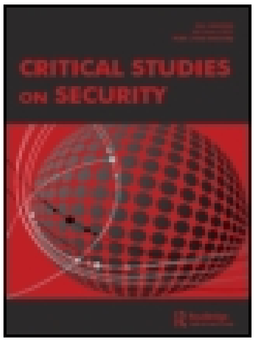


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Antoine Bousquet

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ARTICLE

# Lethal visions: the eye as function of the weapon

Antoine Bousquet

Birkbeck College, University of London, London, UK

**ABSTRACT**
In measure to the development of projectile weaponry, the conduct of modern war has accorded perception with destruction, marshalling and enfolding human vision into ever more sophisticated socio-technical assemblages of targeting. Drawing upon Paul Virilio's notion of a 'logistics of perception', this article charts the four successive orders of targeting constituted by the alignment of the line of sight with the line of fire (aiming), the measurement of distance to a target (ranging), the trailing and prediction of a target's movement (tracking) and the directed navigation to a target's position in space (guiding). Alongside the functional specification of each of these orders is concurrently drawn out the accompanying corporeal regimentations of the organisms thus imbricated. With its capillaries now spanning the wider ranges of the electromagnetic spectrum, the contemporary war machine has however extended its sensorial reach far beyond the confines of its original human strictures. Its culmination may well lie in the advent of laser technology and the promise of a weaponisation of light itself through which the definitive coincidence of perception and annihilation is to be realised, even as it dispenses with the ocular orb.

**KEYWORDS**
Perception; targeting; aiming; tracking; laser; Virilio

Writing over 30 years ago in his seminal enquiry into the 'logistics of perception', Virilio (1989, 26) affirmed that 'for men at war, the function of the weapon is the function of the eye'. Certainly, the most rudimentary of weapons all require hand-to-eye coordination, be they simply the forelimbs provided by nature or the myriad clubbing, cutting or piercing appendages that have been devised to augment their injurious potential. Any offensive action by such a weapon requires its orientation and continuously adjusted guidance by reference to its position and motion relative to its wielder's body and that of the intended target. The information necessary for this purpose is obtained primarily, if not exclusively, via the corporeal visual system.[1] But what Virilio chiefly had in mind in referring to the 'fateful coincidence of eye and weapon' is a much more dramatic convergence and concatenation of perception and lethality under the condition of modernity (110).[2] A survey of the eye at war today would indeed reveal a visual faculty that is exhaustively solicited, augmented and incorporated within an array of socio-technical assemblages of military violence. Central to this historical 'transformation of seeing as primary mode of human perception to seeing as military targeting' (Pettegrew 2015, 8) has been the continuous expansion of the reach and role of projectile weaponry

**CONTACT** Antoine Bousquet a.bousquet@bbk.ac.uk
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capable of striking remote targets since the advent of gunpowder in the early modern era.

Even as the human organism has been disciplined and arrayed to suit martial imperatives, vision has simultaneously become increasingly disembedded from its originary biological substrate through the incremental rationalisation and mechanisation of its functions. For Virilio, this evolution culminates in the emergence of the 'self-sufficient gaze' of 'the machine looking for itself and no longer for some spectator or telespectator' (Der Derian 1998, 9), as exemplified by that of the self-guided missile. This does not however preclude the human organs of perception from persisting elsewhere in other arrangements and deployments, as they are indeed likely to do for some time to come. Yet, we can still submit that under the conditions of modern warfare it is less the weapon that has come to serve as a prosthetic extension of the eye than perception itself which has been caught up in an unrelenting process of becoming weapon.

It is with this history and present unfolding of the concurrence of perception with targeting and its ramifications for weaponised beings that this article concerns itself. In particular, it proposes an account of the specific rearticulations of vision enacted through successive orders of targeting delineated by the activities of *aiming* (the alignment of the line of sight with the line of fire to a target), *ranging* (the visual measurement of distance to a target), *tracking* (the trailing and anticipation of a target's movement) and *guiding* (the directed navigation to a target's position in space). Through both a systematic outline of their general operational principles and the examination of particular material instantiations, this exposé will seek to detail how each new order has constituted a further recasting of perception in an ever-deepening imbrication with weaponry. Finally, while submitting that this same functional schema applies equally to subsequent martial investments of the perceptual field beyond the narrow band of electromagnetic radiation comprised by light visible to the human eye (viz. infrared, radio waves, sound), the article will conclude with a consideration of the significance of the emergence of laser technology. Indeed, laser's stimulated emission of photons delivers not merely another powerful means of sensing the environment and the entities within it but ultimately holds out the promise of a weaponisation of light itself through which the definitive coincidence of perception and annihilation is to be fulfilled.

## The four orders of targeting: aiming, ranging, tracking, guiding

In charting the military mobilisation of vision within the deadly perceptual logistics of the war machine, a distinction is to be made between the four orders of targeting constituted by exercises in aiming, ranging, tracking and guiding. The term of 'order' is here primarily to be understood in the sense of the arrangement or disposition of constituent elements and their relations, although a further semantic resonance connotes the authoritative command or disciplinary instruction entailed by the corresponding marshalling of bodies and machines. However, if there is both a temporal and logical sequence to the emergence of these successive schemas, it is important to underline that they do not come to supplant each other. Rather, each order enfolds the previous one within its own operation: ranging the distance to a target necessitates taking visual aim at it, tracking a mobile entity in space and attempting to predict its future trajectory requires a steady stream of range measurements and guiding a projectile to its intended destination involves continuously tracking their relative positions. Thus, the four orders are co-present in the contemporary battlespace, variously instantiated within specific military assemblages.

