Test Range

Evolution and Role in Weapon Development

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Defence Research & Development Organisation
Ministry of Defence, New Delhi – 110 011

Test Range: Evolution and Role in Weapon Development

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This book is dedicated to the
Proof & Experimental Establishment, Chandipur,
which made me somebody
out of any body in a span of 38 years.

Contents

Preface

Throughout history, from ancient epics like Ramayan and Mahabharat to the present-day Ukrainian war, battles and wars have been a constant reality. The weapons employed in warfare have evolved significantly over time. In the past, bows, arrows, maces, and swords were the primary tools of combat. Today, we rely on firearms, mortars, missiles, and explosives of various types and capacities. The perpetual duel between weapons and their countermeasures has led to the development of increasingly complex weapon systems.

The reliability and effectiveness of these weapons are of utmost importance. They need to be safe to handle while remaining lethal to the enemy. Moreover, they should be efficient, accurate, durable, and easy to operate and maintain. The only way to ascertain these qualities is through rigorous testing and evaluation. Actual firing tests or flight tests for missiles, are conducted to validate their claimed capabilities. Performance parameters are meticulously observed, recorded, and analysed before reaching a final verdict.

A letter addressed to the then government of India in 1894 by one Maj Gen A Walker in which he had sent the proposal for establishing today's PXE at Chandipur is relevant here.

" .... These guns will be of no use unless a satisfactory supply of shells, fuzes, and breech components is assured, and this is impossible without an efficient Proof Department. It is actually unsafe to continue the present scale of manufacture without this safeguard, which has been so much insisted on in England of late years, and I respectfully submit that this department cannot be held responsible for failure, or disaster in the future, if the necessary steps are not now taken to ensure the systematic and careful proof by an independent establishment of all such war material…."

While the successful introduction of new weapons and missiles often receives media attention, the crucial role played by the Test Ranges in the development and evaluation process often goes unnoticed. This book aims to shed light on the significance of Test Ranges in the larger scheme of weapon development and military preparedness.

Chapter 1 briefly traces the evolution of weapon systems from the days of stones and twigs through stones axe, bows and arrows, ballista, trebuchet etc. which used mostly muscular energy. The invention of gunpowder in the 13th century marked a significant shift, replacing muscle power with explosive energy as the driving force behind weapons.

It will be like talking in vacuum if the weapon systems that are tested in a Range are not introduced and their design features not explained. Chapter 2 delves into the intricate details of guns and their major sub-assemblies, including the breech assembly, barrel, muzzle brake, recoil system, carriage, trails, saddle, cradle, and different gears. It also explores the components of ammunition, such as propellants, explosives, cartridge cases, primers, fuzes, and projectiles, using photographs and detailed explanations. The chapter elucidates concepts like high and low explosives, primary, secondary, and tertiary explosives, sensitivity of explosives, explosive trains, deflagration, explosion, detonation, and armor for tanks. The perpetual battle between tanks and anti-tank projectiles is highlighted.

Quality assessment is a critical aspect of weapon development and production. Chapter 3 defines key terms like quality, reliability, efficiency, effectiveness, durability, and failure. It explores the impact of environmental factors like temperature, solar radiation, dust, water, altitude, and humidity on weapon performance. The chapter also delves into the design process, starting from user requirements and qualitative specifications to the stages of design iteration and technology transfer. Multiple developmental firings in a Test Range help bridge the gap between the conceptual weapon and the final product, ensuring it meets the user's requirements. The chapter also discusses documents like "particulars," "sealed particulars," and the Authority Holding Sealed Particulars (AHSP), as well as the role they play in the proof process.

Chapter 4 focuses on how the quality control team at factories monitors and inspects raw materials and production processes. It explains the significance of visual, physical, chemical, and metallurgical tests carried out on samples. Any deviation observed at any stage freezes further manufacture unless remedial steps are taken to investigate and rectify the defects. They draw samples out of production lot to carry out static tests and send to Ranges along with Lab test reports for dynamic tests. How the Ranges proceed to carry out proof on receipt of samples, has been discussed in detail with a few case studies. Without giving a long list of items proofed, suffice it to say that most of the items mentioned have been discussed in detail. Ranges also carry out some non-routine types of firings like 'charge assessment trials', Range Table compilation, Tarage Table compilation, and defect investigation firings. A few case studies provide insight to proof processes.

