Engagement Areas of Missiles in The Proportional Navigated Flight Powered by Air Breathing Engines

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The goals of this research are to test the relationships of appropriate non-line of site (NLOS) missile flight performances and conditionally created their tactical ranges, spaces zones and shooting time during employment on the surface targets. Flight maneuver of distance remote controlled NLOS missile is tested with the conditionally joint constrains coming from flight kinematics with turbo-jet engine of NLOS missile and manner of target motion, typical of rapid reaction attacks. The constraints of maneuverability and flight, in the cruise phase, are considered as the mass point motion to create both unguided (searching) and guided navigated kinematical trajectories, which was designed by the appropriate guidance law. Research used numerical methods to simulate NLOS missile and targets motions in horizontal plane by controlling line of target (LOT) referred at the appropriate flight height. This generates borders of target impact and launching areas, establishes NLOS missile operation time, as well as masses variations for the expected manner of battle flight.

Keyword: *shooting area, range performances, proportional navigation, endurance of flight, non-line of site missile.*

1. INTRODUCTION

The remote control NLOS missiles, designed as particular weapon [1], provides defense roles for the military tactical forces, with an unmanned alternative for attacks from the very low altitude air spaces. These attacks could be conducted on the fixed or mobile surface targets [2]. This new technology for the rapid reaction defensive roles [3] could be alternative to replace air forces usually employed on the water and smooth land surface targets during their offensive penetration actions. These NLOS missile could be previously rocket flight vehicles launched on the cruising velocities and altitudes and propelled in cruising by the air breathing engines. As contributing elements to achieve rapid attack tactics and to deliver weapon effects on the engaged targets by indirect fire, in the best manner [4], continual sources of surveillance data have to be used in NLOS missile flight missions [5]. These missions require simple solution for NLOS missile navigation on the targets.

Targets data collection and distribution system can provide the determined cruising guided trajectories during flight on the single or grouped targets [6]. For NLOS missile with combined propulsion, autonomous (rocket), and air-breathing, their flight regimes and guidance for navigation are usually dependable [7]. Therefore, the fully precise-planned NLOS missile missions on the fixed or mobile target points, using air-breathing propulsion in the cruising, have coupled performance aerodynamical [7,8], and guidance and control system on the constrained guided distances [9,10], respecting limit characteristics of propulsion endurance in the operational flight regimes. Two important tasks depending on the mission and purposes are considered in this paper.

The first is the level of range and flight endurance and the second is the method of navigation and level of autonomous in flight mission.

Both tasks, navigation and ranging, are coupled with the maneuverability constraints of NLOS missile, as consequence of appropriate requests for the guidance system.

The goals of this study are to determine the limited characteristic zones where NLOS missile can deserve launching instants and to achieve impact on the fixed and manoeuvrable target points, in the guided horizontal flight profile determined by mentioned constraints. To determine rapid reaction tactics on the targets, navigation guidance low model is unprepared, and their initial correction is guided during the flight.

2. SUPPOSITION FOR ANALYSIS

The simplest approach for flight navigated calculations could be using of proportional navigation guidance law, realized as 2-D model, within constant flight altitudes and velocities in horizontal planes. The selected navigation constants of guidance law, which direct the maneuvers of flight vehicles and shape of trajectories, have to be also selected [4]. Basic assumed hypothese, in the shooting borders simulation, were:

- Surveillances assessments and CIS (Command Information System) operations are not considered here, but battle theater dimensions of NLOS missile engagement is arbitrarily limited to a horizontal plane,

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27 km x 27 km, at the constant altitude of H=300m above smooth surfaces of the earth.

- The reference frame is Cartesian where the initial point of observation is in the origin. The frame *x*-axis accepted to be directed in the appeared target point within the tolerance of orientated angles that are the part of this research. Researched target courses are opposite or lateral-orientatated of the NLOS missile flight at the 27 km longitude and 4 km left and right latitude away from the origin, figure 1. This constraint is valid for the mobile targets and rapid answer defense by NLOS missile for the attacks of incoming targets from different frontal directions.The launcher provides interfaces and data supplements between NLOS missile and targets tracking sensors.

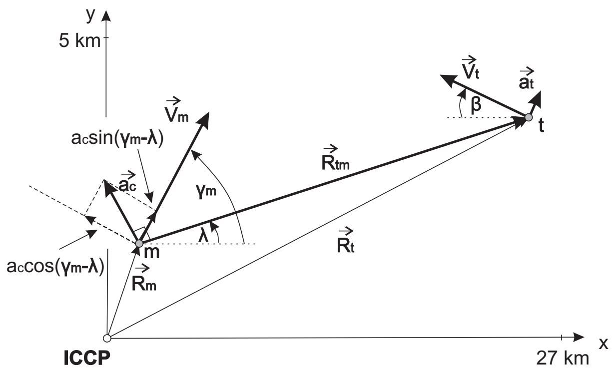

Figure 1. Limited battle field area in horizontal planes and impact geometry

- Maximum shooting distances which could exploit navigation flight to targets is S_{max}, and is constrained by turbo jet engine consumption and NLOS missile fuel tanks capacity.

