

# New Generation Naval Fuze FREMEN Efficiency against New Threats



**61<sup>st</sup> NDIA Fuze Conference**  
*"Fuzing Solutions – A Global Perspective"*  
**San Diego, CA - May 15-17, 2018**

**JUNGHANS Defence** – Max Perrin, Chief Technical Officer

- **Naval Artillery Warfare and Munition Fuze Requirements**
- **FM-CW Proximity Sensor Technology**
- **FREMEN Fuze Introduction**
- **New Threats / New Targets in Naval Warfare**
- **Fuze Performances on Specific Targets**
- **Summary**



**Complete range of fuzes for all types of munitions**

**Key competences in Fuzing technologies, Micro-technologies and Ammunition electronics**



# Naval Artillery - Requirements

- **Past and recent conflicts have stressed the importance of naval artillery use**
  - Renewed interest for naval artillery as **a cost effective and flexible** way to deliver terminal effect on various threats
- **Main requirements**
  - The two usual main operational missions:
    - Naval Fire Support - Shore bombardment
    - Air Defence - anti-aircraft / anti-missile
  - **+ asymmetric warfare** requirements, in particular in close-quarter engagement

- **The operational capability and efficiency of naval artillery and naval munitions are largely driven by the fuze performance**

➔ **Multifunction / Proximity Fuzes**



# Naval Artillery – Electronic Fuzes

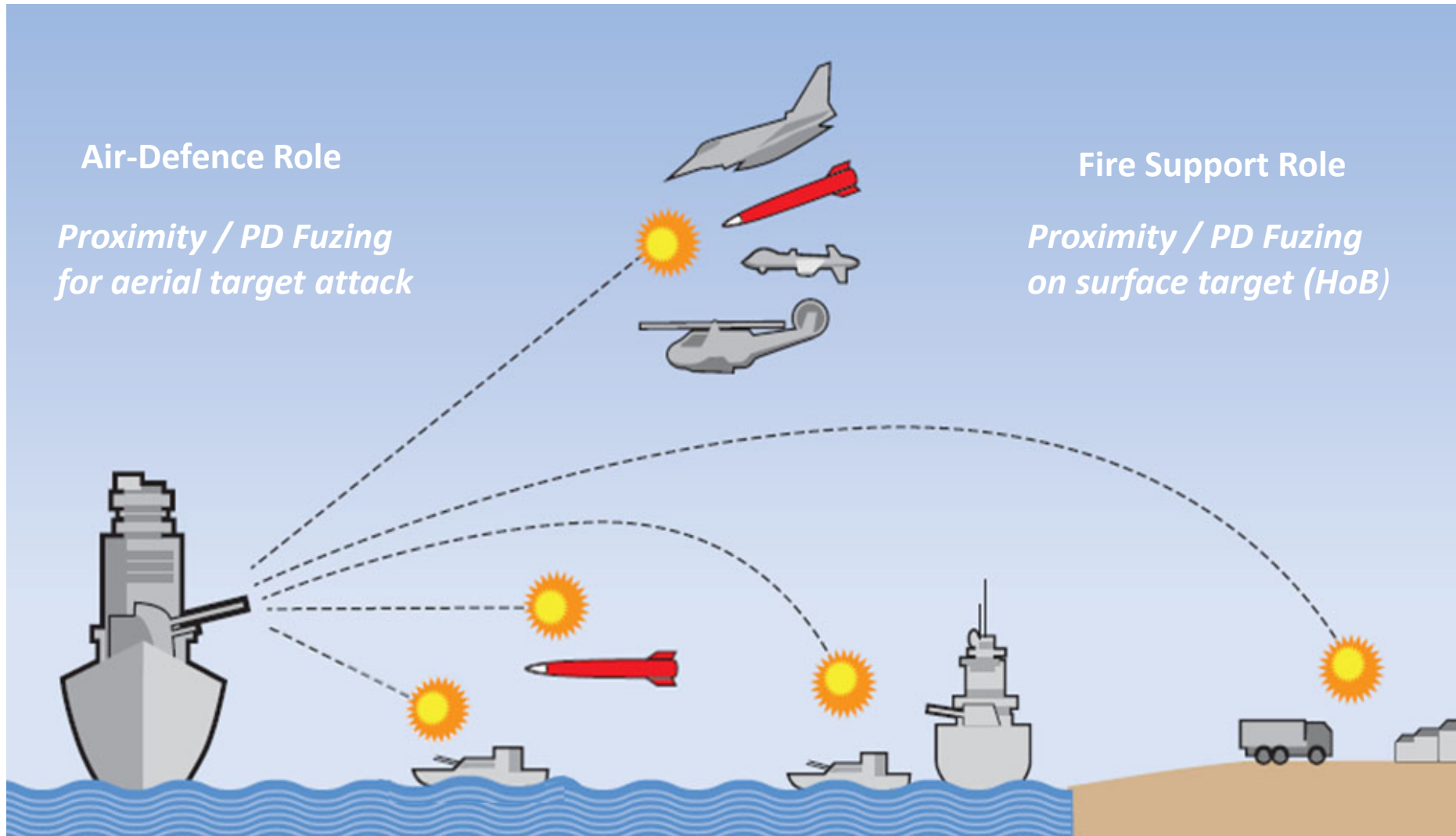
## Main Operational Missions

### Air-Defence Role

*Proximity / PD Fuzing  