Chapter 5 discusses the aspects that need consideration before setting up a Proof Range. Why Chandipur is a location that any country would be proud to have to set up a Proof Range has been explained in detail. Growth of Range infrastructure and expertise over the years at PXE are representative of similar Ranges anywhere in the world. Narratives are anchored around Chandipur and PXE so that examples can be drawn from day to day activities concerning safety, security, instruments, proof techniques, mistakes and lessons learnt from those incidents, problems faced and solutions.

When a Test Range starts functioning it is equipped with the instruments that are available on date and state of weapons planned to be fired from it. Introduction of new instrument or new techniques for data acquisition are demand driven, desire of the Range users keeping pace with new development in weapons. When PXE started functioning it had stop watches for elapsed time measurement, measuring tapes for distance measurement, Boulenge chronograph for velocity measurement, crusher gauges and coppers with screw gauge, for pressure measurement. Range was upto 9000 yards. It has come a long way since then in the mission of providing more precision and varieties to the parameters already being recorded. Time for fuze functioning is no longer measured by stop watch, BTME is deployed. Infrared impulses start and stop electronic timers. Distance is measured by angle measurements by theodolites or electronic distometers. Boulenge chronograph has been replaced by Doppler Radar (DR). The DR records muzzle velocity, spin, velocity-time profile inside barrel, besides long range tracking. Crusher gauges and coppers are still used to measure peak chamber pressures in guns during routine firings. Now electronic Internal Piezo Gauge (IPG) system records pressure-time profile within barrel as a projectile moves within it. Velocity-time and pressure-time profiles are invaluable tools for ballisticians and gun designers. Blast pressure, illumination, sound level, temperature, strain on gun bodies can be measured; ultrasonic method of detecting internal faults deep inside gun, computerised online boroscopefor examination of barrel interior have been created. Chain of networked environmental conditioning chambers capable of conditioning ammunition at as low as –50 °C and as high as 80 °C are now monitored and controlled, remotely. It is now possible to record meteorological parameters upto a height of 35 km. Capability for short term weather prediction over a limited area that helps in scheduling day to day firings has also been built up.

High speed camera systems record transient phenomena like impact of shots on armour, sabot separation of FSAPDS shots. An automated flight follower system gives a visual record of the flight of a projectile for upto 100 to 200 m from the muzzle. This can detect phenomena like physical deformations, break up of shot, displacement/damage to driving band, functioning of base bleed/tracered ammunition, sabot discard, etc., which mostly occur during first 200 m.

A Range fires actual guns and ammunition, and that too of uncertain behaviour. Malfunctioning of weapon, prematures, misfires, cook off, barrel jamming, short ranging of shells, early bursts, splinters flying all over, even barrel burst are bound to occur in a Proof Range. A few case studies of accidents and the lessons learnt have been described. Robust safety measures during storage, handling, transportation at firing points and at target area have now been implemented.

Chapter 6 focuses specifically on missile testing. It begins by explaining the principles of rocket propulsion and the components of a typical missile system, including the airframe, propulsion system, warhead, guidance system, and control systems. Artillery projectiles are 'fire and forget' type, once out of muzzle it is free-flight, range upto some 60 km or so. But missiles range from a few kilometres to thousands of kilometres. These have to be tracked and internal health monitored every moment and navigated during flights. Like any other armament store missiles also need to be tested before introduction into Services. The development phase for a missile is rather long. There is nothing like 'routine proof firings' involving missiles. There is no concept of reproof, double reproof and rejection. Before a missile comes to a Range for flight test, exhaustive static checks of subassemblies and simulation studies are carried out by the designer/developer. Unlike an artillery test Range where the personnel of the Range assemble a round, carry out firings and acquire data, in a missile Range its personnel provide all assistance and instrumentation support for missile launch and data acquisition. Personnel involved in design and development are invariably involved in missile integration, checks and launch. All these aspects have been discussed. Importance and role of countdown document, 'Hold', central timing system, Range clock, etc., have been explained. It is not possible to fully track the flight from a single location, hence a number of down range tracking stations with tracking radars, EOTS, telemetry are activated before a flight. All these are interconnected by fail proof communication system. Along with tracking a missile from launch to splashdown, these also record status of all vital on board subsystems which are in two-way communication with ground control. Even if a missile flight is aborted midway or fails to hit a pre designated target the data from the missile are invaluable for thorough post flight defect investigation. Data is vital for successful flights also.