- NLOS missile could fly navigated at small altitudes with constant velocities of about V_m=180 m/s and with trajectory maneuver radii constrained with 4g accelerations. The magnitudes of NLOS missile velocity are achieved by booster rocket engines, previously firing from launching pod. In the initial flight, NLOS missile is interrupting in to the cruising concentration points (ICCP), located in to the origin of frame and directed in the *x*-axis. This simply provides more rapid reaction effects by helping minimization of launching preparation. Consequently, NLOS missile velocities do not have optimal angles toward guidance line before navigation starts.

Navigation tactic on the targets could be achieved by next assumptions:

- Continual orientation guidance of the velocity vector direction for NLOS missile starts from its initial cruising command positions (ICCP).

- Position vectors R_m of NLOS missile and target vector R_t is measured from ICCP point, figure1.

- NLOS missile's guidance effective range is calculated from the trajectory made by the method of proportional navigation by supposed LOT (line between target position and NLOS missile), with a flight navigation angles of mentioned vectors and lines using the method of proportional navigation with coefficient N_{pr}=5 [4,11,12]. This value is used as fixed, depending of maneuver lateral constrained acceleration of the NLOS missile orientated to the mobile target area.

- The target is fixed mass point and their trajectory could be directed, straight, lateral or oblique line toward NLOS missile flight, within discovered shooting areas figure 1, and with constant speed of V_t=15 m/s.

- The target is a fixed mass point directed in the same manner, but maneuverable with constant speed of 15 m/s, and lateral constant acceleration of a_t=0.07g.

- NLOS missile considers the variable mass point making simple turn in maneuver (not coordinated turn). This coincides with the start of turbo jet engine for cruising of NLOS missile with initial m_0 mass value. As the most important flight performances required for the navigated flight, ranges and endurances appeared.

Ranges are achieved at a constant speed and altitude, which affects appropriate lift to drag ratio L/D to be controlled by autopilot. Two cases have been considered:

- L/D=const, with very low expected decreasing of altitude (less than 1%)
- Constants speed and altitude with no drag changes in maneuver

3. RANGE-ENDURANCE PRELIMINARY ESTIMATIONS

Basic parameters of flight mechanics are reduced to the range of NLOS missile and endurance time. These elements are crucial to determine tactical performances. The longest endurance is given by [13,14]:

$$E = \frac{1}{c_t}\left(\frac{C_L}{C_D}\right)_{\min} \ln\frac{m_0}{m_f} \tag{1}$$

for the L/D=const., at the drag force D which corresponds to the declared trust of about T=40 daN. Endurance of the flight with maximum range for the V=const. and H=const. [13,14], is

$$\mathrm{E} = \mathrm{k_e k_A}[\mathrm{arctg}\left(\mathrm{k'_A m_0}\right) - \mathrm{arctg}\left(\mathrm{k'_A m_{fin}}\right)] \tag{2}$$

where,

$$\mu = \left(\frac{m_0}{m_0 - m_f}\right)^{-1} \tag{3}$$

$$\mathrm{k_e} = \frac{1}{\mathrm{c_t}} \tag{4}$$

$$\mathrm{k_A} = \frac{1}{\sqrt{\mathrm{kC_{Dmin}}}} \tag{5}$$

$$\mathrm{k'_A} = \frac{2\sqrt{\mathrm{k}}}{\rho \mathrm{V}^2 \mathrm{S}\sqrt{\mathrm{C_{Dmin}}}} \tag{6}$$

are engine and aerodynamical performances complex implicit coefficients ($\mathrm{k_e}, \mathrm{k_A}$ and $\mathrm{k'_A}$), which affects endurance and range performances. Ranges trajectory are determined by constant velocity V with endurance time E, by expression,

$$S = V \cdot E \tag{7}$$

Reference to (1) can't provide both V=const. and H=const, and derived endurance used in calculations is only comparative regarding NLOS missile mass losses expressed by (2). Reference to (2) corresponds to the expected case in tactical cruising flight and mass consumptions will be estimated by performances arranged for the full trust force level to evaluate possible mass reserves for the of payload design.

