Naval Gunnery and Early (Mechanical) Computers

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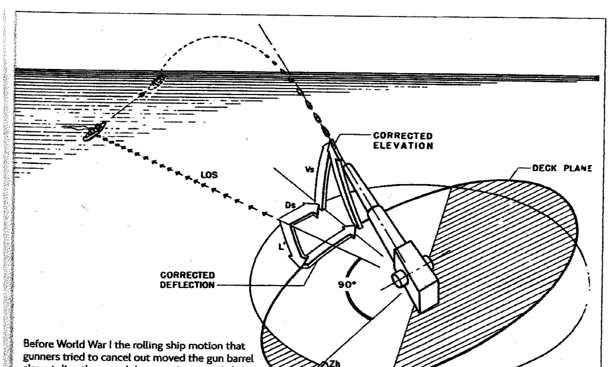
Spring 2013

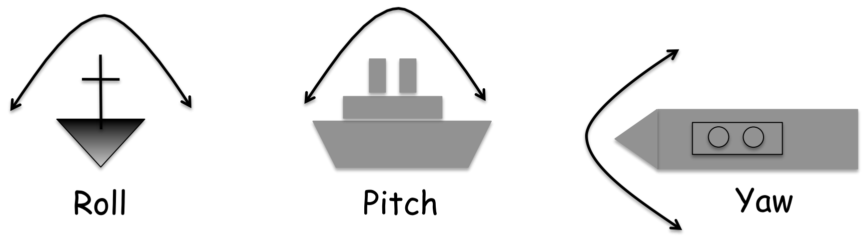
The Gunnery Problem

- Cancel ship's motion
- Range to target
- Range keeping
- Actual shooting



Before World War I the rolling ship motion that gunners tried to cancel out moved the gun barrel almost directly up and down, as it pointed along the broadside. Guns pointing closer to fore and aft were affected by trunnion tilt; the effect of which is shown in this diagram from the 1950 edition of the US Navy's gunnery manual. The US Navy called the effect cross-roll, and the fixed stable vertical (Mk 32) introduced in the 1930s made it possible for a ship to fire at a selected point in the cross-roll. By World War II remote power control made it possible for guns to move to cancel out cross-roll altogether. This diagram shows the effect of trunnion tilt and the sort of corrections needed to deal with it. LOS is the line of sight to the target, the line in which a director *not* corrected for cross-level would point a gun. The gun is mounted in the deck plane, and it is aimed with respect to that plane, but fire control is calculated for a horizontal (non-rolling and -pitching) plane. Until after World War I, navies assumed, in effect, that guns would be fired on the broadside, and that correction had to deal only with the rolling motion of the ship that in effect elevated and depressed them. World War I showed that ships would often fire close to the fore and aft line, so that trunnion tilt might be just as important as the up and down movement of the line of sight. Dealing with trunnion tilt required correction in both train and elevation, but train was the more important error.

The Gunnery Problem

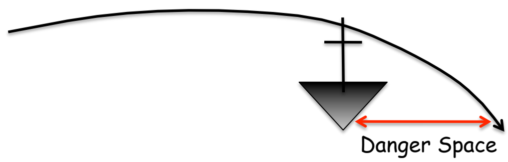


- Continuous aiming only made possible by gyroscopes

Longer Ranges and Larger Guns

- Torpedo Threat (Russo-Japanese War): engage at > torpedo range
  - 800-1500 yds, to 3500 yds at reduced speed
  - Improved to 10000 yds between 1900-1914
- Plunging fire: armor below/above the waterline or topside
  - Heavier guns, flatter trajectories, longer danger space
  - 2x shell weight, 4x distructiveness

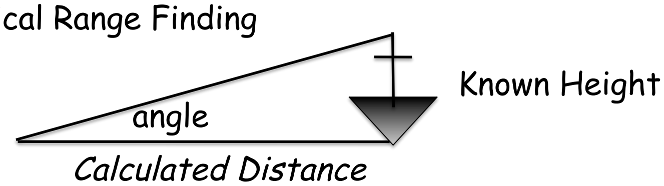
"Danger Space"