Sight selected for a missile test Range needs to have some specific characteristics. It is said that about 30 possible sites from western coast to eastern coast of India were evaluated before finalising the ITR at Chandipur – Baliapal. Why Baliapal was abandoned, inspite of being the best site, has been discussed dispassionately. Chance 'discovery' of Abdul Kalam island and setting up of a Launch complex have been described.

The series of activities that take place at the Integrated Test Range (ITR) at Chandipur or at Abdul Kalam island, once a missile arrives, till handing over of flight data have been elaborated.

Guns or missiles at launch point spew toxic gases into the atmosphere-that are reaction products of propellant burning. These are not exactly benign. Chapter 7 discusses effect of these on the environment with a few experimental data from India and foreign countries. Ground around firing point/launch pad and the target area also contain some pollutants. Fortunately these have not reached dangerous level. That is one of the reasons of siting test Ranges away from thick population. Itarsi and Khamaria were selected for CPE and LPR, respectively, adhering to the same requirement. When PXE was established it was amidst jungles, far from human habitation, where tigers used to roam freely. Abdul Kalam island is also similarly situated. That leaves the target area. At PXE the target area is always sea. Explosive filled shells are rarely fired into the sea. Shells are picked by PXE or taken away by thieves. Those not picked up get buried in the sea. Missiles are similarly made to splash down far into the sea or on uninhabited deserts.

This chapter also discusses the impact of a Range on the society at large, taking PXE and ITR as samples. Ends with hope that someday in the future there will be an organisation in India like the Ordnance Board of the UK, which will be the repository of all data generated at Ranges.

Acknowledgements

First I want to express my gratitude to my ex-colleague Dr PK Dasgupta, Scientist 'F' (now Scientist 'G') for having thought of me when a search was on for a suitable person to compile a monograph on Test Ranges. This was going to be a narrative, the materials for which were to be pieced together after studying vast literature. I was a little apprehensive. Before formally taking up the task I made a trip to Monograph Division of DESIDOC to know more about monographs and how these are written. The then Head of the Division Ms Anitha Saravanan removed my fear of writing through exposure to a few already published Monographs, and boosted my self confidence. Without her persuasive words and encouragement this book would not have seen light of the day. I am indebted to her.

Having been retired from service 7 years prior to this offer and having no personal collection of materials on a Test Range except some teaching materials for the students of the department of Applied Physics and Ballistics of FM University, I had to fall back on the help and support of PXE for this compilation. The then Director Shri R Appavuraj and the present Director Sri DK Joshi went all out to help me in this regard. They arranged for my to-and-fro movement to PXE, allowed unfretted movement within PXE and free access to the resources of Technical Library. When I wanted to incorporate some photographs in the book they readily gave permission. I took full advantage of their domain knowledge in enriching selected portions of the compilation. Shri Joshi even facilitated my visit to CPE, Itarsi and LPR, Khamaria to gather first hand knowledge on how these Ranges work. He even deputed a senior officer, familiar with those Ranges with me for my convenience. He also arranged a guided visit to the Pashan Range ARDE, Pune. No amount of thanks will be sufficient for them.

I also want to thank Maj Gen(Retd) PK Govila and Sri GC Das, ex-Directors of PXE for their encouragement and help in filling certain gaps in the book. I want to thank Dr KK Chand, Scientist 'F'(Retd) who was sort of mobile encyclopaedia for me. He showered me with reference materials in the form of hard and soft copies, whenever I wanted any information from him. This compilation would not have been possible without his help.