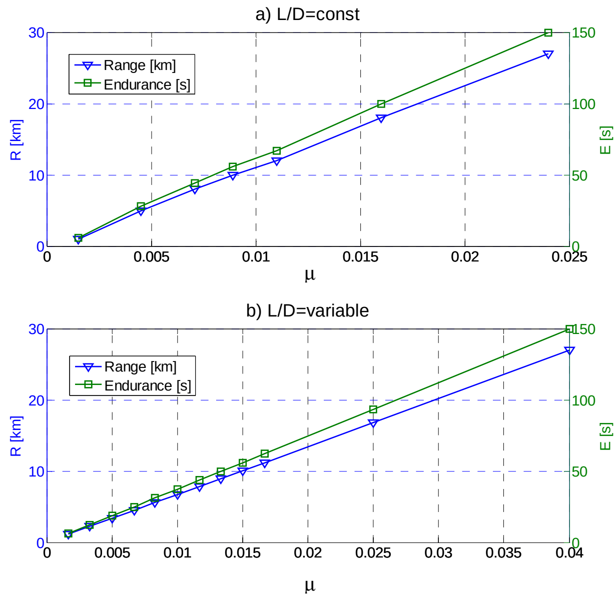

Figure 2. Threshold mass ratio of NLOS missile in the flight ranges (endurances) a) L/D=const b) L/D=variable

Table 1. Referred aerodynamically and flight data

Specific fuel consumption	$c_t,[\frac{kg}{daNh}]$	1.42
Minimum drag coefficient	C_{Dmin}	0.0793
Coefficient of inductive drag	k	0.06
Dynamic pressure (H=300m)	$q,[\frac{N}{m^2}]$	18766
Wing span surfaces (referred area)	$S_w,[m^2]$	0.2659
Lift to drag ratio	C_L/C_D	1.4715
Lift coefficient	C_L	0.11

Data collection used in simulation which refereed aerodynamical and cruise performances do not represent the real endurances of designed flight vehicle, and are taken as the origin of aerodynamically designed requirements for the NLOS missile of about m_0=60kg and turbo-jet engine, table 1, as a model tested for navigation.

Calculation based on (1), (2) and (7), using data in table 1, are shown in figures 2 and 3.

The figure 2 represents the range (left ordinate axes values) and endurance (right ordinate axis values) which share the same relative mass μ, (3) as a variable. This is the representative mass flow ratio for different ranges which NLOS missile passes by trajectories (guided or unguided) as the variable mass point affected by fuel consumption. Determined engine performances, figure 2, a) are valid in (1) in figure 2, b) and correspond to (2). These two equations have different function expressions for endurance E vs. mass ratio μ, but for small values of argument μ it shows small differences in flight endurance time E (μ).

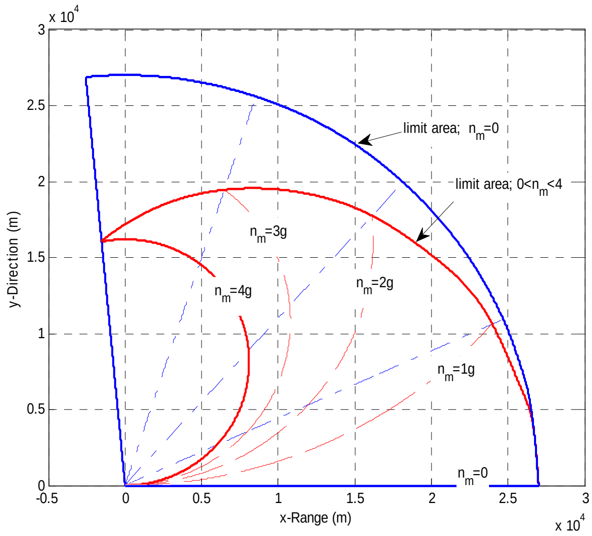

Figure 3. Threshold area of fixed targets engagement by the maximum range

Figure 2 shows that mass consumption of the flight vehicle with constant L/D on the minimum value figure 2 b) and flight with constant velocity at the constant height figure 2 a) corresponds to the differences of about 40%.

This means that flight with constant velocity and height is far from optimum even in the case of minimum L/D values.

Approximation for the shooting time in guidance on the appropriate ranges have to be taken for the guidance and navigation conditions on the values close to the case V=const. and H=const. figure 2 a). Further considerations accepted shooting time of E=150s for the mass ratio $\mu = 0.04$ and maximum range of R=27000 m .

As mentioned, suppositions in figure 3, represent straight line ranges (dashed lines) and origin curve lines trajectories (full lines) restricted by endurance and range. Curved lines satisfy the threshold the flight with lateral NLOS missile acceleration of $a_m = 4g$, with the given velocities taken about of 180 m/s for the NLOS missile. In that sense, figure 3 represents the capabilities of NLOS missile maximum straight line, or maximum maneuvers distances with constant flight velocities.

