

155 MM 45 CALIBRE DHANUSH GUN: A REALITY OR A MYTH

By

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Price in India : ₹ 250*

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Printed in India

Printed by
Xtreme Office Aids Pvt. Ltd.
*Basement Bhanot Building (Below Syndicate Bank)
Nangal Raya Commercial Complex, N.D-110046
Ph.: +91-9811707220
E-mail: xtremeofficeaids@gmail.com
Website: www.xtremeonline.in*

155 MM 45 CALIBRE DHANUSH GUN: A REALITY OR A MYTH

Bofors 155 mm 39 calibre medium artillery gun was a major artillery gun induction in the Army during 1980's. This induction somewhat made up huge shortage of medium artillery guns that the army was facing due to back-loading of obsolete guns like 7.2 inch howitzer, 5.5 inch guns, 100 mm guns among others. However, by turn of the century, the criticality of deficiency of long range artillery guns in the army became severe, mostly due to vintage and lack of any new induction of medium artillery guns. Due to political reasons all connections with Bofors AB Sweden had to be cut off causing severe downstream effect. Spare parts supply and technology upgrade of the existing Bofors guns, thus, got stalled. Around the same time, indigenous initiatives by the Ordnance Factory Board (OFB) to develop a 155mm 52 calibre artillery gun did not succeed. Since 2004, OFB had also been working on Mechanical and Electronic upgrade modules for the 155mm 39 Cal FH 77 BO 2 gun in order to bring it at par with the latest contemporary technology but the efforts could not be brought to a fruitful conclusion. By 2010, the deficiencies of artillery guns started to bite the operational readiness of the army.

It was during the early 2011, a project for manufacture of an indigenous 155mm 39 cal gun system was conceptualized by the army. It started with an idea to make an indigenous gun akin to 155mm 39 cal Bofors gun with the same specifications as that of the existing Bofors gun with the base from the Transfer of Technology (TOT) procured by the Indian Government from Bofors AB, Sweden. Despite difficulties to use the old and, perhaps, dated designs as held with the OFB,



Forging and Manufacture of 155mm 45 Calibre Dhanush Gun
Barrel in Metal & Steel Factory of OFB

this opportunity to develop a new medium artillery gun system as a Greenfield project rejuvenated the OFB. The first firing of the Indigenous Upgraded OFB make 155 mm 39 calibre gun was planned during May 2012 on gun carriages provided by the army. Notably, on request of

the Chairman OFB, duly supported by the DG Arty and DCOAS (P&S), Army had loaned two operational 155 mm 39 cal Bofors guns to GCF.

During the first firing of the newly assembled gun during May 12, in addition to the 155 mm 39 calibre gun as cleared by the Defence Acquisition Council (DAC), an experimental OFB gun was also deployed. This gun was a mechanically upgraded one, comprising of 155 mm 45 calibre barrel, an OFB manufactured high efficiency Muzzle Brake and modified loading system. These had been mounted on the carriage of the other loaned gun along with the electronic upgrade module comprising of the contemporary AGAPS and a Unified Direct Aiming sight with eye safe LRF. The firing by both the guns was permitted by the Director General of Artillery who was present in the ranges, to see the performance of the 155 mm 39 calibre gun. Both the guns performed satisfactorily and the Upgrade Modules got validated in entirety. This paved the way for development of an indigenous electronically upgraded 155mm 45 Calibre Artillery Gun by the OFB, based on the available designs of the original Bofors 155mm 39 calibre gun system.

Subsequently, when the manufacture of indigenous prototypes was undertaken by the OFB, it was realized that consequent to the controversy related to Bofors gun, Indian Government had cut all dealings with Bofors AB Sweden and thus the entire Transfer of Technology (TOT) papers had not been taken over by Indian government agencies, particularly those related to amendments and up-gradations carried out by the Bofors AB Sweden. Thus, there were gaps in the drawings etc which OFB had to fill. Further, since the Transfer of Technology was limited to transfer of documents only, creation / setting up of production facilities at various OFB factories including plant & machinery specifications, special technologies or advice thereto were not provided by the Bofors AB, Sweden. Therefore it was left to the OFB to conceptualize and create the same, suiting to the indigenous production techniques and technology available within the country including metallurgy formulations/ processes. The aim was to develop the new gun on manufacturing technology of

