

A METHOD AND SYSTEM FOR MEASURING FLARE DISPERSION

FIELD OF INVENTION

- 5 Embodiments of the present invention provide a method and system for measuring the dispersion characteristics of a countermeasure flare launched from a countermeasure flare launcher.

10 BACKGROUND

Heat seeking missiles are used to shoot down aircraft. The missiles have a seeker head that focuses on a heat signature of the aircraft engines to direct the missile to the engine prior to detonation.

- 15 One technology that has been developed to defeat heat seeking missiles is the use of countermeasure flares. A countermeasure flare dispenser/launcher is attached to an outside surface of an aircraft. Countermeasure flares are fired from the flare dispenser/launcher when the launch of a heat seeking missile is detected. The flares burn at a very high temperature, causing the heat seeking missile to target the flare, and
20 not the aircraft engines.

- Standard documentation provided with most countermeasure flare systems provides installation instructions that only focus on the optimal launcher installation locations to launch a flare and defeat the missile. However, it is possible that the dispensed flare
25 may contact the body of the aircraft. If the dispensed flare, which burns very hot, contacts the aircraft body, severe damage to the aircraft may result.

Therefore, it would be a great improvement in the art if a method and system could be found to overcome the problem discussed above.

SUMMARY

One aspect of the present invention provides a method of determining a dispersion characteristic of a flare launched from a launcher, the method comprising the steps of: launching a plurality of flares from the launcher; capturing at least one image of each of said plurality of flares using each of a plurality of cameras; using said
5 captured images, calculating a dispersion angle for each of the plurality of flares to determine the dispersion characteristic.

In alternate embodiments, wherein the dispersion angle can be measured from a centerline of a right circular cone having the launcher at an apex of said cone, and
10 the dispersion characteristic may be a minimum safe dispersion angle. The capturing step may further comprise providing a target board perpendicular to a field of view for each of said cameras. The target board may have a checkerboard pattern. The capturing step may further comprise positioning each of said cameras
15 orthogonally to said centerline.

In other alternate embodiments, the capturing step may further comprise: calculating a first offset distance measured from said launcher; calculating a second offset distance measured from the centerline; and positioning a first camera having a first
20 field of view and a second camera having a second field of view at the first and second offset distances; wherein the first and second fields of view intersect. The first and second fields of view may be orthogonal to each other. The step of calculating the first and second offset distances may be performed based on the first field of view, the second field of view, a shutter speed of the first and second
25 cameras, a maximum speed of the flares and an estimated dispersion characteristic of the launcher.

In other alternate embodiments, the first camera may capture a first image of each of the flares superimposed on the target board, the second camera may capture a
30 second image of each of the flares superimposed on the target board, and the step of calculating the dispersion angle may further comprise: translating each of the first and second images to a point; using each of the translated first and second images to map a coordinate of the flare onto a virtual target board, the virtual target board

positioned orthogonally to the cone at the first offset distance; and calculating the dispersion angle based on the coordinate.

In other alternate embodiments, the capturing step may further comprise:
5 calculating a third offset distance measured from the launcher; and positioning a third camera having a third field of view and a fourth camera having a fourth field of view at the second and third offset distances; wherein the third and fourth fields of view intersect. The third and fourth fields of view may be orthogonal to each other. The step of calculating the third offset distance may be performed based on the third
10 field of view, the fourth field of view, a shutter speed of the third and fourth cameras, a maximum speed of the flares and an estimated dispersion characteristic of the launcher.

An alternate aspect of the present invention provides a system for determining a
15 dispersion characteristic of a flare launched from a launcher, the system comprising: a first and a second camera, each of the first and second cameras positioned to capture at least one image of each of a plurality of flares launched from the launcher; wherein the captured images are used to calculate a dispersion angle for each of the plurality of flares to determine the dispersion characteristic.

