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Weight of Shell Must Tell: A Lanchestrian reappraisal of the Battle of Jutland

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ABSTRACT: We re-analyse the 1916 battle of Jutland, the major naval engagement of the First World War, in the light of the understanding of dreadnought fleet tactics that developed over the decade leading up to it. In particular, we consider the interaction of the calculus of Lanchester's Square Law with fleet geometry and the commanders' decisions that determined it, and with the shipbuilding decisions associated with the Lanchestrian trade-off between quality and quantity. We re-examine the behaviour of the commanders in the light of this tactical analysis, and conclude that the outcome of Jutland, in spite of apparent British tactical and technological failings, was the culmination of a decade of consistent and professionally insightful decision-making by the Royal Navy, which built and correctly wielded its decisive weapon, the Grand Fleet, to achieve the required strategic victory.

The 1916 Battle of Jutland remains a subject of undiminished controversy as its centenary approaches.[1] Much of this debate revolves around the question of victory and defeat, and the performance of the British commander, Admiral Jellicoe. The logical tension created by a rare combination of strategic victory and apparent tactical defeat naturally defies consensus. On the one hand Jellicoe, famously the only man on either side who could lose the war in an afternoon, was equally aware that he could not win it in the same time span and receives praise for a calculated performance that maintained Britain's naval supremacy despite a negative and dispiriting exchange of human and material losses. Conversely, Jellicoe's apparently un-British playing of the percentages is contrasted with his subordinate Beatty's embrace of the Nelsonian tradition of dash and daring, which, critics argue, could have delivered a crushing and unequivocal victory to Britain at a pivotal point in the war. The emotional edge to this debate is fuelled further by the addition of a declinist narrative, which places Britain's dramatic losses of capital ships in the context of a perceived ongoing and accelerating industrial and institutional failure, particularly relative to Germany.[2]

[1] The early controversy began with J. E. T. Harper's *Naval Staff Appreciation* (later moderated into K. G. B. and A. Dewar, *Narrative of the Battle of Jutland* (London, 1924)), which was highly critical of Jellicoe (see also J. E. T. Harper, *The truth about Jutland* (London, 1927) and J. E. T. Harper and L. Gibson, *The Riddle of Jutland* (London and New York, 1934)). The written battle raged thereafter, exemplified by the pro-Beatty C. Bellairs, *The Battle of Jutland: the sowing and the reaping* (London, 1920) and the pro-Jellicoe Adm. Sir Reginald Bacon, *The Jutland Scandal* (London, 1924. The definitive history is A. J. Marder, *From the Dreadnought to Scapa Flow: The Royal Navy in the Fisher era, 1904-1919*, 5 vols (Oxford, 1961-1970). For an accessible modern summary see P. Hart and N. Steel, *Jutland 1916 – Death in the Grey Wastes* (London, 2003). For current German perspectives see M. Epkenhans, J. Hillmann, F. Naegler, *Skagerrakschlacht: Vorgeschichte – Ereignis – Verarbeitung* (Munich, 2009). Regarding our title we note that Jellicoe wrote to Churchill on 14/7/1914 that 'The Germans would argue that their guns are of sufficient power to carry their projectiles through our comparatively weak armour [and] it has not been necessary to have heavier guns hitherto. I do not agree with them because I attach so much importance to weight of bursting shell'. A. Temple Patterson ed., *The Jellicoe Papers: selections from the private and official correspondence of Admiral of the Fleet Earl Jellicoe of Scapa* (Navy Records Soc., vols 108 and 111, 1966 and 1968), vol.I, item 31. Fisher was typically more exclamatory: 'After all, the immense superiority of our 13.5" guns MUST tell' (Fisher to Jellicoe, 21/1/1915, Jellicoe Papers, item 103).

[2] See, for example, C. Barnett, *The Swordbearers: Supreme Command in the First World War* (London, 1963). The second of the four case studies in the book is 'Sailor with a flawed cutlass: Admiral Sir John Jellicoe'. The thesis is critiqued in E. Grove, 'How flawed really was Britain's cutlass? A critique of the Barnett thesis', in A. Clesse and C. Coker, *The Vitality of Britain* (Luxembourg, 1993).

Recent work has tended to emphasize either technical issues or command and control within the wider context of the Royal Navy's organizational culture.[3] However, from one crucial perspective Jutland has yet to be addressed. Fifty years of technical development of capital ships had been accompanied by scant hard evidence concerning how best to use them: yet fleet tactics had to be developed, and there is a large body of writing on the topic from the twenty years preceding Jutland, almost entirely neglected in the recent resurgence of pre-First World War naval history.[4] Its central theme is of the quantification and mathematization of the role of the 'big gun'. In the early twentieth century, theorists in many countries were exploring means of predicting victory or defeat in battle through the use of geometry and calculus. The most famous example is the British engineer and scientist F.W. Lanchester's 'square law', which provided a revolutionary understanding of the effects of modern weaponry, and predicted that an outgunned force was likely to suffer an accelerating rate of loss relative to its opponent until it was completely destroyed.[5] Even military

[3] A substantial body of work by Sumida explores various aspects of the use of this rapidly-changing technology, ranging from the problem of fire control (J. T. Sumida, 'British Capital Ship Design and Fire Control in the Dreadnought Era: Sir John Fisher, Arthur Hungerford Pollen, and the Battle Cruiser', *Journal of Modern History*, 51 (1979), pp. 205-230) to that of the optimal range at which to fight (J. T. Sumida, 'A Matter of Timing: The Royal Navy and the Tactics of Defensive Battle, 1912-1916', *Journal of Military History,* 67 (2003), pp. 85-136), although his conclusions are disputed (M. Seligmann, 'A German preference for a medium-range battle? British assumptions about German naval gunnery, 1914-1915', *War in History,* 19 (2012), pp. 33-48). The technical aspects of gunnery control are dealt with by John Brooks, *Dreadnought Gunnery and the Battle of Jutland: The Question of Fire Control* (Abingdon, 2005), caustically reviewed by Sumida (J. T. Sumida, 'Gunnery, Procurement, and Strategy in the *Dreadnought* era', *Journal of Military History,* 69 (2005), pp. 1179-1187; response by J. Brooks, *Journal of Military History,* 70 (2006), pp. 195-200). Lanchestrian thinking is never discussed explicitly in this literature, but Sumida notes the dynamic nature of British tactical thinking, and the Royal Navy's `Intelligent consideration of … fleet fire and movement – that is, the naval historical equivalent of "inherent military probability"'. The Royal Navy's organizational culture and its effect on command and control is explored in a landmark work by Gordon (Andrew Gordon, *The Rules of the Game: Jutland and British Naval Command* (Annapolis, 1997)). However, Gordon does not discuss fleet tactics. The point that they should not be neglected after a period of rapid technological change is made in M. Allen, 'The Deployment of Untried Technology: British Naval Tactics in the Ironclad Era', *War in History,* 15 (2008), pp. 269-293.

[4] Examples will be given below. The most comprehensive bibliography is in Wayne P. Hughes, *Fleet Tactics* (Annapolis, 1986). For a summary of recent work by historians se M. S. Seligmann, 'The renaissance of pre-First World War naval history', *Journal of Strategic Studies,* 36 (2013), pp. 454-479.

[5] F. W. Lanchester, *Aircraft in Warfare: the Dawn of the Fourth Arm* (London, 1916), based on articles in *Engineering*, 98 (1914), pp. 422-423 and pp. 452-453.

analysts, however, are often unaware that the essential conclusions of the Square Law were independently arrived at in the USA (twice), Russia and France.[6] This body of work warned against accepting battle if even slightly outnumbered, and stressed the desirability of an initial unopposed period of fire, however brief, and of dividing an enemy force and destroying it in detail.

The effect of such thinking on the contest between British and German battlefleets was profound. Jellicoe informed Lanchester that 'your N-square law has become famous in the Grand Fleet',[7] and at the strategic level the high German concept of the naval war against Britain, the risk fleet [Risikoflotte], evolved into a classic Lanchestrian plan of detaching and destroying a portion of the larger Grand Fleet and then engaging the remainder on equal or numerically favourable terms [Kraftausgleich].[8]

From the Lanchestrian perspective, apparent certainties relating to Jutland become problematical. The German concentration on armour protection at the expense of gun-power, for example, was not necessarily more rational than the British aim of producing a larger number of hulls with greater numbers of higher calibre guns while cutting expensive corners with lighter and less intricately arranged armour. Nor does this contrast in preparation inevitably paint a picture of British technical and industrial decline, instead suggesting a more nuanced quantitative understanding of the mechanics of fleet action than that of the potential enemy. Similarly, we can now provide a clearer

[6] J. V. Chase, 'A Mathematical Investigation of the Effect of Superiority of Force in Combats Upon the Sea', unpublished secret paper, 1902 (reprinted in Appendix C of Fiske, Fighting Machine, below); Bradley A. Fiske, 'American Naval Policy', USNI Prize Essay, *Proceedings of the United States Naval Institute* [PUSNI] 31 (1905), pp. 1-80; Bradley A. Fiske, *The Navy as a Fighting Machine* (New York, 1916; reissued in the *Classics of Sea Power* series, Naval Institute Press, Annapolis, 1988; Lt A. Baudry (French Navy), *The Naval Battle: studies of tactical factors* (London, 1914); M. Osipov, 'The influence of the numerical strength of engaged forces on their casualties' (1915), translated by R. Helmbold and A. S. Rahm, *Naval Research Logistics*, 42 (1995), pp. 435-490.