The *first order* of targeting covers 'the act of taking aim' that Virilio describes as 'a geometrification of looking, a way of technically aligning ocular perception along an imaginary axis' (1989, 3). With projectile weapons capable of striking adversaries at a distance, there arises a manifest tendency for the line of sight to align itself with the line of fire, as evidenced by the sling, bow or firearm. Where the provision of the projectile's motive energy is entirely delegated to the weapon itself, visual identification of the target and accurate aiming become the primary skills required of its human operator. Sheer physical prowess accordingly takes on less importance in the performance of the very sharp end of soldiering than the smooth and efficient working of the nervous system linking the visual cortex to the appendage – generally a single digit – tasked with initiating the delivery of deadly force. The line of sight thus comes to espouse the character of a lethal perpendicular ray, focused through the frame of iron sights, cross hairs and other reticules along which is realised the alignment of eye, weapon and target.

With the progressive increases in the range and accuracy of firearms, telescopic contraptions permitting the optical magnification of distant objects have come in ever greater assistance to the task of taking aim, beginning with that entrusted to dedicated marksmen. The first systematic use of telescopic sights took place in the First World War, the German forces leading the way with reportedly no less than 20,000 sights in service by the end of 1914. As one British officer conveyed it, exposure of any part of the body for any longer than 3 s would invariably draw German sniper fire and, with accurate ranges of 300 m for those rifles equipped with telescopic sights, direct hits frequently ensued (Pegler 2001, 14). 'Trench periscopes' came into widespread use for this reason, whether as stand-alone observation devices or affixed to a rifle for firing from cover, enabling a continued optical alignment of the gaze with the weapon while simultaneously affecting a physical displacement of the eye through the refraction of light via prisms or mirrors. The role of telescopically enhanced vision on the battlefield has since only increased with the subsequent gains in the lethal ranges attained by snipers. By the Second World War, targets at distances of 600 m could be commonly hit. Today, in the hands of skilled marksmen and favourable conditions, accurate fire in the field can be reliably achieved for ranges of 1200 m and, although exceedingly rare, lethal shots from distances over 2000 m have been reported. Nor are telescopic sights any longer the preserve of snipers and other specialist weapon operators, having in recent decades become a standard accessory issued with infantry rifles within leading militaries.[3]

Although frequently mediated and routed by lenses and other reflecting or refracting surfaces, the first order of targeting thus fundamentally consists of an optical alignment of eye and target along a visual ray that the trajectory of an associated weapon system strives to approximate. It is of course true that any projectile subject to the forces of gravity and atmospheric friction will inevitably take a parabolic trajectory which cannot therefore ever strictly be aligned with a visual ray. So while a broad correspondence of line of sight and line of fire still holds with modern firearms, a shooter may have to account for the arcing path of a bullet when firing at a target lying outside of a given weapon's optimal operational range by estimating distance and either deliberately aiming off target or adjusting their optical sights accordingly.[4]

This crucial consideration of distance and parabolic trajectories brings us to the *second order* of targeting that encompasses the techniques of measurement by eye through which the precise range from a weapon to a target can be determined. Originating in methods of land surveying, the military practice of visual ranging developed alongside the artillery revolution in early modern Europe (Parker 1988). In combination with the science of ballistics, ranging greatly improves the efficiency of targeting where the projected munition must take a strongly parabolic trajectory and a simple alignment of sight, weapon and target is inadequate. Exercises in early gunnery essentially proceeded by rule-of-thumb guesswork and trial and error, with any necessary adjustments to an artillery piece's aim made by reference to the observed divergence between the target's position and that of any stray shots. From the sixteenth century onwards, this largely intuitive practice was supplemented by a range of cognitive aids and instruments such as artillery tables, theodolites, military compasses and gunner's quadrants. Among the purposes of these devices was the application of trigonometric principles for the determination of range through the surveying technique of triangulation. It was known since antiquity, but only rediscovered in Europe with the Renaissance, that for any given triangle it is possible to mathematically derive from the known values of one of its side's lengths and two of its angles the value of all the remaining sides. Thus, for the purposes of artillery, the range to any target can be determined from the measurement of the distance between two surveying positions and of the respective angles formed by the lines of sight from these positions to the target (Figure 1). While there is still here a geometric alignment of vision along an imaginary axis requiring the surveyor to 'take aim' at the target, it no longer necessarily approximates that of the weapon's line of fire. Instead, we see a harnessing of the phenomenological unit of visual perception into a calculative assemblage of geospatialisation through the abstract recombination of distinct lines of sight.

Optical devices for practical deployment in the field would subsequently allow rangefinding to be carried out through the unified phenomenological frame of a single operator. A simple and reasonably accurate technique is that of stadiametric rangefinding in which a reticle with marks of a known angular spacing is superimposed upon the eyepiece of a lens of specified telescopic power. The distance of objects of a known size, such as a soldier or a tank, can then be easily read off from such a telescopic sight. Introduced during the First World War for artillery use, sights adapted for stadiametric range-finding continue to be widely employed for both their ease of use and inconspicuousness, qualities that have made them particularly valued by sniper units.

A more powerful and accurate contraption is the optical rangefinder that was developed at the end of the nineteenth century and thereafter widely adopted by militaries on land and at sea. The rangefinder embodies a striking technical condensation of the above visual surveying technique. The telescopic device consists of an array of lenses and prisms within an elongated tube, the extremities of which serve as the perpendicular base of a right-angle triangle to the object being sighted (Figure 2).[5] The two images entering the device from both ends are brought together in either one or two central eyepieces, depending on the inner mechanism privileged. The *coincidence* rangefinder makes use of a single eyepiece with each image respectively occupying