21st century. Dhanush gun reflects indigenously developed modern 21st century technology medium artillery gun system, using expertise of OFB's in-house highly qualified gun designers and engineers, trained in gun design and weapon technology at Cranfield University, Shrivenham, UK and elsewhere. Notably, Cranfield University is considered to be among the best institute for specialization in weapon technology and weapon design qualifications in the world. OFB also has large number of IIT graduates and post graduates. This talent pool was pooled-in for establishing the Ordnance Development Centres (ODC) at Ordnance Factory, Kanpur and Gun Carriage Factory (GCF), Jabalpur and to set up a manufacturing line in GCF, Jabalpur. ODCs are equipment focused R&D Centres akin to any high end R&D lab, with powers to deal with Institutes of Repute in India and abroad as also with foreign experts/institutions. They are responsible for developing cutting edge technologies, designs and suggest optimal manufacturing processes. They are co-located with the manufacturing facility of the product concerned. The Dhanush focussed ODC is located in GCF Jabalpur.



Design and Manufacture.

As the barrel of the gun was changed to 155 mm 45 cal, the design parameters and some formulation of the ESR steel for the barrel of the gun had to be changed. Salient properties that make “Dhanush” a substantially different gun than the existing 155 mm 39 calibre gun are as follows:-

- **Metallurgy.** Metallurgy of the Bofors gun barrel and chassis is considered gold standard. It is being used in gun manufacture across geographies even today. However, as soon as the barrel length was increased to 45 cal, the pressure dynamics, parameters of acceptable co-efficient of barrel elasticity, barrel droop index and barrel strength values changed. Notably with 23 litre volume of Dhanush barrel chamber as against 19 litre chamber of 39 calibre Bofors gun, the internal ballistics inside the barrel had to change. This issue was researched and worked out by the OFB metallurgists. The muzzle brake of Dhanush gun was designed afresh by OFB gun systems designers, metallurgists, and engineers using latest CAD/CAM and other enabling systems. It is a modern muzzle brake with much higher efficiency as compared to the 155 mm 39 cal Bofors gun muzzle brake. At the production level, improvements have been made in metallurgy, machining and forging process. Thus, the Dhanush Muzzle Brake is not the one that is used in Bofors 155 mm 39 cal barrel. Metallurgy of the carriage of 155 mm 45 calibre ‘Dhanush’ gun is on the lines of the improvements as found in any modern gun system. This improved metallurgy has also been used for other parts of Dhanush gun like Chassis, cradle, recoil and trails. The world class steel for artillery, tanks, mortar barrels and ammunition is manufactured in OFB’s Metal and Steel Factory in Ishapore for over past 100 years.

- **Modern World Class Barrel.** The Dhanush gun barrel is autofrettaged on one of the most modern, computer controlled machines. The autofrettage machine in use is assembled in India by M/S Therelac Engineering, Bengaluru in collaboration with M/S Elmhurst System, USA and Thyssen Krupp of Germany. It can generate up to 14000 bar pressure with Anti-buckling system. This machine was commissioned in 2019. It follows the principle of high hydraulic pressure on the walls of the barrel through compressive stress method rather by cutting through machining operation, as is found in earlier commissioned machines. Unless the process of autofrettage and forging of the barrel is near perfect, the barrel will not give the desired maximum range, shell stability and accuracy. This issue has been adequately taken care by the OFB gun designers, metallurgists and engineers. The quality of steel for the barrels and the process of barrel manufacture is so advanced that even the Bofors Test Centre, Sweden recently indented three 155mm/52 caliber barrels from OFB for testing their new generation ammunition incl RDX and HMX based ammunitions for large caliber artillery guns. BAE Systems have confirmed that the barrels supplied by the OFB, India are performing very well.
- **Chamber Size.** It is common knowledge that chamber size needs to be increased for supporting longer barrels and achieving greater ranges. Since the desired range of the Dhanush gun was kept between 36 and 37 km, new designs had to be worked out using different design tools, simulations and computer based modeling (CBM). Finally, the optimal size of the Chamber for Dhanush gun was decided to be 23 litre for achieving the desired parameters. Chamber size of Bofors is 19 litres corresponding to its maximum range of 30 km. ATAGS has a Chamber of approximately 25 litres. The developments in barrel design, chamber size etc were cleared through stringent process of validations, qualifications and DGQA tests. ARDE/DRDO also helped whenever needed.