[7] Letter from Jellicoe to Lanchester, 15th June 1916, held as B3/18, Lanchester archive, University of Coventry.

[8] The point of departure for German tactics was that 'victory is possible only if the enemy makes mistakes' (Vice Adm W. Wegener, *The Naval Strategy of the World War* (Berlin, 1929; trans. H. H. Herwig, Annapolis, 1989)).

picture than before of the intellectual milieu in which the tactical views of the commanders were formed, of the role of chance and of the dilemmas facing them. Did the catastrophic explosions on British battlecruisers indicate that a greater disaster had been avoided fortuitously, or were they the result of a particular and unlikely combination of circumstances favouring the Germans? Did British commanders lack drive and resourcefulness, or were they simply unwilling to fight the melee battle their enemy needed and craved as the only path to a meaningful victory?

I

It is a truism that almost all of the technical developments in land warfare before the First World War, for example barbed wire, railways and fixed machine guns, favoured defence. In naval warfare, there had been a comparable, unique period of 30 years or so after the development of the ironclad during which defence was supreme, and capital ships could hardly damage each other with gunnery, even at the closest ranges.[9] Consequently, the ancient tactic of ramming was rediscovered.[10]

But development of gunnery continued, and the launching of HMS *Dreadnought* in 1906 represented the culmination of an era in strategic and tactical thinking just as it introduced a new one in warship design. Concentration on clusters of powerful, quick-firing main guns in battleships

[9] For the parallel developments in guns, armour and propulsion from the early ironclads to the First World War see K. Lautenschlager, 'Technology and the evolution of naval warfare', *International Security,* 8 (1983), pp. 3-51.

[10] For this stage of naval tactics see for example G. H. U. Noel, *The Gun, Ram, and Torpedo: Manoeuvres and Tactics of a Naval Battle in the Present Day* (London, 1874) and W. Bainbridge-Hoff, *Examples, conclusions, and maxims of Modern Naval Tactics* (Washington, DC, 1884). Ramming was still considered an option in Lt A. P. Niblack, USN, 'The Tactics of Ships in the Line of Battle', USNI Prize Essay, PUSNI, 22 (1896), pp. 1-28. Interestingly, Adm Doveton Sturdee, best known for his success at the Falkland Islands, claimed in his 1893 Naval Prize Essay to have been the first writer, in 1886, to have decisively rejected the ram (Cdr D. Sturdee, 'The Tactics Best Adapted for Developing the Power of Existing Ships and Weapons (Gun, Ram, and Torpedo) Which Should Regulate Fleets, Groups and Single Vessels in Action', 1893, Royal United Services Institution Naval Prize Essay, in SDEE 1/8, Churchill Archive Centre, Cambridge).

settled the issue between proponents of this solution and advocates of mixed medium and large-calibre armament, and thus between short and long range engagements, though this acrimonious debate would reach a peak of intensity with the arrival of the new vessels. There was no longer any prospect of capital ships demolishing each other with numerous secondary guns[11] or of closing to within ramming distance of modern opponents, and the need for closely controlled tactical evolutions to bring about such a situation was also gone. But there was now a range of fresh problems. What was the newly optimal capital ship, with what displacement and combination of armour, propulsion and armament? And what were the correct tactics for such a fleet in this new era of gunnery accurate at increasingly long ranges?

At its simplest, the Square Law states that, in combat with long-range aimed weapons against which there is no effective defence, the outcome depends on which side possesses the greater `fighting strength', defined to be the weapons' individual effectiveness multiplied by the *square* of their numbers.[12] The 20th century convention was that this process must be described using calculus, and this was done independently by Lanchester in Britain, Osipov in Russia and Chase in the USA.[13] Its implications for naval warfare are most fully explored in the USNI Prize Essay of 1905 by Fiske.[14] In keeping with 20th century usage, however, we will call this body of thought 'Lanchestrian'.

[11] Fiske, 'American Naval Policy', considers carefully the scaling relation between medium (6") and large (12") calibre guns, concluding that the 6" guns fire eight times the weight of shell, but that `if the guns are too small to destroy [the enemy's] turrets and water-line, *this energy is wholly wasted'* (Fiske's emphasis). This is the crucial point on which the new understanding supersedes that of, in particular, the 1905 battle of Tsushima.

[12] The Square Law, normally exclusively attributed to Lanchester, is also clearly stated in Baudry, *The Naval Battle*.

[13] Lanchester, *Aircraft in Warfare*; Osipov, 'Influence'; Chase, 'Mathematical Investigation'. The crux of the square law is a point made in Baudry, *The Naval Battle*. If two ships fight one, then not only does the lone ship receive double the rate of fire, but its own fire is divided. Thus the proportional rates of attrition are in the ratio 1:4, not 1:2. The full implication of this instantaneous truth only emerges when one sums its effects over the full battle.

[14] Fiske, 'American Naval Policy'.

Fiske's essay contained no calculus, but rather modelled big-gun naval combat as a series of discrete salvos, with the implications being drawn from a set of tables – nowadays we might well call them 'spreadsheets' – as opposed to equations. His conclusions were stark: the side with the greater number of guns brought to bear would realise a disproportionate and accelerating advantage, eventually annihilating its opponent with a final remaining force much greater than the initial imbalance. Further, the side which could begin firing first would enjoy a further advantage, again out of all proportion to naïve expectations, as worked out by Baudry in an example in which he gives one fleet a mere four minutes' initial unopposed fire.[15]

Complementing this calculus-based insight was another, based on geometry. In contrast to the Nelsonian era, the big gun was effective at long range relative to distances travelled by ships on battle timescales, so that concentrating weapons no longer required massing of ships.[16] Instead 'applied geometry' was needed, the fleet commander's goal being to arrive at a geometrical configuration in which all of his big guns could be concentrated on his enemy while denying enemy attempts to do the reverse.[17] We can see how this dictation of calculus by geometry played out at

[15] Fiske, 'American Naval Policy'. The point about initial advantage (Fiske, 'Fighting Machine', p291; Baudry, *The Naval Battle*, p116) was well understood by Jellicoe: for example, in the Grand Fleet Battle Orders in force on the eve of Jutland, he states 'I attach the greatest importance to making full use of the fire of our heavier guns in the early stages at long range … [this] may give us the initial advantage in gunfire which it is so important to obtain' (Jellicoe Papers, vol.I, item 226, pp. 243-245). See also Theodore C. Taylor, 'Tactical Concentration and Surprise – in Theory', *Naval War College Review* 38 (1985), pp. 41-51; Wayne P. Hughes, 'Naval tactics and their influence on strategy', *Naval War College Review*, 39 (1986), pp. 2-17.

[16] One finds this point most forcefully made in the Royal Navy. Indeed, `the more widely separated the points from which the fire originates, the more effective tactically is the concentration, because the more difficult it is to counter' (Capt. E. W. Harding, RMA, 'Studies in the Theory of Naval Tactics III', *Naval Review*, 4 (1913), pp. 208-222); 'in a modern fleet owing to the great distance at which the guns can develop their maximum hitting capacity … the principle of C O N C E N T R A T I O N can be effected by the convergence of fire from widely dispersed positions (R. Plunkett-Ernle-Erle-Drax, 'Notes on Grand Fleet Battle Tactics', 16/12/1916 (written for David Beatty), in DRAX 1/18, Churchill Archive centre, Cambridge).

[17] Many authors of the period treat naval tactics as a geometrical problem, for example Baudry, *The Naval Battle* and R. Bernotti, *The Fundamentals of Naval Tactics* (Annapolis, 1912). Even where plane geometry is not explicitly the paradigm, its language pervades tactical writings (for example Capt. E. J. W. Slade, 'Battleships and Battleship Tactics', Royal Naval War College report no.3, 11/1906, in HTN/116/B, Caird Library,

Jutland in Figure 1, which plots (on a logarithmic scale, over time) the ratio of British to German big guns in action. For the British, Lanchestrian advantage is achieved when this ratio is maximized (and *vice versa* for the Germans).

Thus the tactical imperative was to use fleet geometry to dictate calculus, giving a cogent reason, beyond the fleet commander's natural desire to keep his force under control, for a single battle line rather than divisional tactics.[18] The conclusion is that fleet or 'operational' tactics, as opposed to smaller-scale ship or division tactics, became a key determinant of success.[19] The side with the numerical advantage in weapons was guaranteed a successful outcome if it could create the conditions described above. So these developments implied more orderly fleet actions than had hitherto been envisaged. Difficulties in surprising an opponent increased the likelihood that well-matched fleets would meet broadside to broadside with their entire strength in capital ships

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Greenwich). Once again it is in the Royal Navy that we find the case put most strongly, with R. Plunkett-Drax, then on Beatty's staff, asserting that: `It is "Applied Geometry" that must ensure for us the crushing effect to be obtained by bringing all our forces into action at the same moment. Geometry ... Geometry ... Geometry ... The leader of a large fleet should diligently cultivate in himself a "geometric sense"' (Drax, 'Notes on Grand Fleet Battle Tactics', DRAX 1/18; see also 'Grand Fleet Battle tactics', 1/1/17, in BTY/7/2, Caird Library, Greenwich). In the light of this, his public assertion after Jutland that `what we required was … less geometry and more ginger' is blatant hypocrisy (R. Plunkett-…-Drax, 'Jutland or Trafalgar?', *Naval Review* 13 (1925) 238-243).