This figure is repeatable in each quadrant of a horizontal coordinate frame. For searching the shooting regimes of employment, mentioned zones of NLOS missile flight, could be used tactically. For the mobile targets these zones could be different and restricted by the tracking and guidance kinematics which is considered in the next section. In respect of the NLOS missile design, figures 2 and 3 show correlations of ranges and mass of NLOS missile at the end of the flight. Less ranges require less μ which could mean relive mass for more payload at the given fixed initial NLOS missile mass. Variable payloads mean variable ranges, which provides attacks of different target types which strongly influences the ordinances designed payload [15,16].

4. MODEL OF IMPACT KINEMATICS FOR SIMULATION ALGORITM BASED ON NLOS MISSILE NAVIGATION PERFORMANCES

Navigated motion of NLOS missile is observed considering the impact kinematics of two-point systems, the NLOS missile *m* and the target *t*, figure 1. Constrained acceleration of NLOS missile in the flight will be controlled by the guidance law [4,5,6]. Guidance law generates the threshold value of acceleration for the navigation line LOT along the appropriate mission area.

Target tracking sensor integrated in the initial position 0, figure 1, (ICCP), participates with its capabilities in generation of LOT acceleration. In this case, it is approved to take 4g as the value that could be the threshold for the LOT acceleration a_c as a command value for the external NLOS missile navigation loop. NLOS missile endures some value about 4g corresponding to the (23) in the engagement cases of the missions.

The ratio between command a_c, and NLOS missile real acceleration a_m, becomes $\bar{a} = a_c / a_m$ and would be taken as the best coefficient $\mathrm{N_{pr}}$ of the proportional navigation law. This is not tested in this paper, but is the base for the distance controlled automatic guidance command loop, integrated with navigation tracking sensor.

In the inertial reference frame the positions of *m* and *t* are given by the vectors components of the NLOS missile position vector $\mathbf{R}_\mathrm{m} = (R_\mathrm{mx}, R_\mathrm{my})$, and target position vector $\mathbf{R}_\mathrm{t} = (R_\mathrm{tx}, R_\mathrm{ty})$, in the horizontal plane figure 1. The relative distance vector $\mathbf{R}_\mathrm{tm} = (R_\mathrm{tmx}, R_\mathrm{tmy})$, or $\mathbf{R}_\mathrm{tm} = \mathbf{R}_\mathrm{t} - \mathbf{R}_\mathrm{m}$ between the NLOS missile and the target, LOT, is determined by the components on the *x*-and *y*-axis by the next expressions [4],

$$R_\mathrm{tmx} = R_\mathrm{tx} - R_\mathrm{mx} \tag{8}$$

$$R_\mathrm{tmy} = R_\mathrm{ty} - R_\mathrm{my} \tag{9}$$

$$R_\mathrm{tm} = \sqrt{{R_\mathrm{tmx}}^2 + {R_\mathrm{tmy}}^2} \tag{10}$$

Velocity vector components $\mathbf{V}_\mathrm{m} = (V_\mathrm{mx}, V_\mathrm{my})$ of the NLOS missile, and target, $\mathbf{V}_\mathrm{t} = (V_\mathrm{tx}, V_\mathrm{ty})$ are [4],

$$V_{mx} = \dot{R}_{mx} = V_m \cos\gamma \tag{11}$$

$$V_{my} = \dot{R}_{my} = V_m \sin\gamma \tag{12}$$

$$V_{tx} = \dot{R}_{tx} = -V_t \cos\beta \tag{13}$$

$$V_{ty} = \dot{R}_{ty} = V_t \sin\beta \tag{14}$$

This equation is used to integrate position vectors of NLOS missile and target given in (8) and (9).

Vector of relative velocity (relative distance derivative), is equal,

$$\mathbf{V}_\mathrm{c} = \dot{\mathbf{R}}_\mathrm{tm}(t) = -\left[\dot{\mathbf{R}}_\mathrm{t}(t) - \dot{\mathbf{R}}_\mathrm{m}(t)\right] \tag{15}$$

Relative velocity vector $\mathbf{V}_\mathrm{tmx} = \mathbf{V}_\mathbf{tx} - \mathbf{V}_\mathrm{mx}$ and his components projected on the fixed coordinate system are [4],

$$V_{tmx} = V_{tx} - V_{mx} \tag{16}$$

$$V_{tmy} = V_{ty} - V_{my} \tag{17}$$

Using the derivative of (10), and replacing (11), (12), (13) and (14) in to the (16) and (17) scalar value of intensity for relative velocity, becomes,

$$V_\mathrm{c} = -\frac{R_\mathrm{tmx} V_\mathrm{tmx} + R_\mathrm{tmy} V_\mathrm{tmy}}{R_\mathrm{tm}} \tag{18}$$

