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The Ballistics Case Study of the Enrica Lexie Incident

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***Abstract*—**On February 15, 2012 off the Indian coast of Kerala, in position 091702N-0760180E by the oil tanker Enrica Lexie, flying the Italian flag, bursts of 5.56 x45 caliber shots were fired from assault rifles AR/70 Italian-made Beretta towards the Indian fisher boat St. Anthony. The shots that hit the St. Anthony fishing boat were six, of which two killed the Indian fishermen *Ajesh Pink* and *Valentine Jelestine*. From the analysis concerning the kinematic engagement of the two ships and from the autopsy and ballistic results of the Indian judicial authorities it is possible to reconstruct the trajectories of the six aforementioned shots. This essay reconstructs the trajectories of the six shots that cannot be of direct shooting but have undergone a rebound on the water. The investigation carried out scientifically demonstrates the rebound of the blows on the water, the gyrostatic deviation due to the rebound and the tumbling effect always due to the rebound as regards intermediate ballistics. In consideration of the four shots that directly impacted the fishing vessel, the current examination proves, with scientific value, that the trajectories could not be downwards but upwards. Also, the trajectory of two shots that hit to death the two fishermen could not be downwards but only upwards. In fact, this paper demonstrates, with scientific value: The loss of speed of the projectiles due to the rebound on the water; The tumbling effect in the ballistic medium within the two victims; The permanent cavities subject to the injury ballistics and the related ballistic trauma that prevented homeostasis causing bleeding in one case; The thermo-hardening deformation of the bullet found in Valentine Jelestine's skull; The upward and non-downward trajectories. The paper constitutes a tool in forensic ballistics in that it manages to reconstruct, from the final spot of the projectiles fired, all phases of ballistics like the internal one of the weapons that fired, the intermediate one, the terminal one and the penetrative structural one. In general terms the ballistics reconstruction is based on measurable parameters whose entity is contained with certainty within a lower and upper limit. Therefore, quantities that refer to angles, speed, impact energy and firing position of the shooter can be identified within the aforementioned limits. Finally, the investigation into the internal bullet track, obtained from any autopsy examination, offers a significant "lesson learned" but overall a starting point to contain or mitigate bleeding as a rescue from future gunshot wounds.

***Keywords*—**Impact physics, intermediate ballistics, terminal ballistics, tumbling effect.

I. Introduction

THE reconstruction of the fire event has been long and laborious as the data relevant to the reconstruction itself were not immediately available due to the natural confidentiality of the matter. Therefore, the dynamic development of the action was derived in part from the official documents deposited by the Italian and the Indian Governments to the International Tribunal for Law of the Sea (ITLOS) in order to decide which State should have jurisdiction in the matter [1]. Secondly, some information was acquired from few documents made available as open source by the Court of Rome. Last but not least, the extensive documentation available from open sources has been integrated in accordance with a logical sequence. In this way, the development of the examination was reconstructed according to a single logical path or at least according to two or more plausible options, the final results of which were always certified with a scientific analysis.

The analysis of the event requires the subdivision into two integrated macro areas. The first refers to the kinematic contact between the motor ship Enrica Lexie and the fishing boat San Anthony. The elements of the motion of the Enrica Lexie were found to be route 330 and speed 13 knots. The data are confirmed by the navigation logs of the aforementioned ship and by the AIS (automatic identification system). The elements of the motion of the St Antony, according to the testimony of its Commander, was route south with a speed of about 6 knots. The speed of the St Antony fisher-boat has been reconstructed with the resolution of a kinematic problem obtained from the other reliable data. The second refers to the trajectories of the fired bullets and their point of fall on the St Antony hull. In particular, from the firing point, located on the Lexie bridge flap, it is possible to reconstruct external ballistics[1] [2] up to the point of impact. Finally, the terminal ballistics[2] completes the picture. In fact, the traces of the bullets inside the bodies of the two victims (detectable by autopsies) and the nature of the shapes of impact of the bullets on the fishing boat allow to complete the entire ballistic picture from the firing point to the stop point of the bullet. That demonstrates an upward or downward trajectory before the impact of the projectile on the St. Antony.

The significance of this essay is twofold. In fact, it provides an expert opinion for judicial purposes [3] and at the same time is a statement of science aimed at highlighting the risks of "friendly fire". In fact, the "lessons learned" are the prelude for implementing adequate safety rules to avoid that, in the

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[1] External ballistics (a term first used by Marin Mersenne in 1644 derives from the Greek βάλλειν, to throw) [2] is the science that studies the motion of a projectile from the instant in which its acceleration phase ends until it hits the target. External ballistics is generally applied to firearms, and describes the flight of the projectile from the muzzle to the target if non-self-propelled projectiles are used.

[2] Terminal ballistics is the branch of ballistics that studies the interactions between the bullet and the target at the moment of impact and in the following instants.

future, fire actions cause accidents [4].

II. The Kinematic Contact

The reliable data in agreement with both the Italian and Indian versions data refer to the log book of the master of Enrica Lexie that India has filed with ITLOS [5].

"15 Feb 2012· Wednesday - Sailing toward Port Said. Orders to take counter-piracy course. Daily checks and tests.

At noon Pos. L=08 37 N h= 076 30 E, miles covered since downtime: 265 in 8hrs 30 min timetable λ= + SE.

Meteo marine elements as per G.N.P 3 (Navigation Journal- Part 3). At about 1600 hrs, approximately 20 miles from the city of Alleppey (India) a craft was spotted on the radar screen at a distance of 2.8 miles, and the LATORRE VPO was alerted; at first it seemed to be a fishing boat, and it was constantly monitored. As it approached from our starboard side the armed guards of the LATORRE VPO used the floodlight to send (visual) signals and, having received no answer, showed their weapons. Despite such signals, the craft continued on its approach course. At 1600 hrs (UTC 1100) at Lat 09 17.2 N. Long 076 ... SE the craft was 100 meters to starboard from the mid-section of our ship.

The LATORRE VPO saw armed people onboard and fired warning shots into the water. We immediately took contact with the ship-owner and activated the alarm {SSAS). At the same time, I activated the general alarm, sending the crew toward the citadel (i.e., the steering room used as a shelter).

While the situation evolved, the six members of the VPD, Shipmaster Umberto Vitelli, Master Carlo Noviello, Chief Mate James M.S. Vietar, Sailor helmsman Ayyaz Kumandan, who was operating the hand helm, were on the command bridge.

After the warning shots the craft changed its course, moving away from the ship.

During the incident the engine was operating full power. As agreed during the Security Meeting, the presence of personnel on the bridge during management of crisis situations is required only to maintain navigation security, and, in order to avoid endangering the physical safety of personnel or of the very VPO by creating further risks, personnel cannot expose themselves near glass walls or vulnerable areas.

At 1630 hrs the situation was under control. As a further precautionary measure, I deemed it appropriate that the crew stay in the Stby. (unreadable) in the steering room. Subsequently, we were contacted by Italian War Ship Grecale which offered to help. At 1700hrs the alarm was disabled and the crew was allowed to leave the steering room.

After the event, at approximately 1830 hrs, we were contacted by phone by Bombay MR:CC Command and, through 2nd Officer Sahil GUPTA, told us that they had been informed about the suspect pirate attack and, as a result, had seized two crafts"

The *Latorre Report* has been published in the Italian media which is in full agreement with the previous log book of master the Lexie [6].

"15th Febr. 16:00 local time. - While the navy unity M/T [motor tanker, ndr] Enrica Lexie was sailing at the coordinates 091702N - 0760180E 20 nm off the coast of Allepey (India) the officer on guard on the bridge informed the anti-piracy protection team of a target picked up by the on-board radar with no identification number at 3nm at the bow of the unity on a collision course. After monitoring it constantly both by radar and without instruments the target could be identified with a small vessel. At a distance of about 800 yards, we made warning signals using Panerai lights [searchlight, ndr] from the right deck obtaining no results. After having given the alarm, while the vessel was positioning, one of the two members of the protection team on the right deck showed the rifle AR 70/90 raising it. This was useless. The vessel did not change course. At a distance of about 500 yards the first warning shots were fired into the water. But again, the vessel did not turn back. It kept on approaching on a collision course. At about 300 yards a second warning burst was fired into the water after that one of the members of the protection team had given the alarm because on the nearing vessel there were persons with firearms on their shoulders, which were sighted using binoculars. The vessel kept on nearing. Two of us kept on shooting warning shots into the water till the vessel at less than 100 yards changed course on our right side turning back astern. After having turned back astern the vessel did not have a definitive course. Many times it started navigating again towards us. The whole protection team kept on showing the weapons and making light signals using PANERAI lights till the vessel increased its speed and sailed away on open sea. At 17h local time I considered it opportune, in view of the considerable distance from the aggressor, to cease to be in the state of anti-piracy alarm letting the crew leave the cabin. The anti-piracy protection team continued its service on board.

It can be established with certainty "kinematics" that at the distance of 2.8 miles the St Antony showed its port side. With equal certainty it can be established that the St Antony, on her approach course, changed sides showing Lexie her starboard side. This may have happened either if the St Antony has changed its course or has left its elements of motion unchanged. This generates two possible hypotheses which are:

1. The St. Antony changed it course from the original (180°) to a new estimated (150°) during its approach to the Lexie;
2. The St. Antony changed its course (180°) during its approach to the Lexie.

The Possible Kinematic Options

In the first hypothesis (from now on the 1ST Kinematic Option) the St Antony and the Lexie were strictly on a

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collision course and therefore the kinematic development is as shown in Fig. 1[3] [7].

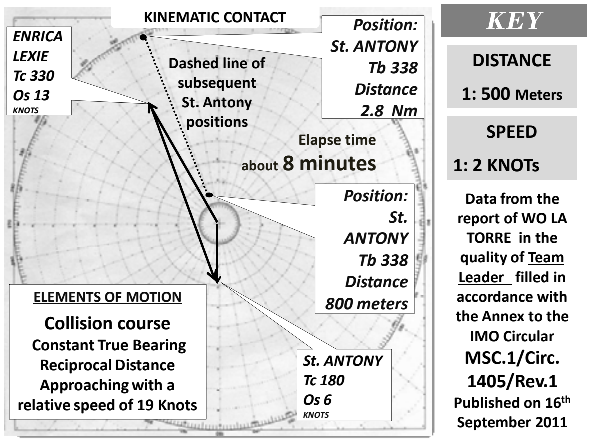

Fig. 1 St Antony and Enrica Lexie were in collision course

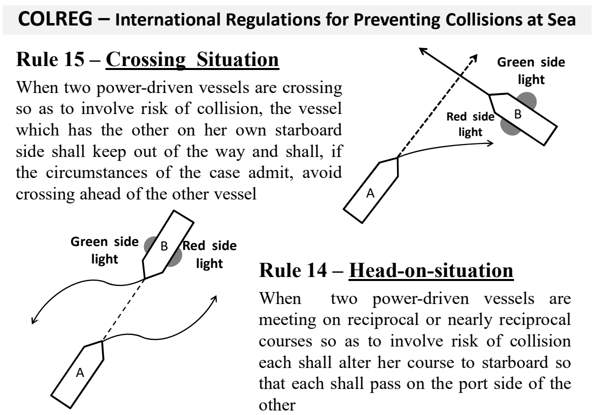

Fig. 2 Enrica Lexie (A) should have turned to starboard or reduce its speed to allow the St Antony (B) to pass in front of her bow

The 1st Kinematic Option does not reflect any official Italian version. Instead, it highlights the author's opinion supported by the reconstruction indicated in Fig. 1[4]. The main nautical fact is the definition of a collision course between two ships. It is characterized by the approaching distance and constant true bearing between the two vessels.