[18] Drax considers divisional tactics in an essay for Beatty of 9th August 1917, held in BTY/7/2, Caird Library, Greenwich. His governing principle is concentration: he notes that the battle-line principle of '"fire at your opposite number" [will] neglect priceless opportunities for concentrated fire at a nearer target'. But of course such concentration can also be effected by a battle line. An intermediate possibility is to fight *en echelon*, as advocated in Lt A. P. Niblack, 'The tactics of ships in the line of battle', *PUSNI*, 22 (1896), pp. 1-28: 'the advantage will always be [to] *echelon*, if correctly manoeuvred against a fleet formed in line, [for] it is [then] difficult to double upon any of them. Yet Bacon, a staunch Jellicoe supporter, was able to write that `in 1900 at the War Course at Greenwich I used to work the tactical board … against all comers, and never could any opponents obtain a tactical advantage by assuming any other formation than line ahead' (Adm Sir Reginald Bacon, *A Naval Scrap-Book, 1877-1906* (London, 1925)).

[19] There is no explicitly *operational* level of tactical thought in pre-First World War writing on naval matters. One has the calculus of Fiske, Chase, Baudry and Lanchester, and the clearly geometrical reasoning needed to exploit it, but, as we saw above, no clear consensus about fleet tactics had emerged. For a modern perspective, see Wayne P. Hughes, 'Naval Operations: a close look at the operational level of war at sea', *Naval War College Review*, 65 (2012), pp. 23-47.

deployed in line of battle. In such a situation, with good visibility and sufficient time for the engagement to be concluded, an almost text-book employment of Lanchester's equations could be played out in which the advantages of concentration could be realised. 'Symmetrical' conditions of this type, in which neither side enjoyed an advantage beyond superiority in materiel, would certainly end in the destruction of the weaker force, at a lesser absolute cost to the larger. The thoughtful and well-read commander of the superior force would be aware of the subtle variations in achievement of these conditions. In such circumstances a fleet which knew itself to be outgunned would refuse battle, and its opponent would enjoy the effective fruits of victory without having to fight.[20]

Lanchester's equations enjoyed great popularity among military analysts in the 20th century, when they were often used to model land battles and campaigns, albeit with only partial success.[21] But land warfare was known to be greatly subject to the fog of war, and the commander of inferior forces could often hope to engineer a partial victory through well-chosen tactics exploiting variable factors such as concealment of forces, superior communications or difficult terrain. The Jutland-era naval battle, however, apparently carried the mathematical inevitability of the Square Law.[22] This

[20] This appears most starkly from the weaker side's perspective, of course: see Wegener, *Naval Strategy of the World War*. On the stronger, British side Sumida notes a division of views between what he calls "agnostic opportunists" and "clandestine pre-empters" (including Jellicoe), with the latter taking clearly the position that battle must only be sought under the correct, favourable conditions (J. T. Sumida, 'Expectation, Adaptation, and Resignation: British Battle Fleet Tactical Planning, August 1914 - April 1916', *Naval War College Review*, 60 (2007), pp. 101-122). The point is perhaps best made by Wayne Hughes, who, quoting Clausewitz on 'engagements that did not take place but had merely been offered', notes that there is no defense in naval war, and that the inferior force always loses (and does so disproportionately badly): `[since] Scheer knew his fleet was decisively inferior, there was never a fight to the finish' (Hughes, 'Naval tactics and their influence on strategy').

[21] For a brief introduction see N. J. MacKay, 'Lanchester combat models', *Mathematics Today,* 42 (2006), pp. 170-173.

[22] At least in fair weather and the absence of real fog. We know of two published attempts to apply Fiske/Lanchester models to Jutland. Joseph Czarnecki, 'N-squared law: An examination of one of the mathematical theories behind the Dreadnought battleship', www.navweaps.com/index_tech/tech-076.htm, accessed 29 June 2012, uses Fiske tables for five cases of small battles between Dreadnoughts, and concludes that 'Britain saw the opportunity to stack the deck and took it.' Colin Lyle, 'A Nelsonian Jutland?', *Journal of the Royal United Services Institute* [*JRUSI*], 140 (1995), pp. 56-60, invokes Lanchester (but without crunching the

was well captured in the military theorist J. F. C. Fuller's assessment of the naval defeat at Coronel: `Cradock's [ships] went to the bottom, not through an act of God, but through an act of mathematical certainty'.[23] The only hope for an outmatched battle fleet was to engineer a situation in which it could engage its whole force against a detached and inferior portion of the enemy's superior fleet, but one of sufficient size to guarantee an overall numerical superiority after this first and lesser victory. For Germany before the launching of Dreadnought, this seemed a forlorn hope given Britain's vast numerical superiority in capital ships. The risk fleet concept functioned only to the extent that the sacrifice of the German fleet might weaken the British unacceptably in the context of a subsequent struggle with a third power, a prospect which it was hoped might make the British politically more amenable in peacetime.

It was true that the Square Law was scalable, so there was a theoretical possibility of an outnumbered fleet breaking up the enemy line and creating a local superiority within the battle at the level of squadrons and divisions. This had a Nelsonian ring, and divisional tactics were thus dangerously appealing to some in the numerically dominant Royal Navy. In the *Dreadnought* age, however, such a situation would represent Germany's best hope of success in fleet action.[24] Before 1906, if the outnumbered force could avoid battle in the first place it was difficult for naval theorists to see such a melee situation arising, but after 1906 the British infatuation with the new idea of the battlecruiser would change this situation and make such an outcome more likely.

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numbers) to support his claim that a more Nelsonian commander would 'eschew the too-unwieldy single line' and thereby have exploited the square law to achieve a crushing victory – and is rebuked by Maj. J. D. Harris, letter to JRUSI 140 (1995), p68, for not considering Jellicoe's knowledge of his technological deficiencies. Indeed, it could be seen as one of the implications of the present paper that it was the Germans who needed a Nelson for strategic victory at Jutland, not the British.

[23] J. F. C. Fuller, *The Foundations of the Science of War* (London, 1926), ch.13, section 8.

[24] The belief that the British would have benefited from a more manoeuvre-based, Nelsonian approach echoed through the inter-war years. Cdr Russell Grenfell, *The Art of the Admiral* (London, 1937), based on his lectures at the Royal Naval Staff College, Greenwich; Captain Richard, French Navy, 'Jutland and the Principles of War', trans. from *Revue Maritime* in *JRUSI*, 67 no.465 (1922), pp. 128-139. No one seems to have understood the randomizing effect of the melee on the Lanchestrian certainty of the battle line, which we quantify below.

II

The logic of Lanchestrian modelling had profound implications for national policy before World War One. It swiftly became apparent that *Dreadnought* presented a level playing field by rendering Britain's previous overwhelming numerical advantage in capital ships null and void, but it is less well-remembered that decisions on future building programmes suddenly carried an increased and enormous weight of responsibility. Germany's risk fleet idea seemed instantly more credible: Germany was unlikely to match massive British building capacity in the short term, especially given the call on resources commanded by her army, but she could hope to build a force sufficient to reduce or eliminate the British margin of superiority at a given moment, particularly if the Royal Navy's global commitments reduced its strength in home waters.

The latter possibility was not realised, however, as the British engaged in a blizzard of effective diplomatic activity to woo traditional rivals, aided unconsciously by the Kaiserreich itself. The aggressive German posture which produced a naval challenge to Britain was replicated in other areas and drew her potential enemies closer together. The Triple Entente neutralised, at least for the present, potential naval rivalry between Britain, Russia and France, and this factor coupled with the Anglo-Japanese alliance and British appeasement of US interests in the western hemisphere enabled a rapid and near total concentration of British capital ships in the North Sea.

Nevertheless, the possibility of dividing and defeating the Royal Navy in the Lanchestrian manner by constructing a sufficiently large force of dreadnoughts and setting traps for a detached part of the Grand Fleet remained very real, and the British had an absolute need to create and maintain a margin of superiority sufficient to preclude any prospect of a clash of full battle fleets, and which could survive attrition through mines, submarine attack or accident.

The battlecruiser was a complicating factor in this argument. The first such vessel, HMS *Invincible*, resembled *Dreadnought* but was much faster, speed being gained at the expense of armoured protection and thus with no compromise in gunpower. Such a vessel could overwhelm any smaller opponent and easily escape an ordinary dreadnought. The battlecruiser concept was appealing to a Navy with global policing responsibilities, but the ships would also be expected to perform reconnaissance for the fleet and then join the line of battle. Regardless of the capabilities of the ships this created danger for the Royal Navy in a number of ways. First, the idea received heavy investment. By 1916, ten battle cruisers were in service, based separately from the battleships of the Grand Fleet at Rosyth, and officially and misleadingly described as the Battle Cruiser Fleet [BCF]. As the Germans were aware, this meant that nearly a third of the Royal Navy's capital ship gun power was seated in vessels which must sail separately to rendezvous with the Grand Fleet before a continuous line of battle could be formed, and which might actually seek out the German fleet separately before such a union could be established. The Commander of the BCF, Rear Admiral Sir David Beatty, was also known to be an aggressive figure, keen to assert independent leadership and who 'wanted to grasp the big picture and see his role in the larger context'.[25] From the German perspective he was, in the context of their plans, the ideal opponent.

The decision to compromise in armour rather than firepower or speed also had obvious dangers, though there were countervailing advantages. As part of the line, British battle cruisers could contribute effectively to a fleet engagement with their heavy armament while the risk created by their lighter armour would be mitigated by the German need to divide their fire against the more numerous British fleet. In their reconnaissance role, however, numerical superiority for the BCF was not guaranteed, and here the thin armour of the vessels was especially dangerous. Beatty's role was to force his way through an enemy screen of similar vessels and find the enemy battle fleet. The perceived need to get in close would nullify the advantage of his heavier guns relative to more lightly

[25] Andrew Lambert, *Admirals: The Naval Commanders who Made Britain Great* (London, 2008), p.363.

armed but more heavily armoured German battle cruisers and expose his lighter armour. There was also an increased prospect of melee situations developing in which the British battlecruisers might suddenly face a grave Lanchestrian disadavantage.

