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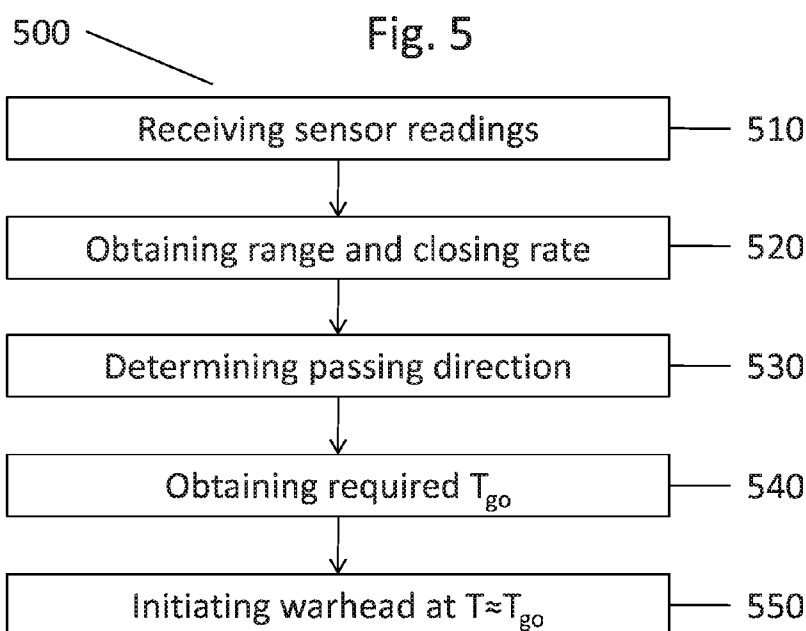
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(54) **Title:** SYSTEM, METHOD AND COMPUTER PROGRAM FOR TIMING INTERCEPTOR MISSILE WARHEAD INITIATION



(57) **Abstract:** An interceptor missile comprising: a warhead; a processing unit; one or more sensors configured to obtain at least one reading enabling determination of a passing direction of the interceptor missile with respect to a target; wherein the processing unit is configured to: receive the reading from the sensors; determine a passing direction utilizing the reading; and obtain a required time T_{go} for initiating the warhead, utilizing the determined passing direction.

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SYSTEM, METHOD AND COMPUTER PROGRAM FOR TIMING INTERCEPTOR MISSILE WARHEAD INITIATION

TECHNICAL FIELD

5 The disclosure relates to a system and method for timing interceptor missile warhead initiation.

BACKGROUND

When an interceptor missile is launched towards a target, the missile is set to initiate its warhead at a certain point-in-time T_{go} . T_{go} can be calculated using
10 various known techniques and methods. However, these techniques and methods do not consider a passing direction of the warhead with respect to the target. There can be at least two passing direction scenarios: (a) tail passing, in which the interceptor passes the target at the aft (the interceptor missile's trajectory passes above the target), and (b) head passing, in which the interceptor passes the
15 target at the nose (the interceptor missile's trajectory passes below the target). As detailed herein, considering the passing direction of the interceptor missile with respect to the target while determining the initiation time of the interceptor's warhead (t_{go}) can increase the lethality of the interceptor missile and increase the likelihood of destroying the target.

20 There is thus a need in the art for a new system and method for timing interceptor missile warhead initiation.

SUMMARY

In one aspect, in accordance with the disclosed subject matter there is
25 provided an interceptor missile comprising: a warhead; a processing unit; one or more sensors configured to obtain at least one reading enabling determination of a passing direction the interceptor missile with respect to a target; wherein the

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processing unit is configured to: receive the reading from the sensors; determine a passing direction utilizing the readings; and obtain a required time T_{go} for initiating the warhead, utilizing the determined passing direction.

5 In some cases, the reading enables determination of a range and a range rate of the interceptor missile with respect to the target and the processing unit is further configured to obtain the range and the range rate from the readings and initiate the warhead when T_{go} is substantially equal to, or smaller than, the range multiplied by the range rate and divided by a power of two of a closing velocity
10 of the interceptor with respect to the target.

 In some cases, T_{go} is obtained utilizing target information indicative of a target type.

 In some cases, T_{go} is a default value when the target type is unknown.

 In some cases, the initiation time is determined such that the number of
15 fragments of the interceptor expected to hit the target is optimal.

 In some cases, the initiation time is determined such that the number of fragments of the interceptor expected to hit a selected part of the target is optimal.

 In some cases, the selected part is the front of the target or the rear of the
20 target.

 In some cases, the required time T_{go} in case the passing direction is indicative of a tail-passing scenario, wherein the interceptor trajectory passes above the target, is different than the required time T_{go} in case the passing direction is indicative of a head-passing scenario, wherein the interceptor
25 trajectory passes below the target.

 In some cases, the sensors are proximity sensors.

 In some cases, the proximity sensors are proximity fuses.

 In some cases, the passing direction is determined also utilizing information relating to the location of the proximity sensors on the interceptor
30 missile, and information of the interceptor missile roll angle and attack angle.

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In some cases, the warhead is omni-directional.

In another aspect, in accordance with the disclosed subject matter there is provided an interceptor missile comprising a warhead and a processing unit, the processing unit configured to determine an initiation time of the warhead based on a passing direction, the passing direction being indicative of a tail passing, wherein the interceptor trajectory passes above the target, or a head passing, wherein the interceptor trajectory passes below the target.

10 In another aspect, in accordance with the disclosed subject matter there is provided an interceptor missile comprising a warhead and a processing unit, the processing unit is configured to: provide data representative of at least two warhead initiation times, each corresponding to a distinct passing scenario associated with a passing direction; calculate an interception passing direction based on data received from one or more sensors of the interceptor; initiate the warhead at an initiation time substantially equal to the warhead initiation time corresponding to the interception passing direction.

In another aspect, in accordance with the disclosed subject matter there is provided a method for timing initiation of a warhead of an interceptor missile, the method comprising: receiving, by a processing unit, readings from one or more sensors configured to obtain at least one reading enabling determination of a passing direction of the interceptor missile with respect to a target; determining a passing direction utilizing the readings; and obtaining a required time T_{go} for initiating the warhead, utilizing the determined passing direction.

In some cases, the reading enables determination of a range and a range rate of the interceptor missile with respect to the target and the method further comprises obtaining the range and the range rate from the readings and initiating the warhead when T_{go} is substantially equal to, or smaller than, the range

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multiplied by the range rate and divided by a power of two of a closing velocity of the interceptor missile with respect to the target.

In some cases, T_{go} is obtained utilizing target information indicative of a target type.

5 In some cases, T_{go} is a default value when the target type is unknown.

In some cases, the initiation time is determined such that the number of fragments of the interceptor expected to hit the target is optimal.

In some cases, the initiation time is determined such that the number of fragments of the interceptor expected to hit a selected part of the target is
10 optimal.

In some cases, the selected part is the front of the target or the rear of the target.

In some cases, the required time T_{go} in case the passing direction is indicative of a tail-passing scenario, wherein the interceptor trajectory passes
15 above the target, is different than the required time T_{go} in case the passing direction is indicative of a head-passing scenario, wherein the interceptor trajectory passes below the target.

In some cases, the sensors are proximity sensors.

In some cases, the proximity sensors are proximity fuses.

20 In some cases, the passing direction is determined also utilizing information relating to the location of the proximity sensors on the interceptor missile, and information of the interceptor missile roll angle and attack angle.

In some cases, the warhead is omni-directional.