According to 1st kinematic option, the St Antony was sailing with the route 180° and a speed of six knots and the distance from the Lexie decreased, in about eight minutes, from 2.8 nautical miles to 800 meters.

The International regulation for preventing collision at sea provides that the Enrica Lexie (target A in Fig. 2) would have to maneuver to leave the precedence to St Antony (target B in Fig. 2).

At a distance of about 800 meters, it is plausible[5] that the St Antony went from route 180 to route 150 parallel to that of the Lexie. In doing so he avoided the collision. This is the maneuvering safety, used permanently in visual navigation without instrumental use. In fact, putting himself on the course parallel to that of the Lexie he had the perception (and the objective reality) that he was no longer on a collision course.

The distance of 800 meters was deduced from the kinematic calculation according to which the course of the two ships created a parallel dual track whose distance was about of 100y ds as specified in the *Latorre Report*.

In the 1st Kinematic Option at a distance of 800 meters, the St Antony, having passed from course 180 ° to 150 °, began to show its port side to the Lexie. Another certain information is the angle formed by the vertical plane containing the trajectories and the vertical plane containing the keel axis of the St Antony. This information was deduced from a judicial report, at the court of Rome, published online (Fig. 3) [8]. This information was also indirectly validated by the Indian authorities in the documentation submitted to ITLOS [9].

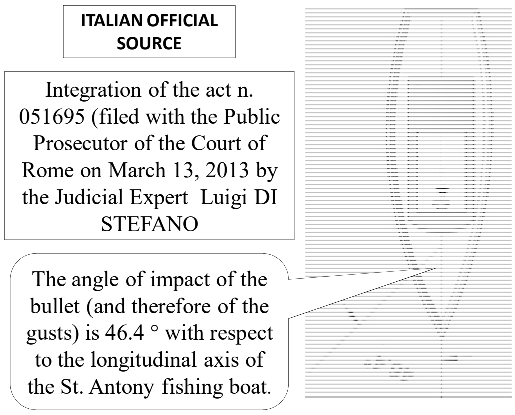

Fig. 3 The angle formed by the vertical plane of the trajectories with the vertical keel plane of the St Antony

From a nautical point of view the above angle (the angle formed between the vertical plane of fire and the vertical plane passing through the keel line) coincides with the Beta angle. In fact, the Beta angle is nothing more than the polar bearing under which the St. Antony aimed at the Lexie's firing point with respect to the direction of its bow.

In any case, it should be assumed that in the vertical firing plane it was included, in addition to the trajectory of the bullet, the firing position on the Lexie and the point of impact of the

[3]Fig. 1 indicates a PPI (Polar Plane Indicator) representation. In the PPI representation, the center of the graph indicates the position of the Enrica Lexie and around the development of the situation according to a representation with polar coordinates.

The PPI representation, used in navigation for anti-collision, provides detections, distances, speeds and routes of the various targets in accordance with the scale related to each circle. It is the representation that the radars give us.

[4] Italy has not made, for now, any judicial assessment. With regard to the investigation, he made only the summary one, namely the Piroli Report.

The summary investigation in the event of a maritime accident has the task of gathering evidence for the subsequent development of the formal investigation which is in any case extra-judicial.

[5] The plausibility was obtained from the possible inverse kinematic reconstruction by knowing the position of the LEXIE, the distance and the maximum possible speed of the St. ANTONY as well as the fact that the two ships were on a collision course or with a CPA (Closest Point of Approach) of near-collision.

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relative bullet on the St. Antony. If this condition is true then we are in the direct shooting condition. This condition is no longer true in the case of a rebound of the bullet on the water, so that the vertical firing plane is deflected due to the effect of the gyrostatic precession as in Fig. 4. So, there can be two possibilities of ballistic trajectories: the direct hit and the rebound one.

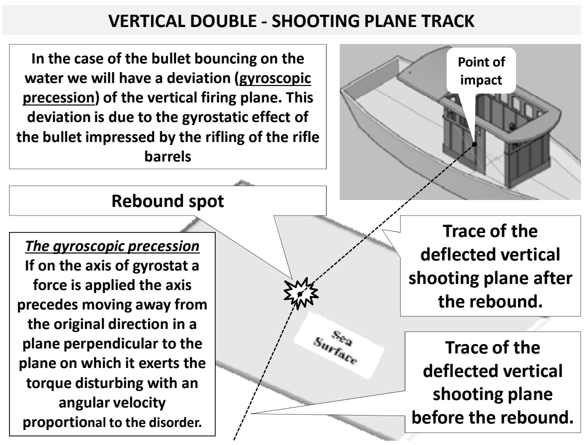

Fig. 4 The deviation of the bullet trajectory after a rebound on the water

The two conditions of direct or rebound shooting are obviously self-excluding for any shooting bullet. In the case of direct firing, we would have a single vertical plane containing the firing point, the trajectory of the bullet and its point of impact. In the case of rebound, we will have two intersecting vertical shooting planes. The first contains the firing point, the initial part of the trajectory and the rebound point of the bullet (from now on the vertical plane of the direct firing). The second (from now on the vertical plane of the bounced shot) contains the bounce point and the subsequent trajectory of the bullet up to the point of impact.

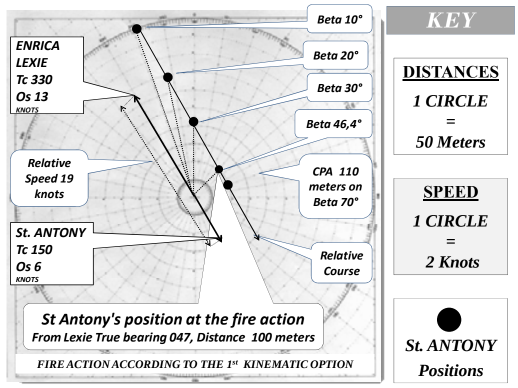

Fig. 5 The reciprocal direct firing positions according to the 1ST Kinematic Option

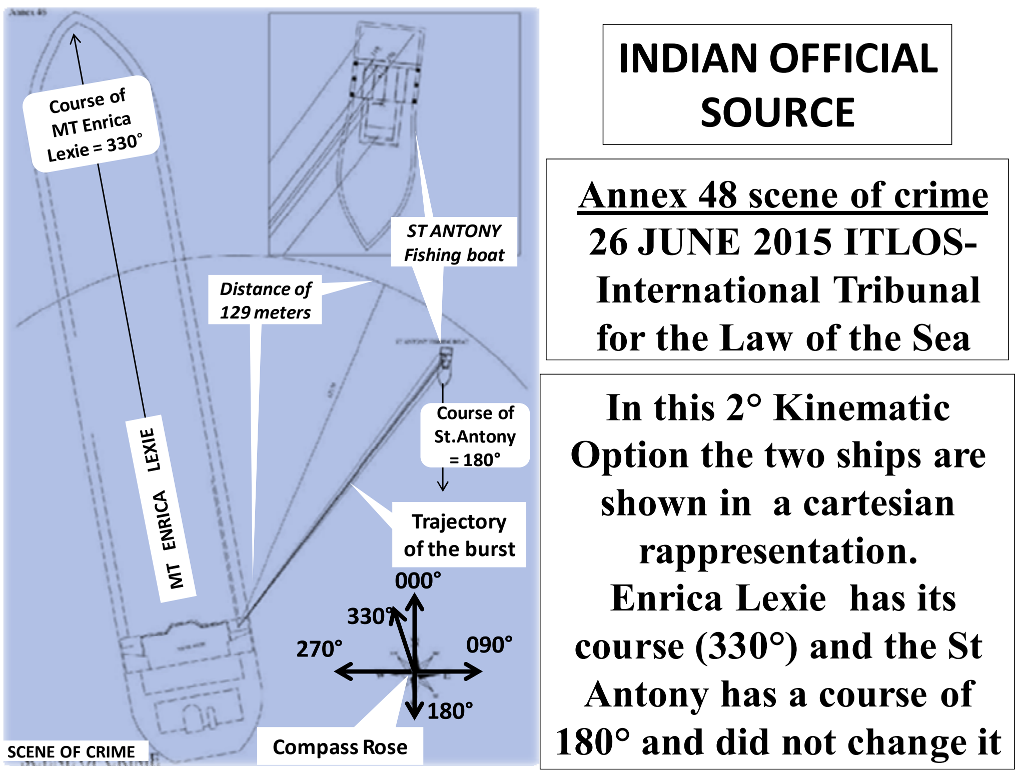

Fig. 6 The Indian official Kinematic Hypothesis

In first instance, the 1st Kinematic Hypothesis considers the only direct shooting, in compliance with the external ballistics of the doctrinal naval fire.

We can establish if there was a flattening of the bullet on

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the water only with terminal ballistics surveys. In fact, if the bullet bounced off the water, it took on particular anomalous movements in which confirmation is highlighted by the impact shape on the target and by the penetration path on it. All this is part analysis of the motion of the projectile during its trajectory of an external ballistic

The direct shot provides a linear geometric dimension that is commensurable with the positions of the two ships and the instantaneous orientation of their respective prows. It is in fact a direct conjunction of the firing point with the bullet impact point. In fact, since there is a single vertical firing plane, it is possible to define, on the horizontal plane (sea surface), the reciprocal positions of the firing point and the point of impact as show in Fig. 5.

According to the 1ST Kinematic Option, the fire action, in accordance with the direct fire, occurred when the Lexie detected the St. Antony for 047 of true bearing and this was at a distance of 100 meters.

There is a 2nd Kinematic Option, presented by India to ITLOS [9] in which the St Antony was not on a collision course but had a CPA (Closest Point of Approach) of 100 yards to starboard of the Lexie, see Fig. 6. This kinematic hypothesis is plausible and is based on the fact that the St Antony did not change its course. As the helmsman of St Antony (Valentine Jelestine) was shot to death during the fire action, there is no evidence of merit.

The kinematic reconstruction is reported on the polar plane indictor diagram of Fig. 7.