But this does not necessarily imply that British technology or attitude to technology was at fault. Indeed, *Invincible* represented advanced thinking that the Germans attempted to copy. The German answer to *Invincible*, the *Blücher*, was conceptually primitive and no match for the British vessel. The subsequent and much more effective German battlecruisers reflected thinking the British had undertaken when the *Dreadnought* concept was new.

The British dilemma was in effect the basic economic problem of possessing limited resources to satisfy unlimited wants, which was constantly in tension with Fisher's desire that Britain lead the naval arms race on all measures. Dreadnought battleships were the single most expensive and technologically advanced items that a state could purchase, and once decisions had been made mistakes could not be redeemed. Having decided on all-big-gun ships, a decision had then to be made about the trade-off between number and quality, a question to which Lanchestrian modelling had a clear answer, with fighting strength given by quality of units multiplied by the *square* of their numbers. The Admiralty was well aware of the grave issues it had to consider and in 1906, while the implications of the new *Dreadnought* design were being explored,[26] a committee was formed under Chairmanship of Captain C. L. Ottley, the Director of Naval Intelligence, comprising technical experts including Jellicoe.[27] It was invited to consider, among other matters, the introduction of a 'fusion' class of capital ship combining the power and protection of the dreadnought battleship and the

[26] Such analysis was already under way even before *Dreadnought*'s sea trials had begun ('HM Ships *Dreadnought* and *Invincible*', 24th May 1906, AL 252/4/8, ALHRB).

[27] This is usually known as the 'Fusion Committee', although the battlecruiser/battleship fusion was one of three matters the committee was formed to consider. It comprised C. R. Ottley (Director of Naval Intelligence, in the chair), J. R. Jellicoe (Director of Naval Ordnance), R. H. S. Bacon, C. Madden, S. Nicholson, H. Jones, H. Orpen, T. E. Crease and Graham Greene. In *Naval Necessities IV*, held by ALHRB, Portsmouth.

speed of the battlecruiser (still referred to as an 'armoured cruiser' by the committee). This would in effect be a fast battleship with heavy armour, powerful armament and great speed. Such a vessel would dominate future engagements between dreadnoughts, but its precise configuration, beyond superiority over all existing designs, was still a matter of conjecture. The one certainty was that it would be very expensive relative to existing dreadnoughts. The committee believed that if Britain's new vessels were to be 'of the "Fusion" class, for the same expenditure we can build only three as against four "Dreadnoughts" … and therefore in 1909 we shall have only a bare numerical superiority over Germany in new Armoured Vessels.'[28]

This was unacceptable, especially as Germany's response, 'should be and probably would be' to build similar vessels emphasizing greater gun power at the expense of 'speed or coal endurance'. The British fleet would thus face a situation in which 'our ships are decidedly inferior to theirs in gunfire'. In terms of the Square Law this meant doom, and the committee was clear that 'speed, though desirable, cannot be assessed at so high a value as a superior number of guns'. The committee agreed that the fusion concept had merit, as a division of such vessels 'would be of great value, owing to their great speed allowing them to be used as a fast "Flanking Division"' for the battle fleet'. It was argued, however, that 'this function is non-existent until we have a sufficient superiority in modern Armoured Vessels over other countries'. Interestingly, this superiority was interpreted, in close conformity with Lanchester, strictly in terms of big-gun firepower rather than number of ships. The committee concluded 'that it should be our first aim to add gun-fire to our Fleet before moving in the direction of greatly increased speed, and that the proposed "Fusion" ships are, for the moment, premature'.[29]

[28] The Fusion Committee's report is held as 'II- Fusion Design of Armoured Design' (sic), in report of Navy Estimates Committee, 1906-7, AL 253/28, Admiralty Library Naval Historical Branch, Portsmouth [ALHRB].

[29] Fusion Committee report.

A momentous decision was thus taken not to construct such vessels until a sufficient quantity of less capable capital ships had been created to make the fusion vessels' appearance decisive. This resolution was accepted by the Admiralty, though it ran counter to the expectations of the First Sea Lord when he established the Fusion Committee.[30] Indeed, the decision was a clear check to Fisher's programme of constant, 'plunging' innovation, and constituted an exemplary case of professional policy formulation and decision-making by a learning organisation.[31] The decision to postpone the 'fusion' ships was prescient in both technical and strategic terms. In 1906, the pace of development was such that the Committee's idea of a fusion ship, involving wing turrets and the new 13.5"gun, would resemble the first super-dreadnoughts of the *Orion* class, and though capable these vessels would have been dated by 1914. Waiting for them would have served little technical purpose and resulted in a more expensive and thus smaller fleet when war broke out. It could even have created for the Germans a window of opportunity during the first few months of the war during which they might have achieved parity or even a small advantage in big-gun fire.[32]

[30] At the meeting of the Sea Lords which instigated the Fusion Committee, it was stated that 'It was desired to bring about a fusion of the two designs' (i.e. battleships and battlecruisers) 'by next year; it seemed possible for this to be done, and it would be a great assistance if the committee would look into this matter.' In *Naval Necessities IV*.

[31] In this we disagree with Angus K. Ross, Four lessons that the US Navy must learn from the 'Dreadnought' revolution, *Naval College War Review* 63 no.4 (2010), pp. 119-143, which argues that Fisher wanted an innovative revolution and the Fusion Committee thwarted this. Ross considers this outcome to be failure, and the lesson (for the 21st century US Navy) the importance of being a 'learning organization'. We instead claim that the Fusion Committee's position was a conscious, technocratic decision which guaranteed British naval supremacy through big-gun firepower. The Royal Navy's qualities as a learning organization are demonstrated throughout the archive material of the period. For example, in 'The Building Programme of the British Navy: The lessons of the Russo-Japanese war in their application to the programme of armoured-ship building of Britain, Germany, and France' (AL 252/3/8, 15th February 1906, ALHRB) we find a balanced and thorough analysis of French, Italian and US commentary on Tsushima (the writer is clearly an attentive reader of *PUSNI*). Similarly 'Admiralty Policy: Replies to criticism' (AL 252/5/8, 15th October 1906, ALHRB) is a thorough and balanced 140-page response to criticism of the *Dreadnought* concept.

[32] A fascinating episode in the development of these ideas is the Sims *vs* Mahan controversy in the USA, which pitched the US Inspector of Target Practice against the great naval historian Mahan in the pages of *PUSNI*. Sims made telling arguments in favour of all-big-gun ships, but the interest for our purposes is in the US-UK interchange of ideas. Sims' paper for Roosevelt, 'Big Battleships of High Speed', was sent in confidence to

The design of the actual fusion ships, the *Queen Elizabeth* Class, was not finalised until 1912. Their new configuration, with eight new 15'' guns of unprecedented power in four turrets, rather than ten 13.5'' weapons in five, provided greater firepower and a saving in weight which was translated into both heavier armour and nearly twice the propulsive power of the previous class of super-dreadnoughts. They also promised to make redundant the concept of constructing separate battleships and battlecruisers, as the new vessels were expected perform both roles capably. Even at this stage, however, technical capability fell slightly short of the true fast battleship, and the battlecruiser survived. The top speed of the *Queen Elizabeth* class fell between the maxima of typical battleships and battlecruisers, and the apparent success of battlecruisers in the early clashes at the Falkland Islands and Heligoland Bight coupled with the return of Fisher as First Sea Lord shortly after the outbreak of war led to the commissioning of two new vessels of the type, *Renown* and *Repulse*. Indeed *Repulse* replaced a battleship of the same name of the *Royal Sovereign* class already in the early stages of construction, the contract for which was cancelled.[33] The *Royal Sovereign* class vessels themselves, though succeeding the *Queen Elizabeths*, also reverted to the lower speed of existing battleships.

Despite wartime reversion to the Battlecruiser concept, the new *Queen Elizabeths* as fusion ships were a genuine advance on the original *Dreadnought* design and, like *Dreadnought*, outclassed all previous vessels afloat when they entered service. The ten 15" ships of this and the similarly-configured but slower and more heavily armoured *Royal Sovereign* class did not join the fleet until after the outbreak of war. Their arrival, however, added massively to the gun power of the existing Grand Fleet, transformed what for Jellicoe was a worryingly narrow margin of superiority into a

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Fisher on 3rd November 2007 (before Roosevelt's January 1907 speech to congress on the topic), and forms the basis of the argument of the Director of Naval Intelligence C. L. Ottley's 'The Strategic Aspects of Our Building Programme, 1907' (AL 253/68, ALHRB), sent to the King's private secretary. Sims restated his argument in 'The Tactical Qualities of the Dreadnought Type of Battleship', *Brassey's Naval Annual* 1907, pp. 391-409.

[33] I. Johnston, *Clydebank Battlecruisers* (Barnsley, 2011), p.92.

decisive advantage, and removed any prospect of a German challenge to the full Grand Fleet. Only two comparable vessels of the German *Bayern* class were completed.