- **Case of Barrel Damage during Firing.** There have been one case of barrel damage and two cases of Muzzle Brake damage during firing of Dhanush guns. Each of the incidents has been investigated by multi-institutional agencies and group of experts. No issue with metallurgy was found. The committee observed that the incidents were outcome of a chain of events rather than any individual component failure. Answer lies in analyzing the behavior of shell movement from breech to the muzzle. Unfortunately no such study is available in India and abroad. Now a study in this regard has been commissioned by the OFB as a R&D project with the Indian Institute of Science, Bengaluru.
- **Weight.** Dhanush gun at approximately 12700 kg is nearly 700 kg more than 155 mm 39 cal Bofors gun. This is due to longer barrel, added systems and strengthened steel. The weight is well within the approved GSQR for the gun.
- **Ordnance.** A new 155mm 45 Cal barrel as well as high efficiency Muzzle Brake was indigenously designed and developed by the Ordnance Development Centre at Kanpur.
- **Barrel Length.** Length of the barrel of Dhanush gun is 877 mm longer than the Bofors gun. The increase in barrel length is considered optimal for achieving internal ballistic performance and provides desired maximum range. The increase in the length of the barrel was arrived at by the OFB barrel designers, metallurgists and engineers, consequent to substantial theoretical and practical research including static and dynamic firing of the barrel under test and later operational conditions.
- **Charge Systems for Firing.** Dhanush gun has a modified loading trough and loading tray that enables it to accommodate larger diameter of bi-modular charge system (BMCS). Basic Bofors design permits only Bag Charges to be used for firing.

Dhanush gun permits both Bag Charges and BMCS modules for undertaking firing of the gun.

- **Range.** The max range of Bofors gun is 30 km whereas Dhanush gun has a range exceeding 36 km. This has been achieved due to new barrel design using best possible OFB manufactured military grade ESR steel for the barrel; following most modern autofrettage process for making of the barrel; duly supplemented by best in the trade heat treatment and highly efficient forging process of the barrel. A newly developed, higher efficiency, modified muzzle brake has also assisted in keeping the stress levels on the Dhanush carriage comparable to the Bofors 155mm 39 Cal BO2 Gun, despite higher muzzle velocities and consequent greater recoil pressure.
- **Accuracy.** Among the most important properties necessary for a modern gun is better accuracy and consistency. This is achieved in Dhanush gun by ensuring greater stability of the shell in the flight derived from optimal internal ballistics and better sighting system, through higher levels of automation and system integration. Dhanush has achieved all these parameters adequately.
- **Gun Laying System.** Bofors gun has a manual laying system through levers. Dhanush has an Automatic Laying System (ALS) based on the Fire Control Computer System (FCCS) on the gun itself. It makes the gun fully autonomous. Hydraulic upgraded actuators with servo valves are used for gun elevation and traverse for auto laying.
- **Ballistic Calculation.** Dhanush gun has an on-board Enhanced Tactical Computer (ETC) enabling advanced target acquisition and accurate fire support quite distinct from Bofors gun where ballistic calculations are undertaken in the battery command post.

- **Gun Positioning.** Each Dhanush gun has an Advanced Gun Alignment and Positioning System(AGAPS) which relies on INS, GPS, CDU and Odometer.
- **Gun Recording.** Dhanush gun has an Inertial Navigation System (INS) and a GPS system as compared to the out-dated Theodolite based system in Bofors.
- **Muzzle Velocity Recording (MVR).** Dhanush gun has an on-board MVR for muzzle velocity feedback and firing data corrections in-situ as distinct from the off-board system in Bofors.
- **Direct Firing.** Dhanush has an Advanced Unified Gun Sighting system comprising of Eye- safe LRF, Day Camera, and Thermal Imaging Sights with an accuracy of ± 1 mils
- **Back-Up Sights.** Dhanush gun has a direct and indirect optical backup sighting system based direct sight (RS 420) and an Indirect Sight (104A) developed by the Ordnance Factory, Dehra Dun. This is in addition to the main Electronic Sights from BEL. Bofors gun is devoid of this facility.
- **Compatibility.** Each Dhanush gun is compatible with Artillery Command and Control System (ACCCS) – Project Shakti.
- **Firing.** Dhanush gun has met all the GSQR parameters of burst and intense firing, high charge/ zone firing, shoot and scoot capability and high angle fire and operations in high altitude ranges.
- **Maneuverability and Veh/APU Drawn Speeds.** Maneuverability tests for Dhanush gun have been carried out under high operational conditions over various terrain and weather conditions. All GSQR parameters have been achieved. The gun, in towed condition, has a cruising speed of 70 Km/h on

metallic roads. It has achieved a max speed of over 5km/h when moving on its Auxiliary Power Unit.

- **Amn.** Dhanush fires all variants of 155mm ammunitions like ERFB BB, ERFB BT, HEER, HE 77B, Smoke(ER), Illumination(ER) and M 107.
- **Accuracy and Consistency.** Dhanush has high levels of accuracy and consistency. They are as follows:-

Indirect Fire

(a) Accuracy—($>\leq/-$) 1.0 %

(b) **Consistency**

(i) Range---($</-\leq$) 0.8%

(ii) Line----- ($</-\leq$) 0.2%

Direct Fire. Dhanush gun has achieved first or second round hit on target size of 3m x 3m, depicting cross section of a tank.