25 In another aspect, in accordance with the disclosed subject matter there is provided a method for timing initiation of a warhead of an interceptor missile, the method comprising determining an initiation time of the warhead based on a passing direction, the passing direction being indicative of a tail passing, wherein the interceptor trajectory passes above the target, or a head passing, wherein the
30 interceptor trajectory passes below the target.

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In another aspect, in accordance with the disclosed subject matter there is provided a method for timing initiation of a warhead of an interceptor missile, the method comprising: providing data representative of at least two warhead
5 initiation times, each corresponding to a distinct passing scenario associated with a passing direction; calculating, by a processing unit, an interception passing direction based on data received from one or more sensors of the interceptor; and initiating the warhead at an initiation time substantially equal to the warhead initiation time corresponding to the interception passing direction.

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In another aspect, in accordance with the disclosed subject matter there is provided a computer program comprising computer program code means for performing the following steps when said program is run on a computer: receiving readings from one or more sensors configured to obtain at least one
15 reading enabling determination of a passing direction of the interceptor missile with respect to a target; determining a passing direction utilizing the reading; and obtaining a required time T_{go} for initiating the warhead, utilizing the determined passing direction.

20 In another aspect, in accordance with the disclosed subject matter there is provided a computer program comprising computer program code means for performing the following steps when said program is run on a computer: determining an initiation time of the warhead based on a passing direction, the passing direction being indicative of a tail passing, wherein the interceptor
25 trajectory passes above the target, or a head passing, wherein the interceptor trajectory passes below the target.

In another aspect, in accordance with the disclosed subject matter there is provided a computer program comprising computer program code means for
30 performing the following steps when said program is run on a computer:

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providing data representative of at least two warhead initiation times, each corresponding to a distinct passing scenario associated with a passing direction; calculating an interception passing direction based on data received from one or more sensors of the interceptor; and initiating the warhead at an initiation time
5 substantially equal to the warhead initiation time corresponding to the interception passing direction.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the subject matter and to see how it may be carried
10 out in practice, examples will be described, with reference to the accompanying drawings, in which:

Fig. 1 is an illustration of an exemplary interceptor missile, in accordance with the presently disclosed subject matter;

Fig. 2 is a block diagram illustrating an example of an interceptor missile
15 mission computer, in accordance with the presently disclosed subject matter;

Figs. 3a and **3b** are illustrations of exemplary passing scenarios, in accordance with the presently disclosed subject matter;

Fig. 4 is an illustration of the number of fragments expected to hit the target depending on the initiation time of the warhead in two exemplary passing
20 direction scenarios, in accordance with the presently disclosed subject matter;

Fig. 5 is a flowchart illustrating an exemplary interception process, in accordance with the presently disclosed subject matter; and

Fig. 6 is an illustration of the calculation of time to T_0 , in accordance with the presently disclosed subject matter.

25

DETAILED DESCRIPTION OF THE INVENTION

In the following detailed description, numerous specific details are set forth in order to provide a thorough understanding of the subject matter.

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However, it will be understood by those skilled in the art that some examples of the subject matter may be practiced with these specific details. In other instances, well known methods, procedures and components have not been described in detail so as not to obscure the description.

5 As used herein, and unless explicitly stated otherwise, the term "memory" refers to any module for storing data for the short and/or long term, locally and/or remotely. Examples of memory may include inter-alia: any type of disk including floppy disk, hard disk, optical disk, CD-ROMs, magnetic-optical disk, magnetic tape, flash memory, random access memory (RAM), dynamic random access
10 memory (DRAM), static random access memory (SRAM), read-only memory (ROM), programmable read only memory (PROM), electrically programmable read-only memory (EPROM), electrically erasable and programmable read-only memory (EEPROM), magnetic card, optical card, any other type of media suitable for storing electronic instructions and capable of being coupled to a
15 system bus, and/or a combination of any of the above .

Usage in the specification of the term "for example", "such as", "for instance", "e.g.", "say", "possibly", "optionally" "one example", "illustrated example", "some examples", "another example", "other examples", "some other examples", "various examples", "one instance", "some instances", "another
20 instance", "other instances", "some other instances", "various instances", "one case", "some cases", "another case", "other cases", "some other cases", "various cases", or variants thereof means that a particular described feature, structure or characteristic is included in at least one non-limiting example of the subject matter, but not necessarily in all examples. The appearance of the same term does
25 not necessarily refer to the same example.

The term "illustrated example" is used to direct the attention of the reader to one or more of the figures, but it should not be construed as necessarily favoring any example over any other.

It should be appreciated that certain features, structures and/or
30 characteristics disclosed herein, which are, for clarity, described in the context of

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separate examples, may be provided in combination in a single example. Conversely, various features, structures and/or characteristics disclosed herein, which are for brevity, described in the context of a single example, may also be provided separately or in any suitable sub-combination.

5 Unless specifically stated otherwise, as apparent from the following discussions, it is appreciated that throughout the specification, discussions utilizing terms such as “receiving”, “obtaining”, “determining”, “initiating”, “providing”, “calculating” or the like, refer to the action(s) and/or process(es) of any combination of software, hardware and/or firmware. For example, these
10 terms may refer in some cases to the action(s) and/or process(es) of a machine such as a computer, that manipulates and/or transforms data into other data, the data represented as physical, such as electronic quantities, and/or the data representing physical objects.

Referring now to the Figures, **Fig. 1** is an illustration of an exemplary
15 interceptor missile, in accordance with the presently disclosed subject matter.

The Interceptor missile 100 in accordance with the presently disclosed subject matter can be any interceptor missile having a warhead, including an air-to-air interceptor missile, a surface-to-air interceptor missile, or any other type of interceptor missile having a warhead.

20 The interceptor missile 100 comprises a warhead 120, which, when activated, can result in fragments of the interceptor missile 100 being sprayed in a certain direction (in case the warhead 120 is designed in this manner) or in all directions (in case the warhead 120 is omni-directional).

In some cases, the interceptor missile 100 further comprises one or more
25 sensors (and in more specific cases two or more sensors) configured to obtain one or more readings indicative of a spatial relativity between the interceptor missile 100 and a target (not shown). The readings can include the range and the range rate between the interceptor missile and a target, which can be obtained from the readings (in some cases the readings can include data enabling

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determination of the range and the range rate and in such cases the range and range rate can be determined utilizing such data).

The readings obtained by the sensors can enable determination of a passing direction, as indicated herein. It is to be noted that in some cases the
5 sensors can be external to the interceptor missile 100 (e.g. they can be located on external platforms, including airborne platforms, ground platforms, etc.).

The passing direction can be indicative of a passing-direction scenario, e.g. a tail-passing scenario, wherein the interceptor missile's 100 trajectory passes above the target, or a head-passing scenario, wherein the interceptor missile's 100
10 trajectory passes below the target. It is to be noted that in some cases additional and/or alternative passing-direction scenarios can exist.

In one particular example, the sensor can be a proximity sensor (e.g. a proximity fuse), having at least two antennas – an upper antenna 150 and a lower antenna 160. The antennas can be positioned in a manner that enables
15 determination of a passing direction of the interceptor missile 100 with respect to a target (utilizing the information relating to the location of the proximity sensors on the interceptor missile, and the interceptor missile roll angle). For example, the antennas can be positioned on substantially opposite sides of the interceptor missile 100 – the upper antenna 150 substantially on the upper side of the
20 interceptor missile 100 and the lower antenna 160 substantially on the lower side of the interceptor missile 100. Such positioning of the antennas results in coverage of a first area by the upper antenna 150 and a second area by the lower antenna 160. It is to be noted that in some cases, in order to determine which antenna is the lower antenna 160 and which antenna is the upper antenna 150,
25 information about the interceptor missile's 100 roll angle is required and can be obtained using known methods and/or techniques.