20 In alternate embodiments, the dispersion angle can be measured from a centerline of a right circular cone having the launcher at an apex of the cone. The dispersion characteristic may be a minimum safe dispersion angle. The system may further comprise a target board positioned perpendicular to a field of view for each of the
25 cameras. The target board may have a checkerboard pattern. The first camera may have a first field of view, the second camera may have a second field of view, and the first and second cameras may be positioned at a first offset distance measured from the launcher and a second offset distance measured from the centerline; such that the first and second fields of view intersect. The first and
30 second fields of view may be orthogonal to each other.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will be better understood and readily apparent to one of ordinary skill in the art from the following written description, by way of example only, and in conjunction with the drawings, in which:

Figure 1 illustrates one method of determining a flare dispersion characteristic according to one embodiment of the present invention;

Figure 2 illustrates a perspective view of one embodiment of a system used to perform the method of Figure 1;

Figure 3 illustrates a side view of a diagram illustrating a potential intersecting field of view between the cameras and the launcher illustrated in Figure 2;

Figure 4a shows a drawing illustrating one method of calculating a grid square size for a target board illustrated in Figure 2;

Figure 4b shows a drawing illustrating one method of calculating a horizontal displacement error for the drawing of Figure 4a;

Figure 5 illustrates a schematic diagram for mapping a flare position in three dimensional space when only a single image of the flare is captured using the system of Figure 2;

Figure 6 illustrates a schematic diagram for mapping a flare position in three dimensional space when more than one image of the flare is captured using the system of Figure 2;

Figure 7a illustrates a target plane at the 3m reference line for the system of Figure 2;

Figure 7b illustrates a target plane at the 6m reference line for the system of Figure 2; and

Figure 7c illustrates the angular and linear distances associated with the target planes of Figures 7a and 7b.

5 DETAILED DESCRIPTION

Throughout the following discussion, the terms "countermeasure flare launcher" and "countermeasure flare dispenser" will be used interchangeably. All references to the term "launcher" and the term "dispenser" indicate that specific device from which the countermeasure flares are fired.

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The applicants have recognized that the flare dispenser must be positioned such that the launched flares do not contact the aircraft body. To effectively position the flare dispenser, the dispersion characteristics of the flare launcher must be known. Specifically, the dispersion angle of the launched flares must be determined. Current
15 flare manufacturers do not provide this information as part of the documentation that accompanies the flare dispenser.

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Embodiments of the present invention provide a method, designated generally as reference numeral 100 in Figure 1, for determining a dispersion characteristic of a countermeasure flare launched from a flare launcher. The method 100 can include a step for launching a plurality of flares from the launcher, as shown with reference numeral 102. The next step is to capture at least one image of each of the plurality of flares using each of a plurality of cameras, as shown with reference numeral 104. Then, using the captured images, calculating a dispersion angle for each of the
25 plurality flares to determine the dispersion characteristic of the flare dispenser, as shown with reference numeral 106. Specific details concerning these steps will be provided below.

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Figure 2 illustrates one embodiment of a system, designated generally as reference numeral 200, used to implement the method 100 of Figure 1. The system 200 can include a flare dispenser 202 mounted on a support 204. A plurality of cameras 206a-d (206b not shown, but see Figure 3), mounted on one or more camera jigs 208, are positioned to capture an image of a flare (not shown) launched from the

dispenser 202. In some embodiments, to facilitate easier image processing and the calculations used to determine the dispersion characteristics of the flare dispenser 202, a target board 210 is provided as a background for the images captured by the cameras 206.

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In the embodiment illustrated in Figure 2, the target board 210 is divided into four segments, 210a opposite camera 206a, 210b opposite camera 206b (Figure 3), 210c opposite camera 206c and 210d opposite camera 206d. Segments 210a and 210c provide a vertical reference surface with respect to the cameras 206 and launcher 202, while segments 210b and 210d provide a horizontal reference surface with respect to the cameras 206 and launcher 202. The division was done to allow for easier transport and assembly for the system 200. It is understood that a single target board 210, or a target board 210 divided into any number of sections, can also be used without departing from the scope of the embodiment. In the
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embodiment illustrated in Figure 2, the target board 210 is divided into a checkerboard pattern of grid squares 212.