Conclusion

The Dhanush gun has undergone extensive DGQA and User validation firings under most stringent conditions over three years, over all possible terrain and weather conditions. It has fired over 4500 shells, under test conditions. The gun is robust in design and is based on most modern automation systems. Its advanced navigation and positioning system permits rapid positioning and aiming capability during day and night engagement of targets. Resources of government sector, public sector like BEL, SAIL and private sector have been utilized in this project. Presently, OFB has achieved 81% indigenization but is confident of reaching greater indigenization in near future. The issues of

manufacturing and QA/QC are 'Key Areas of Excellence' in this project. To achieve the desired quality, GCF has set up a modern Assembly Line in GCF, Jabalpur.

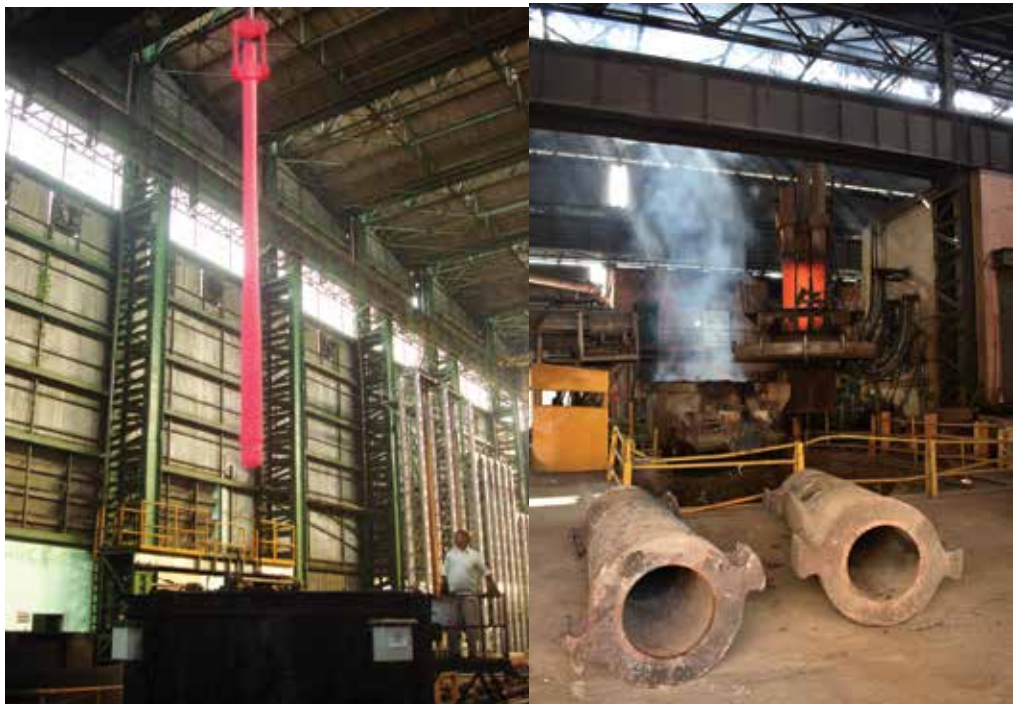
A project of such a magnitude cannot make any headway unless actively supported by the user. OFB has classified Dhanush Project as 'OFB and Artillery Directorate' project. The advice, support and hand holding by the army, especially by the Artillery Directorate, have resulted in making of the Dhanush gun. The Weapon Development Team provided by the Army has been the strongest support system for the project. Similarly, the support provided by the 506 Army Base Workshop (EME), Jabalpur and the DG EME and his team has been immense. DGQA has helped in formulating elaborate Quality Assurance plans at component/ sub assembly levels as well as on the Integrated Gun Assembly Systems developed by the GCF Jabalpur. ARDE/DRDO has helped in formulation of Range Tables. The project has also been a joint effort of the EME officers, 506 Army Base workshop, Jabalpur and Officers/technicians in the GCF/OFB. It is a relationship that continues even to this day. Recently, when Mercedes Benz, the selected OEM of the gun's auxiliary power unit (APU) informed that they have closed down the manufacturing line for the APU engines, 506 Army Base Workshop (EME) and GCF joined hands to successfully modify indigenous Cummins engine to fit into the function as an APU for the Dhanush gun, with much better performance and at a lower cost. The trials for this new APU is underway and once approved for introduction into service, an indigenous solution will be in place to maintain continuity of production. Project Dhanush has followed a new model for executing a project of such a large magnitude in the Make in India domain. This model has derived synergy from the close collaboration between the manufacturers, User and Quality Control organizations. OFB holds the Intellectual Property Rights of Dhanush gun system. All these developments have brought new confidence and synergy among all the stake- holders that will propel them to reach even greater heights in manufacturing under Make in India initiative of the Government of India.