This is called the *closing velocity*. Line of Target (LOT) can be estimated by the expression for line of target angle [4], figure 1,

$$\lambda = \operatorname{arctg} R_\mathrm{tmy} \big/ R_\mathrm{tmx} \tag{19}$$

which derivative in time expressed the angular rate of (LOT) during flight given in the form,

$$\dot{\lambda}(t) = \frac{R_\mathrm{tmx} V_\mathrm{tmy} - R_\mathrm{tmy} V_\mathrm{tmx}}{{R_\mathrm{tm}}^2} \tag{20}$$

The proportional navigation law states that command acceleration a_c is the component of relative acceleration (LOT) if target and NLOS missile have constant velocities. This acceleration is acting perpendicular to the instantaneous LOT and is proportional to the LOT angular rate, target closing velocity and navigation constant $\mathrm{N_{pr}}$, which presents effective navigation ratio, and is given by the expression [12],

$$a_\mathrm{c} = N_\mathrm{pr} V_\mathrm{c} \dot{\lambda}(t) \tag{21}$$

Angular rates for NLOS missile and target during shooting flight are used for the integration of position angles for the velocity vectors and their components determined in (11), (12), (13) and (14), and are [4, 17, 18],

$$\dot{\gamma}(t) = \frac{a_\mathrm{c} \cos(\gamma - \lambda)}{V_\mathrm{m}} \tag{22}$$

$$a_m = a_c \cos(\gamma - \lambda) \tag{23}$$

$$\dot{\beta}(t) = \frac{a_\mathrm{t}}{V_\mathrm{t}} \tag{24}$$

A set of expressed equations was a base for the simulation algorithm in MATLAB for creation of trajectories [19]. The algorithm respects the constraints of the maximum intensity of command acceleration of the NLOS missile compared to the threshold value of the NLOS missile normal acceleration ($a_c \leq 4g$), navigation constant $N_{pr}=5$ determined by the guidance designed loop and also flight endurance performance in the maximum NLOS missile ranges under the supposed conditions. The ratio between the command and the NLOS missile navigation also tested and approved former included hypotheses.

5. SIMULATION RESULTS

To achieve the threshold impacts points under the target motion suppositions referred to as straight line interrupting in the expected battle field area, under the angles toward the *x*-axes of $\beta = 180^o$, $\beta = 270^o$ (90°) and $\beta = 225^o$ (135 °) several (nine plus nine) ranges from ICCP have been tested. Test ranges were from 27 km to 1 km in longitude, and from 0 to ± 5 km in latitude symmetry around the *x*-axis. Coordinates have evolved from velocity integrals simulation in the given points where $R_{tx} \approx R_{mx}$ and $R_{ty} \approx R_{my}$ using guidance law and accepted constrains. Impact points have been simulated, taking the error criteria by (10) given as 15 m. The diagram in figure4 shows the threshold impact points which determine shooting area in a horizontal plane for the straight line mobile targets.

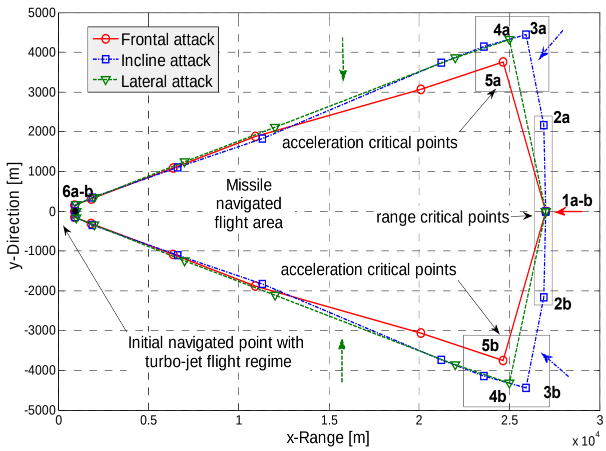

Figure 4. Threshold impact points which determines shooting area in horizontal plane for the straight line mobile targets

The coordinates of these points have been signed as x_{imp}, y_{imp}. The inside of this area impact is probably within a given error. Out of this area impact with target is not possible within given error. Points 1 and 2 are critical by range performances of NLOS missile and 3a, 3b, 4a, 4b, 5a and 5b are critical, both, as threshold command acceleration and flight performances. Lines between points 1-5, 1-3 and 1-4, for both a and b sides of the area in figure 4, for all cases of targets directions (frontal, incline on lateral) are constrained by performances of air breathing powered flight regarding the range and endurances. The lines between points 6-5, 6-4 and 6-3 also for both a and b sides linked group of impact points constrained regarding the achieved command acceleration of about 4g. The typical command acceleration profile, figure 6a, along trajectories, (figure 6a, for the impact points 5, 4 and 3 and also for a and b sides is shown on the figure 4.