for aerial target attack*

### Fire Support Role

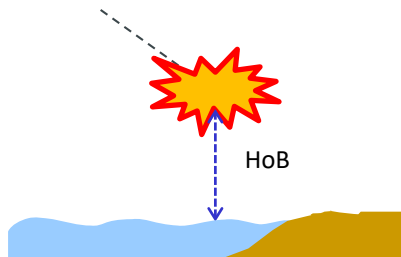
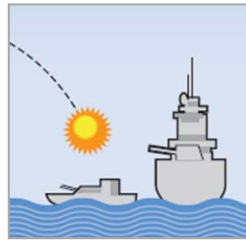
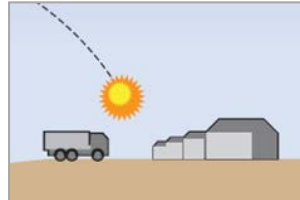
*Proximity / PD Fuzing  
on surface target (HoB)*



# Naval Artillery – Electronic Fuzes

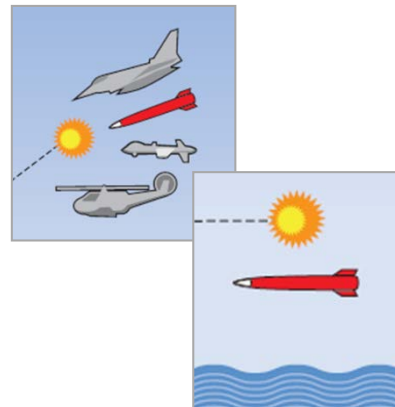
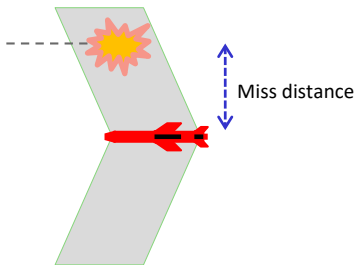
## Proximity Modes

- **on surface targets**  
Height of Burst Mode



Video: firing test on ground surface (live round)

- **on aerial targets**



Video: firing on dummy missile target (no explosive munition, booster only)

**Significant increase of munition terminal effect and kill probability**

# Naval Fuze - Proximity Function

## Challenges for the Fuze Designer

- **Improve the naval fuze proximity radar sensor capabilities**
  - Enable the detection of a various set of targets in various attack configurations, in particular:
    - Slow moving targets, or very high-speed targets
    - Low-altitude flight
    - Low Radar Cross Section
    - In presence of sea clutter
  - Precisely detonate the munition to achieve optimal terminal effect on targets
  - Prevent any fuze triggering on external disturbances such as sea clutter or EM radiations (no early burst)
- **... while keeping**
  - Unit cost down
  - High reliability - even when using sophisticated functionalities
  - Operational flexibility and versatility - no system programming