Dhanush Firing in Pokhran Field Firing Range



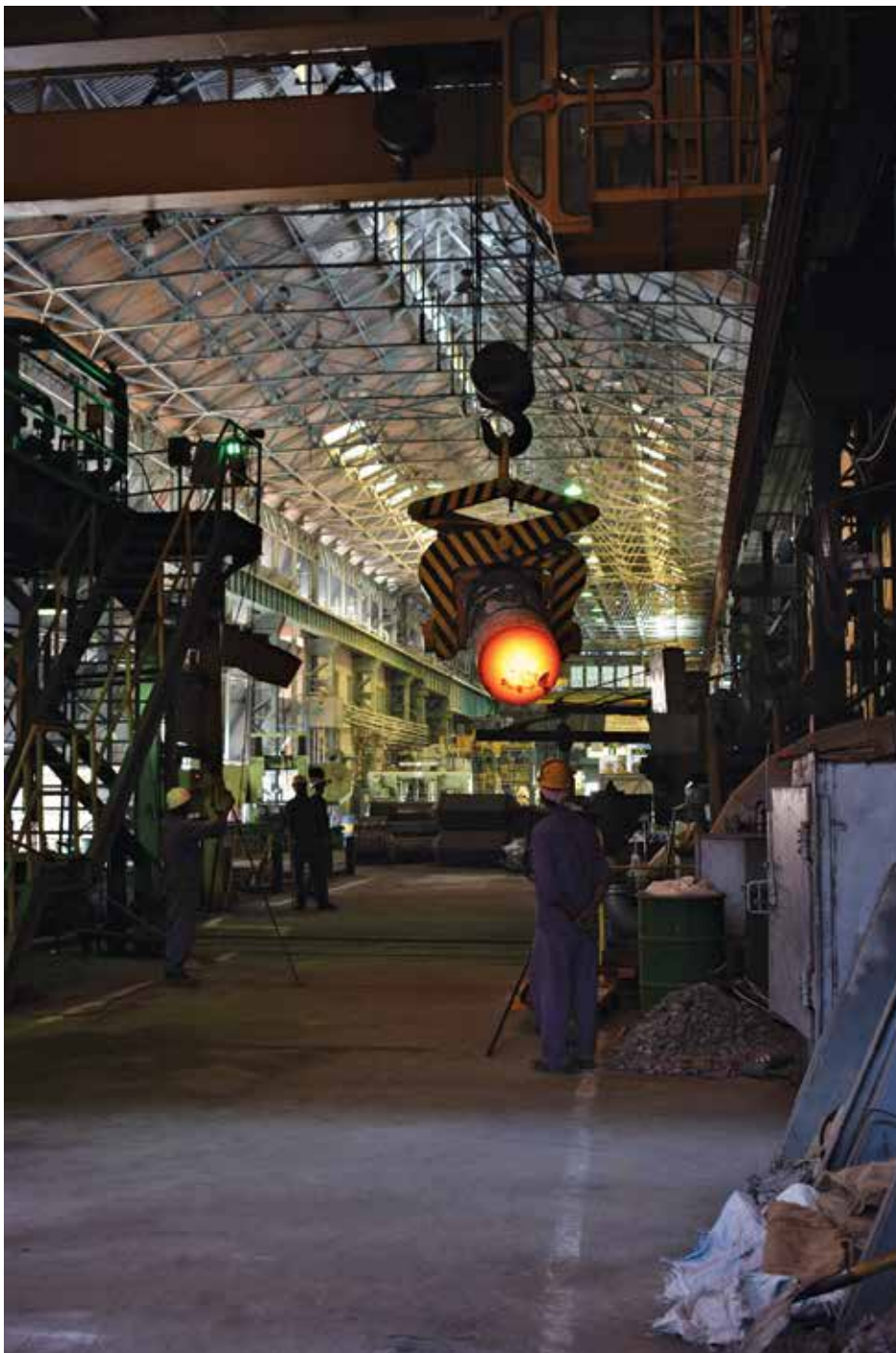
Dhanush Gun Firing in High Altitude Ranges