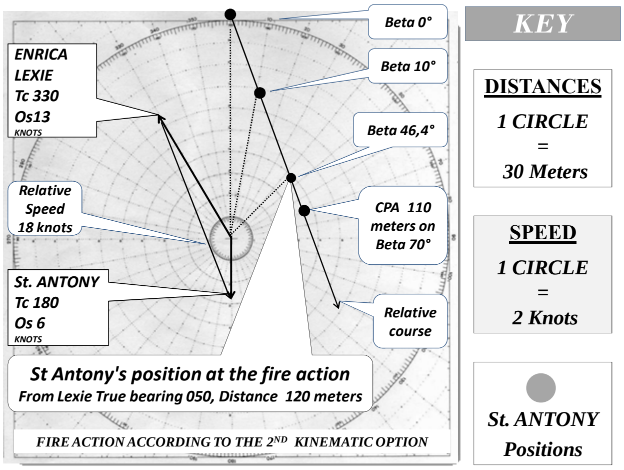

Fig. 7 The reconstruction of the 2ND KINEMATIC OPTION on the polar plane indicator diagram

According to the 2nd Kinematic Option, the fire action, in accordance with the direct fire, occurred when the Lexie detected the St. Antony for 050 of true bearing and this was at a distance of 120 meters. As can be seen, for the purposes of intermediate ballistics[6], the two versions are almost coincident. This means that both versions are compatible with "the scene of crime" in case we were in direct shooting conditions.

[6] The intermediate ballistics describe the trajectory from the fire point to the point of impact on the fisher-boat.

III. The Intermediate Ballistic Parameters

The Enrica Lexie firing station was 24 meters above sea level as can be seen in Fig. 8. The Lexie fired 5.56 x 45 mm NATO bullets with a Beretta AR 70/90 rifle.

The AR 70/90 weapon, (chambered for the NATO 5.56 × 45 mm caliber), is an assault rifle produced by the "*Pietro Beretta Arms Factory*", and is currently adopted by the Italian Armed Forces. The AR-70/90 is an indirect gas recovery automatic assault rifle with a rifled barrel with six right-hand rows with 178 mm pitch.

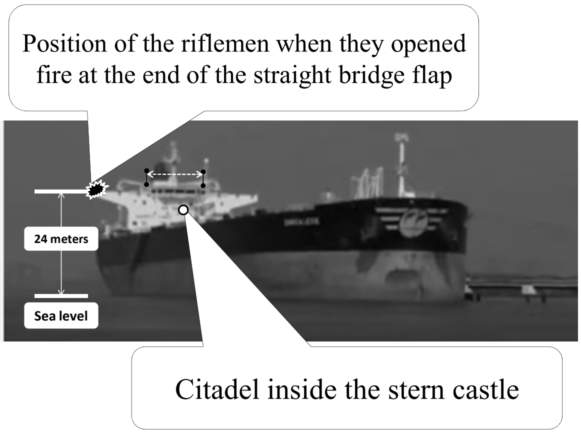

Fig. 8 The parameters of the Enrica Lexie for the purpose of the fire action

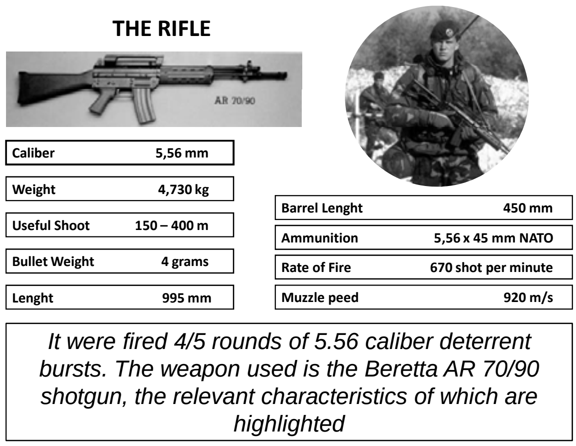

Fig. 9 The principle characteristic of the rifle AR 70/90

TABLE I
223 Remington – 55 Grains Trajectory chart

Caliber	Initial Speed in m/s	Residual Speed in m/s after 100 meters	Residual Speed in m/s after 200 meters	Residual Speed in m/s after 300 meters	Residual Speed in m/s after 400 meters	Residual Speed in m/s after 400 meters
223 Rem	980	795	645	523	424	384
Lost of speed in m/s	0	185	335	457	556	596

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In Fig. 9 are highlighted the main characteristics [10]. Table I shows the trajectory chart relating to the 223 Remingtnon caliber [11].

The 223 Remington caliber is the American version of 5.56 x 54 NATO with the same characteristics of the bullets used by the marines, except for slightly lower muzzle velocity (about 6%), irrelevant and in any case compensable for the validation of the subsequent relevant analytical constructs. So, with the integration of both hypotheses of the kinematic framework it can be established that:

- The shooting point was at an altitude of 24 meters above the sea level;
- The bullets had a muzzle velocity of 960 meters per second;
- The shooting distance (in case of direct trajectory and not rebound one) was between 100 and 120 meters with an impact speed on St Antony of about 780 m/s;
- The trajectories of the bullets (in case of direct trajectories and not rebound ones) were “downwards” according to the Report on Forensic examination of Crime [12];
- The distribution of the blows on the St. Antony is that indicated in Fig. 10 faithfully reconstructed in accordance with the Report on Forensic examination of Crime [12].

The shape of Fig. 10 was obtained by reporting on the vertical plane passing through the keel line the metric measurements contained in the Report on Forensic examination of Crime [12]. Hits A and B are those that hit the fishermen while those 1,2,3 and 4 are those that hit the deckhouse of the St Antony fisher-boat.

The Report on Forensic examination of Crime [12] identifies the traces n. 3 and 4 belonging to a single shot. However, the photographic evidence, from media sources (Fig. 11), unequivocally testifies the existence of two distinct shots.

In the case of direct trajectories, the two kinematic hypotheses clarify, especially for judicial purposes, the parameters of the fire action (distance of shooting and reciprocal position of the two ships during the fire action). However, terminal ballistics are required for a more in-depth analysis that demonstrates unequivocally the existence of direct or rebound shooting.

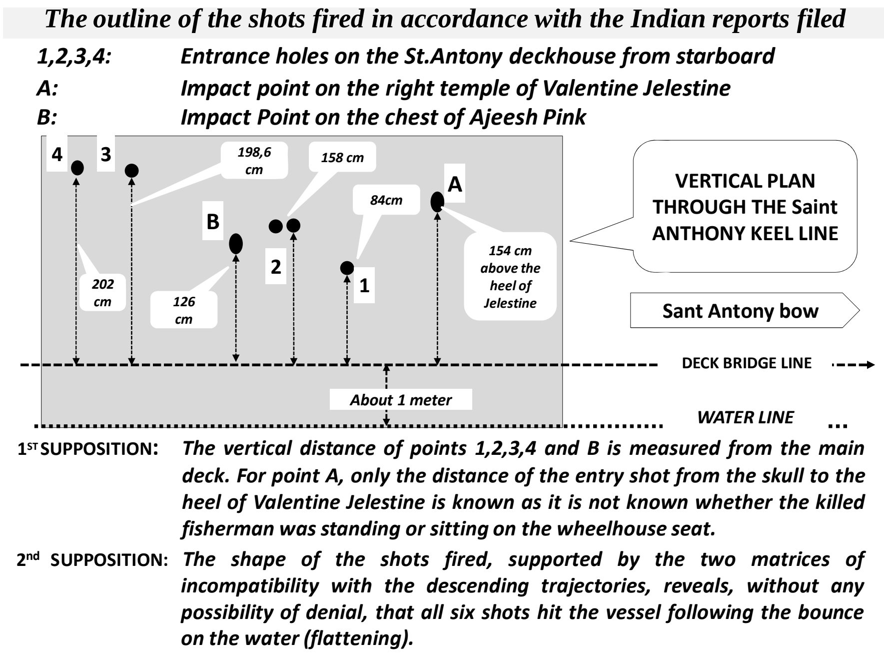

Fig. 10 The projection of the point of impact of bullet on the sagittal plane of St Antony

The results of the terminal ballistics show, in the case of a rebound shot, the existence of an upward trajectory, caused by rebound. Furthermore, the shape left by the bullet on the impact indicates interactions between the bullet and the target at the moment of impact and in the following instants (penetration energy, any movement of the projectile around its own axis of advancement). In case the terminal ballistics shows that the bullet has bounced on the water, it is possible to do an intermediate ballistics reconstruction according to the methodology of Fig. 12. Therefore, in the event of a bounced shot, knowing the altitude (above sea level) of the shooting point and the point of impact, it is possible to obtain the distance to the target at the time of the shot.

In the case of Fig. 12 the Lexie and the St Antony were respectively 452 meters and 47.5 meters apart from the rebound point. Such a calculation can be made by taking into account the heights of the impact hits in Fig. 10. However, only the results of terminal ballistics will be able to confirm or not the existence of the bounced trajectory.

IV. Pertinent Assumptions Related to the Bounce Shot

Bullet bounce is a minor subject in ballistics and its physical rules are unknown to the mass of those who, for work or pleasure, use firearms. Excluding very few exceptions, the rebound is not a desired phenomenon, since the trajectory following a rebound is predictable only with a fair margin of error.

Shock theory, taught in physics courses, does not describe the phenomenon with reference to bullets fired from a firearm and both ballistics and physics books do not address rebound theory for practical purposes [13].

An aspect of interest regarding the rebound is the flattening or the rebound on the water.

The first studies of bounces on water date back to the 1800s and deal with cannonballs [13]. The tactical importance offered by a rebound strike in the navy was considerable. The likelihood of hitting a ship with a bullet traveling at target level was higher than a hit from the sky.