A three meter line 214 and a six meter line 216, as measured from the dispenser 202, are also shown in Figure 2. These will be discussed in more detail below. A
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flare dispenser reference line 218 is shown on each segment 210a-d, of the target board 210. In this embodiment, the flare dispenser reference lines 218 are a centerline of each of the target boards 210. However, it is understood that the flare dispenser could be positioned along a line other than the centerline. In this embodiment, the centerline (not shown) of a right circular cone that extends from the
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launcher 202 and that has the launcher 202 at its apex is orthogonal to each of the reference lines 218. In the embodiment illustrated in Figure 2, the cameras 206a-206d can be placed orthogonally to reference line 218. Similarly, camera 206a can be orthogonal to camera 206b, while camera 206c can be orthogonal to camera 206d. These positions are provided in this embodiment to simplify the calculations
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of the flare positions as the flares are launched from the dispenser 202. It is understood that any arrangement of cameras 206 that allow for multiple images of the dispensed flare to be acquired can be used in system 200. Specific examples of the calculations and positions are provided below.

For the purpose of discussion, the direction of flare travel is the Y axis, the horizontal target boards 210b, 210d lie in the XY plane, and the vertical target boards 210a, 210c lie in the ZY plane. It is understood that these coordinates are provided for the sake of easier discussion. Other coordinate systems can also be used.

In one embodiment, the dispersion characteristics of the flare launched from the flare dispenser 202 were derived by trigonometry from video captured through the 2 pairs of cameras 206a, 206b, and 206c, 206d, mounted orthogonally at a linear distance of 3m and 6m from the dispenser 202. Images captured by the orthogonal cameras can then be digitized and analyzed. In order to capture the images of the flares (step 104, Figure 1), there are a number of factors that must be considered in the set-up of system 200. These factors can include:

- a. Determining the point of interest for camera placement.
- b. Determining the Field of View (FOV) of the cameras.
- c. Determining the distance of the camera jigs from the Trajectory Path.
- d. Determining the size of the target board.

These four factors are all inter-related, based on the type of camera(s) 206 to be used and the speed of the flares launched from the dispenser 202. In the example embodiment discussed herein, the dispenser 202 is a 1"X2"X8" payload dispenser. It launches a 1" by 2" by 8" flare. It is understood that this payload dispenser is provided by way of example only, in order to demonstrate the method 100. The method 100 can be used with any type of flare dispenser 202. The payload dispenser 202 launches the flares at a speed of 25 to 60 meters per second (m/s), depending on the charge used to fire the flares. In order to account for the above factors, the fastest anticipated speed of 60 m/s is used as an initial reference speed.

The cameras 206 used in this embodiment are Sekai Models RSC-A90 and/or RSC-A100 high resolution color cameras. The cameras provide a vertical and horizontal field of view (FOV) of 44° and 56° respectively (manufacturer specifications), which provides

the input for factor "b" above. The cameras 206 have a maximum shutter speed of 1/100,000 of a second. In the discussion that follows, the cameras 206 are operated with a frame rate of 30 frames per second. It is understood that other types of cameras having different photographic characteristics can also be used. Likewise, while Figure 2 illustrates two pairs of cameras 206, 206a and 206b located a first distance from the launcher 202, and 206c, 206d located a second distance from the launcher 202, it is understood that the method can be practiced with only one pair of cameras 206. Since setting up and conducting the test can be an expensive proposition, the use of two pairs of cameras provides redundancy in the calculations.

In order to begin the calculations to determine factors a, c, and d above, it is desirable to provide a base reference as to the probable half cone dispersion area for the dispenser 202. A base reference of 15 degrees was chosen. It is understood that other initial base reference parameters, both larger and smaller, can also be used.

According to points "a" and "d" above, the cameras 206 must be located a certain distance from the trajectory path (camera jig location) and from the launcher 202 (point of interest) to ensure that an image of the moving flare is captured. As previously discussed, for ease of calculations, the assumed trajectory path is projected on the target boards as reference line 218. Essentially, at any given point of interest and camera jig location, the FOV of the cameras 206 will intersect the base reference cone for the dispenser 202. In order to effectively capture the dispersion characteristics, the cameras 206 were placed, at equal intervals of 3m and 6m respectively (lines 214, 216 of Figure 2). This scales the overall set-up to be 8m X 5m. It is understood that other intervals from the dispenser can be used.