I am thankful to armaments experts Dr Nityananda Nayak, Scientist 'G' (retired), Sri B Hazarika, Scientist 'F'; Dr A Banerjee, Scientist 'F' for having provided me with information on latest developments in the field. I also thank Sri TK Biswal, Scientist 'G'(Retd) and his team of officers like Sri RK Sahu, Scientist 'E'; Dr T Sahoo, Scientist 'D' and Ms PN Mohanty, TO 'B' for allowing me to search through the vast collection of photographs to select appropriate ones. They even arranged to photograph some items which I specifically needed for incorporation. I also thank Dr S Padhy, Scientist 'F'; Sri Purujit Kar, TO 'C'; Sri BK Panda, Scientist 'E'; Sri S Shah, Scientist 'E'; Sri KK Bandha, Scientist 'E'; and Dr Dibakar Panda, TO 'B'. All of them helped me with information as and when I needed to refresh my memory about proof techniques and about latest instruments being put to use.

My special thanks are due to Sri SS Panda, TO 'B' of Technical Library who ungrudgingly helped in unearthing many old reports for my reference. I specially thank Sri S Dutta, Scientist 'F', who accompanied me to CPE, Itarsi and LPR, Khamaria.

I thank the then Commandants of CPE, Itarsi and LPR, Khamaria for their hospitality, transport and accommodation arrangements for us; and arranging guided tour of their Ranges; without which the book would have remained incomplete. I am indebted to them. I also thank the then Director of ARDE for having arranged a guided tour of the Pashan Range at short notice.

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Last but not the least, I thank my wife Smt Swarnarekha Mahapatra who tolerated my aloofness for house hold work for three years when I was busy in preparing the manuscript.

List of Acronyms

AAD	Advanced Air Defence
ACF	Annual Check Firings
ACM	Adjusted Charge Mass
AFV	Armoured Fighting Vehicles
AHSP	Authority Holding Sealed Particulars
AIG	Assistant Instructor of Gunnery
AIMS	Armament Integrated Management System
AMIs	Ammunition Maintenance Instructions
AP Lab	Ammunition Preparation Laboratory
AP	Armour Piercing
APC	Armoured Personnel Carrier, Armour Piercing Capped
APCBC	APC, Ballistic Capped
APCNR	Armour Piercing Composite, Non-Rigid
APCR	Armour Piercing, Composite Rigid
AQL	Acceptance Quality Level
ATC	Air Traffic Controllers
ATP	Acceptance Test Procedure
AWS	Automatic Weather Station
BBU	Base Bleed Unit
BCF	Biennial Check Firings, Bio Concentration Factor
BMCS	Bi-Modular Charge System
BMS	Ballistic Measurement System
BPC	Bulk Production Clearance
BTME	Burst Time Measuring Equipment
BTP	Ballistic Test Plates
BVA	Bolt Vent Axial
BVRAAM	Beyond Visual Range Air-to-Air Missile

CCC	Combustible Cartg Case
CCTV	Closed Circuit Television
CD	Complete Detonation
CDR	Critical Design Review
CDS	Command Destruct System
CE	Chemical Energy
CFEES	Centre for Fire, Explosive & Environment Safety
CHC	Cartridge Head Clearance
CIA	Chief Inspector of Ammunition
CLOS	Command-to-Line-of-Sight
CMA	Controller of Military Accounts
CMDB	Composite Modified Double Base
CNES	National Centre for Space Studies
CPCB	Central Pollution Control Board
CQA	Controllerate of Quality Assurance
CRT	Cathode Ray Tube
CTPB	Carboxyl Terminated Poly-Butadiene
CV	Closed Vessel
CW	Continuous Wave
DA	Development Agency
DB	Driving Band
DFR	Detailed Feasibility Report
DGO	Director General of Ordnance
DGPS	Differential Global Positioning System
DGQA	Directorate General of Quality Assurance
DHS	Digital Heat Spy
DIPAS	Defence Institute of Physiology and Allied Sciences
DMI	Doppler Michelson Interferometer
DOF	Degrees of Freedom
DPIC	Dual Purpose Improved Conventional
DPR	Detailed Project Report
DRONA	DRDO Rapid Online Network Access
DRS	Direct Reception System