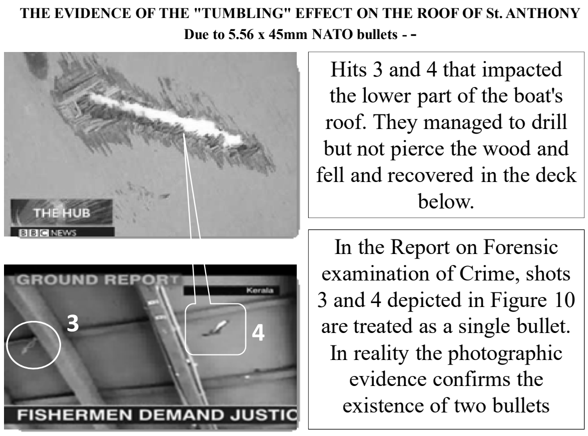

Fig. 11 The existence of the two different bullets n. 3 and 4

THE RESOLUTION OF THE TRIGONOMETRIC EQUATION ON THE VERTICAL PLAN
In case of rebound shot on the sea surface

By placing angle of incidence (α) equals to angle of bounce (β) you get the point of the fall in water (POF) of the bullet knowing the quote of the impact on the target

The quote of the point of impact on St Antony it is supposed 2,5 meters on water line in this table

DISTANCE LEXIE - POF Meters	ARCSIN α h24/dist. POF	ANGLE α	DISTANCE St. ANTONY POF Meters	ARCSIN β h 2,5/dist. POF	ANGLE β	DISTANCE St. ANTONY POF Meters	ARCOSIN β h 1,5/dist. PDC	ANGLE β
380,00	0,063	3,61°	120,00	0,021	1,20°	120,00	0,013	0,74°
400,00	0,060	3,44°	100,00	0,025	1,43°	100,00	0,015	0.86°
410,00	0,059	3,38°	90,00	0,028	1,60°	90,00	0,017	0,97°
420,00	0,057	3,27°	80,00	0,031	1,78°	80,00	0,019	1,09°
430,00	0,056	3,21°	70,00	0,036	2,06°	70,00	0,021	1,20°
440,00	0,055	3,15°	60,00	0,042	2,41°	60,00	0,025	
450,00	0,053	3,04°	50,00	0,050	2,87°	50,00	0,030	
452,50	***0,053***	***3,04°***	***47,50***	***0,053***	***3,04°***	***47,50***	***0,032***	***1,83°***
455,00	0,053	3,04°	45,00	0,056	3,21°	45,00	0,033	1,9°
460,00	0,052	2,98°	40,00	0,063	3,61°	40,00	0,038	2,18°
462,50	0,052	2,98°	37,50	0,067	3,84°	37,50	0,040	2,3°
465,00	0,052	2,98°	35,00	0,071	4,07°	35,00	0,043	2,46°
470,00	0,051	2,93°	30,00	0,083		30,00	0,050	2,87°
480,00	0,050	2,86°	20,00	0,125		20,00	0,075	4,30°
490,00	0,049	2,81°	10,00	0,250		10,00	0,150	8,63°
500,00	0,048	2,75°	0,00			0,00		

the line that solve the poblem

Fig. 12 The reconstruction of the "bounced trajectory" knowing the altitude of the shooting point (24 meters) and assuming the altitude of the impact point at 2.5 meters

Cranz [14] cites a work by Jonquirères from 1883 in which a cannonball, fired at 455 m/s, bounced 22 times, covering a distance of 2470 m.

In 1904 Chrismar, also quoted by Cranz [14], indicated a limiting angle of 25° for the navy artillery shells and maximum ranges that reached 11 km. Although interesting from a historical point of view, these studies had no useful applications for small arms but were the first to demonstrate that a bullet can actually bounce off a body of water.

The rebound angle of a bullet fired against a water surface varies according to the type of bullet but both the critical angle and the rebound angle are usually small, reducing the field of analysis in the experimental stage [15]. In artillery this deviation on a surface, as previously seen in the rebound on liquid surfaces, is called flattening and is characterized by a rebound of the bullet in a new direction that takes into account the aerodynamic forces that previously acted on the 5.56 x 45 mm caliber bullet NATO (kinetic energy, gyroscopic rotation and tumbling effect) and an estimated speed reduction of about two thirds.

Several authors [13], [16], [17] have studied the phenomenon using spherical or pointed bullets fired from pistols and carbines. We briefly report the salient points of the studies, to provide a qualitative summary of the rebound on the water. The details of the tests give the following results:

- There is a limit angle beyond which a bullet no longer bounces, but sinks into the water. With the exception of the data reported in a recent study, the limiting angles of incidence reported in the literature never exceed 7°-8° and the maximum documented rebound angles are always less than 10° [16].
- The maximum rebound angle for the studied short weapon

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bullets (pistol) does not coincide with the limit angle of attack, but before. The maximum documented rebound angle does not exceed 6°-7°.

- The maximum rebound angle for the long gun bullets (rifles) studied does not coincide with the limit angle of attack, but it is inferior (as for pistols in the former point). The maximum rebound angle is slightly larger than that of the pistols and stands at 9°-10 ° in all published studies [13], [16].
- Spherical bullets fired from a smooth barrel (without their own rotation) have a rebound angle smaller than the angle of attack. From the studies of Schöntag and Schöntag in 1972, the limit angle for the rebound is about 5.4° [15].
- Spherical bullets launched from a rifled barrel (with its own rotation) have a rebound angle greater than the angle of attack as long as the impact angle is less than 4°. For angles of incidence greater than 4° the rebound angle decreases. From the studies of Schöntag and Schöntag the limit angle for the rebound is about 5.2° [15].
- Birkhoff's theory to calculate the limit angle applied to spherical bullets provides values with a maximum error of 10% compared to the experimental data. For many forensic problems, accuracy is more than sufficient [15].
- A work by Haag shows that in a speed range between 200-700 m/s the speed does not significantly affect the rebound on the water [17]; Soliman achieved similar results using spheres [18].
- Haag's [17] work highlights significant differences as a function of the geometry and construction of the bullet. The round-tipped half-shelled bullets shattered at angles of attack of just 2°.
- The bullet then rebounding on the water, when the rifling is right-handed, will deviate to the right in the rebounded trajectory after tracing a furrow in the water and therefore losing speed by about two thirds.

The bounce on water follows the same rules as the bounce in general, whether on a solid or liquid body. The graphical representation is shown in Fig. 13 where:

- The impacted body is a solid or liquid body that intercepts the projectile along its flight path at the point of impact (PA), i.e., the point where the projectile touches the surface of the impacted body.
- The plane of impact is that tangent to the body hit at the point of impact.
- The plane of incidence is the plane normal to the plane of impact and along the undisturbed trajectory of the bullet (i.e., before impacting the impacted body).
- The direction of incidence is equivalent to the trajectory of the bullet just before impacting the struck body.
- The angle of incidence (α) is between the plane of impact and the direction of incidence.
- The speed of incidence is that with which the bullet hits the struck body.
- The rebound point (PB) represents the point where the bullet leaves the surface of the impacted body.
- The rebound vertical plane is deviated from the vertical plane of impact due to the gyrostatic effect of the bullet.

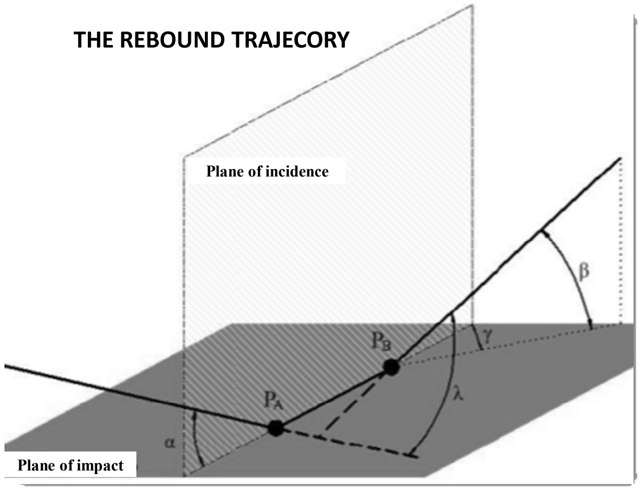

Fig. 13 The trajectory before and after the rebound on water [13]

- The bounce direction is the tangent vector to the trajectory of the bounced bullet from the bounce point (parallel to the velocity vector of the bounced bullet).
- The rebound angle (β) is the one between the impact plane and the tangent to the trajectory of the ricocheted bullet.
- The rebound speed is the speed with which the bullet moves away from the impacted body.
- The lateral deviation (γ) is equivalent to the angle between the plane of incidence and the rebounded plane.
- The length of the trace is equal to the distance between the points PA and PB while the depth of the trace corresponds to the maximum one left on the hit body.

V. Pertinent Assumptions Related to 5.56 x 45 mm Caliber Bullet NATO

The 5.56 x 45 mm caliber bullet NATO is optimized for a useful range of weapons that, in modern firefights, it is useless to exceed 300/400 meters[7] [19], [20]. It has a reduced front section; therefore, it has less surface affected by the impact, consequently greater penetration capacity. However, it has less shock effect, or stopping-power, required instead for cartridges used by the police in law enforcement operations.

The center of gravity of the bullet nose is shifted towards the rear, which makes the ball extremely unstable and prone to

[7] The 5.56 × 45 mm NATO is currently the standard cartridge for assault rifles and light machine guns supplied to NATO troops. The standard 5.56 ammunition in NATO countries is called SS-109 (M-855 for the United States of America); it is equipped with a copper jacketed lead bullet (FMJ) and weighs only 4 grams (62 grains), and a set-back center of gravity [20].

During the 1970s, NATO member countries entered into an agreement to define the second standard cartridge after 7.62 × 51 mm. The 5.56 × 45 mm was chosen as the most suitable for a smaller caliber, but it was not the 5.56 mm M193 cartridge used by the United States at the time, but the Belgian FN SS-109. The new ammunition, unlike the US 55-grain M193, was fitted with a heavier 62-grain bullet (compared to the 55-grain American ammunition) in a semi-piercing configuration. Inside it has a steel indenter with a diameter of .182", lead in the base (tapered, "boat tail") and a hollow point. This configuration allowed to reach higher radii of action, and in particular to drill steel helmets placed 600 meters away. [20]

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tip over if it encounters obstacles, such as bones. Furthermore, as per statistical reports of the Vietnam War, this type of ammunition (223 Remington) caused extremely lacerating wounds, with bleeding almost always fatal (80% of the time) regardless of the initial point of penetration. In fact, the backward center of gravity of the ball, which therefore has the greatest weight in the back (as in the 55grs M193), also causes, on impact, devastating injuries due to the high hydrostatic shock and the backward tilting of the bullet (tumbling effect).

Fig. 14 highlights the three axes integral to the bullet and the rotation movement around the roll axis impressed by the rifling of the barrel.

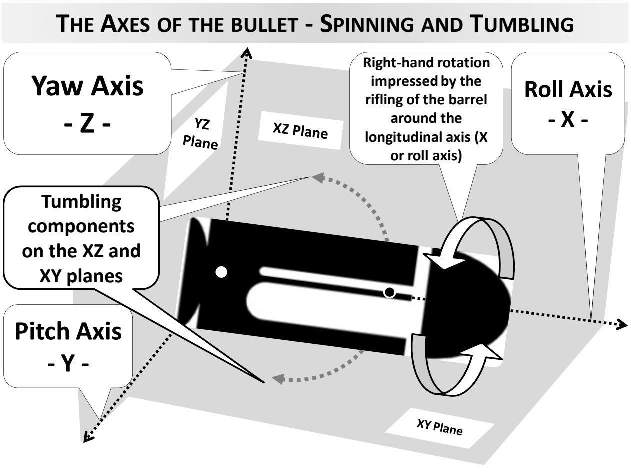

Fig. 14 The tumbling effect on a bullet

The components of the tumbling are represented by the green dashed arrows respectively on the planes, perpendicular to each other, XZ and XY. The experimental results have shown that the longitudinal axis of the bullet (roll axis or X) tends to remain with its orientation unchanged.