In the case of utilizing a proximity sensor, determining which antenna sensed the target (e.g. the lower antenna 160 or the upper antenna 150) can enable determination of the passing direction of the interceptor missile 100 with
30 respect to the target, for example by determining which antenna (e.g. the lower

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antenna 160 or the upper antenna 150) sensed/senses the target in the area covered thereby. In some cases, if the lower antenna 160 sensed the target, the interception scenario is a tail passing scenario, whereas if the upper antenna 150 sensed the target, the interception scenario is a head passing scenario.

5 In some cases, if a certain antenna sensed the target during a certain part of the interception process and another antenna sensed the target during another part of the interception process, the time of sensing can be taken into account and a series of readings received from the sensors can be utilized for determining the evolution of the interception scenario and the corresponding passing scenario.

10 It is to be noted that in the example provided above only two antennas are used, however a larger number of antennas can be used as well (e.g. distributed in a known manner on the interceptor missile 100). It is to be further noted that other types of sensors can be used, such as a radar, an electro-optical sensor, etc., as long as the data acquired by the sensors enables determination of a passing
15 direction scenario (tail-passing or head-passing), and a range and a range rate between the interceptor missile and a target. In addition, in some cases more than one sensor and/or sensor type can be used for this purpose.

 In accordance with the presently disclosed subject matter, the one or more sensors are connected (e.g. via a wired or wireless connection) to a mission
20 computer 110, as further detailed herein with respect to Fig. 2, Attention to which is now drawn.

Fig. 2 is a block diagram illustrating an example of an interceptor missile mission computer, in accordance with the presently disclosed subject matter.

 In some cases, mission computer 110 can be connected to one or more
25 sensors 240 in any manner that enables mission computer 110 (or any component thereof) to receive at least one readings acquired by the one or more sensors 240 including a range and a range rate (or data enabling determination thereof) between the interceptor missile and a target.

 Mission computer 110 further comprises a processing unit 200. Processing
30 unit 200 comprises, or is otherwise associated with, at least one processor (e.g.

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digital signal processor (DSP), microcontroller, field programmable gate array (FPGA), application specific circuit (ASIC), etc.) configured to manage and control different components of mission computer 110 and carry out the relevant operations.

5 Processing unit 200 can comprise a passing direction determination module 220 and an initiation time determination module 230. Processing unit can still further comprise, or be otherwise associated with, a data repository 210.

According to some embodiments of the presently disclosed subject matter, passing direction determination module 220 can be configured to obtain readings
10 acquired by the one or more sensors 240 for determining a passing direction. The passing direction can be indicative of a passing-direction scenario, e.g. a tail-passing scenario, wherein the interceptor missile's 100 trajectory passes above the target, or a head-passing scenario, wherein the interceptor missile's 100 trajectory passes below the target. It is to be noted that in some cases additional
15 and/or alternative passing-direction scenarios can exist.

In some cases, initiation time determination module 230 can be configured to determine the initiation time of the interceptor missile's 100 warhead 120, as further detailed herein, inter alia with respect to Figs. 5 and 6.

Data repository 210 can be configured to store, and enable retrieval of,
20 data indicative of various warhead initiation times (T_{go}), depending on one or more of: a target type, a passing direction, a selected part of the target to be hit, etc., as further detailed herein, inter alia with respect to Fig. 5. Data repository can be part of the mission computer 110, or it can be otherwise operatively connected thereto.

25

Turning to **Figs. 3a** and **3b**, there are shown illustrations of exemplary passing scenarios, in accordance with the presently disclosed subject matter.

In Fig. 3a, a head passing scenario is depicted. In such scenario, the interceptor trajectory 310 of the interceptor missile 100 passes below target 320.
30 In order for the warhead fragments to hit the target 320 in such head passing

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scenario, the warhead initiation should be timed to a certain point in time, Tgo 340, so that the fragments velocity vector 330 will cause the fragments of the interceptor missile 100 to hit the target 320 in a successful manner (e.g. in a manner that will result in destruction of the target 320 or otherwise damaging the target so that it is unable to achieve its mission). It can be appreciated that the fragments velocity vector 330 is derived of the interceptor velocity direction (in the drawing it is aligned with the interceptor trajectory 310) and the warhead fragments velocity vector 330 (e.g. a vector addition thereof). It can be further appreciated that most targets have a larger length then width so that the surface area of the target 320 the warhead fragments are required to hit in a head passing scenario (where the fragments trajectory is substantially lateral to the target) is smaller than the surface area in a tail passing scenario (where the fragments trajectory is substantially perpendicular to the target, as can be seen in Fig. 3b). This results in head passing scenarios being more sensitive to variations in timing of the interceptor missile's 100 warhead in comparison to tail passing scenarios as described with reference to Fig. 3b.

In Fig. 3b, a tail passing scenario is depicted. In such scenario, the interceptor trajectory 310 of the interceptor missile 100 passes above target 320. In order for the warhead fragments to hit the target 320 in such tail passing scenario, the warhead initiation should be timed to a certain point in time, Tgo 340, so that the fragments velocity vector 330 will cause the fragments of the interceptor missile 100 to hit the target 320 in a successful manner (e.g. in a manner that will result in destruction of the target 320 or otherwise damaging the target so that it is unable to achieve its mission). It can be appreciated that the fragments velocity vector 330 is derived of the interceptor velocity direction (in the drawing it is aligned with the interceptor trajectory 310) and the warhead fragments velocity vector 330 (e.g. a vector addition thereof). It can be further appreciated that most targets have a larger length then width so that the surface area of the target 320 the warhead fragments are required to hit in a tail passing scenario (where the fragments trajectory is substantially perpendicular to the

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target) is larger than the surface area in a head passing scenario (where the fragments trajectory is substantially lateral to the target, as can be seen in Fig. 3a). This results in tail passing scenarios being less sensitive to variations in timing of the interceptor missile's 100 warhead in comparison to head passing
5 scenarios as described with reference to Fig. 3a.

Fig. 4 is an illustration of the number of fragments expected to hit the target depending on the initiation time of the warhead, in two exemplary passing direction scenarios, in accordance with the presently disclosed subject matter.

10 As indicated herein, the initiation time of the interceptor missile's 100 warhead (Tgo) has a direct effect on the number of fragments expected to hit the target in each passing scenario. Looking at the graph shown in Fig. 4, the vertical axis represents the number of fragments expected to hit the target (# fragments 404) and the horizontal axis represents the initiation time of the interceptor
15 missile's 100 warhead (Tgo 402). Two curves appear in the graph, one representing an exemplary head passing scenario 410 and the other representing an exemplary tail passing scenario 420. The peak of each curve represents the maximal number of fragments expected to hit the target at the respective passing scenario and each such peak is associated with a corresponding Tgo.

20 Looking at the curve that represents an exemplary head passing scenario 410, it can be appreciated that it has a peak at the point marked "optimal initiation time head passing 430" (i.e. when Tgo equals optimal initiation time head passing 430). Looking at the curve that represents an exemplary tail passing scenario 420, it can be appreciated that it has a peak at the point marked "optimal
25 initiation time tail passing 440" (i.e. when Tgo equals optimal initiation time tail passing 440). It can be appreciated that optimal initiation time head passing 430 is different than optimal initiation time tail passing 440.