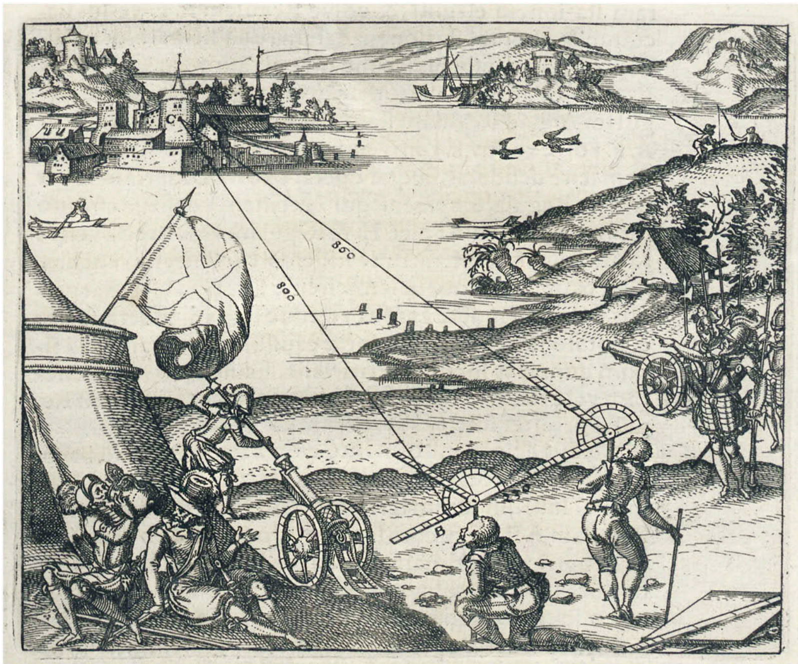

**Figure 1.** Range-finding through triangulation. Illustration from Leonhard Zubler, *Novum instrumentum geometricum* (Basel 1607) [SLUB Dresden/Deutsche Fotothek].

**Figure 2.** Naval rangefinder in a target practice exercise, 1913 [Harris & Ewing collection, prints & photographs division, library of congress, LC-H261-3193].

the upper and lower halves of the eyepiece display. The operator is tasked with aligning the two separate images of the target being sighted by manually orienting the device's internal optical elements. Once the images are in coincidence, the distance to the target can be simply read off the rangefinder which has automatically performed all the necessary trigonometric calculations. In contrast, the *stereoscopic* rangefinder makes use of two eyepieces, one for each image. Here, the operator's visual cortex has to merge both images, producing a stereoscopic image that provides a sense of depth perception. Adjustments are then made to position the target at the same visual distance as reference marks positioned in the eyepieces, with range once again displayed on the rangefinder's instruments. If the stereoscopic contraption is, at least on the surface, closest to unassisted human binocular vision, both types of apparatus enact machinic concatenations of discrete lines of sight that demand that an operator be trained to see in such a way as to perform the device's function of optically determining distance.

In addition to allowing for the visual determination of the distance between a weapon and its intended target, mobilisation of the surveying technique of triangulation further permits the decoupling of the locus of perception from the weapon's position altogether by way of relatively straightforward exercises in geospatialisation. Such procedures are invaluable to the practice of indirect fire where there exists no direct line of sight from an artillery gun to the intended target due to impaired visibility, intervening obstacles or the need for protective cover. In the most basic configuration, surveying takes place from the vantage of a third position from which both target and weapon system can be sighted. The registration of the two ensuing measurements upon the gridded surface of a plotting board then promptly yields the relative positions of one surveyed entity to the other.

The *third order* of targeting encompasses a collection of techniques that use the continuous tracking of a mobile target to derive a prediction of its future position and schedule an ensuing encounter with a lethal projectile. Just as advances in gunnery were yielding marked improvements in the ability to target specific points in *space* through the practice of ranging, a new type of problem was increasingly posed in the twentieth century by the growing mobility of targets, the resolution of which would require the considerably more exigent task of targeting points in *space-time*. Indeed, beyond a certain range, the motion of a non-stationary target relative to a weapon system requires the anticipation of the former's position at the moment at which the fired projectile will reach it. The corresponding practice of 'leading' the target by firing ahead of its present position is one that had long been carried out intuitively by archers and riflemen. Yet, the formidable increases in the range of weapon systems and the mobility of their potential targets undergone in the last century have necessitated the adoption of mechanisms of high-speed computation in order to add prediction to the already existing arsenal of sociotechnical assemblages of perception and localisation.

The inception of such a capability can be traced back to the first decades of the twentieth century and the efforts expended by the major naval powers towards improving the accuracy of long-range fire against other ships. The necessary calculations were highly complex, requiring information on the target's range, speed and course, as well as the firing ship's own motion (its speed and course but also its roll, pitch and yaw) along with the other variables relevant to the directing of artillery fire.[6] Naval gun control consequently saw the functions of perception, localisation and gun laying being disaggregated and redistributed across the warship constituted as an integrated weapon system. Through the use of long-base rangefinders and precision telescopes, officers situated in elevated director towers sighted the position of targets along with the locations at which shots fell. Any firing orders issued went down to a plotting room below deck in which gunnery officers plotted data points, calculated estimations of future positions and, on the basis of artillery tables, passed on the relevant firing solutions to the ship's guns (Mindell 2003, 26). Initially carried out almost entirely manually, all the different elements of the fire control chain would undergo a progressive mechanisation and automation of their functions. While the inconclusive Battle of Jutland of 1916 had exposed the weak performance of the supposedly leading fire control systems of the British Navy with only 3% of shots hitting their intended German targets, it had also simultaneously highlighted the superior operation of the only ship equipped with a mechanised calculating system (20). Automation would proceed apace in the following decades, incrementally integrating the functions of targeting until information gathered from the sighting of enemy units could be directly transferred electrically to a plotting room where, factoring in the ship's own motion sensors, predictive firing solutions would be automatically calculated and transmitted to servo-mechanically controlled and gyroscopically stabilised guns. At the very heart of these integrated systems for fire control was the rangekeeper, an electromechanical computing device that calculated the current target bearing and generated predictions as to its future position for translation into gun laying instructions.

