SPIE.

Compact laser altimeter dedicated to drone ballistic carriers

J. Hastanin, N. Martin, F. Montfort, P. Mathys and O. Flock (**CSL**);
L. Hreczynski (**MECAR SA**)

Abstract: we report the results of investigations on the drone ballistic carriers being developed by our research team and we address specifically the concept of compact laser altimeter dedicated to the ballistic carriers. One of the main challenges facing the implementation of the mortar launched altimeter is to ensure its reliable operation after extremely high launch shock accelerations. This requirement determines the optical concept and materials selection and optimization. Recent mortar gun tests demonstrated that the optical and electronic sub-systems of the first altimeter prototype can withstand launch accelerations of at least 5000g

Introduction. Conventional drone (*MUAV/MFI*) propulsion systems drawbacks

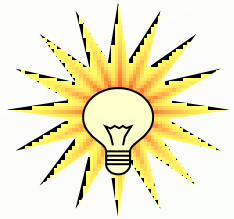
The MUAV/MFI weight and sizes are by definition, very small

- Low on-board energy storage capacity
- Inherent weakness of the propulsion drive systems

- Low flight speed ➔ Long flight time to the operation zone
- High vulnerability to low cost active countermeasures
- Inability to fly in bad meteorological conditions (ex. strong wind)
- Low “efficiency to cost” ratios

The most of the stored on board energy is spent on the auxiliary operations (takeoff, climbing and flight to target zone), useless for the objective (the target zone monitoring)

Introduction. What is our instrumental concept?



Our solutions

- Carrying the drones into target monitoring zone on board of an universal ballistic carrier equipped with an altimeter fuze
- Such ballistic carriers should be developed on the basis of inexpensive standard mortar ammunitions / non-guided rocket and corresponding launcher infrastructures

What is the goal ?

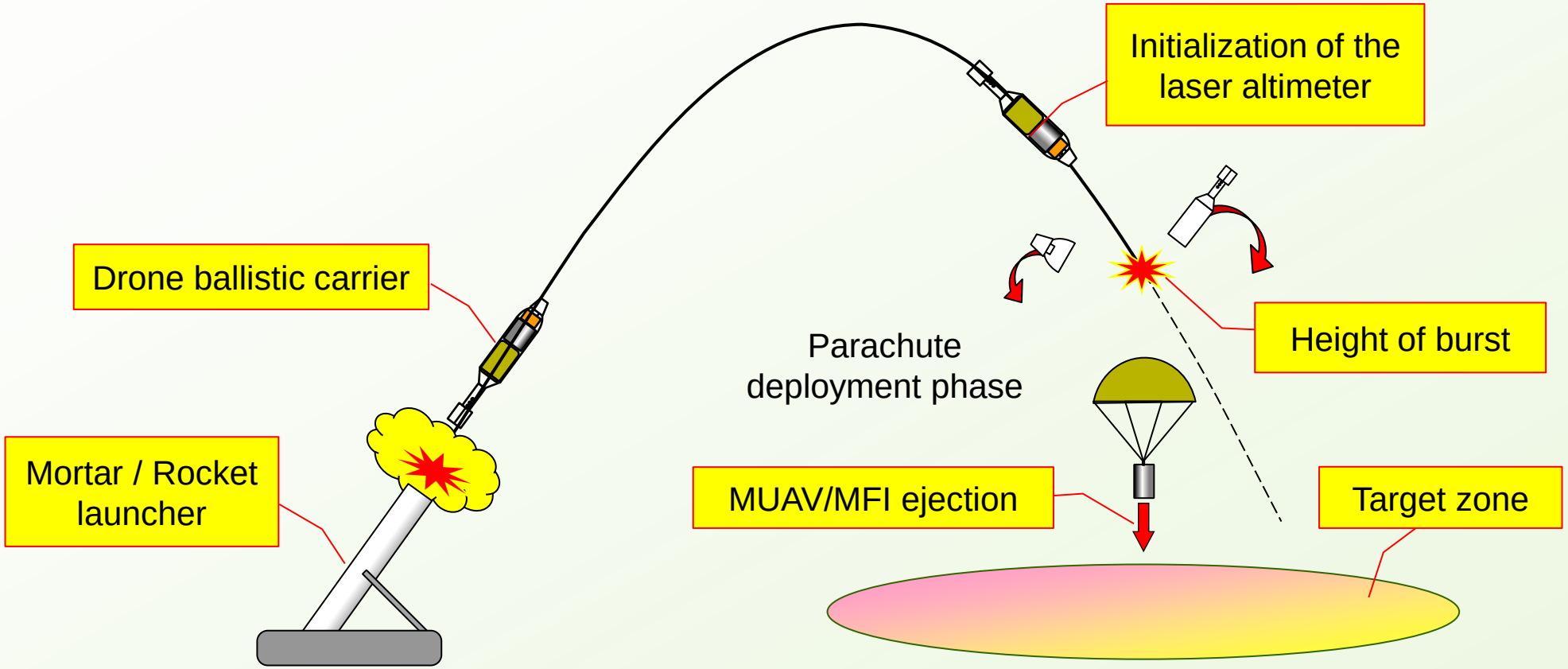
- Very fast flight to the target zone
- Altimeter fuze
- Most common projectiles