DSC	Defence Security Corps
DT&E	Developmental Test & Evaluation
DTD	Directorate of Technical Development
EC	Energetic Compounds
EDM	Electronic Distance Measurement
EED	Electro Explosive Devices
EIC	East India Company
EOI	Expression of Interest
EOTS	Electro-Optical Tracking System
ERA	Explosive Reactive Armour
ESA	European Space Agency
ET	Environmental Tests
EVA	Electronic Velocity Analyser
FAE	Fuel Air Explosives
FCS	Fire Control System
FDM	Frequency Division Multiplexing
FDRA	Fuze Delay Recording Apparatus
FEC	Front End Converter
FFT	Fast Fourier Transformation
FHDR	Fixed Head Doppler Radar
FO	Fibre Optic
FP	Firing Point
FRP	Fibre Reinforced Plastic
FRR	Flight Readiness Review
FTP	Flight Test Proposal
GCF	Gun Carriage Factory, Jabalpur
GOI	Government of India
GPBLL	Gauge Plug Bore Low Limit
GS	General Staff
HE	High Explosive
HEAT	High Explosive Anti-Tank
HES	High Explosive Substitute
HESH	High Explosive Squash Head

HILS	Hardware-In-the-Loop Simulation
HMD	Horizontal Mean Deviation
HP	Horse Power
HPPE	High Performance Polyethylene
HSD	Horizontal Standard Deviation
HTPB	Hydroxy Terminated Polybutadiene
ICBM	Inter Continental Ballistic Missile
IED	Improvised Explosive Device
IFG	Indian Field Gun
IGO	Inspector General of Ordnance
IIP	Instantaneous Impact Point
ILL	Impact Limit Line
INCOIS	Indian National Centre for Ocean Information Services
IP	Internet Protocol
IR	Infra Red
IRIG	Inter Range Instrumentation Group
ISAT	Intensive Standard Alternating Trials
ITI	Indian Telephone Industries
ITR	Integrated Test Range
KLP	Key Location Plan
LAB	Launch Authorisation Board
LBM	Lever Breech Mechanism
LC	Launch Complex
LE	Low Explosives
LFG	Light Field Gun
LNA	Low Noise Amplifier
LOVA	Low Vulnerability Ammunition
LPR	Long Proof Range
MBRL	Multi-Barrel Rocket Launcher
MEMS	Micro Electro Mechanical Systems
MGO	Master General of Ordnance
MoD	Ministry of Defence
MPI	Mean Point of Impact

MRR	Maximum Ricochet Range
MS	Mild Steel
MT	Mechanical Transport
MV	Muzzle Velocity
MVAS	Muzzle Velocity Analysis Software
NAVSTAR	Navigation Satellite Time And Ranging
NBC	Nuclear, Biological and Chemical
NCM	Nominal Charge Mass
NIOT	National Institute of Ocean Technology
NOTAM	Notice to Air Missions
NTP	Normal Temperature and Pressure
NTR	National Test Range
OFA	Ordnance Factory, Ambernath
OFB	Ordnance Factory Board
OP	Observation Posts
OT&E	Operational Test & Evaluation
OV	Observed Velocity
P&T	Posts and Telegraphs
PA	Public Address
PCB	Penetration-Cum-Blast
PCC	Photoelectric Counter Chronometer
PD	Partial Detonation
PD SQ	PD Super Quick
PDR	Preliminary Design Review
PE	Plastic Explosive
PFFR	Pokhran Field Firing Range
PO	Proof Officer
POL	Petrol, Oil, Lubricant
POP	Point of Punch
PPS	Pulse Per Second
PRF	Plug Representing Fuze
PSLV	Polar Satellite Launch Vehicle
PSUs	Public Sector Undertakings