Assuming that a certain minimal number of fragments are required to hit the target (e.g. for destroying it or otherwise damaging it so that it is unable to
30 achieve its mission) is provided, e.g. as indicated by min # fragments 450 in the

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illustrated graph, it can be appreciated that at least in some cases (as shown in the illustrated example) initiating the interceptor missile's 100 warhead 120 at optimal initiation time tail passing 440 when in fact the passing scenario is head passing, can result in a lower number of fragments (e.g. in comparison to the minimal number of fragments 450) will hit the target, thus potentially failing the interception. In a similar manner, initiating the interceptor missile's 100 warhead 120 at optimal initiation time head passing 430 when in fact the passing scenario is tail passing, can result in a lower number of fragments (e.g. in comparison to the minimal number of fragments 450) hitting the target, thus potentially failing the interception.

It can also be appreciated when looking at the illustrated example and as indicated above, that the time sensitivity for initiating the warhead 102 in a tail passing scenario is lower than the time sensitivity for initiating the warhead in a head passing scenario. Looking at the graph, it can be appreciated that the time range for initiating the warhead 102 for a successful interception at a tail passing scenario (marked tail passing range 460) is much wider than the time range for initiating the warhead 102 for a successful interception at a head passing scenario (marked head passing range 470), and thus less sensitive to the timing of the warhead 102 initiation.

It can be thus appreciated that identifying a passing scenario and taking it into consideration when calculating the initiation time of an interceptor missile's 100 warhead 102 is advantageous.

It is to be noted that the illustrated graph is merely an example and it is by no means limiting. For example, in some cases any one of the curves may be different than shown in the illustration. In some cases, the tail passing range 460 and the head passing range 470 can partially or completely overlap. In some cases the minimal number of fragments 450 can be lower or higher. In some cases, the curves can overlap (e.g. when the target has a cubic shape). Other reasons for variations in the graph and/or the curves and/or the optimal initiation

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times and/or the minimal number of fragments and/or the head/tail passing ranges, etc., may exist.

Having described the relevancy of the passing scenario determination for the interception process, attention is drawn to **Fig. 5** is a flowchart illustrating an exemplary interception process, in accordance with the presently disclosed subject matter.

According to certain embodiments of the presently disclosed subject matter, processing unit 200 can be configured to perform an interception process 500 (e.g. utilizing passing direction determination module 220 and/or initiation time determination module 230).

For this purpose, processing unit 200 can be configured to receive at least one reading of a range and a range rate (or reading/s enabling determination thereof) between the interceptor missile and a target (block 510). In some cases, the readings received in block 510 are obtained by the spatial relativity sensor/s 240. As indicated herein, the spatial relativity sensor/s 240 can be proximity sensors (e.g. proximity fuse/s).

Although reference is made to proximity sensors, it is to be noted that any other sensor that can obtain data that enables determination of range and a range rate between the interceptor missile and a target can be used, *mutatis mutandis*. For example, light sensing diodes or lasers can be utilized as sensors for obtaining the range and the range rate or data enabling determination thereof. It is to be noted that in some cases, there may be a need of at least two sequential readings from the sensors as some sensors cannot obtain data including the range and the range rate in a single reading.

It is to be further noted that in some cases the range and a range rate (or data enabling determination thereof) between the interceptor missile and a target can be obtained by sensors external to the interceptor missile 100. For example, data obtained by a radar system that is monitoring the interception can be used

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(e.g. a ground radar system or an airborne radar system, for example carried by an airplane that can be located nearby an estimated interception location, etc.).

In some cases, the processing unit 200 can utilize the readings obtained in block 510 for obtaining the range of the interceptor missile 100 to the target (its distance therefrom) and the range rate of the interceptor missile with respect to the target (block 520). In case the readings do not contain such range and range rate, but data that enables determination thereof, processing unit 200 can be configured to determine the range and the range rate utilizing the readings.

Processing unit 200 can be further configured to determine a passing direction of the interceptor missile 100 with respect to the target (block 530). In some cases, the passing direction can be determined directly utilizing the readings from the sensors. For example, it can be determined that if the lower antenna sensed the target, the interception scenario is a tail passing scenario, whereas if the upper antenna sensed the target, the interception scenario is a head passing scenario.

Based on the passing direction, the processing unit 200 can be configured to obtain a required initiation time for initiating the warhead (block 540). In some cases, the initiation time is relative to T_0 which is the time in which the distance between the interceptor missile 100 and the target is minimal (the minimal distance between the interceptor missile 100 and the target is also referred to herein as Miss Distance, or MD). The determination of the time to T_0 (how long will it take the interceptor missile 100 and the target to get to MD) is detailed herein with reference to Fig. 6).

Assuming for example that for a tail passing scenario the initiation time is 10 milliseconds, this can imply that the warhead initiation should occur 10 milliseconds before T_0 .

It is to be noted that the initiation time can be pre-determined (e.g. based on a-priori knowledge and/or experiments and/or estimates, etc.) and stored for example on data repository 210. It is to be further noted that the initiation time can in some cases depend on one or more variables such as: target information

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(e.g. a target type and/or information indicative thereof, a target shape and/or information indicative thereof, etc.), a passing direction, a selected part of the target to be hit, etc. Thus, for example, assuming that the initiation time depends on a passing direction, a target type, and a selected part of the target to hit, 5 having knowledge of the passing direction in a specific interception process, a specific target type to be intercepted during the interception process, a specific part of the specific target to be intercepted during the interception process, can enable retrieval of the corresponding initiation time from data repository 210.

Processing unit 200 can be further configured to initiate the warhead when 10 the time to T_0 is equal (or substantially equal, e.g. within a certain range, e.g. several milliseconds/microseconds, etc.) to the initiation time (which, as indicated above, is relative to the time the MD is minimal) (block 550). For this purpose, in some cases, the processing unit 200 can be configured to monitor the time to T_0 , and compare this time with the initiation time.

15 It is to be noted that in some cases the initiation time (T_{go}) in case the passing direction is indicative of a tail-passing scenario, wherein the interceptor trajectory passes above the target, can be different than the initiation time (T_{go}) in case the passing direction is indicative of a head-passing scenario, wherein the interceptor trajectory passes below the target.

20 It is to be further noted that in some cases the initiation time is determined such that the number of fragments of the interceptor expected to hit the target, or as selected part thereof (e.g. the front of the target or the rear of the target), is optimal.

It is to be still further noted that the interception process 500 is assumed to 25 occur in a stage where neither the interceptor missile, nor the target, accelerate. In case either one (or both) accelerates, the acceleration needs to be calculated as well and taken into account in the determination of the passing scenario and in the determination of the initiation time of the warhead 102. In addition, the interception process 500 is assumed to occur when the target does not maneuver, 30 however in cases the target does maneuver, such maneuvering can also be taken

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into account in the determination of the passing scenario and in the determination of the initiation time of the warhead 102. In addition, the interception process 500 is assumed to occur when the target has no attack angle or a constant attack angle lower than a certain threshold (e.g. 30/20/10/5 degrees, etc.), however in 5 cases the target's angle of attack is not constant, or not lower than the threshold, the actual angle of attack of the target can also be taken into account in the determination of the passing scenario and in the determination of the initiation time of the warhead 102.

It is to be further noted that all or part of the processes described with 10 reference to blocks 510 to 550 can optionally be performed by a combination of one or more processing units external to the interceptor missile 100 (e.g. a processing unit of a ground station, an airplane that launched the interceptor missile 100, a satellite, etc.).

It is to be still further noted that in some cases, fewer, more and/or different 15 blocks than those shown in **Fig. 5**, may be executed and not necessarily in the order prescribed in **Fig. 5**. In some cases, one or more of the blocks illustrated in **Fig. 5** may be executed in a different order and/or one or more groups of blocks may be executed simultaneously.