→

- High robustness against environmental factors and active countermeasures
- Reliable operation over all possible types of terrain in the target zone
- Very attractive efficiency to cost ratio

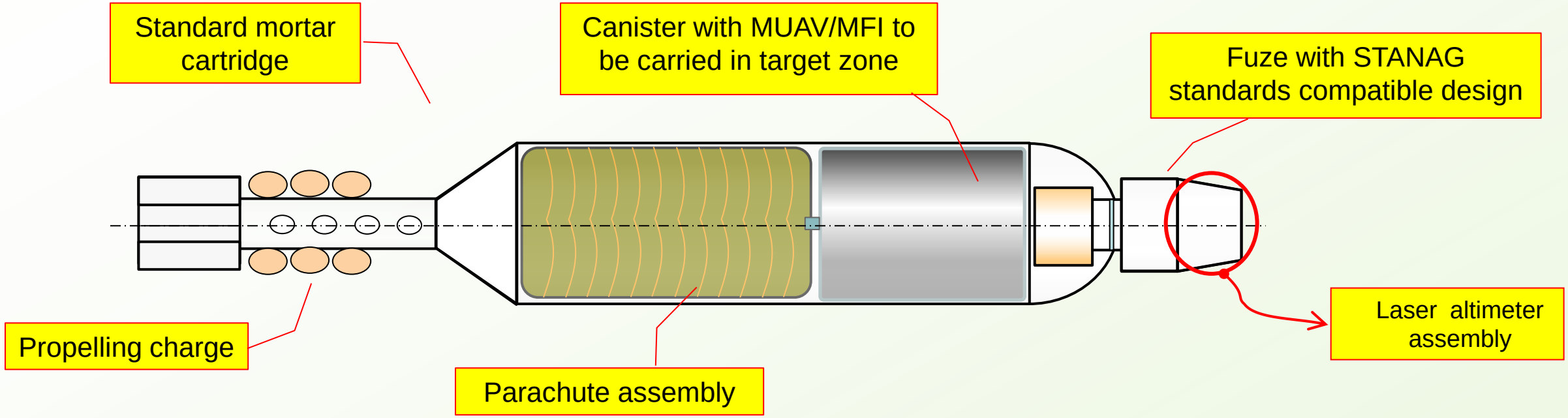
Introduction. What is our instrumental concept?

Proposed concept principle (very simplified illustration):



Drone ballistic carrier design under development

not in scale



- Two power supply formats are possible:
  - ✓ from an activated by setback shock reserve battery
  - ✓ from a wind driven turbine alternator

  } And / Or
- The prototype architecture is designed following a modular concept
- At least two alternative backup solutions can be deployed in case of altimeter failure

Introduction. Our instrumental concept. Why mortar ammunitions / unguided rockets?