Forging of Dhanush Barrel



Barrel under Manufacture in MSF, Ishapur



Barrel of Dhanush under Manufacture in MSF/OFB, Ishapur



Evolution of 155/45Cal Dhanush Gun



Design & development

Dhanush Phase

A big leap

Gun No 7-12

User Exploitation Trials 2015-18

PSQR Trials and User Trials

Project Dhanush

155 mm FH Project Dhanush

OFB Prototype 3 to 6 2013-14



155 mm FH Mech. Upgrade
- Ordnance design & Proof
- Muzzle brake design & Proof
- Carriage stress analysis

155 mm FH Upgrade
OFB Prototype -1,2 2011-12



21% to 81% Indigenisation

Setting 'Gold' Standards for future system evaluation

USER EXPLOITATION

- Introduced for the first time
- Familiarization and training of users
- To establish reliability of progressive indigenization
- To generate feedback on configuration and design improvement
- Undertaken on Gun nos. 007-012

- **1520 rounds Fired in 3 Phases from 6 Guns (July 2016 to June 2018)**

USER EXPLOITATION



■ Phase I
■ Phase II
■ Phase III

Major Firing Trials / Evaluation

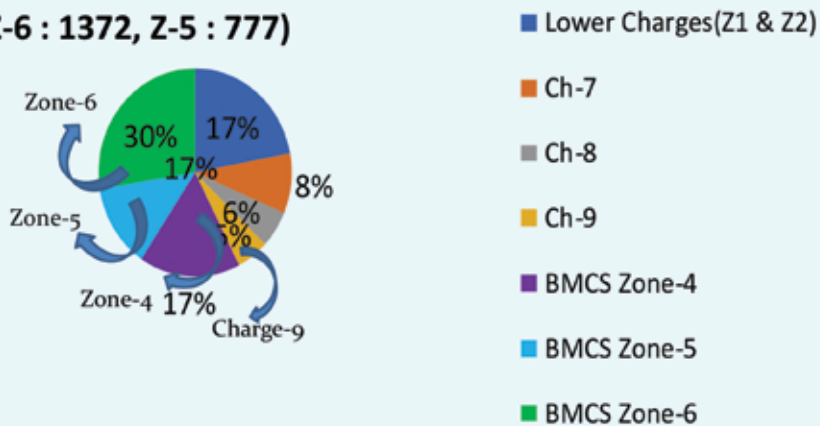
Upgrades Validation Firing	- May 2012
PSQR Validation Firing	- Apr-May 2013
Winter Firing Trials	- Mar' 2014
Summer firing trials	- Jul-Aug' 2014
DGQA Evaluation	- Oct'2014- Jun' 2015
Confirmatory trials	- Sep' 2015
MET	- Aug-Sep' 2015
EMI/EMC Trials	- Jun'2016/Apr'17
Confirmatory trials(Non-Firing)	- Sep'2016