PTA	Pilotless Target Aircrafts
PWT	Pocket Weather Tracker
PXE	Proof & Experimental Establishment
QE	Quadrant Elevation
QF	Quick Firing
QR	Quality Requirements
R&A	Range and Accuracy
RA	Royal Artillery
RAC	Range Advisory Committee
RCM	Recommended Charge Mass
RFNA	Red Fuming Nitric Acid
RFP	Request for Proposal
RHA	Rolled Homogeneous Armour
RPM	Respirable Particulate Matter
RSO	Range Safety Officer
RT	Range Table
RTMV	Range Table Muzzle Velocity
RTRS	Rail Track Rocket Sled
RTS	Reagan Test Site
SAD	Safety Arming Distances
SAM	Surface-to-Air Missile
SCC	Semicombustible Cartg Case
SCDAS	Supervisory and Control Data Acquisition System
SD	Self Destruction
SDSC	Satish Dhawan Space Centre
SFC	Strategic Forces Command
SHAR	Sriharikota High Altitude Range
SRMP	Single Round Maximum Pressure
SP	Self Propelled
SPM	Suspended Particulate Matter
SQC	Statistical Quality Control
T&E	Test and Evaluation
TB	Thermobaric

TBM	Theatre Ballistic Missiles
TCV	Tactical Core Vehicle
TD	Trial Detail
TDM	Time Division Multiplexing
TEL	Transportable Erector Launcher
TERLS	Thumba Equatorial Rocket Launching Station
TFR	Temporary Flight Restrictions
TOT	Transfer of Technology
UATT	User Associated Technical Tests
UDC	Upper Division Clerk
UDMH	Unsymmetrical Dimethylhydrazine
UMCS	Uni-Modular Charge System
UVT	Universal Variable Time
VADR	Velocity Analysing Doppler Radar
VDU	Visual Display Unit
VMD	Vertical Mean Deviation
VPDA	Vertical Phase Danger Area
VSD	Vertical Standard Deviation
VT	Variable Time
VTC	Vertical Target Consistency
WAN	Wide Area Network
WBDAPS	Wide Band Data Acquisition and Processing System
WMD	Weapons of Mass Destruction
WTTS	Wireless Trigger Transmission System

CHAPTER 1

Weapons: Prehistoric to Twenty First Century

1.1 INTRODUCTION - NEED FOR WEAPONS

In the prehistoric days, when fire was yet to be invented, human life was extremely stressful. Humans had to compete with carnivorous animals for food. They had to protect themselves from those predators lest they should end up as food of those animals. When a man picked up a stone or a twig of a broken tree and threw it at his adversary (and the competitor) to ward off immediate danger, weapon was born. Then it was solely for self preservation. Now it is not exactly so. Weapons and wars are as old, (and as modern and ingenious) as human civilization. From a stone to a stick to swords to bows and arrows of prehistoric times to today's nuclear capable ICBMs, "weapon" has come a long way, keeping pace with growth of technology. Weapon development and the arms bazaar have often been catalysts for pushing growth of science and technology. The epics of all old civilizations are full of fights, wars, and destructions.

Emperor Ashoka's Kalinga War in which lakhs of people lost their lives is one example from Indian history. Almost whole of the Middle Ages were full of raids, battles and wars involving Europe and Middle East. Hundred years war between England and France is one sample from Europe. The two World Wars in the twentieth century surpassed all past records in death, destruction and devastation. War and conflict are not likely to end in the foreseeable future. Arms race will continue. More and more efficient and effective weapons are sure to be developed. All wars can come to an end by fighting with nuclear weapons. No fighters would be left thereafter to fight and human civilization would start all over again ab initio. It is for nothing that somebody had appropriately commented "only the dead has seen the end of war". The development of weapons has greatly influenced the course of wars and formation/reformation of nation states. This chapter glances through the most important weapons, from technology point of view, that existed from pre-historic times to the use of gunpowder as a propellant till late nineteenth century.

Weapons in the pre-gunpowder era could be put under three general categories: direct body contact with enemy, use of muscular energy, and transfer and storage of muscular energy. Those weapons were not of as complicated mechanisms as of today. Only physical strength and muscle power were the tools to fight with. Number of subsystems in a complete weapon was only a few. Pre-delivery testing of its serviceability was neither very complicated nor rigorous. From 19th century onwards weapon systems designs have undergone sea change which would not have been possible without assessing the impact of each design modification to an existing system by as many means as possible, the last one being carried out with live firings from a Test Range. As they say, "seeing is believing".