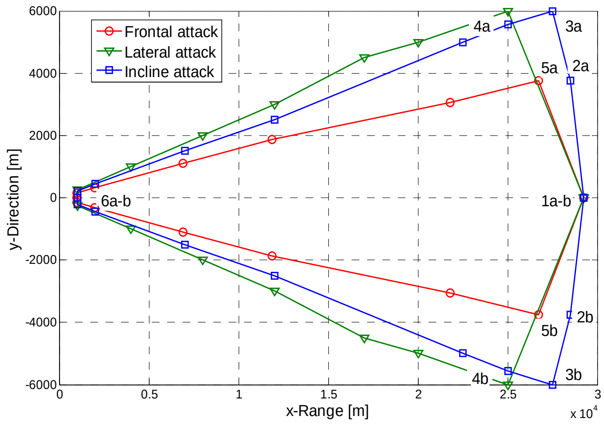

Figure 5. Threshold guidance launch area for the expected impact points

NLOS missile and targets, joint simulation during motion, initiates in the points disposed on the battle area, is given in the figure 5. These points are signed as x_L and y_L, and determined by expressions,

$$x_L = x_{imp} + V_t t \cdot |\cos\beta| \tag{24}$$

$$y_L = y_{imp} + V_t t \cdot |\sin\beta| \tag{25}$$

for the $\beta \in \left(90^o, 135^o, 180^o, 225^o, 270^o\right)$.

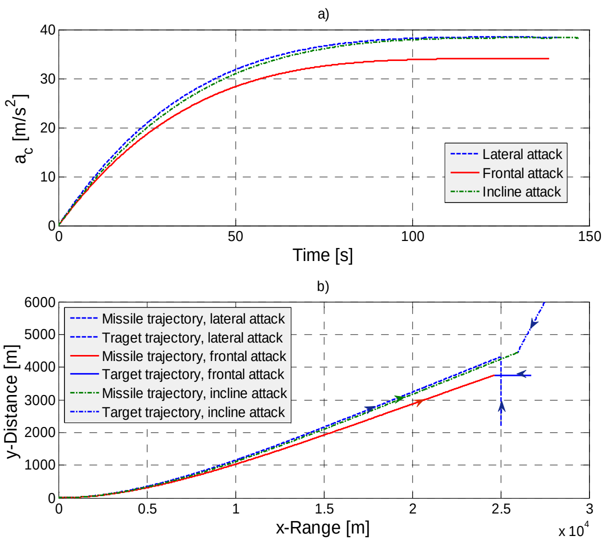

Figure 6. Command acceleration (a) and trajectories (b) for the threshold position of targets in linear motion

The generated area represents the positions where target is engaged by the guidance law. The inside of this area is the impact area given on the figure 4, where impact points realize shoots. In that sense, NLOS missile is in the ICCP position with $\gamma = 0$, as the initial condition when target is anywhere on or in the lines given in figure 5.

Further achieving of impact points requires flight endurance which is maximum in the point 1a-b and point 2a and 2b of 150s.

Other points of targets-NLOSmissile engagement have less impact time and are not critical for the NLOS missile performances. This diagram represents launching of guidance flight, and is the part of the main battle time readiness for NLOS missile. Points (1a, 2a, 3a, 4a, 5a and also for the corresponding b part of area as well as 6a-b) figure 5, correspond, by their numbers to the same numbers of impact points given in figure 4, but simulated for the beginning moments of targets motion.

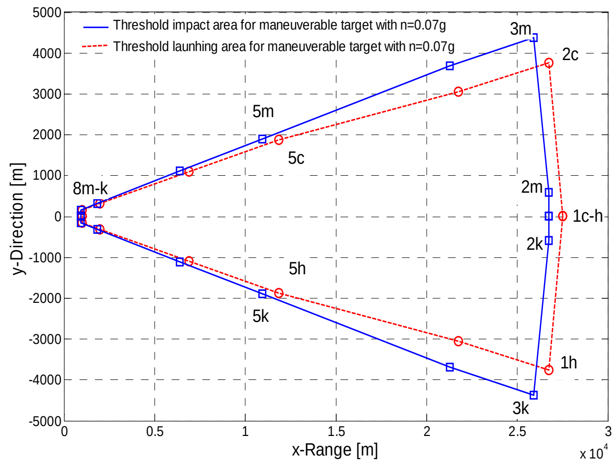

Figure 7. Threshold guidance impact and launch areas for the expected impact points for the maneuverable targets

Real initial launching pod requires back position of ICCP (far of 0). This is necessary because NLOS missile booster phase required to achieve flight velocity about 180 m/s.