An important and significant experiment was carried out on March 20, 2003 in Fort Dix in New Jersey (USA). Actually the "New Jersey Division of Criminal Justice" conducted the Wallboard Test with the H&K G36E rifle [21]. The barrel length of the H&K G36E is 48 cm long, that means 3 cm longer than the one of the AR 70/90. The test was conducted with the following 4 types of Remington 223 ammunition:

1) 55 grain Federal Ball with a muzzle velocity of 1003 meters per second;
2) 69 grain Federal Hollow point with a muzzle velocity of 893 meters per second;
3) 60 grain Hornady Tap with a muzzle velocity of 887 meters per second;
4) 65 grain Remington Soft Point with a muzzle velocity of 1003 meters per second;

The test was carried out by a structure of 3 vertical trestles on which 4 plywood boards were fixed as shown in Figs. 15 and 16.

From Figs. 15 and 16 it emerges that the bullets enter and exit from the first two tables with circular section holes while they enter and exit from the following ones with ellipsoidal section holes (diversified according to the type of ammunition) which shows that the bullet has pierced a body (first two boards) which caused the triggering of forces that determine tumbling rotation.

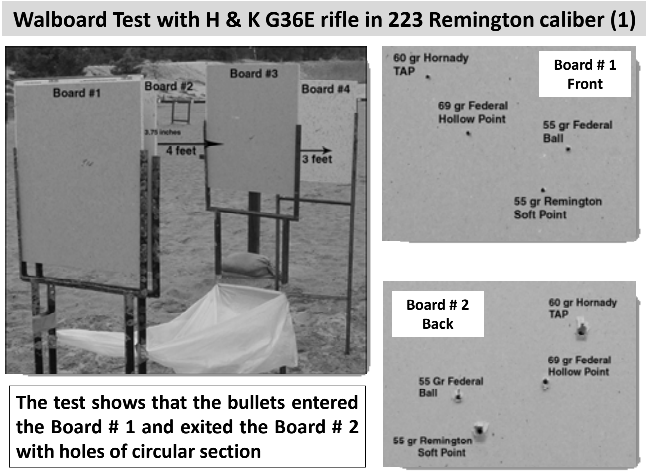

Fig. 15 Wallboard Test with the H&K G36E rifle 1st part

The experiment established a cornerstone, already known from the statistics of the Vietnam War, that the Remington caliber 223 (and therefore also the caliber 5.56x 54 NATO) starts the tumbling even after piercing bodies of little resistance. The experiment also showed that backward tilting does not occur on the pitch axis (X) but also in combination with the yaw axis (Y)

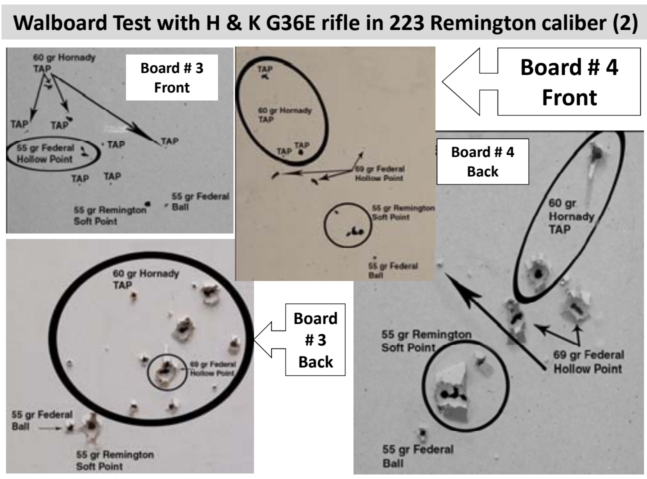

Fig. 16 Wallboard Test with the H&K G36E rifle 2nd part

The triggering of the forces that generate the tumbling was also originated with the rebound of the bullet. Another peculiarity of the 5.56x 45 NATO bullet (which also applies to the 223 Remington) is the possibility that it shatters depending on its speed of impact. In Fig. 17 the results of various firing tests as the respective impact speeds are indicated [22].

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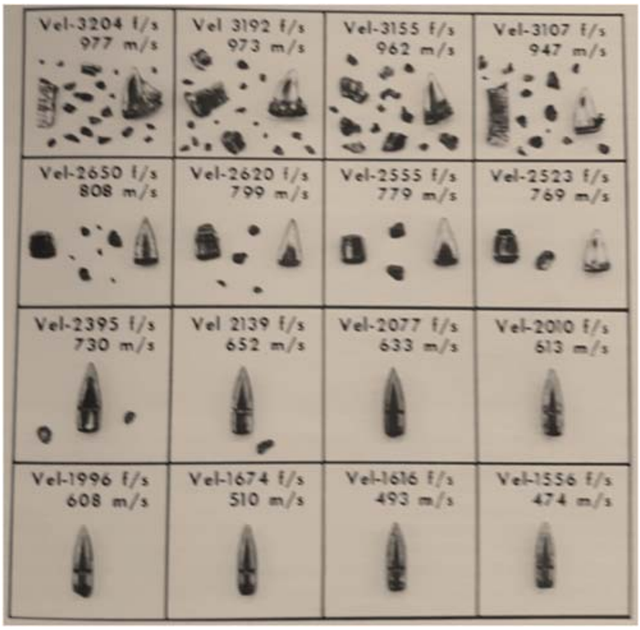

Fig. 17 The fragmentation of a 5,56 x 45 NATO bullet in function of its speed of impact [22]

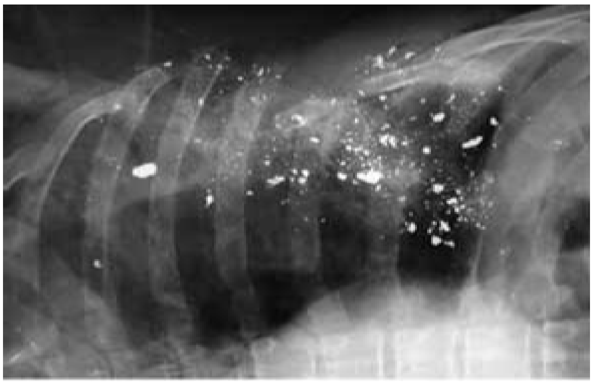

Fig. 18 The fragmentation of the 5,56 caliber bullet occurred in the chest of the victim after the impact with his/her own ribs [23]

In Fig. 18 the dispersion of the metal fragments of the bullet, after the impact with the soft tissues of a human body, was observed by X-rays [23]. As can be seen from Fig. 17, the 5.56 x 45 bullet remains intact if on impact it has a velocity lower than 633 m/sec (2077 f/sec). The initial velocity of 980 m/s decreases to 633 m/s after it is reached a muzzle distance of more than 200 meters. Furthermore, with the due speed, the 5.56 bullet also shatters on impacting bone tissues.

Main Concepts on Bone Fracture

The current literature on bullet-hit bones is expressed in the following points [22]:

- "If a hollow bone is hit by a bullet with a smaller caliber than the diameter of the bone, the fracture is mainly caused by the hydraulic pressure that is created inside the medulla.
- If a bone is flat, (meaning no tissue that can act as a fluid within a closed vessel) the damage caused is typically a simple hole without extensive crack formation. In this case the mechanics are described by applying the impact of a bullet against a rigid layered target. This type of injury is referred to as a "drill hole fracture". However, it should not be understood that the hole is a consequence of the "drilling" action of the projectile which rotates around its longitudinal axis. In fact, it is not the rotational effect that pierces the bone (it is irrelevant to the effects of terminal ballistics), but it is a classic mechanical fracture according to the perforation of laminas, septa and thin materials model.

When shooting at thin targets, a very curious phenomenon is observed. Suppose we are firing a bullet at a sheet of metal. We call threshold energy (E_{THR}) the energy level just insufficient to pierce the foil. If we slightly increase the bullet's energy by bringing it to E_{BUL} ($E_{BUL} > E_{THR}$) it will pierce the foil.

By measuring the velocity of the bullet, we will have a residual energy behind the perforated target (E_{RES}). Surprisingly it should be noted that the energy used for perforation (E_{DRIL}) is less than the threshold energy (E_{THR}) required to pierce the lamina! That is:

$$E_{DRIL} = E_{BUL} - E_{RES} < E_{THR}$$

From the balance of the previous formula, a notable consequence is obtained:

The speed lost in drilling is smaller than the speed required for drilling [22].

The threshold velocity necessary to initiate bone penetration is indicated by several authors as approximately 60 m/sec. (200 ft/sec.) [22], [24], [25]

- Generally speaking, a bullet hitting or puncturing a bone is not deflected from its intra-corporeal trajectory, be it a long or short weapon. There is a systematic exception to this rule, which occurs when a bullet has reached the end of its stroke and has exhausted and almost completely exhausted its penetration rate. In the latter case, the bullet stops within a few centimeters of the bone that deflected its trajectory [22], [26]-[28].

We remind you that the human body, although conceptually identical between subjects, has a rather wide structural variation, and in wound ballistics it happens from time to time some cases that clearly go beyond the general rules and it is difficult to explain [22]"

VI. The Forensic Ballistics

Forensic ballistics is a branch of forensic science that includes investigations in order to reconstruct the events relating to a crime in which a firearm was used, aimed at defining responsibilities and imposing the sentence. One aspect of forensic ballistics involves gunshot wounds.

Engineer Cristian Bettin in his work "Gunshot wounds - 2018 edition" [20] describes very well what wound ballistics is and what it offers:

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"The wound ballistics studies the interaction between damaging agents belonging to the category of kinetic energy penetrators, such as small arms and shrapnel bullets and the target's living biological tissue (humans, animals). It is a branch of general ballistics, limited only to the terminal part, of which it deals with the projectile/splinter interaction considering only live targets.

The wound ballistics studies the dynamics (movements and deformations) of a bullet or splinter within a target and describes the actions as well as the short-term reactions that these dynamics induce in the tissues of the affected organism.

The wound ballistics explains the causes of a gunshot wound, unambiguously describing which physical parameters contribute to causing damage to the target, but does not deal with the consequences on the human body from a medical point of view.

Pathophysiological reactions induced by the stresses generated by the bullet/splinter fall within the sphere of ballistic trauma which includes topics unrelated to wound ballistics, such as blood loss, shock, infections and death."