# New Generation Naval Artillery Fuzes

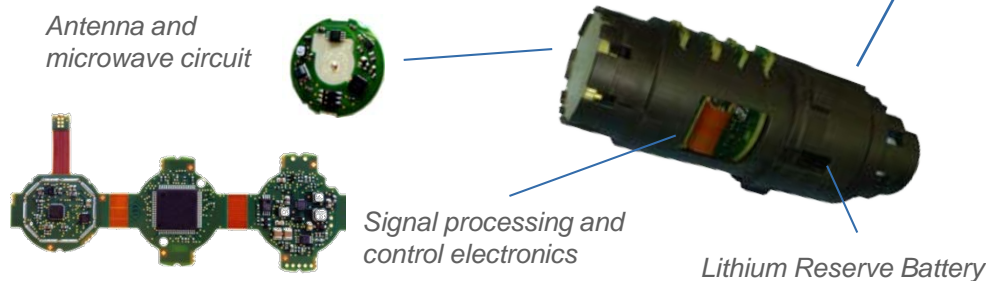
## *FREMEN* Fuzes

- ***FREMEN* New Generation Naval Multifunction Fuze Family**
  - Developed in 2 calibers: 100mm & 76mm
  - Ongoing contracts from French MoD for qualification and production
    - Qualification successfully achieved
  - Adaptation to 127mm (5") caliber
- **Fully autonomous fuze: no need for mode setting**
- **Based on common electronic module**

*FREMEN 100*

*FREMEN 76*

*FREMEN 127*





## *Benefit from FM-CW Radar Sensor Principle compared with CW Doppler Fuzes*

- **Frequency Modulation**

- $F_b = 2D/c \cdot \Delta F / T$

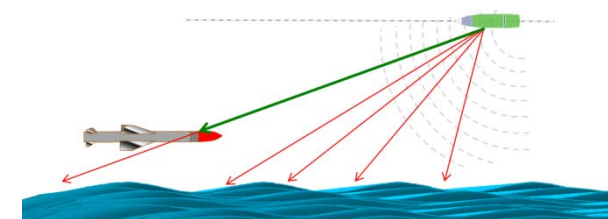
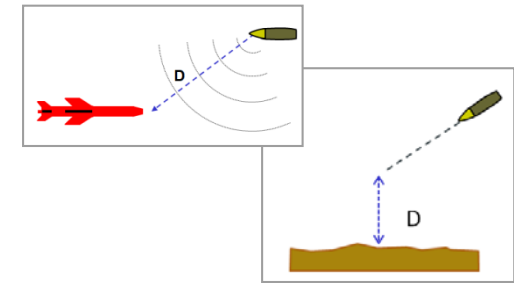
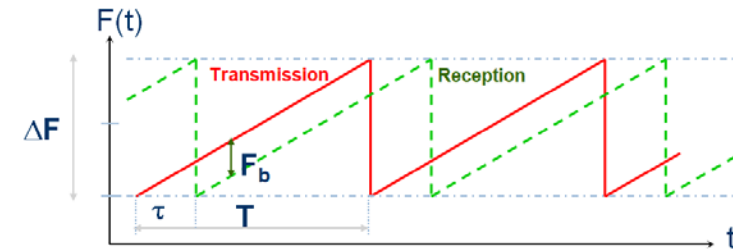
- ⇒ Beat Frequency  $F_b$  is proportional to the target distance  $D$

- **Target information provided by FMCW sensor**

- Radar Cross Section: from the signal amplitude
  - Relative target velocity: from the Doppler signal
  - **+ Target distance**: from the beat frequency