Nothing would however drive the automation of targeting within space-time faster and further in the interwar years, and then with even greater intensity during the Second World War, than the so-called anti-aircraft problem. Both on land and at sea, the task of fire control was immensely complicated by the appearance of high-speed aerial vehicles that moved in three rather than two dimensions. The central challenge lay in the final instance less in the addition of this further dimension, since the analytical problem of targeting was not fundamentally different from that of naval fire control, than in the drastic reduction in the time available for the computation and transmission of effective firing instructions from tracking observations. The enhancement of anti-aircraft defences thus became a major priority during the Second World War, with much of the leading work conducted under the auspices of the Office of Scientific Research and Development (OSRD), the agency set up to coordinate scientific research for the American war effort. The array of projects funded by the OSRD focused on various aspects of the anti-aircraft problem with differing degrees of success but had the overall effect of further tightening the systemic integration of the constitutive elements of *perception* (supported by optical rangefinders and tracking telescopes in the first instance, thereafter progressively displaced by the new electromagnetic technology of radar), *computation* (executed by devices known as rangekeepers, predictors, gun directors and eventually simply as computers) and *gun laying* (increasingly performed by electro-hydraulic remote control). At the outset of the war, as many as 14 people were required to perform the tasks of observation and tracking at an anti-aircraft position with the information being manually relayed to the gun controllers. The implementation of automatic control and the electrical relaying of information would however soon result in a marked reduction in the reliance on manpower along with dramatic improvements in speed and reliability of execution (Bennett 1996).

This is not to say that the human component was thereby rendered insignificant. Indeed, it remained essential to the operation of these systems but its corporeal embedding into them deepened accordingly. Gyro gunsights, such as the US Navy's Mark 14, required the operator to take visual aim at a target aircraft, maintaining the sight's reticule locked upon it as it moved through the air while the device calculated the necessary lead and adjusted the gun's actual aim. Its manufacturer promoted the new sight in 1941 by claiming that it 'broadens the mental powers of the gunner, frees him from tasks requiring judgment, and enables him to devote his entire attention to the accurate "tracking" of enemy aircraft' (Mindell 2003, 221). The gunner, no longer having to intuit the trajectory of the target, could become a dedicated servo-mechanical vision machine, the continuous tracking by the human eye providing the vital informational input for the sight computer's aiming of the gun. The same principle can be seen at work in the tachometric bombsights deployed in the Second World War for the conduct of aerial bombing. The famous Norden bombsight involved the bombardier sighting the target through a visual cross hair, adjusting the settings on the bombsight's state-of-the-art mechanical computer until the cross hair remained stationary as the bomber approached the target. With control over the aircraft speed and course momentarily handed over to it, the bombsight then automatically triggered the bomb release on the basis of a complex real-time calculation involving air drag, aircraft speed and altitude and direction and speed of wind.

For Patterson (2009), all these targeting apparatuses are 'specifically dedicated to augmenting, informing and enframing the soldier's process of seeing' and 'directly shape the actions of which he is a capable' through 'a process in which the human body is re-educated by the machine to act according to a new paradigm of visuality'. The act of seeing becomes here synonymous with the rapid scanning of the visual field for a movement or object of interest, followed by a focusing and locking of the gaze upon an identified target as it is continuously tracked across the field of vision. This sustained fixing of the target by the eye generates the data stream necessary to automatically derive predictions of the target's future behaviour and direct deadly force against it – 'to see is to model is to comprehend is to destroy' (42). Yet, with the eye itself being simultaneously disciplined into a visual regime of calculability and control, the optical sight can be properly said to (en)frame the eye just as much as the would-be target.

This regime of militarised perception would seep deeply into the post-war scientific culture, providing a conceptual framework through which the human organism could be reinterpreted along computational lines. Having served during the war in the RAF's (Royal Air Force) Signals branch, the influential British neuropsychologist Gregory (1966, 93) would develop a cybernetic understanding of human perception of movement with reference to the 'two movement signalling systems' of the 'image/retina' and 'eye/head' in which the edge of the retina acts as 'an early-warning device, used to rotate the eyes to aim the sophisticated object-recognition part of the system on to objects likely to be friend or foe'. Employing terms explicitly derived from those employed in gunnery 'where similar considerations apply when guns are aimed from the moving platform of a ship', Gregory articulated a conception of human vision framed in terms of a dynamic process of tracking and targeting. This cybernetic paradigm of vision and targeting has further come to serve as the template for what Jordan Crandall (2006) refers to as a generalised mode of operability for the detection, processing and codification of moving phenomena. Whether the phenomenon in question is 'a stock price, a biological function, an enemy, [or] a consumer good', its tracking and the resulting generation of future predictions promise to afford a 'real-time perceptual agency' and the gain of a strategic advantage in the relevant 'competitive theatre'. Tracking thus stands as the 'dominant perceptual activity in a computerised culture where looking has come to mean calculating rather than visualising in the traditional sense and where seeing is infused with the logics of tactics and manoeuvre'.

Yet, with regard to the original anti-aircraft problem, it was eventually recognised that, for all the technical advances of the Second World War, a satisfactory solution could not ultimately be obtained on an entirely ballistic basis. Accurate prediction of the future position of a highly mobile target at a precise moment in time was simply found to be impossible to achieve reliably, particularly at the supersonic speeds of travel that soon became available after the war. Several sources of uncertainty indeed conspire to undermine any attempts at predicting the future location of an aircraft through an extrapolation of its prior motion (Wiener 1942). For one, the trajectory of an aircraft is rarely smooth, with unintended irregularities introduced by both the pilot and an array of mechanical and aerodynamical factors. Secondly, significant measurement errors (or 'noise') are introduced by both machines and human operators into the tracking data. Finally, even if a successful technical system could be devised that satisfactorily mitigated these uncertainties, it would inevitably lead to enemy pilots purposefully taking evasive action to frustrate any prediction of their flight course.