Gunshot wounds are thus cataloged: [22]

- Penetrating wounds (dead-end): In a dead-end wound, the bullet gets stuck in the body. The channel through which wounds caused by short weapon bullets is often straight. With rifle bullets, the medium may have a deviation of the trajectory even without having come into contact with the bones. Low-energy projectiles can deviate from their trajectory as a result of contact with the bones. In rare cases the bullet follows the curvature of the tissue, for example an intracranial bullet with insufficient energy to pierce or stick into the cranial case at the exit, or on the contrary, insufficient energy to pierce the skull but sufficient to slide under the skin, in contact with the bone.
- Piercing wounds: They are characterized by an exit hole. *Intra-corporeal* passages with deviation from the straight line are rare. Bullets with low energy are unlikely to puncture even outgoing clothes.
- Lacerated wounds: They are due to a tearing or stretching action, as well as cutting. They appear edematous with extensive bruising, necrotic areas and strongly irregular margins; in general, they are scarcely bleeding. They have a marked tendency to infection and therefore require an accurate surgical toilet with removal of the mortified and irregular flaps. It is not always possible to suture them, indeed, in certain cases, it is advisable to leave them open so that they heal by second intention.
- Lacerated-bruised wounds: This type of wound, which combines the nature of lacerated and bruised ones, represents the most frequent traumatic injury. Their characteristic makes them particularly prone to infection and consequently to long healing times with unsightly scarring.
- Smear wounds: The smear creates a "groove" wound on the body surface.
- Rebound wounds: A rebound wound is formed when a bullet is deflected from an intermediate target before hitting the human body. Following the intermediate impact, the bullet will fly with a larger angle of attack than usual and when it hits it will immediately go sideways, causing entry wounds atypical compared to a direct hit.
- Blunt wounds: A firearm generates a blunt wound when the bullet does not have enough energy to pierce the skin and penetrate the body.
- Explosive wounds: When a bullet, with high kinetic energy, hits an organ full of liquid (for example the heart) or the skull, the induced radial pressure can cause the external structure of the organ to burst. If the blow to the head is associated with the expulsion of the brain, the injury is called Krönlein's (by the author who first described the phenomenon) [29].

The identification of the entry and exit holes in perforating wounds is based on the recognition of the morphological signs of the wounds and the traces/residues (textiles or gunpowder) that may be present on the surface of the body and/or on clothing. In some cases, internal indicators of the body may also be useful (for example the distribution of bone fragments, splinters from the bullet or textile fibres). What provides a clear picture is the victim's autopsy examination. In fact, it testifies, in addition to the traumatic cause of death, the path of the bullet inside the body. It can in fact be inferred if the bullet had a linear path or if it had decomposed rotations such as tumbling. In this case a fatal hemorrhage is very easy because the scarring surfaces for hemostasis are of such amplitude that it is not possible to rescue the victim. Another element that can be obtained is the verification of tumbling. In fact, it is possible to establish if the bullet already had this movement before the impact on the victim's body or if this was activated after the penetration process of the bullet.

In the case of the victims of St Antony the autopsy surveys were carried out by Dr. K. Sasikala in the *"Post-Mortem Report of Mr Ajeesh and Mr Valentine 16 February 2012"* [30].

VII. The Forensic Ballistics on the Crime Scene of Crime n. 02/2012

The first case, of forensic ballistic, that is analyzed below is related to the bullet that caused the death of A.JEESH PINK that means the bullet marked with the letter B in Fig. 10. The analysis, however needs to be divided into two separated parts to have a complete picture of indisputable forensic value. The first one involves the intermediate ballistics relating to the trajectory from the shooting point (from now on the SP) to the point of entrance of bullet (from now on the PEB) into the victim's body. The reliable information up to this point are the height of the SP (24 meters above sea level) and the altitude of the PEB (2.26 meters above sea level).

We can have two external ballistics options, mutually exclusive, that, anyway, both fit the two kinematic options mentioned in Section II "The Kinematic Contact":

- The first ballistics option is a direct trajectory. In this case

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the bullet with a muzzle velocity of 980 m/s hit the PEB at a distance of 100/110 meters at a height of 2,26 meters on the sea level (see Fig. 10) with an impact speed of about 780 m/s (see Table I);

- The second ballistics option is a bounced trajectory. In this case, the bullet with a muzzle velocity of 980 m/s hit the point of fall in the water (POF) at a distance of 452,5 meters (see Fig. 12 – the line that solve the problem) reduced its speed of two thirds up to 150 m/s and hit the PEB at a further distance of 47 meters with a residual velocity of about 100 m/s (Interpolation between Table I and Fig. 12).

The second part of the analysis is strictly interconnected with the wound ballistics which means the type of path of the bullet, in the victim's body, from the PEB to its stop point.

The fundamental document for this second part of the analysis is the autopsy examination that allows us to falsify one of the two hypotheses, of external ballistics, previously mentioned.

Dr. Sasikala autopsy examination is thus entirely reported [30]:

"Dr. K.Sasikala, Professor of Forensic Medicine and Police Surgeon, certify as hereunder:-

Dead body of an adult male by name A. JEESH PINK aged about 21 years was sent by the Sub Inspector of Police, Coastal Police Station Neendakara with a requisition dated, 16/02/2012 through the CPO.5297 for conducting postmortem examination and report.

The body was in charge of the CPO.5297 who identified it as that of the deceased in Cr.No.02/12 of Coastal Police Station, Neendakara. The postmortem examination commenced al 3.30 PM on 16/02/2012 and was concluded al 5.30 PM on the same day. The following findings were observed.

Body was that of a moderately nourished adult man of height 162 cm and weight 62 kg. Eyes partly open, conjunctivae pale, corneas clear. Pupils dilated and equal on both sides. Other external body orifices were normal. Finger nails were blue. Dried blood stains were found as streaks on the right side of the chest, top of right shoulder, front of chest and abdomen. Dried blood stains were seen on the inner aspect of right thigh. Fluid blood was found coming through the wound on the right side of front of chest.

Callosities were found (1) on the outer aspect of both ankles (2) on the front and inner aspect of palms and tips of thumb and index finger of both hands. Tattoo mark of 'PINK' was seen on the outer aspect of right arm 15 cm below the top of shoulder. Smell of fish present on the body.

Rigor mortis present in the jaws, knees and ankles and absent in other parts of the body.

Postmortem staining was faint at the back, not fixed. There was no sign of decomposition. (Body was not kept in the cold room).

Injuries (Ante-Mortem):

1. Lacerated penetrating wound of entrance 2.7 x 1.6 cm with an abrasion of 0.2 to 0.3 cm broad around horizontally placed on the right side of front of chest, the inner end 7.5 cm outer to midline and 8cm below collar bone.

The lower margin was 126 cm above heel. Chest cavity was found penetrated through the second intercostal space and third costal cartilage.

The costal cartilage was found fractured and fragmented and the following organs were found transfixed in that order:

(i) middle lobe of right lung 2 x 1.5 cm, 2 cm inner to the inner border and 3.8cm above the lower margin;
(ii) front aspect of pericardium 1,3 x 1.2 cm;
(iii) right atrioventricular junction l.7 x 0.8 cm, 3.2 cm inner to the right border;
(iv) right ventricle interventricular septum and left ventricle obliquely 5.2 x 1.8 cm, 6.5 cm above the apex. Papillary muscles near the interventricular septum was found lacerated and chordae tendinae ruptured;
(v) back aspect of pericardium 3. 7 x 1 cm, 3.9 cm above apex;
(vi) left dome of diaphragm 3 x 1.5 cm, 4.3 cm 10 left of central tendon;
(vii) left lobe of liver 4.5 x 3 cm, 0,5 cm inner to the left margin;
(viii) front wall of stomach l.7x l.3cm, and 3.4cm below the lower curvature and 7.3cm distal to cardiac end;
(ix) back wall or stomach 1.3 x 0.5 cm, 2.4 cm above the greater curvature at the cardiac end;
(x) and terminated in the inner border of spleen 4.3 x 3.7 x 2.9 cm.

A metallic bullet of length 2.4 cm and maximum circumference 1.9 cm with a pointed tapering tip was found in the spleen covered by blood clot.

The bullet was found compressed at the base and the base measured 0.7 x 0.4 cm. Surface of bullet showed multiple vertical markings along the long axis.

Pericardial cavity contained 20 ml of fluid blood and 110 gm of clot. Right chest cavity contained 450 ml of fluid blood 190 gm of clot. Peritoneal cavity contained 120 ml of fluid blood and a few small clots adhering to the omentum and loops of intestine. Wound was directed downwards backwards and to the left obliquely.

2. Lacerated wound 3.5 x 2. 7 x 0.3 cm on the front inner aspect of right forearm the lower margin was 5,5 cm above wrist with a skin flap of size 2 x 1.5 extending downwards from the lower inner margin. The margin around except at the region of skin nap showed an abrasion 0.3 to 0.6 cm broad. Muscles underneath were found exposed.

No burning, blackening or tattooing seen around the injury nos. (1) and (2).

3. Multiple small abrasions 1.6 x 0.5 cm horizontal on the front of right side of chest just outer to the inner end of injury n. (1).
4. Abrasion 0.5 x 0.5, on the inner aspect of right leg 12

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cm below knee.

Brain (1280 gm) congested and edematous. Air passages congested and contained blood stained fluid. Lungs: Right-274 gm, was pale; lcfl-362 gm, was congested. Heart weighed 296 gm. coronary arteries appeared normal. Intima of aorta was red in color. Kidneys (right 142 gm, lefl-112 gms), were pale with distinct corticomedullary demarcation and cortical bleeding. Stomach was full with rice and other unidentifiable food particles having no usual smell, mucosa pale. Urinary bladder empty, its mucosa was normal. All other internal organs were pale otherwise normal.

Opinion as to Cause of Death:

Death was due 10 firearm injury sustained to chest (injury No.1)."

The bullet described a downward trajectory after the PEB to its arrest point in the spleen where was found intact. Its trajectory is highlighted in 10 steps from the autopsy exam (Fig. 19).

The projectile ended its trajectory without crumbling but it was recovered whole; which means that it had a speed at the PEB less than 635 m/s (see Fig. 17). Furthermore, at the PEB the bullet fragmented the third coastal cartilage that means that it has a speed of impact of more than 60 m/s. In addition, as can be seen in Fig. 20, the sections of the internal cavity are very different for any other of the ten points mentioned.