- **Extraction of the target parameters by spectrum analysis**

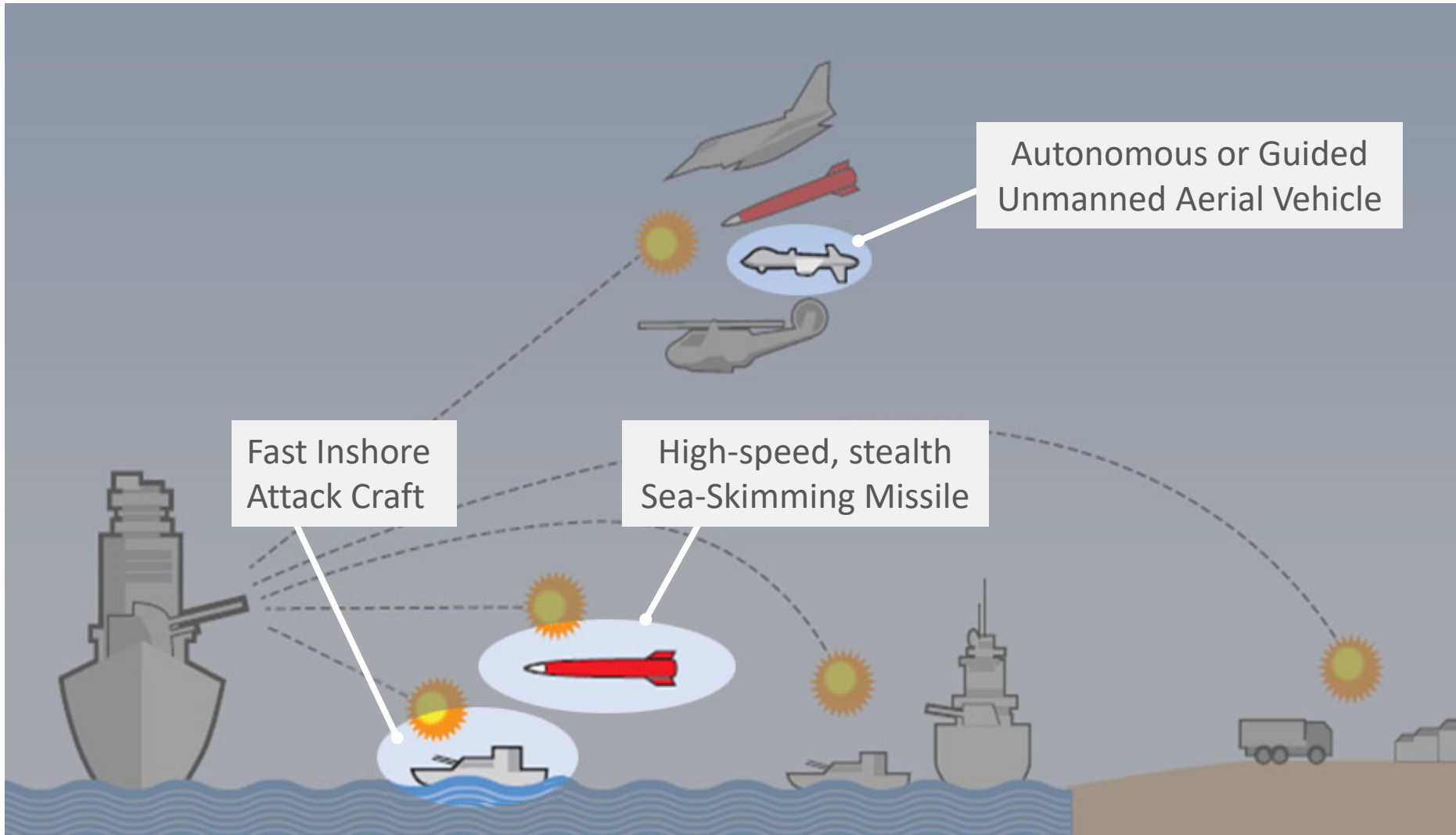
- Range gated processing to isolate sea-clutter from valid targets



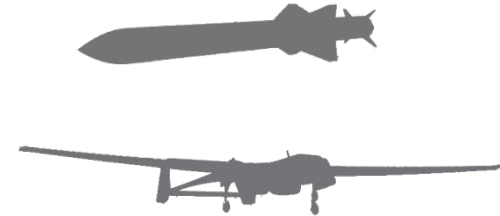
**FMCW sensor provides a key information on the target: its DISTANCE**