Necessary to overcoming this impasse was the constitution of a *fourth order* of targeting in which elements of the targeting process become relocated into the projectile itself via the introduction of guidance systems that permit the adjustment of its trajectory in mid-flight. A general estimation of the ideal ballistic path prior to the projectile's release still remains in many cases desirable but, crucially, a guided munition has the capacity to steer itself towards its target and correct for any deviations. Whether entirely self-contained within the munition or spatially distributed across discrete entities, fully automated or requiring manual input, all varieties of guidance systems are essentially comprising the same fundamental functional components. In the terms of art, a sensor serves as the munition's 'eyes' in establishing and maintaining a 'line of sight' to the target. A control system thereupon establishes the relative geometry between munition and target, contrasts it with the desired geometry and generates the steering commands necessary for their convergence. Effectors then translate these commands into the required mechanical adjustments, be they solely the orientation of aerodynamic control surfaces (as with guided bombs) or their combination with thrust control (as with self-propelled missiles). In enabling the process of tracking to be extended in this way until the very point of impact, the net effect of guidance is to dramatically enhance the potential accuracy of targeting far beyond anything possible with simple ballistic fire control.

In the Second World War, the technical challenge of implementing weapon guidance found a ruthless but effective solution in the Japanese kamikaze pilot. As a post-war report by the American National Defense Research Committee (1946, 198) recognised, 'the simplest method of obtaining target discrimination is through its recognition by intelligence' and 'the Japanese suicide missiles employed exactly this technique, using human organisms to guide the missiles'. Although 'economy as well as considerations of humanity' were deemed to recommend against the use of humans, an attempt to recruit 'lower organisms' into the process of targeting was nonetheless pursued in one of the most singular research programmes of the war. Directed by the psychologist B.F. Skinner who would subsequently find fame for his behaviourist work, *Project Pigeon* proposed nothing less than to entrust the guidance of missiles to live beings of the peristeronic variety.

The underlying principle of this peculiar guidance system was simple enough, as presented by Skinner (1960) in his later writings: 'an image of the target was projected on a translucent screen as in a camera obscura. The pigeon, held near the screen, was reinforced for pecking at the image on the screen. The guiding signal was to be picked up from the point of contact of screen and beak'. Through the fastidious instillation of conditioned reflexes, the bird could be made to ignore any distractions occasioned by loud noises, vibrations and acceleration so as to diligently perform the necessary responses to visual stimuli for the correction of any deviations of the missile from its intended destination. Skinner's research showed that, following a careful process of selection, those pigeons that proved most responsive to the operant conditioning could, through exposure to relevant aerial photographs, be successfully trained to follow a variety of targets on land and at sea, ignore other objects in the visual field, and even consistently prioritise a single target when several were visible. In order to hedge against any aberrant pecking by a single animal, the design of the homing-pigeon system eventually evolved to house three birds, the sum of their individual behaviours 'democratically' determining the guidance instructions to be conveyed to the missile (Figure 3). The programme was deemed to hold enough promise for the OSRD to award it $25,000 in June 1943. Skinner would later maintain that its cancellation in the following year had less to do with the actual performance of the guidance system than the stubborn notions of fancifulness that inevitably attached themselves to his avowedly 'crackpot idea'. This assertion receives some credence from the decision by the Naval Research Laboratory to revive the project in 1948 under the denomination of ORCON (for 'organic control') and support it until 1953, by which time the superiority of electronic guidance systems had become incontrovertibly established.

Despite its lack of fruition, the entire endeavour still nonetheless merits our attention as more than an eccentric footnote in the history of guidance technology. Following on from the prior regimentations of bodily vision already outlined, Project Pigeon presents us with an unadorned expression of the further marshalling of organic sense perception and its attendant network of reflexes into a control mechanism for the extension of the targeting circuit into the projectile itself. Conditioned to disregard all other possible stimuli and strapped into a harness excluding any other freedom of action, the selected bird is rendered into a cybernetic control unit that tirelessly processes a flow of visual information into a corresponding set of corrective actions, steering its vehicle towards its intended target and thereby making itself the unwitting agent of its own annihilation. Or, as Skinner put it to his funders, 'we have used pigeons, not because the pigeon is an intelligent bird, but because it is a practical one and can be made into a machine, from all practical points of view' (Capshew 1993, 851).

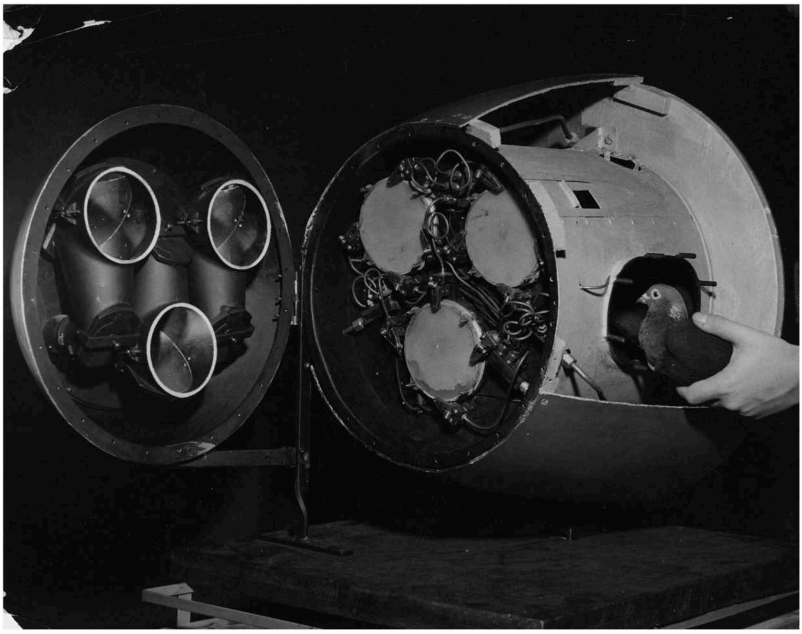

**Figure 3.** Three-pigeon missile guidance system [B. F. Skinner foundation].

An alternative to the wholesale assimilation of the living organism into the guided weapon was however sought in the recruitment of the technology of *television* into military assemblages of remote perception and control. As an electro-optical system for the transmission and reception of moving images at a distance, the invention of television fired the military imagination early on. The radio transmission of live images promised to definitively untether the eye from the immediate locus of its corporeal shell and allow it to view in real-time remote locations and events without the requirement of a direct line of sight. Following a demonstration of the latest technology in 1933, one US admiral noted the uses that might be made of it to 'scout the enemy with television equipment in a plane, direct the fire of our gunners and make great advances in aerial mapping' (Magoun 2007, 79). Most tantalising of all was the prospect of conjoining television with radio control for the realisation of a telepresence that would bring perception and action at a distance under the unitary phenomenological frame of a single operator.