20 Turning to **Fig. 6**, there is shown an illustration of the calculation of time to T_0 , in accordance with the presently disclosed subject matter.

The time to T_0 (the time until the interceptor missile 100 and the target arrive at the minimal distance there between) can be calculated using a Pythagoras equation on a right triangle as depicted in the figure. The first edge is 25 the Miss Distance 620 itself (i.e. the minimal expected distance between the interceptor missile and the target assuming the interceptor missile warhead will not be initiated), which is a constant number. The hypotenuse is the range between the interceptor missile 100 and the target (marked R 610 in the figure). The third edge is the distance of the interceptor missile from the point at which it 30 will be at the minimal distance from the target (marked $V_c(t-T_0)$ 630), and it is

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calculated by multiplying the closing velocity (V_c) between the interceptor missile and the target (i.e. the difference between the velocity of the interceptor missile and the target) with the time that it will take the interceptor missile 100 and the target to arrive at the minimal distance there between (time to T_0 or $t-T_0$, which is the purpose of the calculation).

It can be appreciated that the Pythagorean Theorem can be applied on the right triangle, and therefore:

Formula 1:

$$(V_c(t - T_0))^2 + MD^2 = R^2$$

10

In order to find $t-T_0$, we can calculate a derivative of formula 1 with respect to the time, and therefore:

$$(2V_c(t - T_0)) * V_c + 0 = 2R * Rdot$$

Where V_c is the closing velocity between the interceptor missile and the target, R is the range between the interceptor missile and the target, and $Rdot$ is the range rate ($Rdot$) between the interceptor missile and the target. As V_c , R and $Rdot$ are known, as detailed herein, inter alia with respect to Fig. 5, $t-T_0$ can be calculated accordingly:

$$t - T_0 = \frac{R * Rdot}{V_c^2}$$

20

It will be understood that the subject matter contemplates that a system or part of a system disclosed herein may be for example, a computer. Likewise, the subject matter contemplates, for example, a computer program being readable by a computer for executing a method or part of a method disclosed herein. Further contemplated by the subject matter, for example, is a computer readable memory tangibly embodying program code readable by the computer for executing a method or part of a method disclosed herein.

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The term “computer” should be expansively construed to cover any electronic system which includes at least some hardware and has data processing capabilities, even if not labeled as such. For example, a computer may be in some cases be capable of manipulating and/or transforming data represented as
5 physical, such as electronic quantities, within the registers and/or memories of the computer into other data similarly represented as physical quantities within the registers, memories, and/or other such information storage, transmission and/or display elements of the computer.

While examples of the subject matter have been shown and described, the
10 subject matter is not thus limited. Numerous modifications, changes and improvements within the scope of the subject matter will now occur to the reader.

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CLAIMS:

1. An interceptor missile comprising:
 - a warhead;
 - 5 a processing unit;
 - one or more sensors configured to obtain at least one reading enabling determination of a passing direction of the interceptor missile with respect to a target;
 - wherein the processing unit is configured to:
 - 10 receive the reading from the sensors;
 - determine a passing direction utilizing the reading; and
 - obtain a required time T_{go} for initiating the warhead, utilizing the determined passing direction.
- 15 2. The interceptor missile of claim 1 wherein the reading enables determination of a range and a range rate of the interceptor missile with respect to the target and wherein the processing unit is further configured to obtain the range and the range rate from the readings and initiate the warhead when T_{go} is substantially equal to, or smaller then, the range multiplied by the range rate
- 20 and divided by a power of two of a closing velocity of the interceptor.
3. The interceptor missile of claim 2 wherein T_{go} is obtained utilizing target information indicative of a target type.
- 25 4. The interceptor missile of claim 2 wherein T_{go} is a default value when the target type is unknown.

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5. The interceptor missile of claim 1 wherein the initiation time is determined such that the number of fragments of the interceptor expected to hit the target is optimal.
- 5 6. The interceptor missile of claim 1 wherein the initiation time is determined such that the number of fragments of the interceptor expected to hit a selected part of the target is optimal.
7. The interceptor missile of claim 6 wherein the selected part is the front of the
10 target or the rear of the target.
8. The interceptor missile of claim 1 wherein the required time T_{go} in case the passing direction is indicative of a tail-passing scenario, wherein the interceptor trajectory passes above the target, is different than the required
15 time T_{go} in case the passing direction is indicative of a head-passing scenario, wherein the interceptor trajectory passes below the target.
9. The interceptor missile of claim 1 wherein the sensors are proximity sensors.
- 20 10. The interceptor of claim 9 wherein the proximity sensors are proximity fuses.
11. The interceptor missile of claim 9 wherein the passing direction is determined also utilizing information relating to the location of the proximity sensors on the interceptor missile, and information of the interceptor missile roll angle
25 and attack angle.
12. The interceptor missile of claim 1 wherein the warhead is omni-directional.
13. An interceptor missile comprising a warhead and a processing unit, the
30 processing unit configured to determine an initiation time of the warhead

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based on a passing direction, the passing direction being indicative of a tail passing, wherein the interceptor trajectory passes above the target, or a head passing, wherein the interceptor trajectory passes below the target.

5 14. An interceptor missile comprising a warhead and a processing unit, the processing unit is configured to:

provide data representative of at least two warhead initiation times, each corresponding to a distinct passing scenario associated with a passing direction;

10 calculate an interception passing direction based on data received from one or more sensors of the interceptor;

initiate the warhead at an initiation time substantially equal to the warhead initiation time corresponding to the interception passing direction.

15 15. A method for timing initiation of a warhead of an interceptor missile, the method comprising:

receiving, by a processing unit, readings from one or more sensors configured to obtain at least one reading enabling determination of a passing direction of the interceptor missile with respect to a target;

20 determining a passing direction utilizing the readings; and

obtaining a required time T_{go} for initiating the warhead, utilizing the determined passing direction.

25 16. The method of claim 15 wherein the reading enables determination of a range and a range rate of the interceptor missile with respect to the target and wherein the method further comprising obtaining the range and the range rate from the readings and initiating the warhead when T_{go} is substantially equal to, or smaller than, the range multiplied by the range rate and divided by a power of two of a closing velocity of the interceptor missile with respect to
30 the target.

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17. The method of claim 16 wherein T_{go} is obtained utilizing target information indicative of a target type.
- 5 18. The method of claim 16 wherein T_{go} is a default value when the target type is unknown.
19. The method of claim 15 wherein the initiation time is determined such that the number of fragments of the interceptor expected to hit the target is
10 optimal.
20. The method of claim 15 wherein the initiation time is determined such that the number of fragments of the interceptor expected to hit a selected part of the target is optimal.
15
21. The method of claim 20 wherein the selected part is the front of the target or the rear of the target.
22. The method of claim 15 wherein the required time T_{go} in case the passing
20 direction is indicative of a tail-passing scenario, wherein the interceptor trajectory passes above the target, is different than the required time T_{go} in case the passing direction is indicative of a head-passing scenario, wherein the interceptor trajectory passes below the target.
- 25 23. The method of claim 15 wherein the sensors are proximity sensors.
24. The method of claim 23 wherein the proximity sensors are proximity fuses.
25. The method of claim 23 wherein the passing direction is determined also
30 utilizing information relating to the location of the proximity sensors on the

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interceptor missile, and information of the interceptor missile roll angle and attack angle.