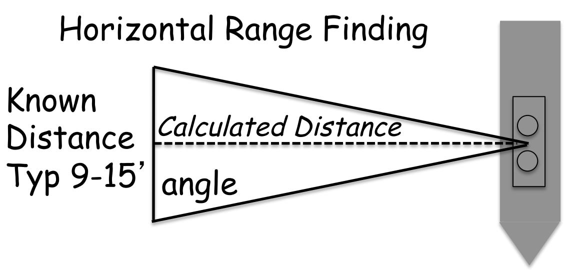
	13.5in/45	12in/50
Muzzle velocity	2060 feet/sec	2567feet/sec
danger space at		
2000 yards	348 yards	572 yards
4000 yards	157 yards	227 yards
8000 yards	58 yards	75 yards
12,000 yards	28 yards	33 yards

Range Finding

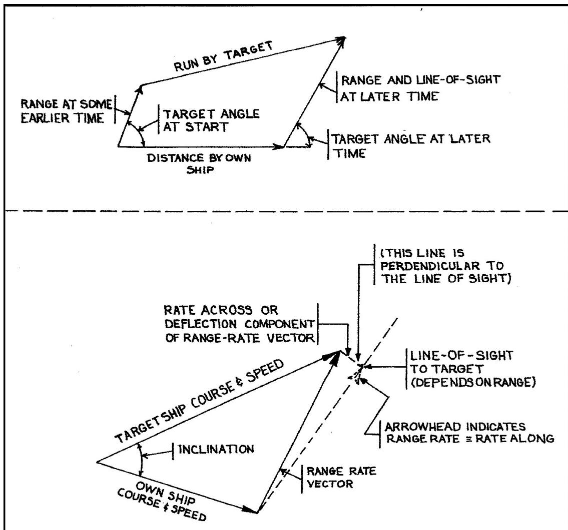
Vertical Range Finding



Horizontal Range Finding



What happens at night?



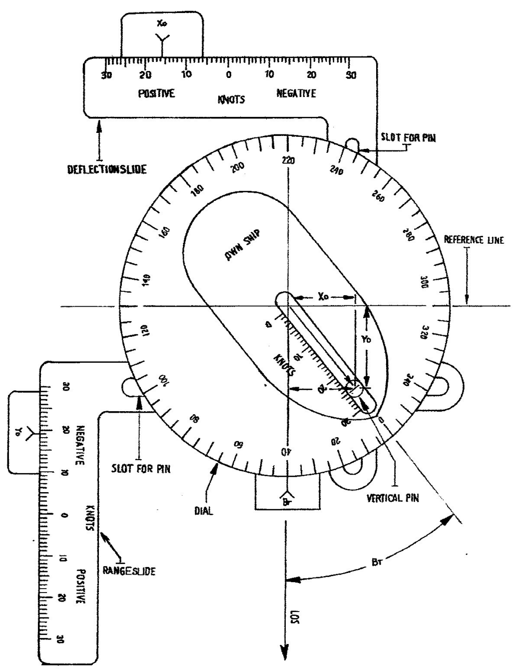
As a gunnery lieutenant, John Saumarez Dumaresq made a fundamental discovery: that the range rates (across and along) did not depend on the range, only on target course and speed. The top diagram shows the gunnery problem (it did not matter whether the target is moving towards the shooter or away from it). The lower diagram shows the way in which the rates at which own ship and target move (their course and speed) give the rate (a vector: speed and direction) at which the range is changing – the quantity the fire-control system needs. The Dumaresq gives the two components of the vector, the rate along (in the direction from shooter to target), which was also called the range rate, and the rate across (deflection – but in knots, not in terms of degrees of bearing). The Dumaresq modelled the situation, using a bar pointing at the target to select the range-along component of the range rate. Own-ship and enemy-ship bars modelled the vectors of own-ship and enemy-ship course and speed. The operator had to estimate inclination (the angle between own and enemy course) and enemy speed. Dumaresqs and their equivalents were the basis for the later mechanical fire-control computers, because they enabled the computers to translate enemy-course and speed estimates into rates that could be integrated to give range and bearing.

(A D BAKER III)

Range Keeping

Dumaresq's idea survived into World War II fire-control computers, but typically own and target motion were separated. The US Navy's component solver, illustrated here, was essentially a Dumaresq, displaying the range rate (vertical slide) and the rate across (deflection slide, horizontal). In effect the motion of the other ship was set to zero (a separate dial gave data for the other ship). The positions of these slides in turn represented quantities that could be added and multiplied to produce range rates for integration. The relationship between rate along and rate across is set by the pin in the dial showing speed and bearing (Br). A range-keeper had two such dials, one for target and one for own ship, set so that the line of sight (LOS) connected them. The target dial in turn rotated as the fire-control solution was generated.