1

Among the existing techniques of projectiles firing, the mortar and unguided rockets launching technologies ensure the lowest possible shock accelerations

Low cost of the required materials and components

Inexpensive final product (drone ballistic carriers)

2

Mortar rounds are quite common on the market

- Low cost and duration of the 1st prototype development and its military certification
- Low cost of large-scale manufacturing of drone ballistic carriers

However, we do not limit ourselves to this type of drone carriers !

Future research → Projectiles (mortar rounds & man-portable rockets) designed specifically for the drone ballistic carrying applications

Introduction. Our instrumental concept. *FAQ*

What are possible payloads of proposed drone ballistic carrier ?

- Almost all types of autonomous flying and land-based MUAV/MFI
- Conventional optical MUAV/MFI for video-imaging monitoring in visible, infrared and ultraviolet spectral ranges (forest fires, anti-terroristic operations, anti-drone, …)
- MUAV/MFI for environmental RF, biochemical* and radiation monitoring (nuclear accidents, …)

Why a fuze with an integrated altimeter?

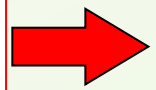
Deployment of MUAV/MFI at optimal altitudes

Why a laser TOF altimeter ?

Unknown type of terrain in the target zone (mountains, precipices, flat terrain,…?)

However, we do not limit ourselves to this type of altimeters !

Alternatives /Backup solutions (under development)



- ✓ Flight time method
- ✓ External control
- ✓ etc.

NB.: the laser altimeter involves practically all key subsystems of the most common MUAV/MFI dedicated for optoelectronic observation missions. Accordingly, the results of this study offer useful insights for the development of the MUAV/MFI compatibles with the proposed ballistic carrier technology

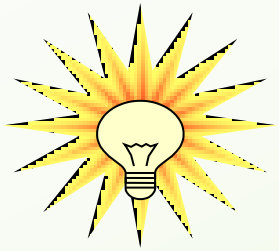
* Involving lab-on-chip technologies, as well as conventional biochemical analysis approaches

First proof-of-concept prototype of the laser altimeter fuze

Main challenges

High shock accelerations at carrier launch

The free space available in the standard mortar fuze to integrate an altimeter is very limited (by mortar ammunition standards and air intake)



Our solutions

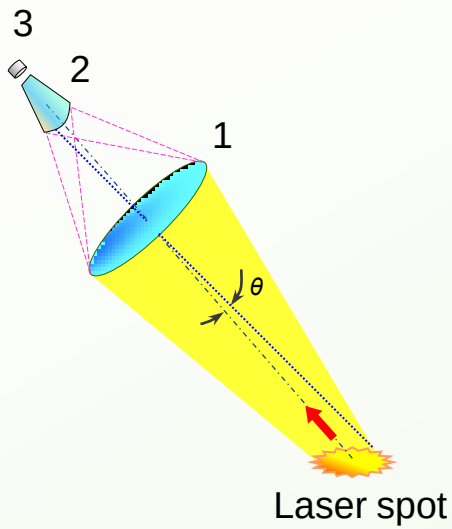
- Plastic optical components and lens mount (low weight & high shock resistance)
- Minimum possible number of refractive optical elements
- Circular design of PCBs (printed circuit board)
- Elastomer bonding of critical electronic components

- Two operating modes: monopulse & multipulse
- An original low-noise amplifier
- Two-stages receiver optical concept involving Fresnel refractive and/or reflective, as well as non-imaging optics components (*under investigation*)
- Receiver collimator primary stage involving a Fresnel dome-type lens