PUBLIC PRIVATE PARTNERSHIP

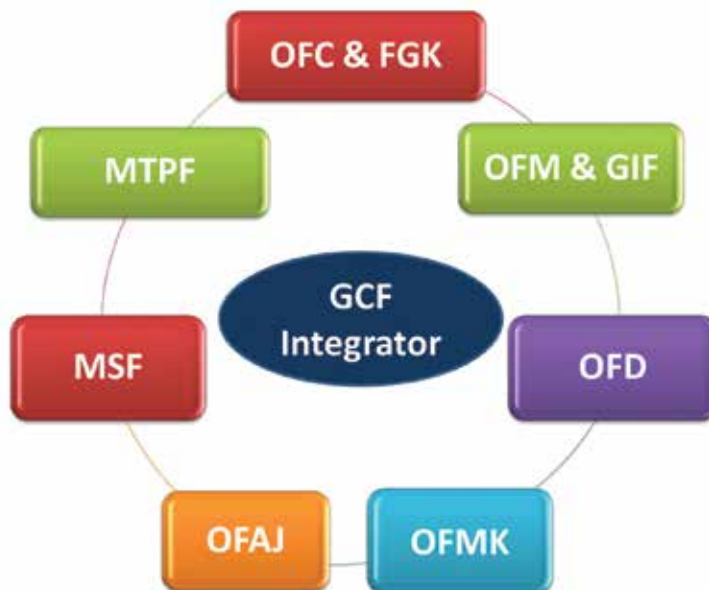


FIRINGS TILL 09th June 2018

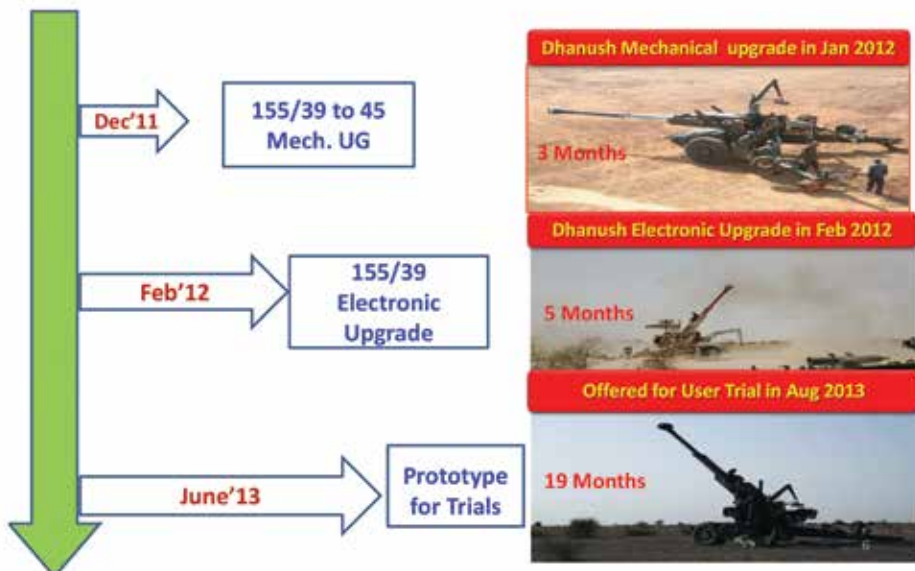
Round Fired 4599 nos
(Z-6 : 1372, Z-5 : 777)



OFB SISTER FACTORIES CONTRIBUTION



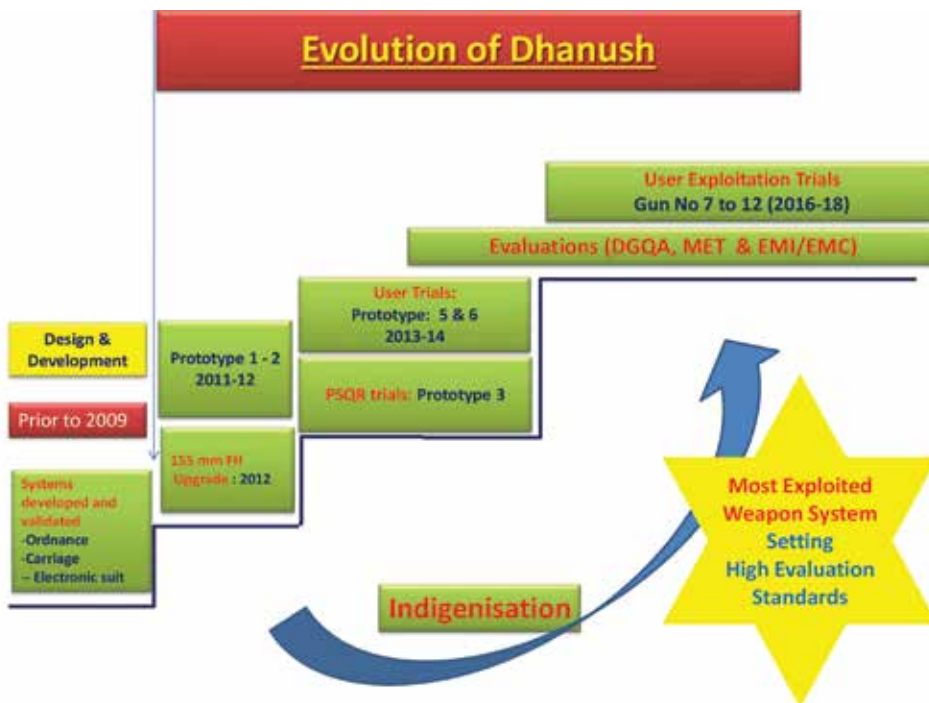
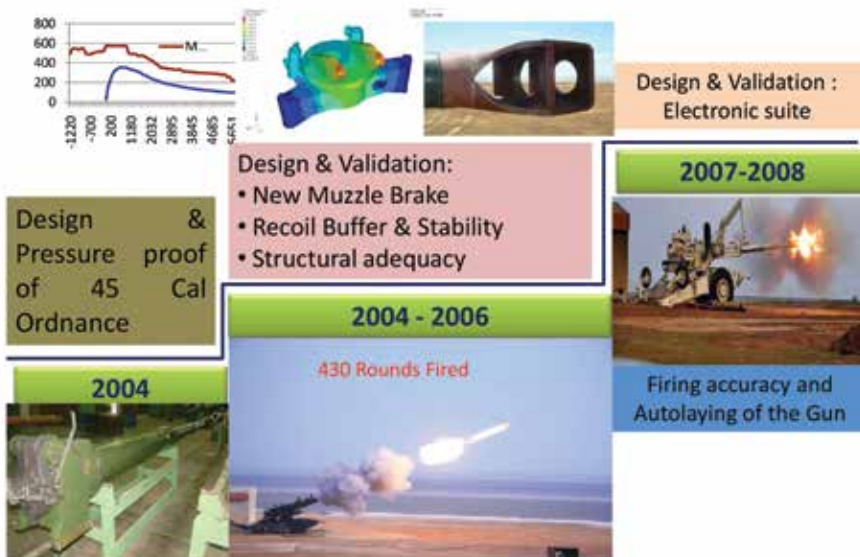
Timelines & Achievement