In adopting what was, effectively, a mathematical approach to their situation, the British had implicitly taken a view on a mathematical issue, of what is the unit of offensive and defensive force concentration. A simplistic view would assert that this was the capital ship, but in Lanchestrian war destruction is wrought in proportion to the number of effective weapons, big guns in the context of 1916.[34] The British had thus determined to place guns on the water as quickly as possible. By the time the last ship of the four *Nassau* class vessels was commissioned in May 1910, the Royal Navy had commissioned seven dreadnought battleships and three battlecruisers. The value of this approach became still more apparent when the characteristics of the *Nassau* class became known. Despite their heavy armour and high build quality the German vessels were, as with *Blücher*, backward in important respects. The *Nassau*s had obsolete reciprocating engines rather than the turbines of all British dreadnoughts. The vessels carried an imposing twelve guns compared to the standard British ten, but had four wing turrets, two on each side of the vessel which could not fire across deck. Thus only eight guns could be fired in broadside and a third of the ships' firepower was wasted. The guns were of 11" calibre, when the British were already moving to 13.5" all along the centreline.

A ship with its main armament unable to bear in broadside, or completely wrecked in battle, contributes nothing in the Lanchester equations except to the extent to which it deflects fire away from still-active ships. The unit, rather, is the set of weapons which stands and falls together. Fiske reached the unambiguous, definitive conclusion that the appropriate unit was the big-gun turret,

[34] The belief that the ship is the unit can lead to views such as 'sea battles based on [big guns] were bound to be indecisive because heavy guns hardly ever sank ships' (R. Garcia y Robertson, 'Failure of the heavy gun at sea, 1898-1922', *Technology and Culture,* 28 (1987), pp. 539-557). In contrast we argue not only that such battles can be won, by destroying turrets, but that Lanchestrian certainty of outcome can lead to strategic victory after inconclusive fighting.

and this view remains persuasive.[35] German turrets enjoyed no special advantage over British in terms of protection and were no less likely to be disabled or destroyed in action.[36] They also contained guns of lesser calibre than their British opponents, though this deficiency would tell only at long ranges, given the greater accuracy of the smaller German guns and the limited effectiveness of British shells before 1916. From this perspective, that of a battle of gun turrets, the British advantage in gun power fully justified pre-war policy if their weapons were employed to full effect. However, if the explosions on the British battlecruisers represented a generic fault in Royal Navy dreadnought design, so that the destruction of a turret entailed the destruction of the ship, then the whole ship would have to be considered the relevant unit of mass, with radical effects on the Lanchestrian balance in Germany's favour.[37]

A complicating factor in addressing this issue is again the separate command of the Grand Fleet under Jellicoe and the BCF under Beatty. The latter's aggressive style of command has been identified by some as having an effect on the vulnerability of his vessels, both in the manner of their deployment, and in their gunnery training and the procedures they employed in action. Jellicoe, by contrast, has been characterised by his critics as a cautious technocrat, lacking the fighting spirit necessary in a fleet commander. The Admiralty's assiduous pre-war planning to provide a fleet suitable for war was thus at the mercy of those employed to use it.[38]

[35] 'each [big-gun] turret with its guns should be regarded as a *unit*. There seems to be no escape whatever from the conclusion that we should recognize the combination as our *unit of offensive and defensive power*...' (Fiske's italics), Fiske, 'American Naval Policy', p. 28.

[36] J. Campbell, *Jutland: an analysis of the fighting* (London, 1986).

[37] For a recent treatment see N. A. Lambert, ''Our Bloody Ships' or 'Our Bloody System'? Jutland and the loss of the battle cruisers, 1916', *Journal of Military History,* 62 (1998), pp. 29-55.

[38] A wide-ranging recent source is James A. Yates, *The Jutland Controversy: A case study in intra-service politics, with particular reference to the presentation of the Battlecruiser Fleet's training, conduct and command,* PhD thesis, University of Hull, 1998.

III

Having built a fleet calculated to guarantee strategic victory under Lanchestrian conditions, it then became essential to a successful outcome that this fleet be commanded so as to bring such conditions about. The contrast between Jellicoe, commander in 1916 of the Grand Fleet, and Beatty, commander of the BCF, was in many ways representative of their intellectual environment. The impact of new technology and new thinking created a fast moving debate in which a considerable degree of erudition was required to keep up.[39] Jellicoe was just such a technical intellectual and made it his business to keep abreast of developments and explore their implications. Beatty represented the opposite end of the spectrum. Self-consciously Nelsonian, he interpreted this tradition in terms of aggressive, thrusting leadership and an overriding requirement to close with the enemy and impose his will. Beatty did not consider his style of leadership to be unintelligent or ignorant, and his reflective professionalism has been noted.[40] He was, however, overtly anti-intellectual and was not alone in so being. HMS *Dreadnought* attracted the hostility of this faction, which did not accept the sudden strategic and tactical shifts it necessitated. Jellicoe thus represented a new and untested rationality, and in his command role faced the additional burden that his hard thinking about the fleet action of the future would be contested and in some powerful quarters disregarded.

[39] In the Royal Navy, a central figure in the *Dreadnought*-era investigation of ship (as opposed to fleet) tactics is Admiral Sir William May, commander of the Home Fleet 1909-11 and (while C-in-C at Plymouth) umpire of its exercises in 1912-13. Papers in MAY/10, Caird Library, Greenwich, show detailed understanding of how big guns and increasing ranges emphasize the importance of plotting, spotting and rate change. This can be contrasted with the writings of old-schoolers such as Adm Sir Cyprian Bridge, *The Art of Naval Warfare: introductory observations* (London, 1907), or Adm Sir R. N. Custance (writing anonymously as 'Barfleur'), *Naval Policy: a plea for the study of war* (London, 1907), who stresses the need for concentration, but fails to understand that the long range of big guns changes the way this is best achieved.

[40] Lambert, *Admirals*, p.346.

Jellicoe's writings before Jutland make clear his careful consideration of the tactics necessary to bring about Lanchestrian victory. Despite his well-known apprehensions concerning torpedoes, he intended to open fire at medium to long ranges and continue doing so for several minutes even after he knew that torpedoes had been launched against him, taking advantage of their slow running to create the crucial few minutes of unopposed fire before evasive action became necessary.[41] He also appreciated that long ranges and high speeds made close control of his fleet essential, both to engineer Lanchestrian conditions of force concentration, and to extricate the fleet intact from an engagement without danger of defeat in detail. As noted earlier, concentration of fire now required not massing of ships but rather fleet dispositions which guaranteed concentration of gunfire, a very different proposition which made the Nelsonian emphasis on the granting of great latitude to subordinates, now known as 'mission command', peculiarly inappropriate.[42]

[41] Sumida, in 'A Matter of Timing' and 'Expectation', believes that Jellicoe sought a medium-range battle, while Seligmann, 'A German preference?', contends that Jellicoe was well aware of the German excellence at long-range shooting and sought to match it. Of course improvement in gunnery was rapid, and Jellicoe would have well understood that neither side could expect to have perfect knowledge of the other's state of development. His views therefore had to be fluid. He clearly understood the importance of opening fire at the longest possible ranges as early as 1906: 'The function of artillery is not only to destroy the enemy ... but also to prevent the development of his power *by doing so at ranges at which he is unable to make an effective reply* [Jellicoe's emphasis]. … It is curious to note that although this fact has been long recognised in shore fighting ... it has never until recently been sufficiently recognized in naval warfare. ... The recent development of the prospect of hitting frequently at long ranges is the all-important fact...' (Jellicoe, 'Considerations of the Design of a Battleship', AL 252/4/8, ALHRB). During the war we may note the subtle shift between August 1914, when he wrote that 'deployment at long range may give us the initial advantage in gunfire it is so important to obtain, but there can be no doubt that we must gradually close the range to obtain decisive results' (Addendum to Grand Fleet Battle Instructions, 'Jellicoe Papers' vol.1 , item 38, p61), and May 1916, which has 'I attach the greatest importance to making full use of the fire of our heavier guns in the early stages at long range … the range should be between 15,000 and 10,000 yards, the latter being reached as the enemy's fire is overcome; in the early stages of an action I do not desire to close the range much inside 14,000 yards' (Grand Fleet Battle Orders, 'Jellicoe Papers', vol.1, item 225, p. 244). His governing principle – naturally enough, and perfectly that of Fiske, Baudry and Lanchester – was that 'our system must be that which … will enable the highest rate of accurate fire' (Jellicoe, 18/1/15, `Remarks on the use of director firing from the main armament', held in ADM 137/1995, National Archives, Kew, and cited in Sumida, 'Expectation').

[42] Drax's essay in BTY/7/2, noted above, remains equivocal on divisional tactics. He understands Fiske's principle that 'concentration requires isolation' (Fiske, Fighting Machine, p263) but fails to reach a clear view on whether such concentration requires departure from line-ahead tactics. He wants divisions to be able to exploit transient opportunities available to them, but knows that dividing a fleet can lead to defeat in detail, a

Jellicoe therefore faced a tension between some degree of certainty about the correct tactics for employing his big guns, alongside great uncertainty about both their effectiveness and the possible importance of the mine and torpedo.[43] The actual outcome of the battle would not necessarily be the most probable outcome, and Jellicoe's heavy burden of responsibility and reflective temperament dictated a cautious appraisal of an action long anticipated. Blessed with a telling margin of superiority in gun power, and a high probability of victory in symmetrical circumstances, Jellicoe had a duty to be wary of any factor that might move the balance of probability in favour of his opposite number: and in the deployment of ever more powerful modern weaponry in the cramped confines of the North Sea, such dangers were many.[44]

IV

Despite a number of naval actions in 1914, the tactics of the Dreadnought clash were first put the test at Dogger Bank in January 1915, when British and German battlecruisers met. This skirmish is of

stark conclusion of Fiske and Lanchester. A possibility which was not explored in pre- or post-First World War Lanchestrian thought, however, is symmetric random fragmentation of the opposing fleets, whose main effect, while not changing the *average* outcome, is to inject much greater randomness (quantification of this is given in a later note). For Jellicoe, a melee would have randomised his perfect Lanchestrian battle. For Scheer, a melee against *part* of the Grand Fleet might have been ideal.