In 1934, the Radio Corporation of America (RCA) engineer Vladimir Zworykin put forward a concrete proposal for the development of a 'flying torpedo with an electric eye', in effect a glide bomb fitted with television and remote control. As Zworykin (1946, 294) explained, 'after it has been released the torpedo can be guided to its target with the short-wave radio control, the operator being able to see the target through the "eye" of the torpedo as it approaches'. Under this arrangement, the human eye becomes in effect coterminous with that of the missile itself, hunting down its target until the latter fills the entire field of vision, the very instant at which perception and its object are simultaneously obliterated. Although it received no immediate funding, Zworykin's proposal outlined a tangible scheme for the use of television for missile guidance that would gain new momentum with the outbreak of the Second World War.

In the event, television only came to play a marginal role in the conflict even though RCA did go on to deliver over 4000 television systems to the US military (Abramson 2008, 9). The challenges of employing television for remote guidance in the manner that Zworykin had imagined proved considerable due to the need for the miniaturisation of the equipment and the difficulties posed by radio signal interference. Despite substantial expenditure, these obstacles could not be overcome in time to make a meaningful contribution to the war and only a few experimental weapon systems were ever deployed in the field. The Navy did develop a television-guided pilotless aircraft to be used as a flying bomb against naval targets and envisioned the production of a thousand of these 'assault drones'. But persistent technical problems and the military brass's loss of interest meant only a fifth of the original order was fulfilled and operational roll-out was limited to a few sporadic attacks against the Japanese. In the European theatre, the Air Force secret programme Operation Aphrodite sought to remotely guide war-weary B-17 bombers laden with explosives onto selected targets. A pilot and flight engineer would be responsible for getting the bomber airborne and setting it on course before bailing out and handing over control to the crew of a second aircraft tasked with leading the bomber to its target by reference to televisual images. Over a dozen missions were attempted but all ended in failure and the programme had to be abandoned. With the German work on television guidance for the Hs-293 glide bomb proving no more conclusive, the American post-war assessment (National Defense Research Committee 1946, 4) could only conclude that 'no television-missile system was successful as World War II closed'.

Subsequent efforts would prove more fruitful with the noted performance of the American television-guided bomb Walleye in the Vietnam War leading to a wider adoption of successor weapons such as the Maverick AGM-65A/B missile and GBU-15 glide bomb. With all these systems, the operator is not required to guide the missile all the way to its target and can instead opt to use the on-board camera to visually lock onto a target before handing control over to automatic guidance. Live video feeds are also presently a crucial feature of the operation of remotely piloted vehicles, notably supporting the targeting process of unmanned 'hunter-killer' aircraft such as the Predator or Reaper (Chamayou 2015). Yet, television is merely one among the many sensor technologies to have not only been integrated into the guidance systems that have proliferated since the Second World War but also more broadly incorporated within the perceptual arsenal of the modern war machine.

## Towards the weaponisation of light itself

Just as the four orders of targeting encompassed by the activities of aiming, ranging, tracking and guiding are co-present, albeit in varying concatenations, in contemporary military assemblages, each of these functions is liable to be fulfilled through any number of investments of the perceptual field. As the cybernetician Norbert Wiener (1989, 23) pointed out in 1950, 'every instrument in the repertory of the scientific-instrument maker is a possible sense organ' and certainly we have witnessed an unrelenting extension and concomitant weaponisation of perception far beyond the narrow visible range of light that the human eye and its optical enhancements can apprehend. In particular, the progressive discovery and annexation of the wider electromagnetic spectrum of light have dramatically expanded the perceptual ambit of the war machine. The capture of infrared frequencies has lifted the veil of nocturnal obscurity and enabled the detection of radiant heat sources (Arnquist 1959). Radar technologies have harnessed radio waves to record the presence and motion of objects in space over vast distances in practically all atmospheric conditions (Buderi 1996). And beyond the electromagnetic spectrum, the properties of acoustic phenomena have been corralled into new sensorial capacities in the forms of sound ranging and sonar (Namorato 2000). Each of these sensorial conduits has in turn been harnessed into countless weapon systems under the four orders of targeting and their conjugations of perception and destruction. The human operator, to the extent that it is still in the loop, must thereon typically do with second-order visualisations of these sensor inputs.

Of particular note however is the advent of laser technology with its regimentation of individual photons into concentrated beams of light. Indeed, laser provides not only another perceptual technique to be integrated into the existing modalities of targeting but further holds out the tantalising promise of an energy weapon lancing through space at the very speed of light. Through the controlled release of photons from the excitation of atoms and associated shifts in the energy states of electrons, laser devices are able to radiate forth tight directional beams of light of narrowly restricted electromagnetic wavelengths. In accordance with the specific material medium being stimulated and the related wavelengths of light correspondingly emitted, these rays take on different properties such as colour and visibility to the human eye, duration, range and power. Following the assembly of the first working device in 1960, laser has been recruited to fulfil all of the targeting functions of detection, ranging, tracking and guidance, in addition to which it can serve as a directed energy weapon with singular properties.

As with sound and radio waves, laser beams can be employed for range-finding by measuring precisely the time needed for a laser pulse to be reflected off a target. Already deployed in the field by various countries by the close of the 1960s, laser rangefinders have today almost entirely supplanted their optical counterparts for the estimation of distances due to their superior accuracy, convenience and operational ranges. With high repetition rate devices permitting the continuous tracking of rapidly mobile targets, laser rangefinders are a major component of contemporary fire control systems. Laser range-finding has furthermore given rise to the remote sensing technology of light detection and ranging in which the range to every point in a given field of view is measured, generating detailed three-dimensional models of the scenes surveyed to a resolution superior to that afforded by radar.