First proof-of-concept prototype of the laser altimeter fuze

Key original concepts proposed for the receiver optical system*

Concept of the two-stages receiver

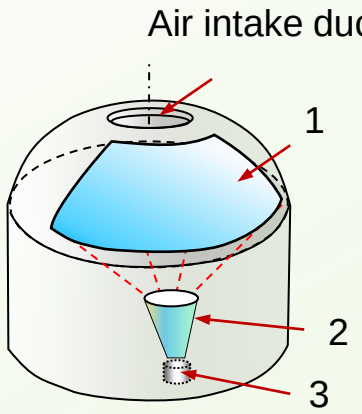


1- Primary lens 1 (bulk or Fresnel)

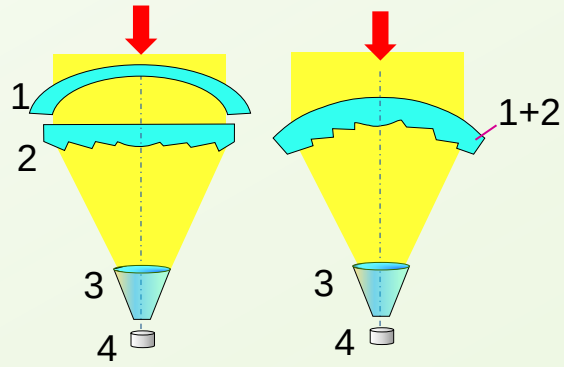
2- Secondary non-imaging concentrator (*p. ex., parabolic or conic one*)

3- APD

Concept of the non-circular receiver optics



Concept of the receiver primary stage based on a Fresnel dome-type lens

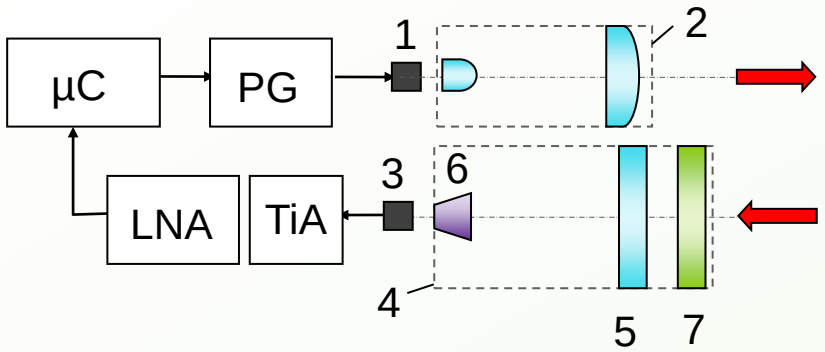


1- Aerodynamic fairing
2- Fresnel lens (bulk or thin fold)
3- secondary non-imaging concentrator
4- APD

* see the detailed explanation in the attached paper

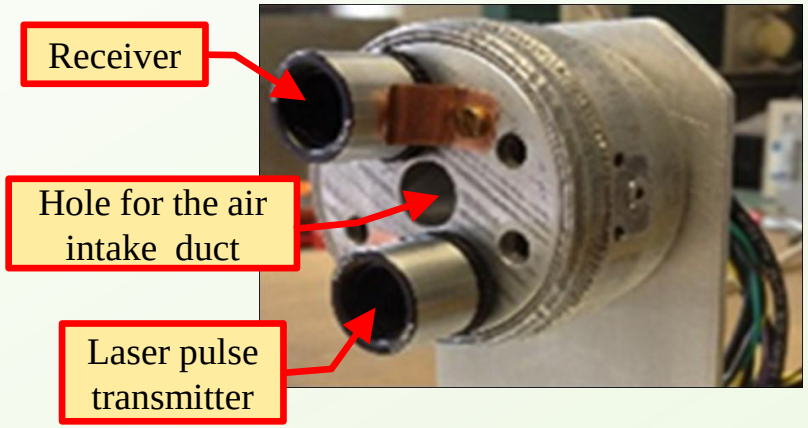
First proof-of-concept prototype of the laser altimeter fuze

Structural scheme:



1- infrared pulsed laser diode
2- transmitter collimator
3- APD
4- receiver two-stage collimator
5- collimating lens
6- non-imaging secondary concentrator
7- optical band-pass filter

TiA- transimpedance amplifier
LNA- low-noise amplifier
PG- pulse generator
µC- microcontroller

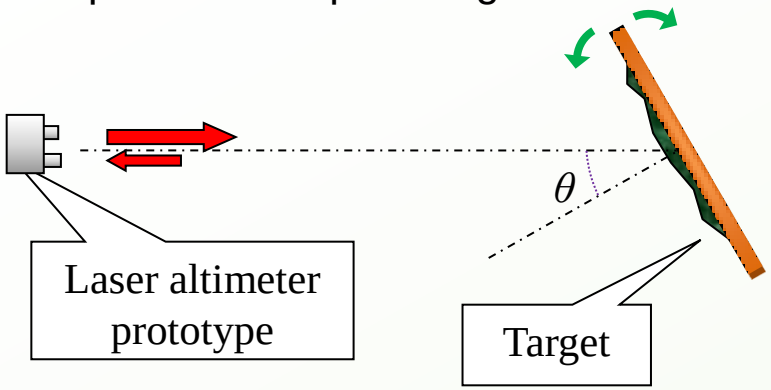


Main features :

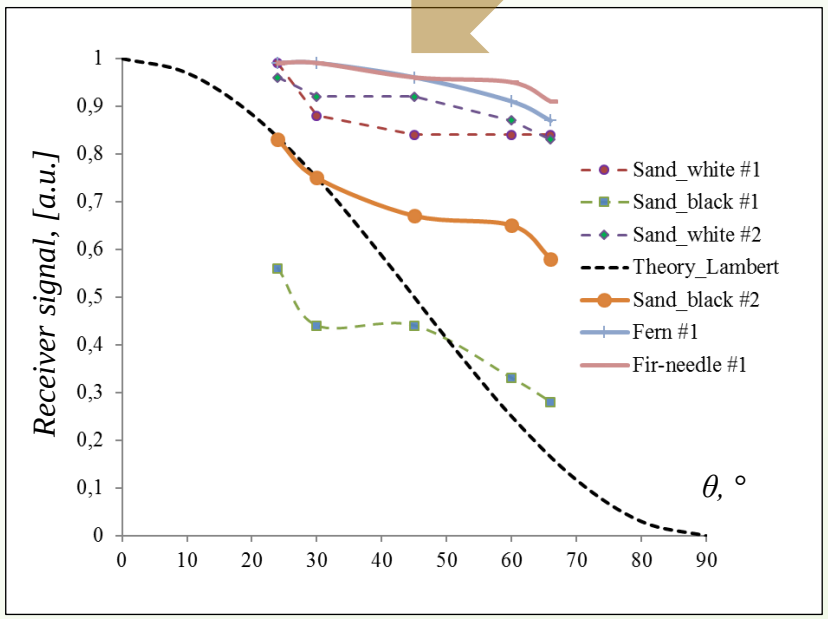
- Conventional “Time-of-Flight” method: laser diode + avalanche photodiode
- Infrared spectral range
- Cost minimized
- Low power consumption level
- Original low-noise amplifier

First proof-of-concept prototype of the laser altimeter fuze. The altimeter fuze 1st prototype testing

Principle of accomplished goniometrical tests:



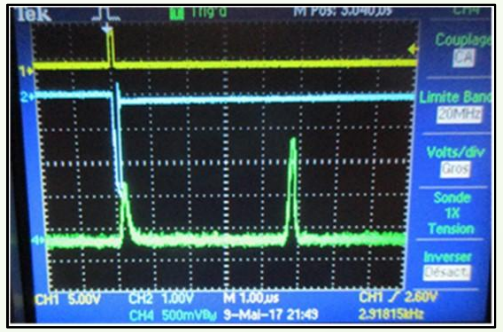
Various samples of vegetation, sands, clays and rocks



Two operating modes:

Receiver output signal

Monopulse operating mode



Multipulse operating mode

Tests on the natural targets :

Proof-of-concept prototype of the laser TOF altimeter. Experimental results

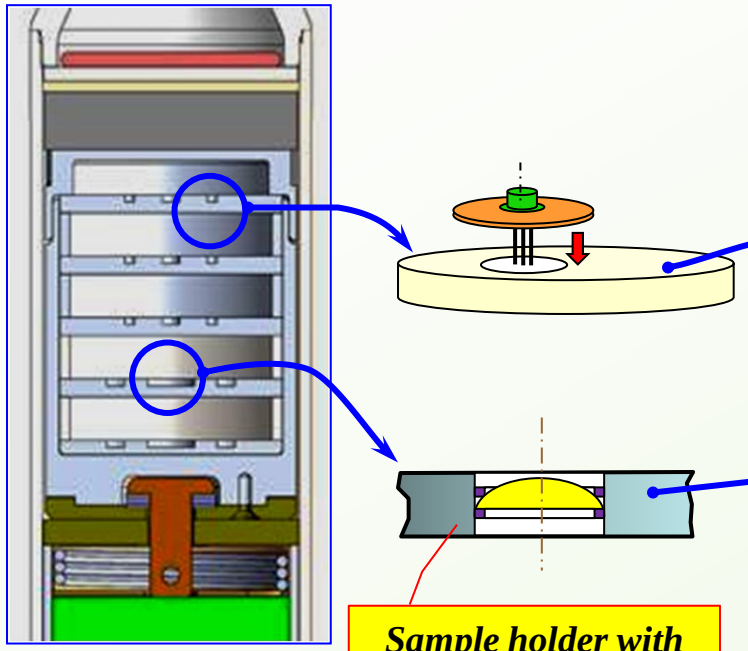
Summary of optical test results

- Available angular range: from 0 to 45 (= projectile firing available angular range)
- Demonstrated height measurement range for natural targets (forest, sandstone, urban buildings, rocky surfaces, etc.): 500 m (mono-pulse mode) and 1000 m (multi-pulses mode)

Proof-of-concept prototype of the laser TOF altimeter. Experimental results

Firing tests (using a 80-mm mortar)

Canister assembly designed for mortar fire tests of the altimeter key components and sub-systems:



Sample holder with tested components

1st prototype of the canister for MUAV/MFI carrying

Tests accomplished:

- ✓ shocks tests using a drop shocks machine
- ✓ shocks during at the parachute deployment phase
- ✓ real mortar fire tests with different propelling charges

Summary of firing test results

Demonstrated robustness to mechanical shocks : 5000g (approx.)

Prospective:

- Propelling charge involving multilayer powder (to reduce the shock magnitude)
- Wind turbine with lateral air intakes
- Backup solutions involving not-optical approaches (to be published)
- Not-parachuted aerodynamics principles
- Guided drone ballistic carriers

Conclusion:

- An original concept of the compact laser altimeter dedicated for drone ballistic carriers is proposed and experimentally investigated
- A high mechanical robustness of the key sub-systems of the developed altimeter is experimentally demonstrated
- Currently under optimization: full-function prototype of the altimeter fuze

Thanks!

***ACKNOWLEDGEMENTS**:*

The authors would like to thank the Walloon region funding for the financial support through the ELECTROHOB project

Our group welcomes partnerships to develop this technology

***CONTACT**:*

Centre Spatial de Liège, Space sciences, Technologies and Astrophysics Research (STAR) Institute, Université de Liège,
Liège Science Park, Avenue du Pré-Aily; B29; 4031 ANGLEUR, Belgium, Tél: +32.4.382.46.00; Fax: +32.4.367.56.13

https://www.csl.uliege.be jhastanin@uliege.be

MECAR SA, Petit-Roeulx-lez-Nivelles, B-7181, Belgium, Tél: +32(0)67 876 411; Fax: +32(0)67 211 823; http://www.mecar.be