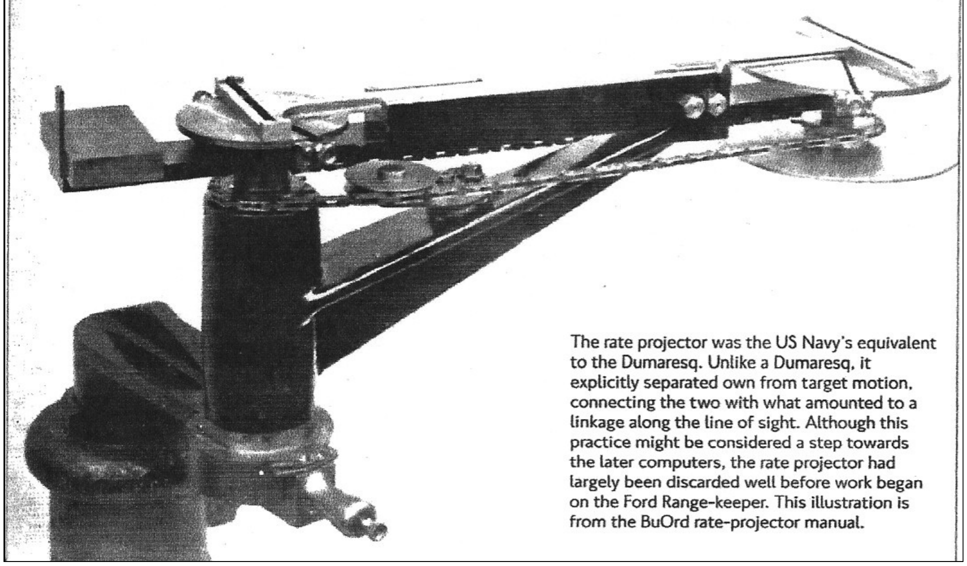
(A D BAKER III)



PRINCIPLE OF THE COMPONENT SOLVER

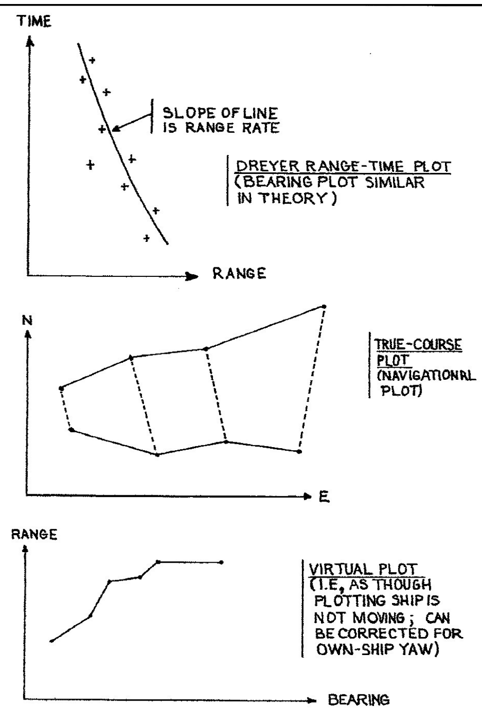
Range Keeping

Range Keeping

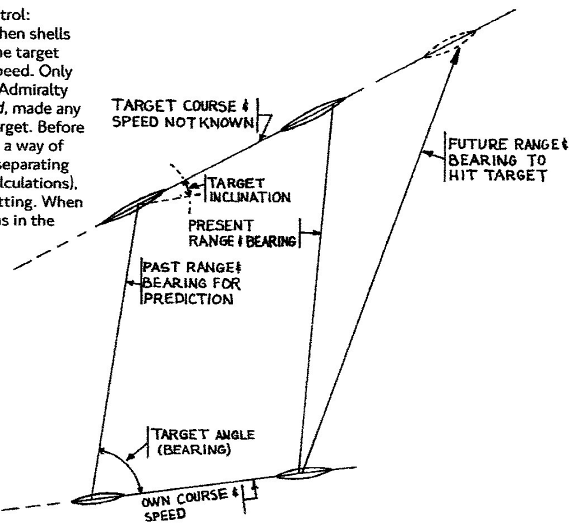


The rate projector was the US Navy's equivalent to the Dumaresq. Unlike a Dumaresq, it explicitly separated own from target motion, connecting the two with what amounted to a linkage along the line of sight. Although this practice might be considered a step towards the later computers, the rate projector had largely been discarded well before work began on the Ford Range-keeper. This illustration is from the BuOrd rate-projector manual.