# Electronic Fuzes for Naval Artillery

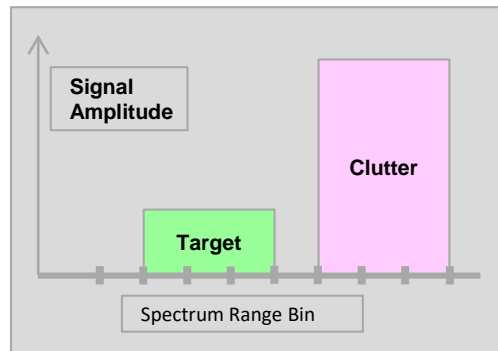
## Focus on New Threats



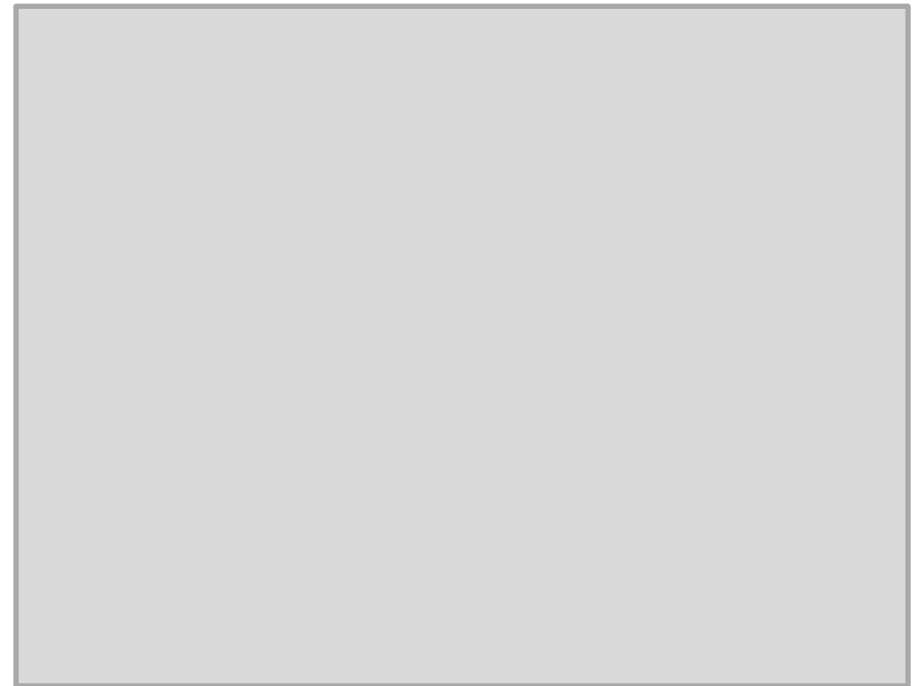
- **Targets with RCS < 0.1m<sup>2</sup>**
  - Stealth anti-ship missiles
  - Autonomous or guided Unmanned Aerial Vehicle
- **Detection especially challenging in the following configurations:**
  - Low altitude target - sea-skimming configuration
    - Disturbance from sea clutter (radar-echoes from sea waves)
  - Low speed
    - in particular for CW Doppler fuzes, using only doppler signal difference
- **Benefits from FMCW + spectrum analysis / digital signal processing**
  - Ability to discriminate the target signal from sea-clutter
    - Continuous measurement of target distance – Beat frequency signal
    - Relative velocity measurement (if any) – Doppler signal
  - Even in adverse conditions
    - For small RCS targets
    - In presence of a strong sea clutter (rough sea state)



- **Target signal extraction by spectrum analysis**



*Spectrum analysis – target detection*  
(animation)



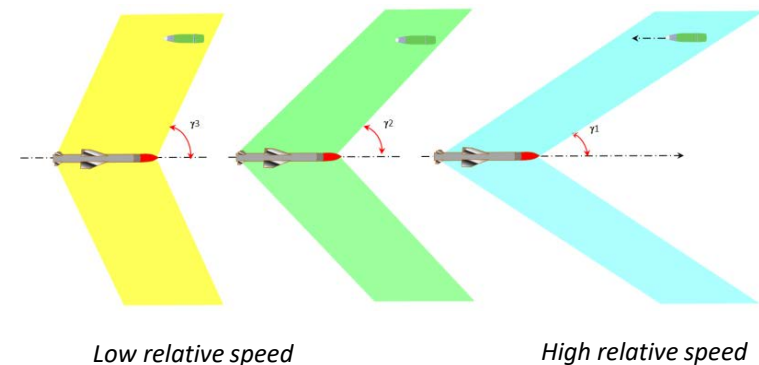
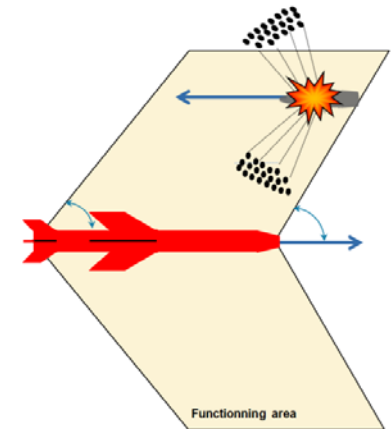
**FREMEN Fuze is able to extract low-RCS target from clutter**