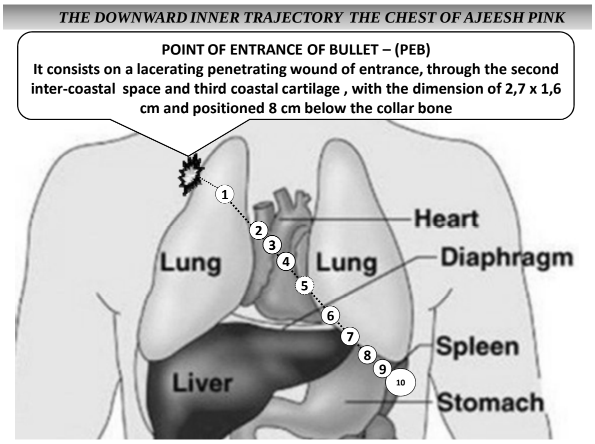

Fig. 19 The PEB and the ten passages described in the autopsy exam

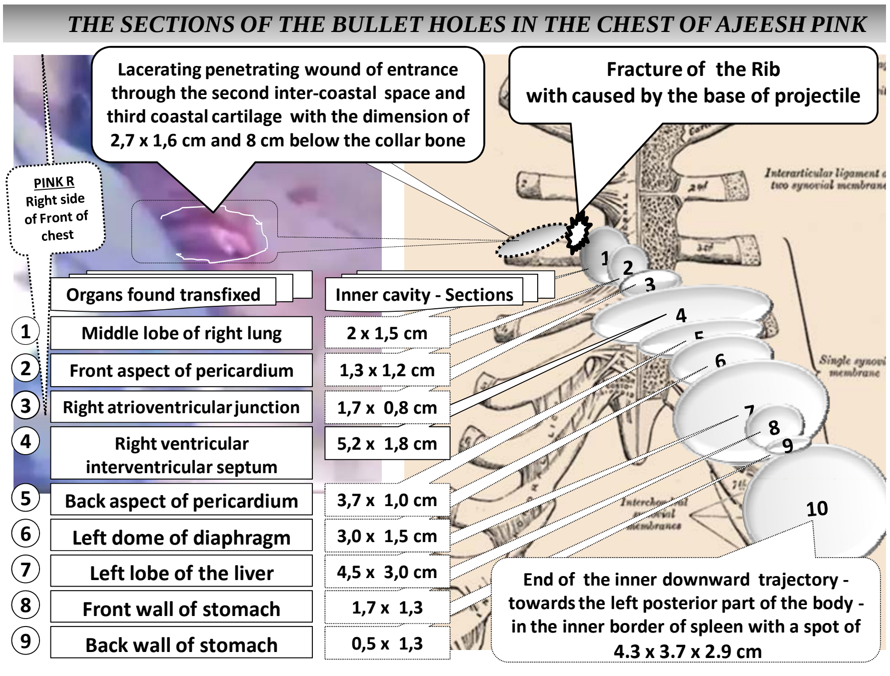

Fig. 20 The PEB and the ten passages described in the autopsy exam

The sections are ellipsoids, identified by a major and a minor axis[8] with different length from the counterpart of the other sections as seen in Fig. 20. That means that the bullet had a tumbling motion inside the victim's body. In fact, if it had been a direct trajectory, despite an impact speed less than 635 m/s (for any possible aside reasons), the internal path would still have had a linear cylindrical cavity. We must also consider that at the PEB the wound did not consist of a cylindrical hole without abrasions but in one lacerated penetrating wound of entrance 2.7 x 1.6 cm with an abrasion of 0.2 to 0.3 cm broad around as mentioned in the autopsy exam. Furthermore, the rib would have been perforated by a cylindrical hole and no displaced fracture would have been detected. In fact, in the recovered projectile there is a deformation at the base that is no longer cylindrical with a

[8] For the sake of completeness, sections 1 to 10, shown in Fig. 20, are on a scale of 1 to 1.

radius of 0.7 mm but a compressed ellipse with axes 0.4 by 0.7 (Fig. 21) which means that the bullet hit not with the front section, but with the lateral longitudinal section. This unequivocally postulates that the bullet was in tumbling before reaching the PEB and had blasted on the water. Basically, the first ballistic option is scientifically excluded while the only alternative is the second ballistic option that means the rebound of bullets. In a nutshell, as graphically shown in Fig. 21 after the rebound, the bullet took an upward trajectory and a backward tilting movement. It hits the knee first and then the victim's forearm reaching the PEB with a speed of about 100 m/s. It hit the third in an upright position, shattering it[9]. It bounced off the second rib taking a downward trajectory ending in the victim's spleen.

From the autopsy examination it is not possible to identify the orientation of the axes (minor and major) of the 10 sections of the internal trajectory with respect to the sagittal line of the victim's body. However, the aforementioned orientation is irrelevant to the analysis conducted. In fact, whatever the rotation axis of the tumbling has been, it does not change the effects of the Wound Ballistics or those of the ballistic trauma.

The second case, of forensic ballistic, that is analyzed below is related to the bullet that caused the death of Valentine Jelestine that means the bullet marked with the letter A in Fig. 10.

Dr. Sasikala autopsy examination is thus entirely reported [30]:

"I, Dr. K.Sasikala, Professor of Forensic Medicine and Police Surgeon, certify as hereunder:-

Dead body or an adult male by name VALENTINE@ JELESTINE, aged about 50 years was sent by the Circle Inspector of Police, Coastal Police Station, Neendakara with a requisition date, 16/02/2012 through the CPO.No.5255 for conduc1ing postmortem examination and report.

The body was in charge of the CPO.No.5255 who identified it as that of the deceased in Cr.No.02/12 of Coastal Police Station, Neendakara. The postmortem examination commenced at 2.00 PM on 16/02/2012 and was concluded it 3.30 PM on the same day. The following findings were observed.

Body was that of a moderately nourished adult male of height 164 cm and weight 57 kg. Fluid blood present in right ear and scalp hairs. Scalp hairs on the right side of front of head matted with blood. Right side of face swollen. Dried streaks of blood seen on the lower lip, front of chest and right side of neck and dried blood stains present on palms and fingers of both hands and lower lip. Right leg slightly abducted at the hip and flexed at knee. Eyes partly open, conjunctivae pale, cornea clear, pupils dilated. Finger nails blue and mouth pale. Smell of fish present on the body. Callosity (i) 3.5x2x 1.2cm on the outer aspect of left foot 3.5cm below the outer aspect of ankle (ii) 2x2x2cm on the outer aspect of right foot 3cm below ankle.

[9] The fracture is justified by the previous assumption: If a hollow bone is hit by a bullet with a smaller caliber than the diameter of the bone, the fracture is mainly caused by the hydraulic pressure that is created inside the medulla.

Rigormortis present in knee und ankles, feeble at hip and absent in other parts of the body. Postmortem staining was faint at the back, not fixed. There was no sign of decomposition. (Body was not refrigerated).

Injuries (Ante-Mortem);

1. Lacerated penetrating wound of entrance: 1 x 0,7 cm with an abrasion collar of 0,1 to 0.2 cm broad around, obliquely placed on the right check, its upper inner margin 3.7 cm outer to the lower margin of right ala of nose and 4 cm below the outer angle or eye (and was 8.5 cm in front of the tragus of ear). A small piece of skin tag of size 0.5 x 0.2 cm was found on the outer margin just above the lower border.

The lower margin was 154 cm above heel. There was no evidence of burn, blackening or tattooing around. Abrasion collar was wider on the inner margin. Soft tissues of right side of face showed infiltration or blood over an area of 10,5 x 10 cm extending up to the coronoid process of jaw bone and was found extending downwards to the lower margin of submandibular salivary gland and to back of tongue and to the lower border of hyoid bone over an area of 6.2 x 2 x 0.3 cm. The wound track was found extending obliquely upwards by fracturing the coronoid process of mandible, entered the skull cavity through the petrous part of temporal bone with the wound of exit 0.7 x 0.7 cm on the back aspect in the petrous part of temporal bone 0.8cm behind the pituitary fossa and 1.2 cm 10 right midline.

Dura around was found tom irregularly backwards with the small bony fragmented around found attached to its edges. Whole of petrous part of temporal bone fractured and fragmented and was found extending to the front wall of pituitary fossa and found separating it from the body of sphenoid bone.

The right half of fragmented petrous part of temporal bone and adjoining middle cranial fossa was found separated from the posterior cranial fossa. Pituitary gland showed softening. Under aspect of right frontal lobe, 6.4 cm below the tip showed a contusion 1.5 x 1 x 3 cm. A metallic bullet with a pointed tip was found on the under surface of brain in the subdural space. It measured 3.1 cm in length and 2 cm in circumference al a point 2.4 cm above the base. The tip was pointed. 11 was found irregularly compressed side ways at the base with a bent in the upper half. The base was hollow and measured 0.6 x 0.4 cm. Multiple markings were seen on the surface along its long axis. Brain showed bilateral subarachnoid bleeding. Fluid blood present in the ventricles. Sulci narrowed and gyri flattened. The track of the wound was directed upwards backwards and to the left in an oblique line.

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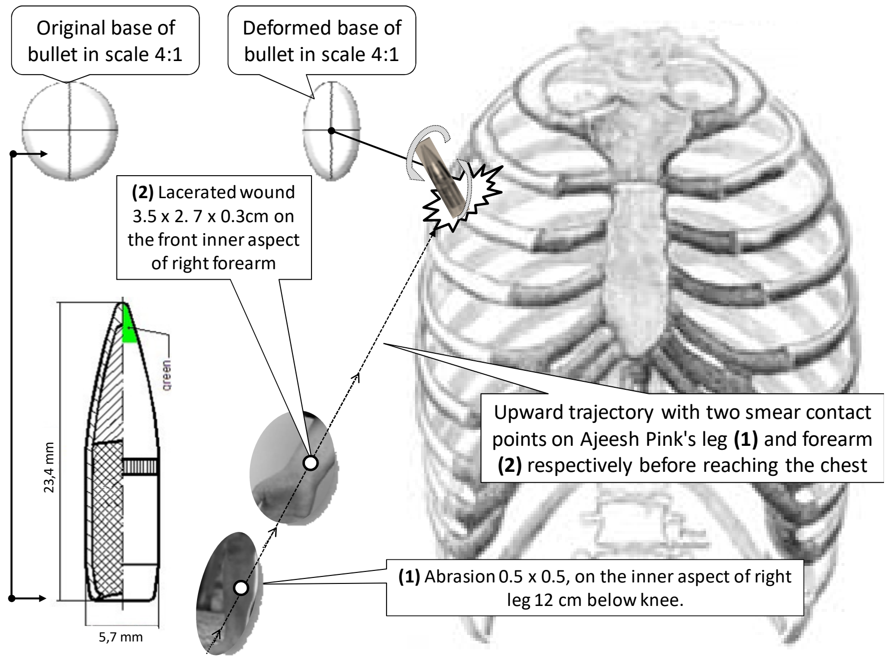

Fig. 21 The upward trajectory before the PEB

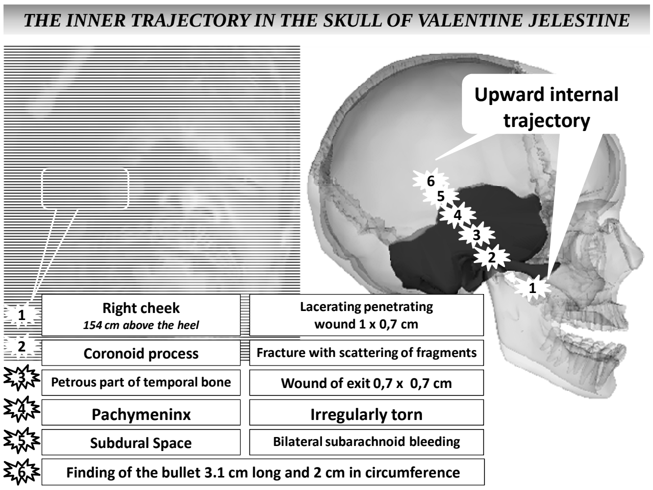

Fig. 22 The upward trajectory on the body of Jelestine Valentine

2. Contusion of scalp 1.2 x 1 x 0.3 cm on the top of head in the midline and 11.5 cm above the root of nose.
3. Multiple small abrasions over an area of 1.5 x 0.5 cm on the bock of right arm 3 cm above elbow.
4. Abrasion 0.7 x 0.5 cm on the outer aspect of right elbow with a curved abrasion 0.8 x 0.3 cm on the outer end.
5. Abrasion 1.2 x 0.5 cm, on the front of the leg 10 cm below knee
6. Multiple small abrasion over an area of 1 x 0.5 cm, on the front of left leg 7cm below the knee.