Figure 3 illustrates a side view, designated generally as reference numeral 300, of the FOV 302b, 302d for the cameras 206b, 206d, respectively, illustrated in Figure 2, intersecting the base reference cone 304 for the dispenser 202. The FOV 302b has an angle 303b, while the FOV 302d has an angle 303d. Likewise, the base reference cone 304 has a half cone angle 305, as measured from the reference line 218. As stated above, for the cameras 206 used in this embodiment, the angles 303b and 303d are 53 degrees, while the half cone angle 305 is 15 degrees.

The intersection of the FOV 302b with the base reference cone 304 produces a line 308. Similarly, the intersection of the FOV 302d with the base reference cone 304 produces a line 310. Lines 308 and 310 represent the widest anticipated flare dispersion, prior to the test. Figure 3 also shows a scale 312, in meters. In order to ensure that the cameras 206 capture an image of the moving flare when fired from the dispenser 202, the camera jig location and point of interest must be selected so that lines 308, 310 are sufficiently long.

In this embodiment, the height of the jig 208 was set at 5m above the target board 210. This places the cameras 206b, 206d 3 meters from the reference line 218. The flares are launched from the dispenser with a maximum initial speed of 60 meters/second. With the cameras 206 mounted at 5m above the target board 210, and assuming a frame rate of 30 frames per second, it was derived that at least 2 fields (equivalent to 1 frame) can be captured at the 3m point, and 1 field (equivalent to half a frame) can be captured at the 6m point, when the flare travels along lines 308 and 310. This represents the worst case situation, where the flares deviate from the line of firing and the field of regards is smallest. It is understood that other flare dispensers having different launch characteristics will require a different placement of the cameras 206 to effectively capture the images desired.

The discussion of the placement of cameras 206b, 206d also applies to the placement of cameras 206a, 206c. These cameras were, therefore, placed 3m from the reference line 218 on target boards 210b, 210d, respectively.

Once the camera positions are fixed, one can then determine a minimum size of the target board 210. The target boards 210a-d are used to allow the captured images to be superimposed on a reference plane. This facilitates the analysis of the subsequent results. In this embodiment, a 'checker-board' design for the target board 210 was decided. When using a checkerboard design, the size of the grid squares 212 must be determined. Ideally, the cameras 206 will capture the image of the moving flare at the exact point where the measurement is to be made. In this embodiment, those points are 3m and 6m. However, since the flare is moving, and the cameras 206 do not provide

continuous image coverage, a certain size for the grid squares is required. It is understood that other designs for the target board 210 can also be used. Furthermore, it is understood that no physical target board 210 need be used. It is possible to superimpose a target image on the captured images to calculate the position of the flares. All such design alternatives are considered to fall within the scope of the embodiments described.

Figure 4a shows a drawing, designated generally as reference numeral 400, illustrating one method of calculating a grid height for grid squares 212 of the target board 210. Drawing 400 shows the flare dispenser 202, an offset distance 402, a potential measurement accuracy angle 404, and a potential grid height 406 for the target board 210 (not shown). To provide a measurement accuracy for the flare position determined by the cameras 206, the accuracy angle 404 was set to $\pm 0.5^\circ$. It is understood that an accuracy angle of between 0.25° and 1.0° can also be used. Given an accuracy angle of 0.5° , the grid height 406 in the X plane is derived to be 0.025m. Since the flare will appear as a big ball of fire in the captured image, a practical grid size on the order of 10 times bigger is decided. This simplifies the approximation of the flare location if it falls between 2 grids.

Figure 4b shows a diagram, designated generally as reference numeral 420, illustrating one method of calculating a horizontal displacement error using a 0.25m grid square, as calculated above. Diagram 420 shows the flare dispenser 202, the offset distance 402, a grid square 212, and a flare image location 422 on the leading edge of the grid square 212. The flare image location 422 makes an angle α 423 with respect to the launcher 202. Diagram 420 also shows a displaced flare location 424 on the trailing edge of the grid square 212, forming an angle γ 425 with respect to the launcher 202. The difference between angles 423 and 425 can be used to calculate a maximum displacement error, since the angular difference will be the largest for the closest grid square 212 illustrated in Figure 4b.