[43] Uncertain discussion of torpedo tactics pervades the literature before Jutland. For example, within one journal, the *Proceedings of the US Naval Institute*, one has: V. Cuniberti trans. T. Withers Jr, 'All torpedoes!', *PUSNI,* 40 (1914), pp. 27-31, advocating a fleet of small semi-submersible torpedo boats; Lt R. A. Dawes, 'Battle Tactics', *PUSNI*, 41 (1915), pp. 1873-1895, offering a turn away (but not towards) as a fleet tactic when under torpedo attack; and H. H. Frost, 'The problem of firing at a fleet under way with long-range torpedoes', *PUSNI,* 39 (1913), pp. 681-698. Perhaps the final word should go to Lt Chester W. Nimitz, 'Military value and tactics of modern submarines', *PUSNI*, 38 (1912), pp. 1193-1211: 'The steady development of the torpedo [and the] submarine … will result in a most dangerous offensive weapon, … which will have a large part in deciding fleet actions.'

[44] In this light, Jellicoe's famous turn away from Scheer after crossing the 'T' makes greater sense. The standard view of Jellicoe's critics is that he should have turned towards the High Seas Fleet, perhaps losing a few battleships wounded by torpedos, but accepting such losses in pursuit of victory. But these wounded ships could easily have crippled the Grand Fleet's perfect line and thereby denied him the conditions essential for that victory.

significant interest, as it is on many levels a small-scale precursor to the opening 'Run to the South' of the Jutland Battle. It reveals to us both the tactics chosen by Beatty and Hipper and the relative merits of the ships.

Dogger Bank is usually considered to be an opportunity for decisive British victory,[45] lost only by an untimely signal from Ralph Seymour in the disabled *Lion*. The contemporary accounts are strikingly triumphal, but the later experience of Jutland suggests this attitude to be misplaced. Had the three engaged ships – *Tiger*, *Princess Royal* and *New Zealand* – continued against the three remaining German ships, a successful result was unlikely for a number of reasons.[46]

The standard of gunnery in the BCF was known to be well below that of the Grand Fleet. There were no facilities for gunnery training at Rosyth and these could only be provided when BCF divisions were sent in rotation to the Grand Fleet base at Scapa Flow. Nor was Beatty inclined to emphasize accurate gunnery. His view was that rate of fire was more important and thus safety features that might have reduced this were disregarded, creating the danger, later revealed at Jutland, of a turret penetration transmitting explosive fire to the ships' magazines with catastrophic results. The Germans, by contrast, are considered to have learned much from the battle in this respect, due to the fortuitous escape of *Seydlitz* from a flash explosion not unlike *Lion*'s near-miss 16 months later. It is also now accepted that British powder was much more combustible than German, placing a premium on stringent measures to limit the transmission of flash explosions.

Even had British ammunition handling procedures been impeccable, the older British battlecruisers were rendered as obsolescent as the hapless *Blücher* in their scouting role by the

[45] Hughes, Fleet Tactics, p75; Capt J. Cresswell, Royal Naval Staff College lecture (1932), Churchill Archives Centre CRES 3/2

[46] A quantitative study by the authors using modern Bayesian methods is N. J. MacKay, A. C. Price, A. J. Wood, 'Weighing the Fog of War: Illustrating the power of Bayesian methods for historical analysis through the Battle of the Dogger Bank', to appear in *Historical Methods.*

appearance of the new German battlecruisers with heavier armour and similar armament. Of the three ships pursuing the German battlecruisers, the armour of *New Zealand* could not have withstood the concentrated fire of German 11" and 12" guns at medium range. Finally all shortcomings were compounded by poor fire distribution, which left *Moltke* unmolested when *Tiger* mistakenly concentrated on *Seydlitz*. This was a deadly mistake as the gunnery of even German battlecruisers deteriorated sharply when under fire, in contrast to their excellent performance when not engaged. This error was repeated at Jutland, when *Derfflinger* was not taken under fire and doubled up with *Seydlitz* on *Queen Mary.*

Tactically, it is clear from this battle that Beatty had failed to comprehend key ideas from pre-war tactics: the simultaneous engagement of the fleet, positioning of flagship, and use of speed and greater gun range to secure unmolested firing, Fiske and Baudry's five minutes. The first, especially, would come back to haunt the BCF in the early stages of the Jutland encounter.

The outcome of Dogger Bank might seem to presage a catastrophe for the Royal Navy. The chances of the German High seas Fleet encountering the overconfident BCF in isolation and exposing its weaknesses were high and the Germans executed just such a plan when they put to sea on May 31 1916. Previous attempts to achieve this result had been frustrated by circumstance and the timidity of Admirals Pohl and Ingenohl, who were reluctant to risk the High seas Fleet except in overwhelmingly favourable conditions, and had reason to fear the wrath of the Kaiser if they did. The new and aggressive commander of the High Seas Fleet, Scheer, succeeded in his primary aim of drawing the BCF out of Rosyth, but the initial dispositions suggested a German rather than a British disaster.

Jellicoe was aware of the German plan through interception of cracked German communications, and put to sea to rendezvous with the BCF and surprise Scheer with the concentrated Grand Fleet. A chance factor also unhinged the German plan, as the 3rd Battlecruiser Squadron [3BCS] had been

detached to Scapa Flow for gunnery practice and temporarily replaced at Rosyth by the 5th Battle Squadron, [5BS] consisting of four of the five new *Queen Elizabeth* class battleships, easily the most powerful warships at sea on the day. Apart from generic faults in British shells, they possessed none of the shortcomings of the battlecruisers to which they were attached, particularly in terms of accurate gunnery.

The German plan was to meet Beatty with the High Seas Fleet's battlecruisers under Hipper and draw them on to the approaching High Seas Fleet for destruction. The unsuspecting Hipper, however, with five battle cruisers seemed destined to meet ten British capital ships. In such circumstances the Square Law promised an inevitable result. The encounter would be symmetrical, in Lanchestrian terms, but of course this did not mean an even contest. British ships armed with 15" and 13.5" guns could engage Hipper's 11" ships beyond effective range of their own main armaments and he would have no prospect of concentrating his 12" fire on the weaker British vessels before his fighting power was eliminated. Nor would he have time to retreat on to the HSF before being destroyed, as his ships were slower than the enemy battlecruisers, and almost matched by 5BS

However, the different phases of the battle produced aspects of the extremes desired by both sides. The weaknesses in Beatty's signalling displayed at Dogger Bank were repeated and, in his eagerness to get at Hipper, he left 5BS behind. His poor deployment of 5BS far to his rear created a third subdivision of the Grand Fleet. This made possible Hipper's survival and presented him with opportunity. Though Hipper was unable to avoid battle, and even without 5BS the Square Law suggested a negative outcome for his five battecruisers against Beatty's six, circumstances favoured him. Beatty's ships closed to within the effective range of German guns before opening fire, and though this resulted from poor visibility rather than calculation, the effect was to place his long-armed but thin-skinned force of battlecruisers in unnecessary danger. Poor fire distribution left *Derfflinger* unmolested and enabled Hipper to achieve moments of effective numerical superiority in

the ragged running fight which developed when the battlecruisers met.[47] These circumstances suggested the elimination of Beatty's force, in the first place because the Square Law would not function to his advantage, and then after the immediate loss of *Indefatigable* (Fig.1, point A) because it would start to work against him. However, unlike Hipper, the speed of his vessels gave him the option of disengagement.

The dynamics of this process are clear from Figure 1, with Beatty failing to achieve concentration, and thereby a favourable gunfire ratio, during the first twenty minutes. When 5BS closed the range sufficiently to engage (Fig.1, B), the BCF finally achieved concentration and Hipper was placed in apparently mortal peril. Beatty was able to open the range between his battlecruisers and those of the enemy, reducing the effectiveness of their smaller main armament, while 5BS engaged Hipper's force effectively at such range that they had no means of reply. However, 5BS at this stage could only engage the rear of Hipper's line and, unpleasant though this was for *Moltke* and *Von der Tann,* Hipper's newest and most powerful vessels *Lützow* and *Derfflinger,* with 12" guns along the centreline, were still in action with Beatty.

The loss of *Queen Mary* to an explosion occurred at this point of the battle (Fig.1, C). The importance of *Derfflinger*'s escape from British fire at the outset of the battle has been dismissed on the grounds of the German ship's poor initial shooting,[48] but she had still not been hit when credited with the fatal salvo against Queen Mary, firing in conjunction with *Seydlitz*, and had not suffered the

[47] We noted earlier that symmetric random fragmentation of the opposing fleets in an otherwise-deterministic Lanchestrian battle has the effect of randomizing the outcome. This can be quantified. For example, the randomness introduced by splitting each fleet into two fragments is equivalent to a standard deviation (*i.e.* typical variation) in the ratio of the fleets' numbers of 16%, and thereby a typical variation in square-law fighting strengths of 36%. Put simply, allowing such division creates a high degree of randomness, which can easily overturn the certainty of a Lanchestrian advantage. At their simplest, the tactical imperatives facing Jellicoe and Scheer are, as so often, best captured by Hughes: 'A major part of skill and expertise is recognizing and avoiding situations dominated by uncertainty when superior, and creating opportunities for uncertainty for the enemy when inferior.' Wayne P. Hughes, 'Uncertainty in Combat', *Military Operations Research,* 1 (1994), pp. 45-57.