Simulation test was also realized for the mobile targets in the maneuver for the cases of expected lateral acceleration referred as, a_t=0.07g. Target motion changing the direction in maneuvering run, after meant it has been engaged on the point of shooting zone given in figure 4.

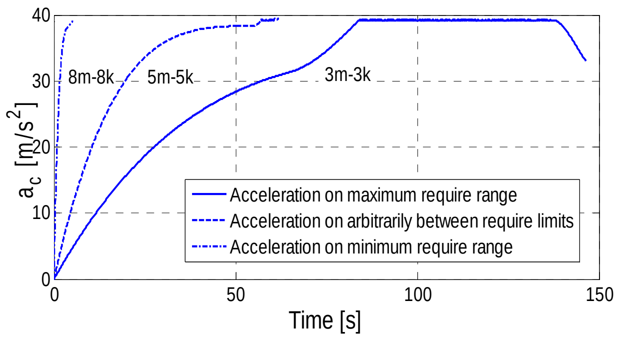

Figure 8. Command acceleration for maneuverable target (overloading a_t=0.07 g)

Several cases of maneuverable targets have also been tested according to the same points around the former launch and impact borders designed in mentioned areas, figure 7.

Impact area determined by impact points, in these cases, is very close to the impact points with the former tested linear moved targets and oriented according to the opinion that low maneuverable targets with low speeds can not rearrange impact points area for this type of NLOS missile. This is proved according to the ratio of velocities for NLOS missile and targets, which is about 12 times more for the NLOS missile.

6. DISCUSSION

Some duscution coming from this simple simulation test shows the next:

- Command accelerations example in figure 8 shows, in most cases, maximum values for the shorter time achieved on the trajectories. Continuation of navigation in further flight is with the maximum acceleration to the end of impact points.
- Integration kinematics of NLOS missile flight is constrained by the expected targets maximum ranges for battle engagement. This could be tactical input.
- Flight velocities could vary but for the cruising flight regimes is expected to be an appropriate constant adopted for searching and manoeuvring requirements and to track terrain form by masked flight toward targets.
- By this, namely tactically referred constraints, NLOS missile that uses turbojet engine takes endurance time and velocities for the navigation flight as one constrained pair and lateral acceleration as the other and gave very spread areas of shooting possibilities in the non-guided searching remote controlled regimes.
- Guided navigation flight also accepted with constant intensity velocities, which minimizes shooting time on the surviled, tracked and identified targets, is the best manner to avoid targets searching and flight loitering, and is expected to be in a horizontal plane in the NLOS missile cruising regimes.
- For the rapid answer tactics reliable shooting is the most distinguishing item and targets could not be left it to be found by NLOS missile arrival. In that case, launching has to be orientated roughly toward targets area and promptly linked with target motion. Velocity vector line of NLOS missile could be unprepared by the direction and initial angular rates to the LOT. Consequently, this requires time to turn itself toward LOTs as the best position for the full proportional navigation of guidance law. This makes less allowable lateral areas of shooting, which shows simulation tests.
- Interrupting targets on different shorter ranges along protected battle fields diminished lateral impact zones of reliable shoots for any straight line moved targets with maximum velocities of about 15 m/s.
- Threshold target impact zones distance for the frontal, lateral or oblique targets motion toward NLOS missile flight is about 1km to 27km. It is rigidly constrained by board acceleration accepted as 4g for the LOT reffer by missile navigation.
- Targets which change directions toward and away of NLOS missile shoot, could be also successfully impacted. This concept extends areas, development for the straight lines target motion to about 3%, because of small targets velocities and low manoeuvrable ascelerations. This extension is not significantly change regarding shooting areas by direction and ranges.

- Acceleration of the NLOS missile is less than threshold guidance acceleration but fully fills requirements of navigation LOT acceleration, sooner for the short ranges targets engagements and slower for the higher ranges. Manoeuvrable targets impose sooner achievement of threshold acceleration and trajectories are more curved.

- Generally, shooting areas of free searching flight regime by remotely controlled NLOS missile gave launching posibilities for the targets expected impact zones in each quadrant of horizontal plane between 0 ± 100^o. These areas are within the circle ranges of 27 km for straight lines flight, and 19.5 km of lateral oblique curved flight.