By applying trigonometric analysis, the maximum horizontal displacement error is calculated at approximately 9.22%. For ease of construction and set-up, system 200 includes 2 vertically oriented target boards 210 and 2 horizontally oriented target boards

210. Each target board 210 is 4m square with grid squares 212 measuring 0.25m square, as calculated above. For ease of discussion, the target boards 210 are labeled as 210a (near vertical), 210b (near horizontal), 210c (far vertical), and 210d (far horizontal). It is understood that a single target board 210 can be used, and that the specific design discussed here is provided by way of example only.

As discussed above, it is possible that two fields will be captured by the cameras 206a, 206b positioned at the 3 meter offset point (214 in Figure 2). It is then necessary to determine a flare position based on either one or two images. Figure 5 illustrates the situation where only one image is captured, while Figure 6 illustrates the situation where two images are captured. It is understood that the discussion of Figure 5 also applies to cameras 206c and 206d placed at the 6m offset point (216 in Figure 2).

Figure 5 illustrates a schematic diagram, designated generally as reference numeral 500, for mapping a flare position in three dimensional space using the system 200 and method 100 when a single image of the flare is captured by the cameras 206a, 206b. For ease of illustration, the components of the system 200 are shown in a single plane. Diagram 500 shows cameras 206a and 206b opposite target boards 210a (S) and 210b (B) respectively. Diagram 500 also shows a target plane 502, a flare position 504 as captured by the cameras 206a, 206b, the three meter target line 214, and the flare dispenser position line 218. The side-view camera 206a is looking at, and will capture, an image 504a of the flare superimposed on the Y-Z plane in free space. The plan-view camera 206b is looking at, and will capture, an image 504b of the flare superimposed on the X-Y plane in free space.

These 2 points 504a, 504b, will then be translated to the 3m line, shown as points 506a, 506b for purposes of illustration in Figure 5. A dotted line 510a represents the straight-line view of the target point 506a captured from the camera 206a. Similarly, a dotted line 510b represents the straight-line view of the target point 506b captured from the camera 206b. This shifting of the target points to the edge of the board takes into consideration the possible parallax error when viewing the target from the camera at a distance of 5m from the target boards 210b and 210a.

The point 508 where the 2 dotted lines 510a, 510b intersect will be the flare position in free space on the target plane 502 when fired from the dispenser 202. Note that the target plane 502 is actually perpendicular to the planes of both target boards 210a, 210b.

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Figure 6 illustrates a schematic diagram, designated generally as reference numeral 600, for mapping a flare position in three dimensional space using the system 200 and method 100 when multiple images of the flare are captured by cameras 206a, 206b. For ease of discussion, the reference numbers used in Figure 5 will also be used in Figure 6, with the exception of the image numbers. A first position 602a, 602b of the flare is captured by cameras 206a, 206b, respectively. A second position 604a, 604b of the flare is also captured by cameras 206a, 206b, respectively. Given the small change in time between the image captured at the first position 602, and the image captured at the second position 604, it is assumed that the flare travels a straight-line path between the positions 602-604. The position where the path of the flare crosses the 3m line 214 is designated 605a, 605b. This point is then translated to the edge of the target board, as was done in Figure 5, and is shown as 606a, 606b. The point 608 where the 2 dotted lines 610a, 610b intersect will be the flare position in free space on the target plane 502 when fired from the dispenser 202.

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Figure 7a illustrates the target plane 502 at the 3m reference line 214. Figure 7b illustrates a target plane 700 at the 6m reference line 216. Figure 7c illustrates the angular and linear distances associated with the target planes of Figures 7a and 7b. In Figures 7a and 7b, a plurality of circles 702 is shown. The circles 702 indicate the half cone angle of deviation from a line extending outwardly from the flare dispenser 202. As shown in Figure 7c, for any given linear distance X 704 from the dispenser 202, and any given half cone angle β 706, a corresponding radius Z 708 of the circles 702 can be calculated using Formula 1 below:

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$$Z = X \tan \beta \quad (1)$$

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Table 1 summarizes the various circle radii for the conditions outlined in the discussion above.

X (m)	β (°)	Z (m)
3	5	0.26
	10	0.53
	15	0.80
	20	1.09
	25	1.40
	30	1.73
6	5	0.52
	10	1.06
	15	1.61

TABLE 1

Using the system 200 according to the method 100, test data was collected to determine a dispersion characteristic of a flare fired from the flare dispenser 202. The flare dispersion characteristic was determined by mapping the flare position in the target planes for a plurality of test firings of the dispenser 202.