Laser has also been widely integrated into the available suite of weapon guidance systems. Within such assemblages, a target designator directs a coded laser beam at a target, allowing a munition's laser target seeker (generally an infrared sensor) to lock onto the beam's reflections and steer a trajectory to the intended destination. Among the first such systems to enter service, the Paveway laser-guided bomb (LGB) was deployed over South-east Asia in 1968. Most famously, it was credited with inflicting critical damage on the Thanh Hóa Bridge in 1972 after the structure had survived hundreds of previous aerial attacks. By the end of the war, no less than 28,000 LGBs had been dropped and, according to one estimate, just under half of them achieved direct hits on their targets, against a mere 5% of the unguided munitions dropped (Boot

2006). Such reported levels of accuracy predictably drove the further adoption of laser guidance which, with the arrival of microchip technology permitting a miniaturisation of its components, would become a major enabler of the new vision of aerial 'precision bombing' showcased during the 1991 Persian Gulf War. While guided weapons represented in reality a mere 7% of the total munitions expended in that conflict, LGBs have since gone on to play a prominent role in all major theatres involving the US forces, from Yugoslavia to Afghanistan and Iraq.

If laser has to date primarily been adopted to support the targeting of bombs and missiles, it is now increasingly migrating to smaller ballistic weapons. Laser sights have long been available as a visual aid to the aiming of firearms, particularly in low-light conditions, by emitting a beam or spot visible either by the naked eye or via a night-vision device. More sophisticated integrations of laser into firearms have however recently begun to emerge, adapting technology previously reserved to larger weapon systems. In 2013, the Texas-based company TrackingPoint introduced a laser-enabled 'precision-guided firearm' with the claim that it dramatically increases first round hit probability at ranges of 1000 yards and above without the requirement for advanced marksmanship training (Hutchinson 2013). The weapon's video scope permits the 'tagging' of a target by locking a laser rangefinder onto it, providing an instantaneous measurement of distance and continuous tracking of movement. The on-board computer thereupon calculates the ballistic solution, accounting for an array of factors such as bullet drop, wind, temperature, humidity and firearm incline. The weapon's operator then only has to align the scope's cross hair with the target tag, the ballistics computer automatically firing the gun at the opportune moment. In removing the need for the skills and experience normally indispensable for sharpshooting at long distances, TrackingPoint has proudly proclaimed its product to be 'democratising accuracy', edging closer to making sensorial acquisition the sole task demanded of a firearm operator (Anderson 2013). As for the US military, it is already looking ahead to the next generation of technology in which laser guidance will be incorporated into the firearm's projectile itself. In 2012, Sandia National Laboratories, a subsidiary of the Lockheed Martin Corporation, announced they had successfully conducted tests of a small calibre bullet capable of steering itself towards a laser-designated target located 2000 m (1.2 miles) away. A similar programme entitled Extreme Accuracy Tasked Ordnance is also under way under the aegis of the Pentagon's advanced research agency (Ackerman 2015).

Yet, for all these successful applications, the potential employment of laser that has most mesmerised military minds from its very inception is as a directed energy weapon, with all its echoes of the enduring science fiction trope of the 'death ray' (Fanning 2010). It is no doubt with such an end in sight that the head of the Army Ordnance Missile Command expressed in 1962 the view that 'laser may be the biggest breakthrough in the weapons area since the atomic bomb' (Seidel 1987, 114). While designs to produce an operational weapon that would revolutionise warfighting in the manner of its nuclear counterpart have to date been frustrated, it has not been through want of trying or the absence of progress towards the realisation of that goal.

Relatively low-energy lasers can already be effectively weaponised for the purpose of blinding light-sensitive receptors, be they electro-optical (particularly sensors operating in the infrared range) or biological, to wit, the human eye. A certain grim irony can be found here in the fact that the special sensitivity to light that has made the eye such a precious adjunct to weaponry simultaneously renders it uniquely vulnerable to invisible rays of weaponised light. Following a campaign by the Red Cross and concerned governments, a UN ban on 'blinding laser weapons' was agreed in 1995, requiring of signatory states that they refrain from employing lasers to 'cause permanent blindness to unenhanced vision' resulting from retinal burns and intraocular bleeding (United Nations 1995). Under its terms, the infliction of 'temporary' blindness and pursuit of attacks against optical equipment (including those that might thereupon cause permanent blindness to their user) are still permitted.[7] A range of laser 'dazzlers' designed to disrupt infrared sensors and assail the human eye is thus in service today. The real prize for the military remains however a laser weapon capable of destroying targets such as missiles or aircraft by imparting critical thermal damage to their bodies, a task which requires much more powerful beams and still presently faces substantial technical obstacles.

The appeal of a practical high-energy laser weapon to the military is considerable (Anderberg & Wolbarsht 1992). Unaffected by gravity, laser beams move in a straight line at the speed of light, reaching any would-be target virtually instantaneously. Since there is no need to account for the parabolic trajectory that characterises a ballistic projectile or to anticipate the future position of a moving target, a laser weapon greatly simplifies the problem of fire control, accordingly increasing the probability of a direct hit. In addition, the narrow focus of a laser beam promises greater target discrimination and reduced collateral damage. Since laser beams can also be made invisible (at least to the naked eye), their detection and the determination of their point of origin are rendered more difficult to the enemy. Finally, a laser weapon dispenses with the need for ammunition and its associated logistical chain, relying solely on a reliable, if abundant, power source for its operation. For all these reasons, a high-energy laser appears in principle to be an almost ideal weapon that could confer a potentially decisive advantage to the military that acquired it first.