- For the rapid reaction shootings [1,2,3] against penetrating targets interrupted by maximum velocities, direct, lateral, oblique, or manoeuvrable manner motions, NLOS missile weapon have much less angles in frontal quadrants of the frame between 0 ± 9^o to 10^o depend of targets approach direction and/or targets manoeuvring. Launching or readiness for NLOS missile to be navigated also have the threshold targets zones position replaced forward of impact zones and distributed along ranges of penetration target points. This gave launching angles for the NLOS missile expected to start navigation proceedings between angles $0^o \pm (8^o \div 12^o)$ at the ranges 29 km, and lateral directions of about 6 km depend of directions of targets motion during penetration attacks.

- Computer simulation of the expected mission is a central activity in the developed methodology, and the results of the experiments executed by means of the realized simulators should answer the question whether the satisfactory performances of the NLOS missiles are achieved, along with simultaneous fullfillment of technical and tactical criteria.

Once adopted, the new NLOS missile weapon enriches the existing solutions knowledge base with new concepts, which has an important impact to future solutions of such and similar complex military systems. It is of particular importance that the methodology includes and enriches the existing technical solutions set, both during and after the system's life cycle. On the other hand, the experience acquired during research and development, as well as in the course of testing and later exploitation, has been incorporated in this methodology of complex military system combat use [3]. Such influences in certain extent the critical analysis of the existing and creating new principles of combat tactics and millitary units organization especially on the lower tactical levels.

7. CONCLUSION

Unconventional and asymmetric warfare, so prevailing in our time, have questioned usability of traditional indirect fire artillery units. Artillery and air forces as well as other services units are usually powerful, but very expensive resource. That opens two directions of further activities in the area: development of new, essentially different generations of artillery mobile weapons (AMWs), and research of new tactical and operational procedures in their use, such as the rapid attack tactics on the distance concentrated low manoeuvrable targets.

Upgrading certain types of artillery by NLOS missile, and their provision with equipment appropriate for future war conflict challenges, opens possibilities for introduction and competitiveness in the world market.

Unfortunately simulations of battle field area engagement capabilities have shown numerous constrains of NLOS missile using as remote or semi-remote control weapon.

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NOMENCLATURE

a_c	Command acceleration
a_t	Target normal acceleration
a_m	Missile acceleration
C_{Dmin}	Coefficient of minimum drag
C_D	Drag coefficient
C_L	Lift coefficient
c_t	Specific fuel consumption
D	Drag force
E	Endurance
m_0	Initial mass
m_p	Propellant mass
N_{pr}	Coefficient of proportional navigation
$\mathbf{R}_m$	Vector position of missile
$\mathbf{R}_t$	Vector position of target
$\mathbf{R}_{tm}$	Relative vector position between missile and target
$\dot{R}_{tm}$	Rate of relative position between target and missile
t	Time
$\mathbf{V}_m$	Missile Velocity vector
$\mathbf{V}_t$	Target velocity vector
x_L	Target position at the moment of launching on x-axis
x_{imp}	Impact position on x-axis
y_L	Target position at the moment of launching on y-axis
y_{imp}	Impact position on y-axis

Greek symbols

β	Angle between target velocity and referent x-axis
$\dot{\beta}$	Angular rate of target velocity
γ	Angle between missile velocity and referent x-axis
$\dot{\gamma}$	Angular rate of missile velocity
λ	Angle between Line of Target and referent x-axis
$\dot{\lambda}$	Angular rate of Line of Target
μ	Mass ration

Acronyms

NLOS	**N**on **L**ine of **S**ite
LOT	**L**ine **O**f **T**arget
ICCP	**I**nitial **C**ruising **C**ommand **P**osition
CIS	**C**ommand **I**nformation **S**ystem
AMWs	**A**rtillery **M**obile **W**eapons

ЗОНЕ ЗАХВАТА РАКЕТАМА У ПРОПОРЦИОНАЛНО НАВОЂЕНОМ ЛЕТУ СА ВАЗДУШНО РЕАКТИВНИМ ПОГОНОМ

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Циљеви овог истраживања су тестирање односа одговарајућих летних перформанси посредно управљаних ракета и условно креирање њихових тактичких, просторних зона и времена гађања током употребе на површинске циљеве. Маневар лета, посредно даљински управљане ракете је тестиран са условно повезаним ограничењима која проистичу из кинематике лета са турбомлазним погоном ракете и начина кретања циља, типичног за изненадне нападе. Ограничења способности манервисања у лету, у фази крстарења, су разматрани као модели кретања материјалне тачке ради креирања невођених (претраживања) и вођених навигационих кинематских трајекторија, пројектованих по одговарајућем закону навигације. У истраживању је коришћен нумерички метод за симулирање кретања посредно управљане ракете и циља у хоризонталној равни контролисањем линије циља на одговарајућој висини лета. Ово генерише границе зоне поготка и зоне лансирања, успостављене помоћу оперативног времена лета посредно вођених ракета као и могућих варијација масе за очекивани начин борбеног лета.