26. The method of claim 15 wherein the warhead is omni-directional.

5

27. A method for timing initiation of a warhead of an interceptor missile, the method comprising determining an initiation time of the warhead based on a passing direction, the passing direction being indicative of a tail passing, wherein the interceptor trajectory passes above the target, or a head passing,
10 wherein the interceptor trajectory passes below the target.

28. A method for timing initiation of a warhead of an interceptor missile, the method comprising:

providing data representative of at least two warhead initiation times, each
15 corresponding to a distinct passing scenario associated with a passing direction;
calculating, by a processing unit, an interception passing direction based on data received from one or more sensors of the interceptor; and
initiating the warhead at an initiation time substantially equal to the warhead initiation time corresponding to the interception passing direction.

20

29. A computer program comprising computer program code means for performing the following steps when said program is run on a computer:

receiving readings from one or more sensors configured to obtain at least one reading enabling determination of a passing direction of the interceptor
25 missile with respect to a target;
determining a passing direction utilizing the readings; and
obtaining a required time T_{go} for initiating the warhead, utilizing the determined passing direction.

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30. A computer program comprising computer program code means for performing the following steps when said program is run on a computer:
- determining an initiation time of the warhead based on a passing direction, the passing direction being indicative of a tail passing, wherein the interceptor trajectory passes above the target, or a head passing, wherein the interceptor trajectory passes below the target.
31. A computer program comprising computer program code means for performing the following steps when said program is run on a computer:
- providing data representative of at least two warhead initiation times, each corresponding to a distinct passing scenario associated with a passing direction;
 - calculating an interception passing direction based on data received from one or more sensors of the interceptor; and
 - initiating the warhead at an initiation time substantially equal to the warhead initiation time corresponding to the interception passing direction.