With the theoretical possibility of high-powered beams recognised even prior to the creation of the first laser device, the pursuit of weaponisation was coeval with their practical development. In particular, the prospect of shooting down incoming nuclear warheads exerted a particular attraction in the fraught context of the Cold War, with the Air Force Chief of Staff, General Curtis LeMay, publicly predicting in 1962 that 'beam-directed energy weapons would be able to transmit energy across space with the speed of light and bring about the technological disarmament of nuclear weapons' and warning of the need to get ahead of the Soviets (Peoples 2010, 119). By 1978, the US Department of Defense had devoted over $1 billion dollars to researching high-energy lasers without having produced anything remotely approaching a useful weapon (Seidel 1987, 145). While lasers powerful enough to destroy targets in test conditions could be constructed, the size and energy requirements of the contraptions alone made them impractical. A renewed drive was made in the 1980s under the Reagan administration's Strategic Defense Initiative (SDI), notably through a research programme dubbed Excalibur that proposed to develop an X-ray laser powered by a nuclear explosion. In what turned out to be a wildly optimistic assessment, Edward Teller, one of the project's chief scientists and already renowned as 'the father of the hydrogen bomb', suggested in 1984 that 'a single X-ray laser module the size of an executive desk which applied this

**Figure 4.** Airborne laser Turret [Lockheed Martin].

technology could potentially shoot down the entire Soviet land-based missile force' (Goodchild 2004, 365). The lack of tangible progress and the demise of SDI with the end of the Cold War did not however put an end to the ambition of fielding laser missile defences, albeit of a more modest remit. In 1996, the US Air Force and Boeing began collaborating on the YAL-1 Airborne Laser which involved mounting a high-energy laser onto an aircraft for the purpose of destroying ballistic missiles in the boost phase immediately following their launch (Figure 4). Although a few successful tests against dummy missiles were conducted, the $5 billion programme was eventually cancelled in 2012, having failed to establish the practicality of an operational deployment. Undeterred by this setback, the Missile Defense Agency is now seeking to fit the next generation of high-energy lasers on unmanned aerial vehicles (Freedberg 2015). To these high-profile anti-ballistic missile schemes can be added a plethora of other laser weapon systems that have been conceived and trialled over the years for use against aerial vehicles, rockets, artillery shells, mortar rounds, mines and other ground targets.[8]

Field deployments of such systems have so far been limited and no high-energy laser weapon can yet claim to have significantly impacted upon the conduct of war. Nevertheless, faith in the future viability of laser weapons and the invaluable military benefits that could accrue from them appear undiminished and the present proliferation of government-funded and commercial programmes around the world suggests that a number of systems may well enter service in the coming decades. The persistence of the drive towards laser weaponry should not surprise us as such, so completely does it appear to fulfil the convergence of perception with targeting that we have traced this far. Already capable of performing all the sensorial tasks required to support the targeting of kinetic force, laser's ultimate promise is to weaponise light itself, marshalling photons into a lethal beam coincident with the visual ray. The line of sight will then have finally become truly coterminous with the pure, cold line of abolition, even as it threatens to dispense altogether with the human orb that first originated it.

Building on Paul Virilio's original insight into the intimate relation between the eye and war, we have sought here to specify the orders of targeting that have, through their successive regimentations of perception, incrementally extended the reach and precision with which deadly weaponry can be aimed. In so doing, we gain a greater understanding of some of the specific ways in which 'bodies are incorporated into war fighting assemblages as operating agents, at the same time that the locus of agency becomes increasingly ambiguous and diffuse' (Suchman 2015, 6). Indeed, for all the present concerns expressed over the possible dangers posed by lethal autonomous weapons or so-called killer robots, the foreseeable future is more likely to involve the ever tighter imbrication of human and machine in the global battlespace. What the present survey underlines is that these entanglements are hardly novel – war has long invested the human circuits of perception, tethering and rewiring them to the imperatives of targeting. Yet, as our incorporation into these martial assemblages deepens further, it becomes ever more pressing to attend to the critical question of the endurance of a human autonomy increasingly evanescent and otherwise perhaps destined to be some day no more than a faint ghostly presence in the war machine.

## Notes

1. One could for instance mention the importance of hearing, and specifically the vestibular system contained in the inner ear, for spatial orientation and proprioception.
2. In the original French (Virilio [1984] 1991, 145), the term of 'confusion fatale' lends itself to being translated as both 'lethal' and 'fateful'.
3. Since 2007, the US Army has commissioned close to 200,000 units of the 4× magnification Advanced Combat Optical Gunsight (ACOG) for fitting on the M4 carbine and M16 assault rifle.
4. At the greatest ranges, wind speed and direction become significant factors in addition to bullet drop.
5. Although larger devices provide greater accuracy over longer distances by increasing the base length of the range-finding triangle, their size naturally restricts their mobility and renders them vulnerable to enemy spotting, thus limiting their deployment to the Navy and rear positions. The largest rangefinder ever built was the Barr & Stroud FZ assembled for the coastal defence of Portsmouth in 1923 with a base of 30 m and reliably measuring distances to objects as distant as 30 km (Moss and Russell 1988, 112).
6. These include air temperature and density, wind, rotation of the earth, parallax and differences in elevation between the positions of the guns and the sighting systems, and the internal and external ballistics of specific guns and projectiles.
7. In fact, the risk of irreversible ocular damage is considerably increased if laser radiation passes through magnifying optics such as binoculars before striking a human eye.
8. Recent US programmes would include the Army's THEL (Tactical High-Energy Laser) and ZEUS laser systems, the Air Force's ATL (Advanced Tactical Laser), the Navy's LaWS (Laser Weapon System), and DARPA's HELLADS (High Energy Liquid Laser Area Defense System).

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No potential conflict of interest was reported by the author.

## Notes on contributor

***Antoine Bousquet*** is a senior lecturer in International Relations at Birkbeck College, University of London. His main research interests are concerned with war and political violence, the history and philosophy of science and technology, and social and political theory in the digital age. He is the author of *The Scientific Way of Warfare: Order and Chaos on the Battlefields of Modernity* (Hurst Publishers, 2009) and has published articles in a range of peer-reviewed journals. A second monograph on technologies of perception in war entitled *The Martial Gaze: The Logistics of Military Perception in the Age of Global Targeting* is forthcoming in 2018.

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