1.2 WEAPONS OF THE STONE AGE

First it was hand-to-hand fighting through hands, legs, nails, teeth, and wrestling - through body contact only. If the adversary tried to flee, or if the adversary had to be followed, be it another human being or an animal, body contact was out of question. A pebble, a stone or a broken twig of any tree, anything he could hold, aim, and throw gave rise to non-contact weapons, which derived the motive force for projection from his muscle only. There was a limit to the distance to which such an irregularly shaped projectile could be projected. During the Stone Age, stone made axes, knives, maces appeared. An attempt was made for the first time to give a regular shape to a stick with a pointed head and thus appeared spear. This was also a contact weapon to charge at the enemy. The next logical step was sort of javelin, a longer version, which could be thrown to a longer distance because of its 'ballistic shape'. Figure 1.1 represents a pre-historic stone axe.

Next stage was the design of bows and arrows, in and around 6000 BC. The bow stored the energy of one's pull generated by straining his muscles, as potential energy, transferred it to the bowstring as potential energy imparting kinetic energy and killing power to the arrow. The maximum energy that could be stored was limited by how much the bow could be bent by pulling the bowstring towards him in a single coordinated movement

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About the Monograph

The defence capability of a nation rests upon its weapons and ammunition system, "weapons" for brevity, and the armed forces' confidence in their effective utilisation. Designing weapons goes beyond drawings and simulations as accurately simulating transient impulsive loading conditions is impractical. Test Ranges, "Ranges" for brevity, play a pivotal role by resolving these challenges through actual firings, facilitating incremental developments and final acceptance of weapons. The capabilities of a range are intimately tied to the weapon itself.

This monograph introduces weapons with the necessary details to comprehend range functioning. It covers weapon types, complexities, payload delivery, propulsion systems, target neutralisation, safety, reliability, life cycle, performance in extreme climates, and high-speed impacts. The book explores the attributes of an ideal Range and discusses qualitative and quantitative methods for assessing weapon performance. It delves into Range infrastructure, techniques, and the establishment of the Proof & Experimental Establishment (PXE) in 1895, supported by visual aids such as photographs, tables, case studies, and anecdotes.

The author advocates for consolidating three Ranges-PXE in Chandipur, CPE in Itarsi, and LPR in Khamaria–under unified administrative and technical control, preferably independent of the Defence Research and Development Organisation (DRDO) and the Directorate General of Quality Assurance (DGQA).

This monograph serves as a valuable resource for scientists, engineers, and professionals engaged in weapon design, development, production, quality assurance, and Range operations. It is equally informative for individuals interested in national defence, providing comprehensive insights into the critical aspects of weapons and Ranges, illuminating their interconnectedness in safeguarding the nation's defence.

About the Author

Shri PK Mahapatra joined PXE, Chandipur, as a JSA I in August 1969 after completing MSc in Mathematics in 1968 and retired as a Scientist 'F' in October 2007. He worked in the fields of Computer, Propellant proof, Instrumentation, Materials Management, Administration, and HRD. He completed a 3 month's course in "Programming and Applications of Electronic Computers" from the ISI, Kolkata in 1971-72 on his own. He brought in Computer era to PXE in 1982. His notable achievements were compiling propellant proof reports bypassing reference to all Tables. Another was conversion of angle measurements in range to linear equations to determine spatial coordinates of the point of impact of projectiles. These were besides softwares for Finance, materials management and ammunition management.

His other passion was PXE itself. Compiled 100 years history of PXE titled "Proof-The Trail Blazer", released in 1996 during centenary celebrations. He played a significant role in saving a heritage building of PXE from demolition–the building which predated PXE and used as office of the Heads of PXE for about 80 years. Today it is the Centenary Museum and Archives.

In 2006, he helped Fakir Mohan University, Balasore to design a Course entitled "MSc in Applied Physics and Ballistics". He taught topics like Internal and Intermediate Ballistics, Weapon Systems and Ammunition as a Guest Faculty from 2009 to 2014. He was also a member of the Senate of the University from 2016 to 2019.

He contributed papers to journals and seminars in fields like Proof Techniques, Ballistics, Computer Applications in Proof Range. He also presented papers and delivered talks at several UGC sponsored Workshops and Seminars in colleges in and around Balasore in topics like Ballistics, e-governance, Analytical Hierarchy Process, God Particles, and Cryptography, etc.

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