The test data yielded the following results with the dispenser mounted in various positions: At the 3 metre and 6 metre mark, it was found that the majority of the payloads were dispersed within the 5° half-cone. The remaining payloads had a wider dispersion angle. Using the collected data, a minimum safe dispersion angle was calculated.

It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

CLAIMS

We claim:

1. A method of determining a dispersion characteristic of a flare launched from a launcher, the method comprising the steps of:

5 launching a plurality of flares from the launcher;
 capturing at least one image of each of said plurality of flares using each of a plurality of cameras;
 using said captured images, calculating a dispersion angle for each of the plurality of flares to determine the dispersion characteristic.

10 2. The method of claim 1, wherein the dispersion angle is measured from a centerline of a right circular cone having the launcher at an apex of said cone.

15 3. The method of claims 1 or 2, wherein said dispersion characteristic is a minimum safe dispersion angle.

20 4. The method of any one of the previous claims, wherein said capturing step further comprises providing a target board perpendicular to a field of view for each of said cameras.

25 5. The method of claim 4, wherein said target board has a checkerboard pattern.

30 6. The method of any one of claims 2-5, wherein said capturing step comprises positioning each of said cameras orthogonally to said centerline.

35 7. The method of any one of claims 2-6, wherein said capturing step further comprises:

 calculating a first offset distance measured from said launcher;
30 calculating a second offset distance measured from said centreline; and
 positioning a first camera having a first field of view and a second camera having a second field of view at said first and second offset distances;
 wherein said first and second fields of view intersect.

8. The method of claim 7, wherein said first and second fields of view are orthogonal to each other.

5 9. The method of claim 7 or 8, wherein the step of calculating the first and second offset distances is performed based on said first field of view, said second field of view, a shutter speed of said first and second cameras, a maximum speed of said flares and an estimated dispersion characteristic of said launcher.

10 10. The method of any one of claims 7-9, wherein the first camera captures a first image of each of said flares superimposed on said target board, the second camera captures a second image of each of said flares superimposed on said target board, and the step of calculating the dispersion angle further comprises:

translating each of the first and second images to a point;

15 using each of the translated first and second images to map a coordinate of said flare onto a virtual target board, said virtual target board positioned orthogonally to said cone at said first offset distance; and

calculating said dispersion angle based on said coordinate.

20 11. The method of any one of claims 5-10, wherein said capturing step further comprises:

calculating a third offset distance measured from said launcher; and

positioning a third camera having a third field of view and a fourth camera having a fourth field of view at said second and third offset distances;

25 wherein said third and fourth fields of view intersect.

12. The method of claim 11, wherein said third and fourth fields of view are orthogonal to each other.

30 13. The method of claim 11 or 12, wherein the step of calculating the third offset distance is performed based on said third field of view, said fourth field of view, a shutter speed of said third and fourth cameras, a maximum speed of said flares and an estimated dispersion characteristic of said launcher.

14. A system for determining a dispersion characteristic of a flare launched from a launcher, the system comprising:

5 a first and a second camera, each of said first and second cameras positioned to capture at least one image of each of a plurality of flares launched from the launcher;

wherein said captured images are used to calculate a dispersion angle for each of the plurality flares to determine the dispersion characteristic.

10 15. The system of claim 14, wherein the dispersion angle is measured from a centerline of a right circular cone having the launcher at an apex of said cone.

16. The system of claims 14 or 15, wherein said dispersion characteristic is a minimum safe dispersion angle.

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17. The system of any one of claims 14-16, further comprising a target board positioned perpendicular to a field of view for each of said cameras.

18. The system of claim 17, wherein said target board has a checkerboard pattern.

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19. The system of claims 17 or 18, wherein said first camera has a first field of view, said second camera has a second field of view, and said first and second cameras are positioned at a first offset distance measured from said launcher and a second offset distance measured from said centreline; such that said first and second fields of view intersect.

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20. The system of claim 19, wherein said first and second fields of view are orthogonal to each other.

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