# FREMEN Fuze - Qualification Firing Tests on Sea-skimming Missile

- **Video: Proximity on target (Sea-skimming missile)**

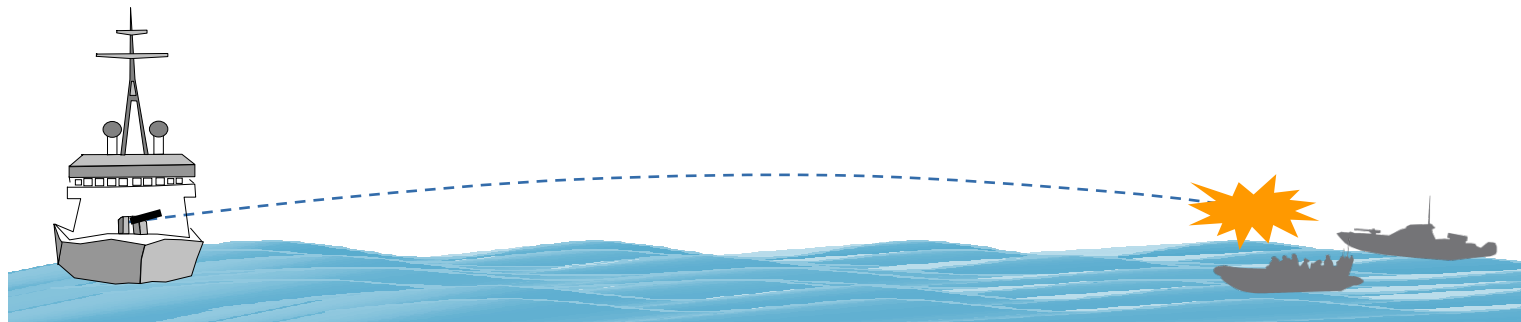
# Operation on High-velocity Missile Terminal Effect Optimization

- **Terminal effectiveness of the munition is directly driven by the precise time of initiation of the explosive charge**
  - Effectiveness area: defined by various parameters
    - Target/shell relative velocity, fragmentation spreading pattern and velocity, missdistance, size of the target
  - Range of relative velocity (target vs munition) is very wide, from 0 to several mach numbers
- **FREMEN fuze FMCW sensor is able to accurately measure both distance and relative velocity of the target**
  - Provides the precise location of the munition over the target
  - thus decides the optimum bursting point to achieve maximum effect



**FREMEN Fuze is able to actually define the optimum initiation time**

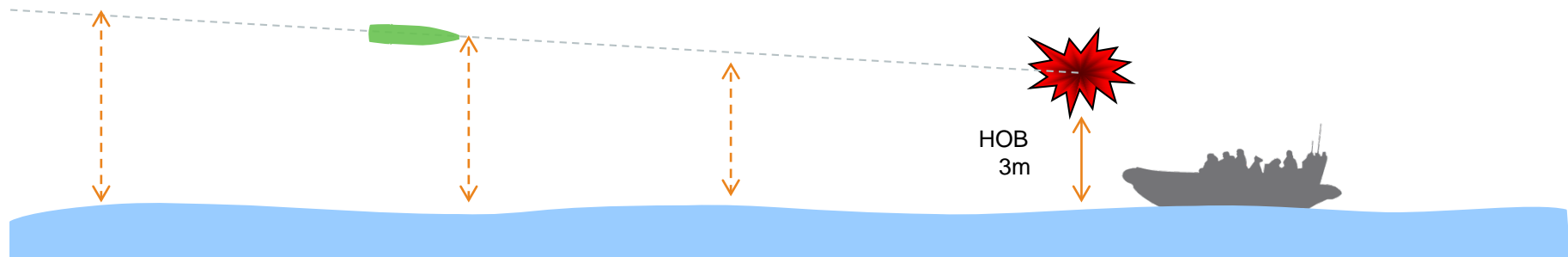
- **Fast Inshore Attack Craft (FIAC) threat is in the focus of many western navies**
  - Difficult targets to defeat, in particular in case of "swarm" attack
  - Close-quarter engagement / Direct Fire configuration
- **Modern Naval Artillery can be the suitable and optimal solution to achieve this specific ASuW operations**
  - Low cost, flexible, quick reaction
  - Especially when using high performance munition / fuze to achieve optimal effect on target