Opinion as to Cause of Death:

Death was due to firearm injury sustained to Head (injury No.1)."

The trajectory describes an upward trajectory like it is modeled in Fig. 22. As you can see, the blow was directed from the bottom towards the aft and impacted the victim's skull at an estimated speed of 100 m/sec similar to the one against PINK.

There was no fracture but only perforation as the skull is made up of flat bones without medulla[10]. Also, in this case the first ballistics option is not applicable, and then only the second ballistics option which fully fits the fire scenario.

For the other shots that hit the fishing boat (as per Fig. 10) it is necessary to refer to the ballistic report of Dr Nisha [11].

In particular on reference to the bullet n. 1 of Fig. 10 reported the projectile trajectory n. 3 of ballistic report [11]:

> "Projectile Trajectory No.3: An oval shaped hole of dimension 5.1 mm x 5.5 mm was found on the outer side of the starboard side wall of the wheelhouse at a distance or 67 cm from the rear right corner of the wheelhouse at a height of 82 cm from its deck. Inversion was found on the edges of the hole. This could be the entry hole of the projectile. Another oval shaped hole of size 5.3 mm x 5.7 mm was found on the inner side of the same wall at a height of 55 cm from the wooden floor of the wheelhouse. Eversion was found on edges of the hole. This could be the exit hole of the projectile -on the wheelhouse wall. An oval shaped hole of dimension 7.7 mm x 26.9 mm with inverted edges was seen on the regulator of the LPG cylinder (with number GM/L 8756004) which was placed on a pit on the rear portion of the wheel house. The oval shaped hole on the regulator was at a distance of 71 cm from the exit hole on the

[10] If a bone is flat, (meaning no tissue that can act as a fluid within a closed vessel) the damage caused is typically a simple hole without extensive crack formation. In this case the mechanics are described by applying the impact of a bullet against a rigid layered target.

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wheelhouse watt. From inside the regulator, steel core of a bullet and some other metallic fragments having the appearance of lead were recovered. Holes of dimension 6.1 mm x 6.S mm, 6.4 mm x 4.8 mm, 5.5 mm x 7.1 mm and 4.8 mm x 4.7 mm were also seen on the regulator which could be the exit holes of the fragmented pieces. The remaining pieces of the bullet could not be recovered. After passing through the wheelhouse wall, the bullet may hit the regulator of the LPG cylinder and got fragmented. The direction of trajectory of the bullet was downwards and point toward the sea.

In Fig. 23 there are pictures showing the entry hole of the bullet. Fig. 23 also shows the section of a 5.56 bullet and compares with the sections of the entry and exit holes from the vertical bulkhead.

As you can see, the analogies with the wallboard test (aforementioned Figs. 15 and 16) clearly show that the bullet had an interference that can only be justified by the bounce on the water. In fact, the traces of the abnormal dimensions of the entry and exit holes on the side bulkhead clearly indicate the anomalous rotation of the bullet and an upward trajectory. This is also confirmed by Fig. 24 which clearly indicates that the regulator of the LPG cylinder (with number GM/L 8756004) is 10 cm higher than the wheelhouse floor than the hole inside the bulkhead. Also in this case, the first ballistics option is not applicable, and then only the second ballistics option which fully fits the fire scenario.

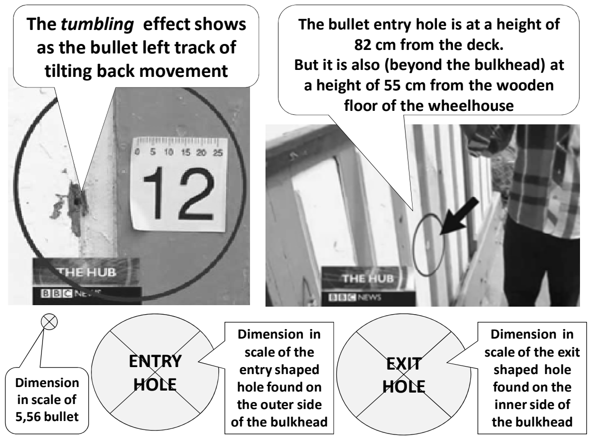

Fig. 23 The dimensions of the entry hole in the outer vertical bulkhead

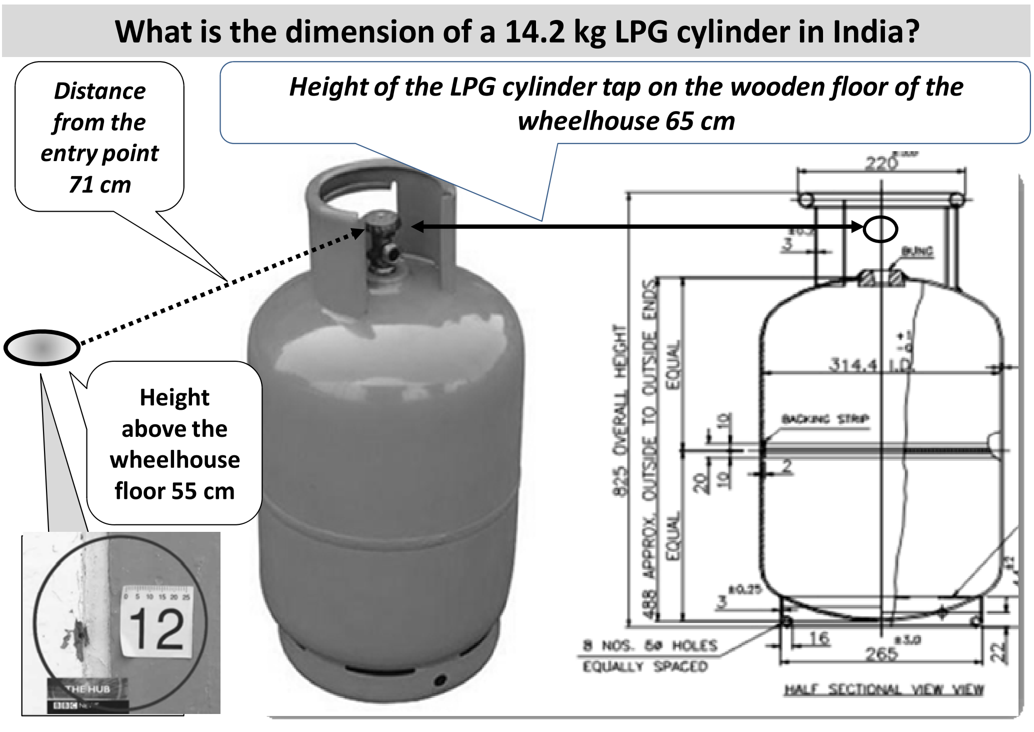

Fig. 24 The quote of the regulator of the LPG cylinder was 10 cm higher than the quote of the entry hole in the bulkhead [31]

In particular on reference to the bullet n. 2 of Fig. 10 reported the projectile trajectory n. 2 of ballistic report [12]:

"Projectile Trajectory No.2: In the fishing boat, two oval shaped holes of dimension 5.5 mm x 2.2 mm and 4.2 mm x 3.6 mm were found each on the edges of two perpendicularly placed wooden planks on the outer rear corner on the starboard side wall of the wheelhouse. It was at a height of 159.4 cm above the deck of the boat. Inversion was seen on the edges of both holes. This could be the entry holes of the projectile. Another oval shaped hole of dimension 3.0 mm x 2,2 mm was detected on the right corner of rear side wall of the wheelhouse. It was at a height of 158 cm from the deck of the boat. Eversion was seen on the edges of this hole. This could be the exit hole of the projectile. On visual examination, pattern of deposit of gunshot residues were not detected around any

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of the holes specified above. On examination it was found that the path from entry to exit of the projectile on the wooden plank was a straight line of length 1.2 cm. The direction of trajectory of the projectile was downwards and pointed towards the sea."

In Fig. 25 the photos show the side of the vessel hit as indicated in the ballistic report. Also, in this case the first ballistics option is not applicable, and then only the second ballistics option which fully fits the fire scenario. In fact, if it had been a direct trajectory the projectile number 2, from an altitude of 24 meters on the sea level, after hitting the deckhouse on the starboard side had stuck on the main deck not being able to end up in the sea. Just as the first ballistic option for shots 3 and 4 (already mentioned in Fig. 11) cannot be applied as seen in the summarized Fig. 26.

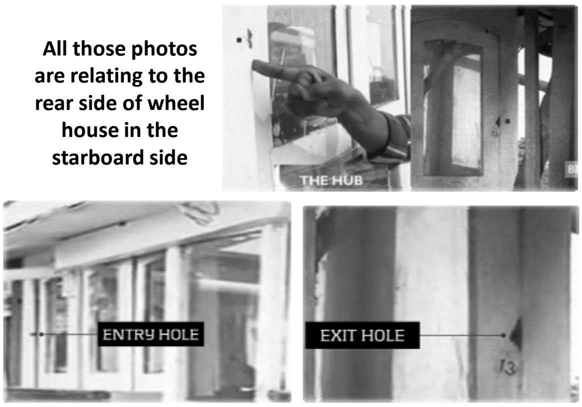

Fig. 25 Pictures related to projectile trajectory number 2

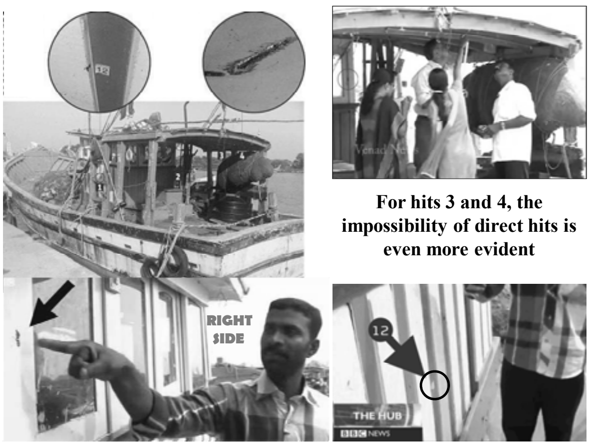

Fig. 26 The final evidence of upwards trajectories for all the bullets that hit the fisher-boat

VIII. Conclusion

As conclusive remarks it can be established that all the shots that hit the St. Antony bounced off the water. From the judicial point of view this proves that it was a deterrent fire authorized by the international soft law standards promulgated by the International Maritime Agency (IMO). But it is equally true that the safety rules for the deterrent should be revised in consideration of having corner safety sectors inhibited from deterrent fire.

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