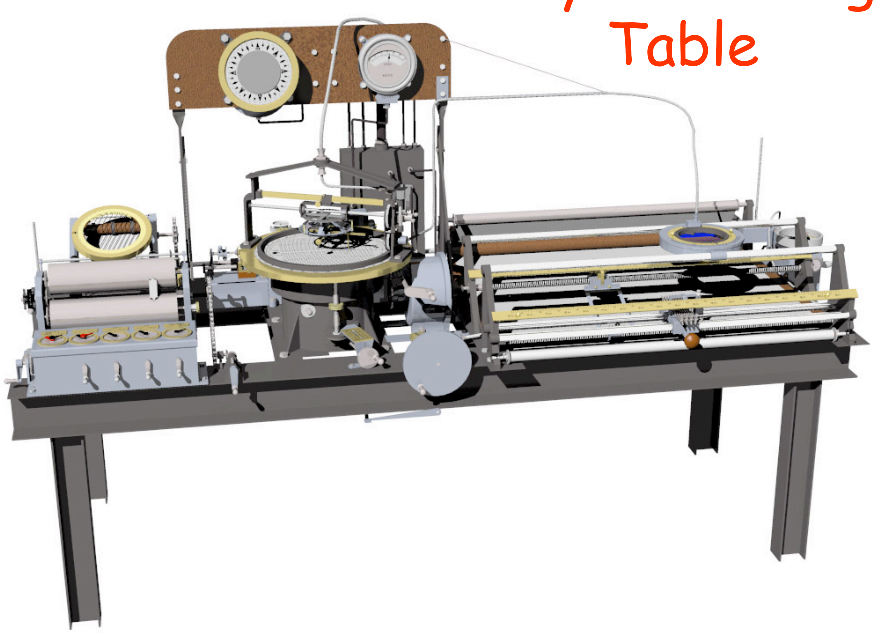
Navies tried three different kinds of plotting to project ahead target range and bearing. One method was to separate out range and bearing in the hope that although they were actually interconnected, that connection would be relatively weak. This was Dreyer's concept. A range-versus-time plot (which the US Navy called, simply, a plot) is shown. The alternative (tracking, to the US Navy) was to try to reproduce the actual motions of shooter and target. In this sketch, the dashed lines represent observations of range and bearing by the shooter (the lower line); the straight lines between observations are estimates of motion. Pollen tried to mechanise this type of plotting. It became easier once good gyro-compasses became available. The third type was a virtual-course plot, as though the plotting ship was not moving. It turned out to be the worst of all, because own and target motion could not easily be disentangled.
(A D BAKER III)



Range-keeping was the basis of fire control: predicting where the target would be when shells had to arrive. Prediction required that the target follow a straight course at a constant speed. Only the very last mechanical computer, the Admiralty Fire Control Table Mk X in HMS *Vanguard*, made any attempt to deal with a manoeuvering target. Before that, the mechanical computers offered a way of dealing with own-ship manoeuvers (by separating own-ship from target motion in their calculations), so that a ship could manoeuvre while hitting. When two ships with such systems engaged, as in the Komandorski Islands in 1943, the results could be entirely indecisive, because both ships could manoeuvre freely. Systems began with what could be measured directly: target bearing angle and target range. Since they could be measured at intervals, as shown, the rates at which they changed could also be measured. That was not enough, because the rates varied over time (and were interconnected). After World War I several navies bought inclinometers, which tried (with limited success) to measure target inclination, ie, course, range, bearing rate, and inclination together gave target speed. Present range and bearing are where the target is right now. The gun has to be pointed ahead of the target (deflection) and aimed at a different (advance) range to hit. The official Italian fire control handbook published in 1933 described a series of six alternative pairs of data that could be used for prediction. Which were best depended on the circumstances.
(A D BAKER III)



Dryer Plotting Table



For More Information

- http://en.wikipedia.org/wiki/Frederic_Charles_Dreyer
- http://www.dreadnoughtproject.org/