# Fast Inshore Attack Craft Threat

## Direct Fire / Surface Target Configuration

- **Deliver effect against FIAC threat remains challenging for naval artillery**
  - Point Detonating munition or Time programmable airburst munitions:
    - Either very low hit probability or complex fuze programming with dedicated and expensive weapon system
  - Proximity fuzing: very challenging in direct fire configuration
- **FREMEN new generation fuze is featuring a unique, major capability for naval engagement: HoB mode on sea surface, in direct fire operation**
  - FREMEN fuze incorporates dedicated algorithms to cope with this tricky configuration, achieving continuous trajectory measurement, providing accurate HOB and enhanced terminal effect





# FREMEN Fuze - Qualification Firing Tests

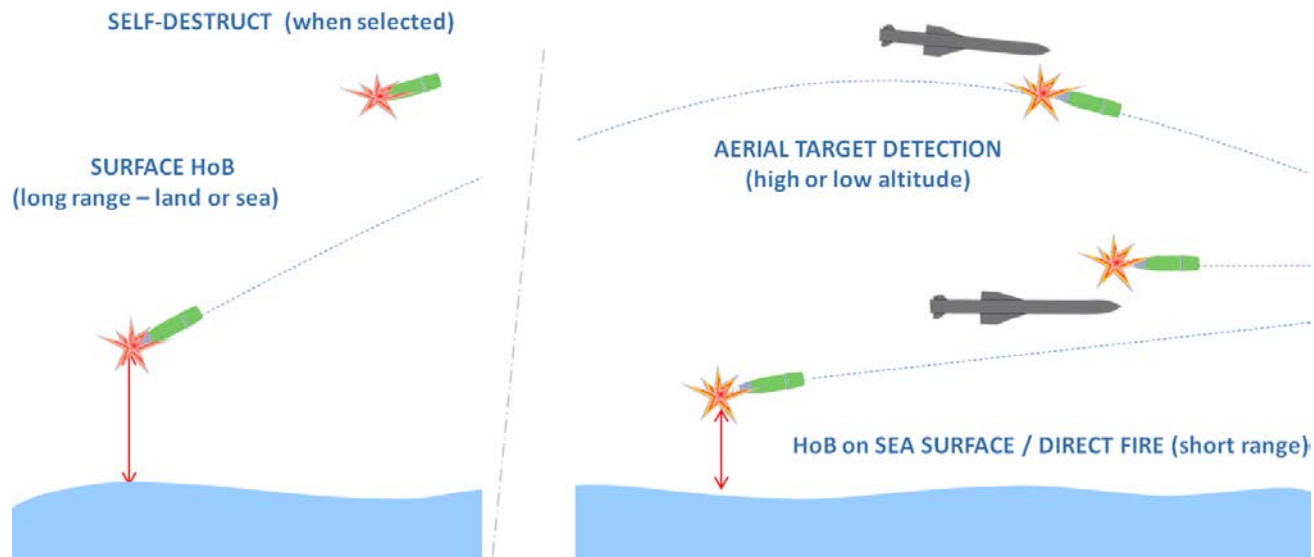
## Low HOB / Surface Target

- **Proximity mode on surface / direct fire**

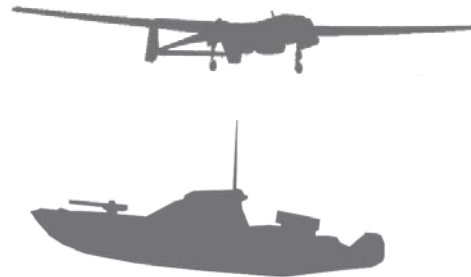
# FREMEN Fuze – Operational Modes

## Fully Autonomous Operation

- **FREMEN Fuze autonomously selects either air defence or surface fire mode**
  - The sensor continuously analyses target signals and triggers as soon as a target is detected with valid criteria - either aerial target or surface target
- **FREMEN Fuze is able to efficiently achieve a very broad range of missions *without requiring programming operation prior to firing***
  - Very versatile and flexible, useable on any weapon system, free from setting issue



- **Naval artillery fuzes have to meet demanding operational requirements, in particular with increasing new asymmetric threats**
- **JUNGHANS Defence is proposing the FREMEN new generation of multifunction fuze providing new capabilities to modern naval artillery**
- **FREMEN fuze is achieving unmatched detection performances. It enables to defeat a wide variety of targets, while operating fully autonomously without fuze programming**
- **FREMEN fuze technology can be provided in various naval artillery calibers**



# Thank you for your attention.

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