[48] Campbell, *Jutland*, p. 39.

sharply degrading effects of battle damage on her fire control. Even without the explosion, the Square Law suggested a catastrophic result for the British battlecruiser in this unequal exchange. With 5BS in action, however, the undergunning of the German 11" ships promised to be the decisive weakness on either side if this action were to continue. *Von der Tann* particularly began to suffer immediate and severe damage. In fact, the arrival of Scheer and the rest of the High Seas Fleet (Fig.1, D) brought the 'Run to the South' phase of the battle to a close and turned the tables again.

Beatty was now decisively outnumbered and his only option was to reverse course and seek union with the Grand Fleet. This was also his duty as he had in effect succeeded in his scouting role and located the enemy fleet. The phase of the battle known as the 'Run to the North' thus began, though not quite yet for the *Queen Elizabeths* of 5BS, which still on a southward course passed Beatty's ships heading north, waiting anxiously for the order to execute a delayed signal to turn (Fig.1, E). When this arrived each ship of 5BS turned in sequence and faced the concentrated fire alone while turning, creating a situation which these uniquely valuable vessels should never have faced and in which the Germans might again have achieved their desired risk-fleet result. Once again Beatty's failure to understand the Lanchestrian dynamic is starkly visible in Figure 1, where between points D and F we observe a reversal of the gunfire ratio in the Germans' favour, the only period of the battle during which this was achieved. Catastrophe was avoided, however, and 5BS was able to stay ahead of the pursuing enemy, absorb a number of hits and damage enemy vessels with effective gunnery, before action was broken off (Fig.1, F).

In both phases of the scouting duel, the Germans enjoyed a visibility advantage, with the British ships outlined against the setting sun while their own were concealed in the murk to the East. However, in the Run to the North, the duel between Hipper and Beatty continued and in stark contrast to the Run to the South Beatty had the better of it. Beatty was now much more careful to use his superior speed, increasingly apparent as the Germans' inferior brown coal took its toll, to dictate the range of engagement for his battlecruisers, while *Valiant* and *Barham* of 5BS scored

repeatedly against Hipper's ships. Though the results of this continuing engagement were undramatic, they suggest the likely outcome had Beatty deployed wisely in the run to the south with his full force. Beatty, however, now achieved success by delivering the unsuspecting High Seas Fleet onto Jellicoe's guns, again reversing the advantage.

When the battle fleets met (Fig.1, G), Jellicoe having successfully deployed in battle line to port, an ideal Lanchestrian positional situation was created in which the High Seas Fleet would normally be destroyed (Fig.1, H, at 1830). Again poor visibility favoured the Germans enough to save them, for although the orientation of the fleets relative to the setting sun was reversed in favour of the British, general visibility by this time was patchy and in places reduced almost to zero, negating Jellicoe's numerical advantage and momentarily reversing it when *Invincible*, ranging with 3BCS ahead of Jellicoe was suddenly exposed by a change in the light. This misfortune led, as with *Queen Mary*, to adverse Square Law concentration in which she was exposed (a few minutes after Fig.1, G) to the fire of two German ships, *Lützow* firing the salvo resulting in *Invincible's* fatal explosion (at point H in Fig.1). Nevertheless, the accuracy of the shooting of 3BCS was clearly improved by their training at Scapa Flow, and *Invincible* is credited with inflicting fatal damage on *Lützow* before her demise. Thus the oldest battlecruiser and the newest present at the battle effectively sank each other.

Confronted with the concentrated Grand Fleet Scheer had no option but flight. He successfully executed the battle turn away practised for such an occasion (Fig.1, I), aided by poor visibility which prevented at least half of the Grand Fleet's battleships from engaging,[49] and vanished into the murk before turning and blundering into Jellicoe again (Fig.1, J, at 1900). The turn away then had to be repeated, but was 'a shambles' compared to the first attempt: on this second occasion, visibility was better for the British, many more of Jellicoe's ships found targets, and the manoeuvre was poorly executed under heavy fire (Fig.1, K, not sharply defined). At this point, the square law 'was beginning

[49] Campbell, *Jutland*, p.155.

to tip the High Seas Fleet down a steepening slope to oblivion',[50] but the disarray of Scheer's ships was ultimately masked by the laying of smoke, a well-executed destroyer attack on the Grand Fleet forcing a turn away, and a sacrificial charge by his battlecruisers. In this 'death charge' on the British fleet, further poor visibility saved Hipper's ships from extended punishment and enabled them to escape, but in a rare clash of the newest vessels *Derfflinger* was 'shattered', primarily by the new 15" battleship *Revenge,* losing two of her four turrets in a matter of moments.[51] In better conditions, neither of Scheer's about turns would have saved him if conducted in full view of the concentrated Grand Fleet. Nevertheless, the point of decision had been reached and Jellicoe had, in strategic terms, won.[52] No bright prospect other than escape remained to Scheer, and he later crept past Jellicoe in the dark.

V

The British capital ships lost at Jutland were all battlecruisers. Two of the three lost were among Britain's oldest vessels of this type, less well protected and armed than later ships: the real shock was the loss of the new *Queen Mary*, which can nevertheless be matched against the equally valuable *Lützow* despite much heavier loss of life on the British ship. There is little evidence to point to systemic weakness in British ship design and doctrine in the context of dreadnought encounters. Shortcomings relate more to the habits of the BCF and Beatty's idiosyncratic leadership, all of which had been on display at Dogger Bank.

[50] Gordon, *Rules of the Game*, p. 461.

[51] Gordon, *Rules of the Game*, p. 459.

[52] Jellicoe had at least twice previously stated his attention not to be drawn into a fleet engagement deep in the German Bight late in the day. Letter from Jellicoe to Capt Frederic Dreyer, 9th July 1915, Churchill Archives Centre, DRYR 3/1; memorandum from Jellicoe to Adm Sir Henry Jackson, 12th April 1916, Temple Patterson, The Jellicoe Papers, vol.1 item 213.

Apart from this, sources agree that British cordite was much more likely to explode than German, and that if both fleets had been equipped with the British propellant at least one German capital ship would have met the same fate. However, catastrophic explosion required a fire or cordite detonation reaching a main magazine, and the evidence of the battle was that such a fate was by no means overwhelmingly probable in British ships. All the British losses involved a shell penetrating a gun turret, causing a cordite fire which transmitted itself to a main magazine and triggered a catastrophic explosion. Only a fraction of German hits could be expected to hit a turret, and a smaller fraction to penetrate. *Lion* was hit 13 times by the 12" shells of *Lützow* in addition to the near-fatal turret hit, and *Tiger* was hit 13 times without seeming likely to sink. Among turret hits, not all would cause catastrophe, which was preventable by alert fire control and flooding of magazines as on *Lion*. *Queen Mary* exploded some time after being hit, implying, for whatever reason, unsuccessful fire fighting and damage control.

If the probability of a catastrophic hit from a single shell was very low, German chances of inflicting such a blow would obviously be increased if more guns could be brought to bear on the target. When outnumbered, German guns were less likely to score a turret hit than British, but the different phases of the fighting at Jutland provided occasions when this was not so. *Queen Mary* and *Indefatigable* were lost when the former was fired on exclusively by more than one German ship for a period of time and the latter when she became detached from the line. Similarly, *Invincible*, though in the van of the Grand Fleet, was two miles ahead of it when fatally hit in chance conditions of suddenly improved visibility for the Germans facing odds of 2-1.

It is usually assumed that the battlecruisers' adopted role as a fast wing of the Grand Fleet was a mistake which placed them in mortal danger. However, if they had met the Germans as part of the Grand Fleet in line of battle their chances of survival would have been greater than when skirmishing with German battlecruisers. A heavily outnumbered German fleet could not have expected to concentrate the weight of fire on any one battlecruiser that they actually achieved at Jutland, and at

the outset of action a number of British ships would have received no fire at all, most likely those which overlapped the German line at either end, where the battlecruisers expected to be stationed.

A further factor working against the Germans was that their prospects of achieving catastrophic hits, although slim, were greatest at the outset of battle. Jellicoe was consistent in his view that the first five minutes of fire were likely to be decisive, no doubt influenced by his reading of pre-war material.[53] Though German ships could remain afloat after sustaining enormous damage their utility in a fleet encounter would cease when the last of their main armament was silenced. This would occur at an increasing rate as the battle progressed with a concomitant reduction in their capacity to inflict equivalent damage on the British. The rate and effectiveness of the fire of German battlecruisers also degraded rapidly as the vessels received hits, whether or not they penetrated the armour: the kinetic energy imparted by the impact of the large British shells was considerable, producing a shock effect on the crew and degrading the effectiveness of sensitive fire control equipment.[54] In this context, the failure of the BCF to engage the new and dangerous *Derfflinger* early in the battle was a grave error. Generally inaccurate shooting by the BCF also handed Hipper the early initiative, stressing again the value of the 'first five minutes'.

Thus none of the apparent weaknesses of British ships relative to German was likely to affect a broadside-to-broadside encounter of the battle fleets decisively. The strengths resulting from earlier decisions, chiefly in terms of numerical superiority in ships, guns and gun calibre, were much more important. In Lanchestrian terms, German success would have to be achieved through their longed-for Kraftausgleich. They put to sea on May 31 1916 with precisely this intention, and during that day and the following night the Lanchestrian balance shifted fluidly between the opposing sides, more

[53] Fiske, American Naval Policy; Baudry, *The Naval Battle*.