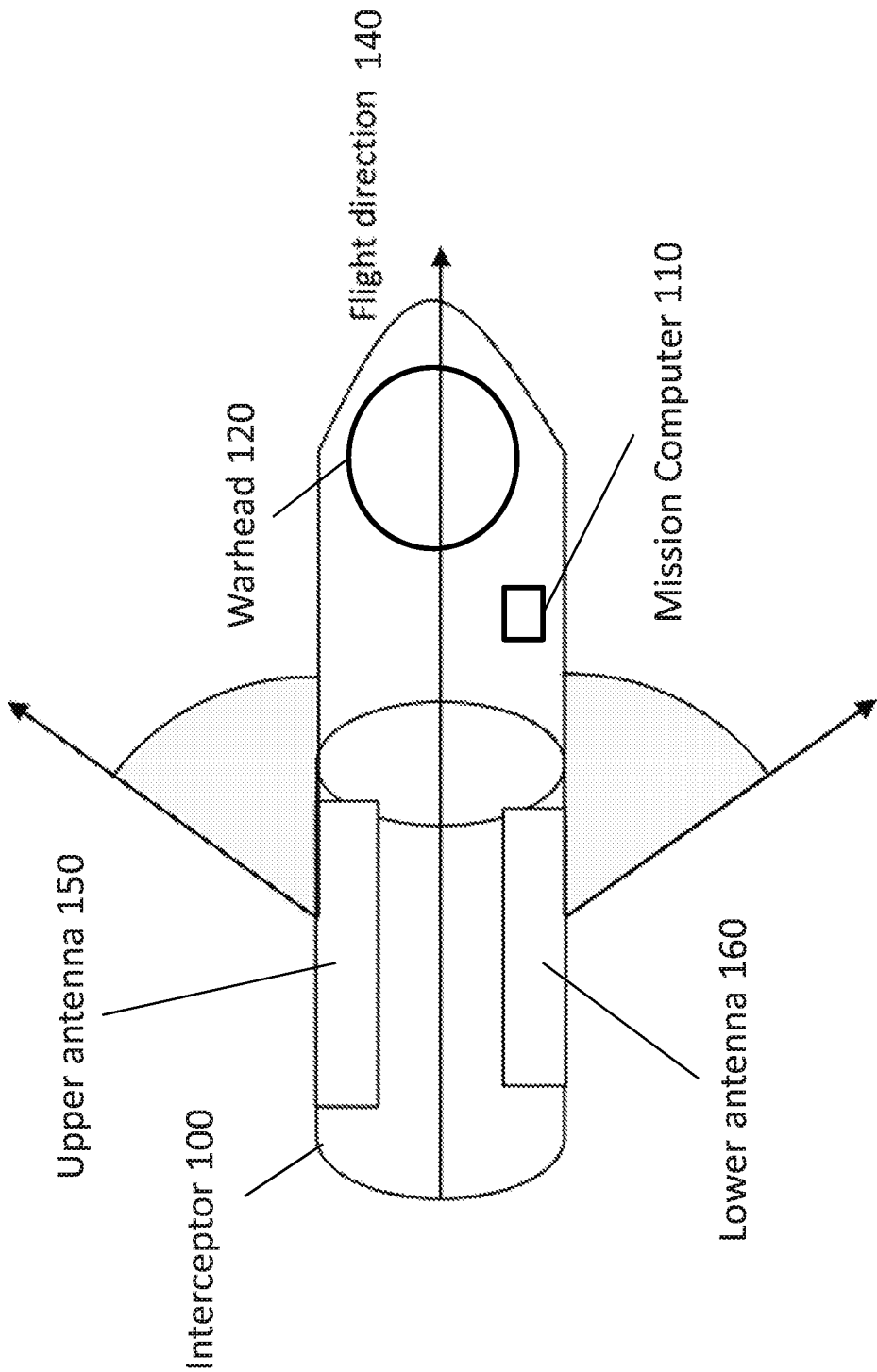


Fig. 1

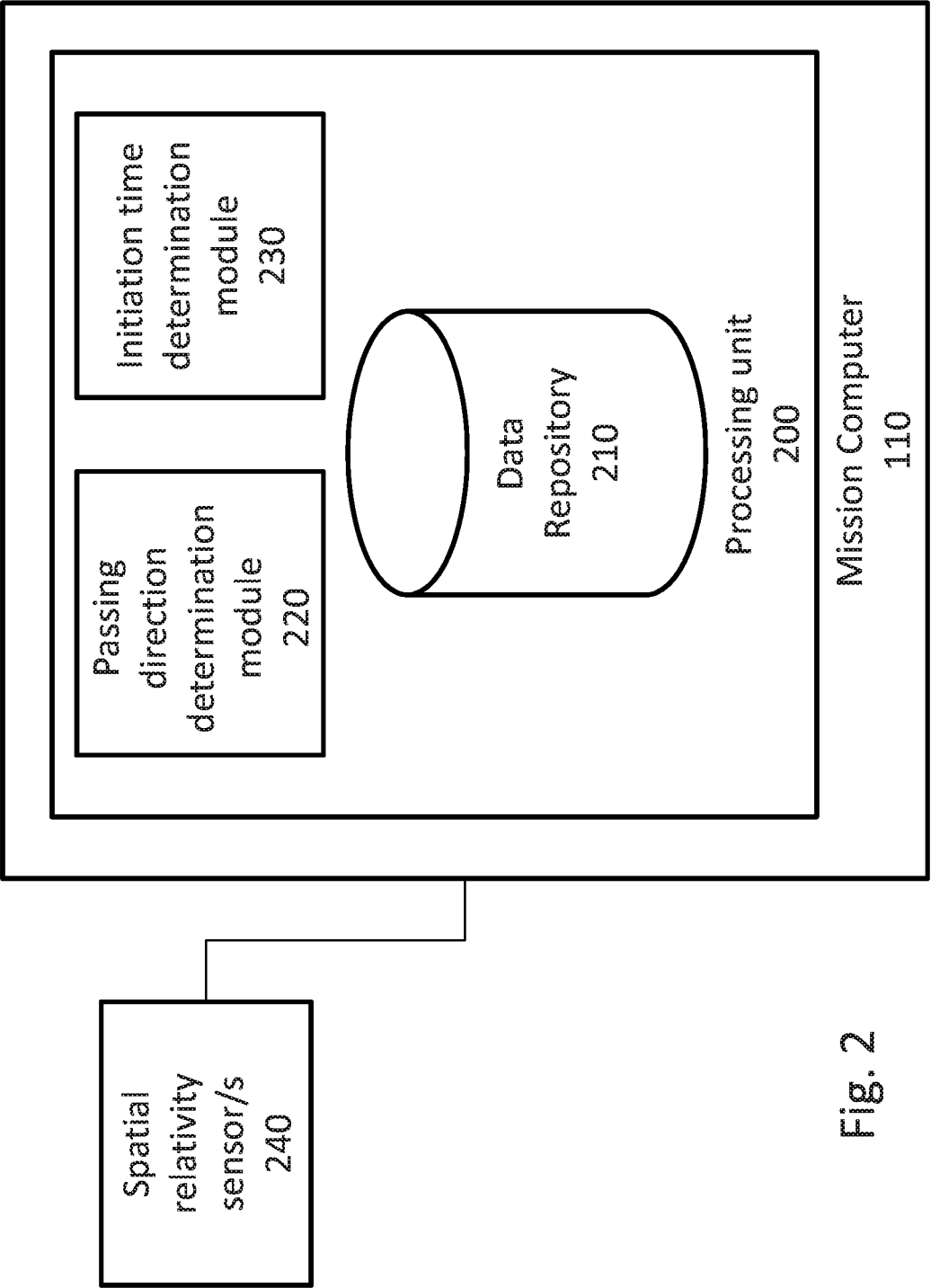


Fig. 2

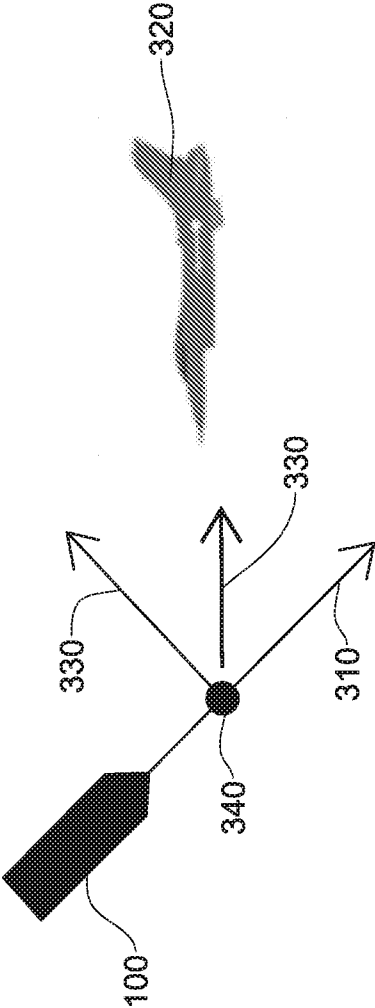


Fig. 3a

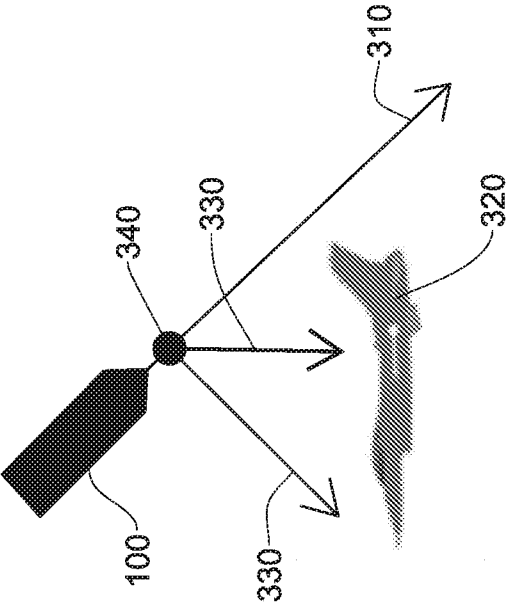


Fig. 3b

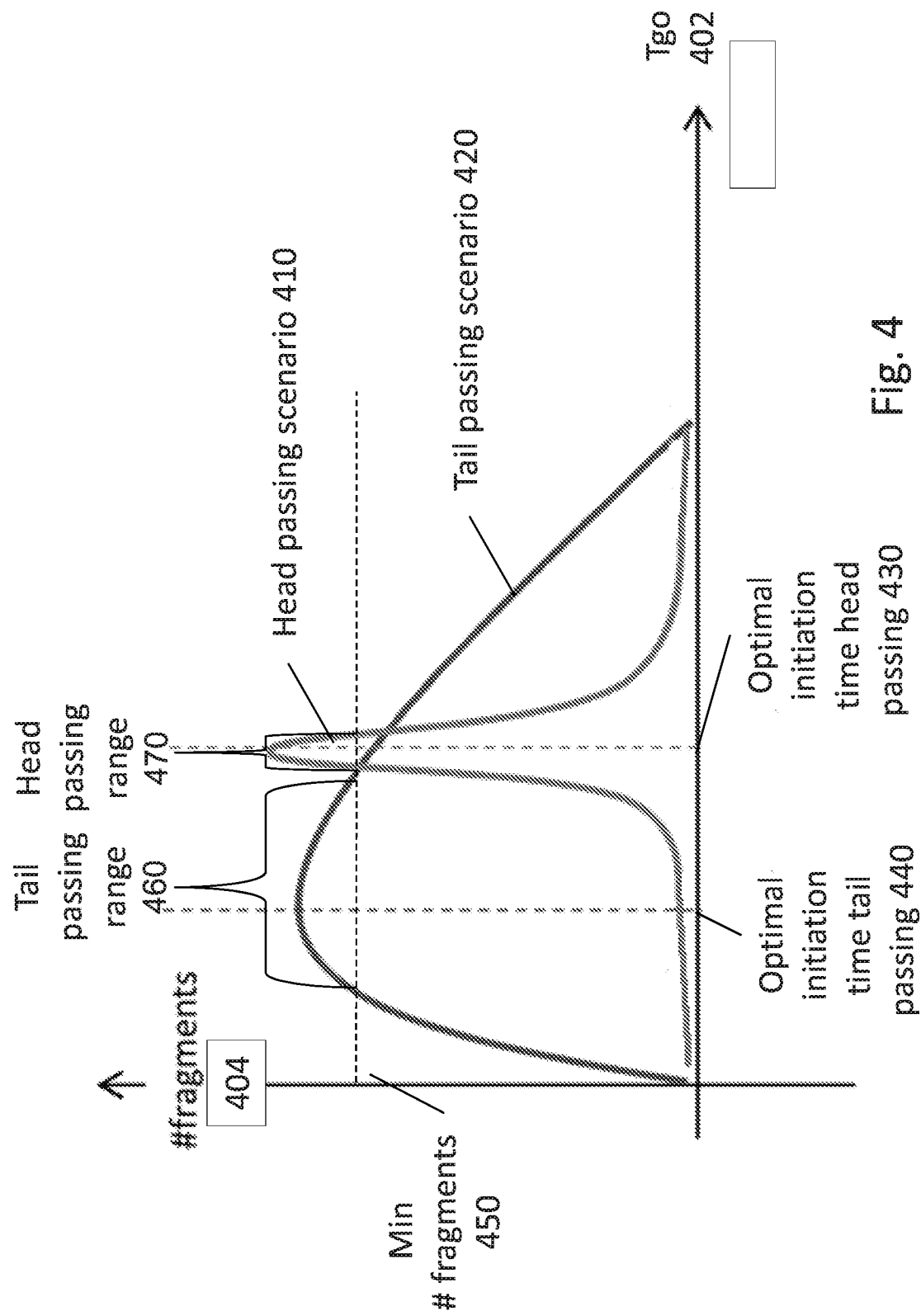


Fig. 4

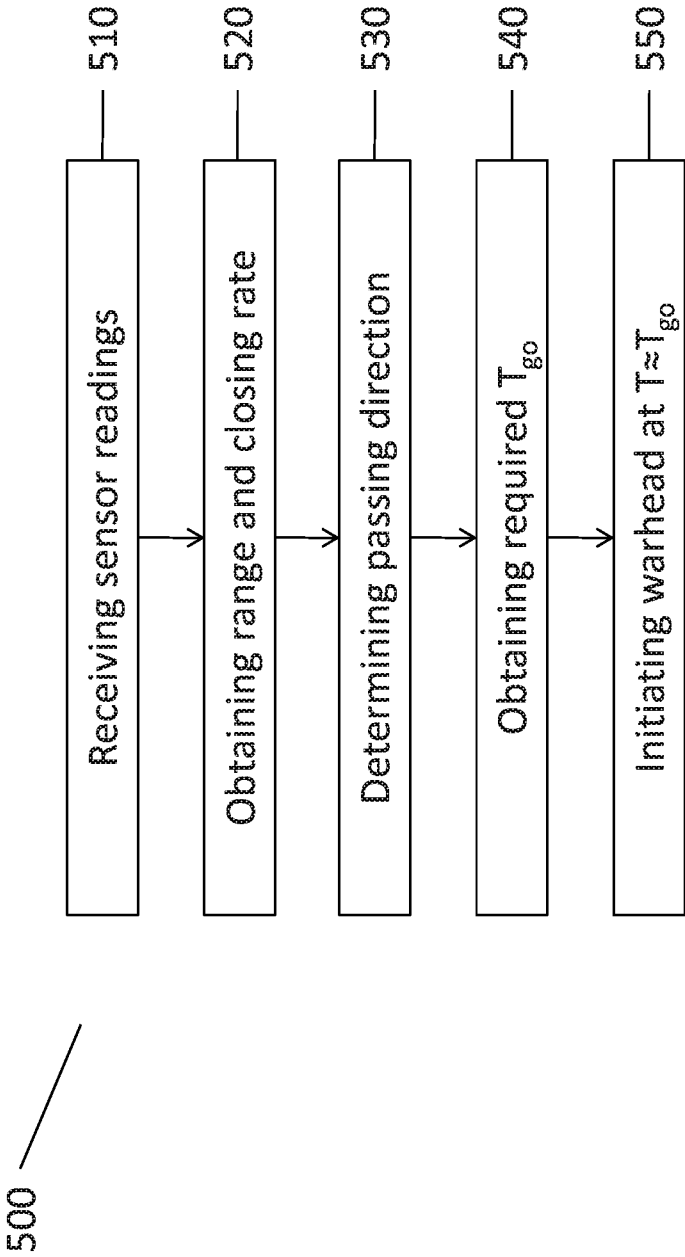


Fig. 5

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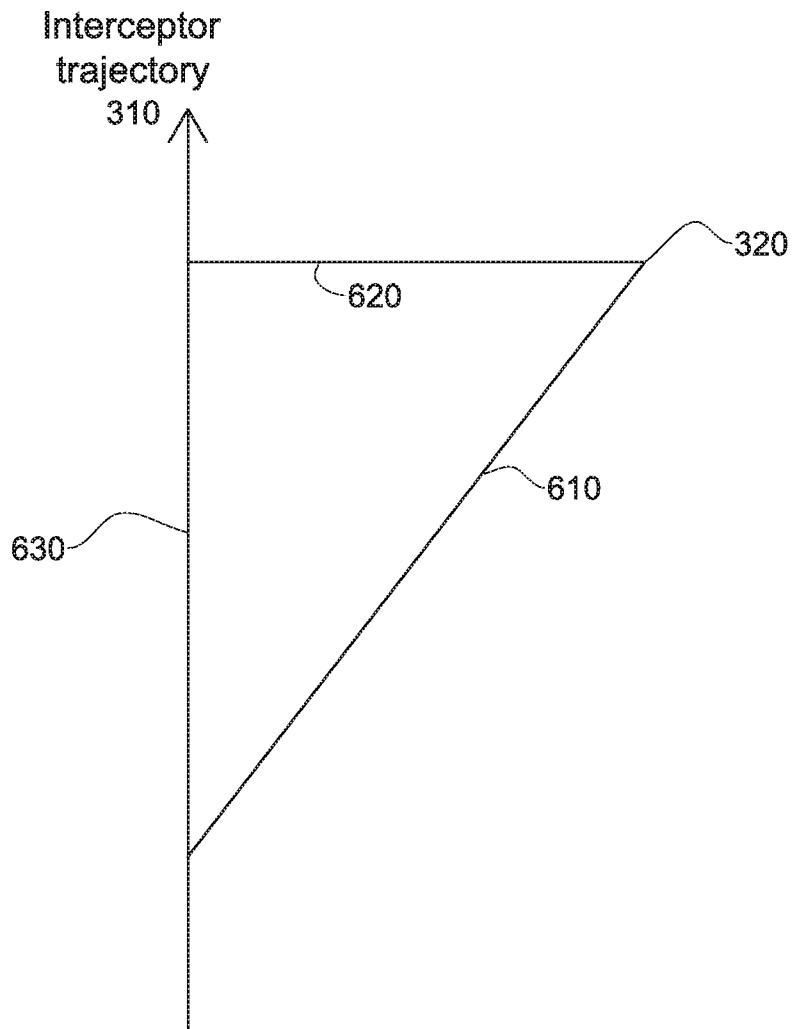


Fig. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IL2016/051016

A. CLASSIFICATION OF SUBJECT MATTER IPC (2016.01) G05D 1/12, F42B 15/00 According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) IPC (2016.01) G05D 1/12, F42B 15/00 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) Databases consulted: THOMSON INNOVATION, Esp@cenet, Google Patents, FamPat database Search terms used: Interceptor, missile, warhead, aerials, sensors, aft, tail, head, nose, initiation time, trigger time, target		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2006238403 A1 RAFAEL ARMAMENT DEVELOPMENT AUTHORITY 26 Oct 2006 (2006/10/26) Entire document	1-31
A	EP 2475952 A1 TDA ARMEMENTS SAS 18 Jul 2012 (2012/07/18)	1-31
A	FR 2519752 A1 SERAT 18 Jul 1983 (1983/07/18)	1-31
A	US 6209820 B1 MINISTRY OF DEFENSE ARMAMENT D 03 Apr 2001 (2001/04/03)	1-31
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 07 Dec 2016		Date of mailing of the international search report 18 Dec 2016
Name and mailing address of the ISA: Israel Patent Office Technology Park, Bldg.5, Malcha, Jerusalem, 9695101, Israel Facsimile No. 972-2-5651616		Authorized officer COHAY Mattan Telephone No. 972-2-5651611

INTERNATIONAL SEARCH REPORT

Information on patent family members

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				IL	125455	A	10 Dec 2003