mean	-0.56	0.12	-0.62	-0.82	-0.24	1.35
Std Dev	1.07	1.34	0.71	1.06	1.72	1.46
RMSE	1.21	1.35	0.94	1.34	1.74	1.99

LESSONS LEARNED & FUTURE WORK

-**Hard requirements on mission operations**

… dull, dirty & dangerous

-**EGNOS instead of RTK-based solutions**

… sufficient accuracy, necessary integrity

-**Updated high-precision DSMs for mission plan**

…1st step to collision avoidance

-**Smaller, better RGB and thermal cameras**

… enable smaller UAVs to be operated

-**Multi-use UAV platform**

… exploit the UAV concept versatility

-**UAV dynamics might be aggressive**

… sensor modelling and fusion is a key task