[54] The capacity of bursting British shell to degrade German fighting capacity is well documented in Yates, The Jutland Controversy.

than once changing radically within seconds as each sought to achieve a Clausewitzian point of decision [Schwerpunkt].

VI

From a Lanchestrian perspective both sides flirted with disaster at various stages of the Battle of Jutland. However, the Germans achieved a three to one advantage in dreadnoughts sunk, and more importantly escaped extermination. This result seemed to defy Lanchestrian probability as it was understood at the time. Each of Scheer's massive blunders was an unforced error which would have cost him his fleet had not random factors involving weather and circumstantial British deployments developed exactly as they did on the day.

When the fleets set sail, the forewarned British in advance of Scheer, the most probable outcome was the destruction of Hipper's battlecruisers by the reinforced BCF, possibly for the loss of one or two British battlecruisers, but with the firepower of 5BS ensuring British predominance. After this, Scheer would necessarily have returned to port with all hope of a future challenge to the Grand Fleet abandoned. Beatty's weaknesses, and those he tolerated in his subordinates, threw away this favourable situation and for a time offered the Germans exactly the limited yet portentous victory they sought. However, Beatty's unstable dynamic produced a still less probable event: a clash of the fleets in which Scheer could not prevail. Taken as a whole, however, the battle produced at the strategic level exactly the outcome that Lanchester's logic would predict. The full Lanchestrian battle, with its certain defeat, must always be declined by the numerically-inferior force.[55]

The twenty five British dreadnought battleships of less than 15" main armament were not everything that could be desired but, in mounting 127 turrets of twin guns of at least 12" calibre,

[55] Hughes, 'Naval tactics and their influence on strategy', as noted above.

they nevertheless provided a fleet-in-being large enough, by a narrow margin, to deter any German thought of engaging in a full fleet action without previous attempts at partial attrition. This was in itself a decisive strategic result, but must be considered a bluff if British ships were markedly inferior to their German equivalents. Evidence suggests that this was not the case. Marginally inferior British build quality per unit was offset by incremental improvement, superior numbers and gunpower: the culminating vessels in the British production process, the *Queen Elizabeths*, were outstanding vessels by any standard.

Judgements of the technical qualities of opposing ships should also recognise that the British and German fleets were engaged in a process of technological leapfrog during a period of extraordinarily swift development, and on occasions such as Jutland vessels produced in the early part of the period could find themselves outclassed when encountering newer vessels. At Jutland the British fielded six battleships in the ultimate dreadnought configuration of fore and aft turrets along the centreline, to two German battlecruisers of the same type, one of which was lost. As might be expected, *Lützow* and *Derfflinger* were deadly opponents to other battlecruisers and older dreadnought battleships, but when *Derfflinger* encountered *Revenge* , the battleship overpowered the battlecruiser in a match of generationally compatible vessels in which *Derfflinger*'s limited main armament was not effectively offset by enhanced armour. In sum, the Germans were outnumbered and at least matched in technological terms by the Grand Fleet, and this being the case tactics became of paramount importance.

Thus the adverse balance of British losses indicated not overall weakness but rather that Jutland was the great Lanchestrian battle that never quite happened, as Scheer was twice able to decline its culmination when he knew himself to be moments from destruction. Nevertheless, at the operational and tactical levels the battle still respected a Lanchestrian dynamic, as the shifting fight between squadrons and ships produced moments of battle when concentration was realized and the resulting advantages accrued, broadly favouring the Germans. The costly British victory at Jutland is,

therefore, best understood in Lanchestrian terms as a race for concentration which Jellicoe ultimately won. Although this was not converted into German ships sunk, and critics on both sides were quick to contrast Jutland with Trafalgar, the effect on the enemy's will to fight was much the same and Jellicoe's actions and his understanding of his situation must be considered sound.

Jutland should therefore be seen as a victory shaped from 1905 to 1916 by a developing but integrated vision of fleet policy and tactics which enabled Fisher's programme of perpetual technological advance to be carried through to strategic success. Essential to this was numerical superiority, dictated by the crux of Lanchester's argument, the quantification of the trade-off between numbers and quality.[56] The Royal Navy, for all its flaws, was a learning organization, in which reforming drive was balanced by technocratic experts making finely-balanced decisions in a rational manner through a period of intense technological and tactical change. It got the big decisions right, building and correctly wielding its decisive weapon, the Grand Fleet, to achieve the required strategic victory.[57]

[56] Ironically Lanchester's anticipator Bradley Fiske missed this point when he wrote in 1920 that 'the German navy was the better, and was vanquished merely because it was the smaller'. B. A. Fiske, review of Jellicoe, 'The Grand Fleet', *American Historical Review* 25 (1920) 280-282.

[57] Thus the Grand Fleet exemplified what Hughes calls the 'strategy-tactics dialectic', and the point of his title: Hughes, 'Naval tactics and their influence on strategy'. That modern navies have lessons to learn from such history is emphasized by LtCdr B. Armstrong, `Now Hear This – "If We Are to Remain a World Power"', *PUSNI*, 139/5/1 (2013), p. 323.

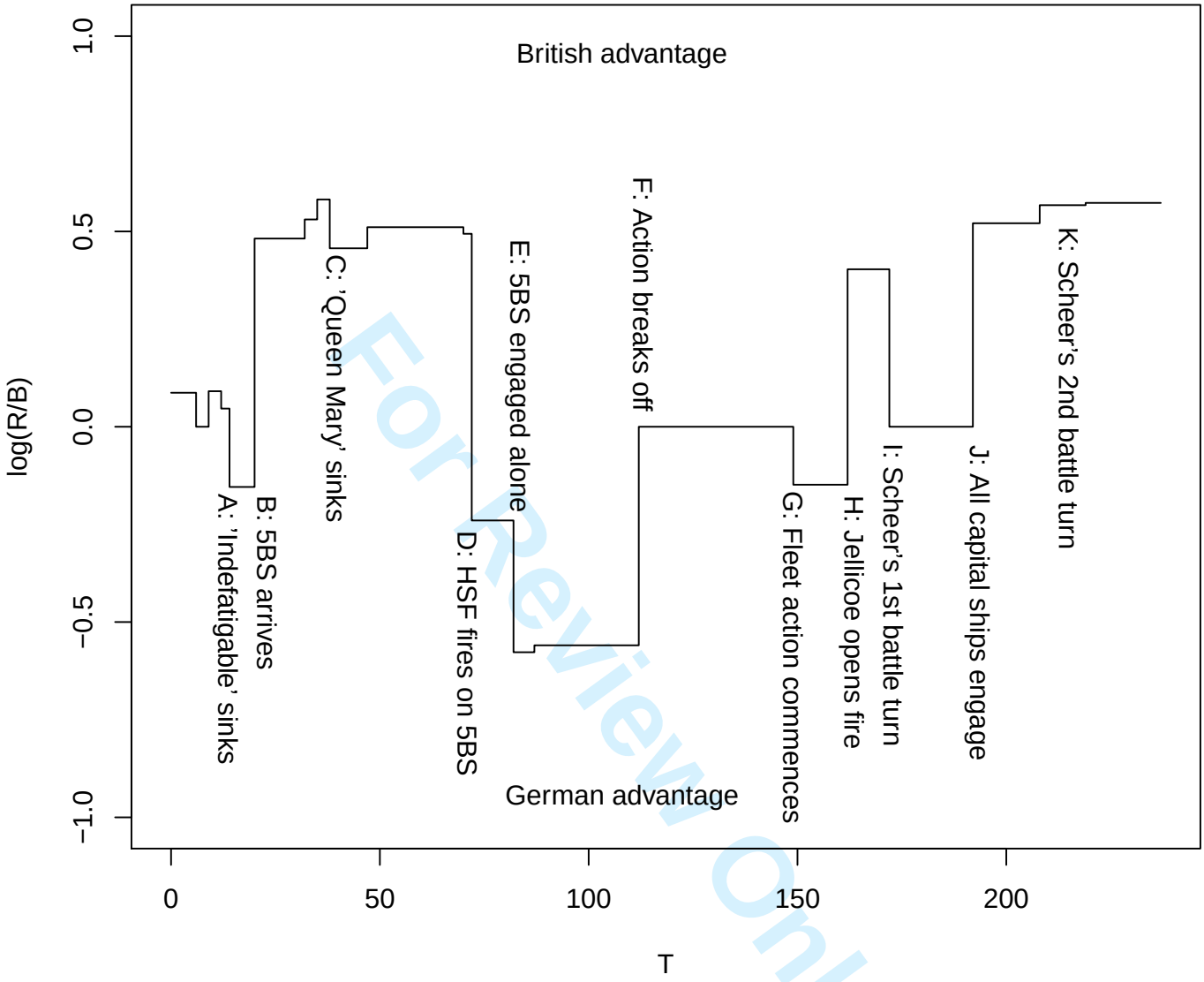

Figure 1. British/German big-gun fire ratio *vs* **minutes elapsed during Battle of Jutland.** Natural logarithm of R ('Red') British divided by B ('Blue') German guns of 11" calibre or above and in action, *vs* time 1548+T minutes on 1st June 1916. (The ordinate is set to zero when no big guns are in action.) Data from Campbell, *Jutland*, 1986. Plotting the ratio in this way measures the asymmetry of the engagement, but not its overall scale. The supreme tactical goal on each side was to effect a fleet *geometry* which optimized this ratio and thereby the Lanchestrian *calculus*.