DHANUSH- A NATIONAL EFFORT....



Development prior to Dhanush



Support by User

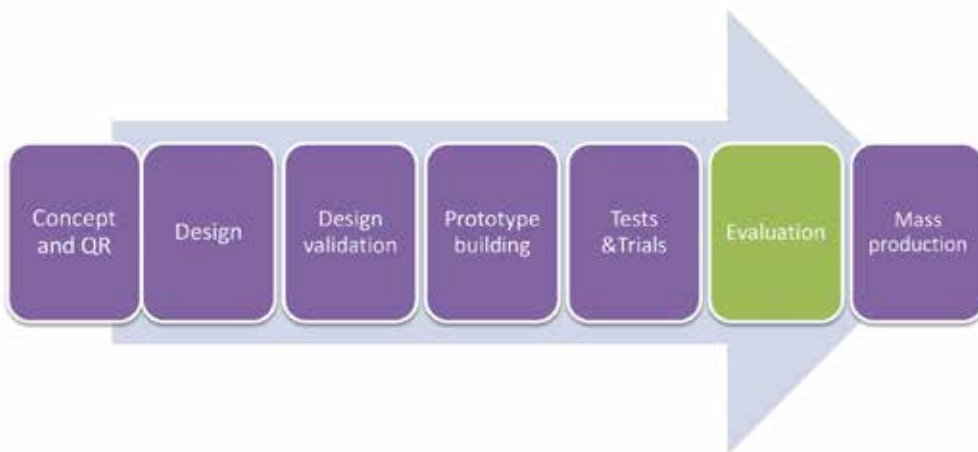
WDET constituted with one Brig from Arty Dte. with members from User, EME, DGQA and, stationed at GCF are closely associated with the project.

506 ABW assisted in integration/de-integration of the Gun system and in training of GCF personnel

Allotment of Ranges and logistic support for OF Personnel during firing trials at PFFR, SFFR by the User

Attachment of Gun Det during various trials

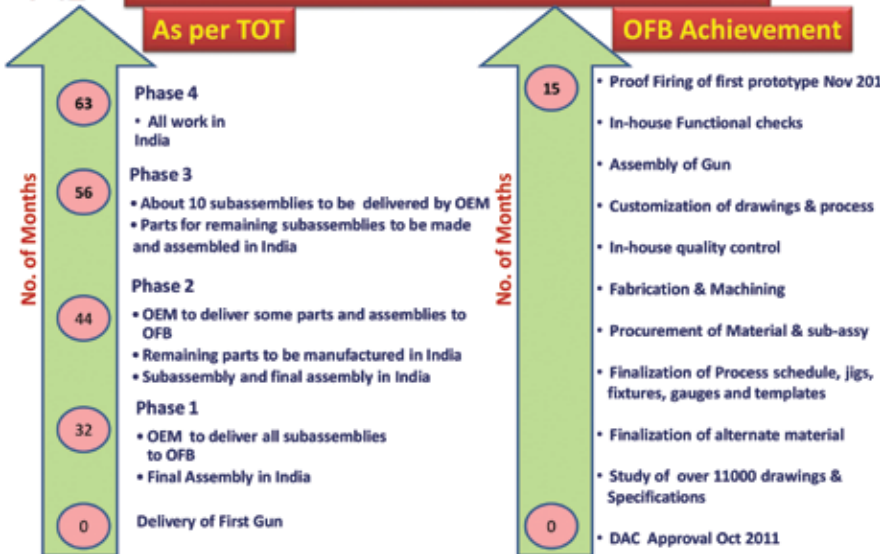
PHASES OF PROJECT DHANUSH





INDIAN ORDNANCE FACTORIES

INDIGENIZATION TIMELINE



DHANUSH MECHANICAL MODULES

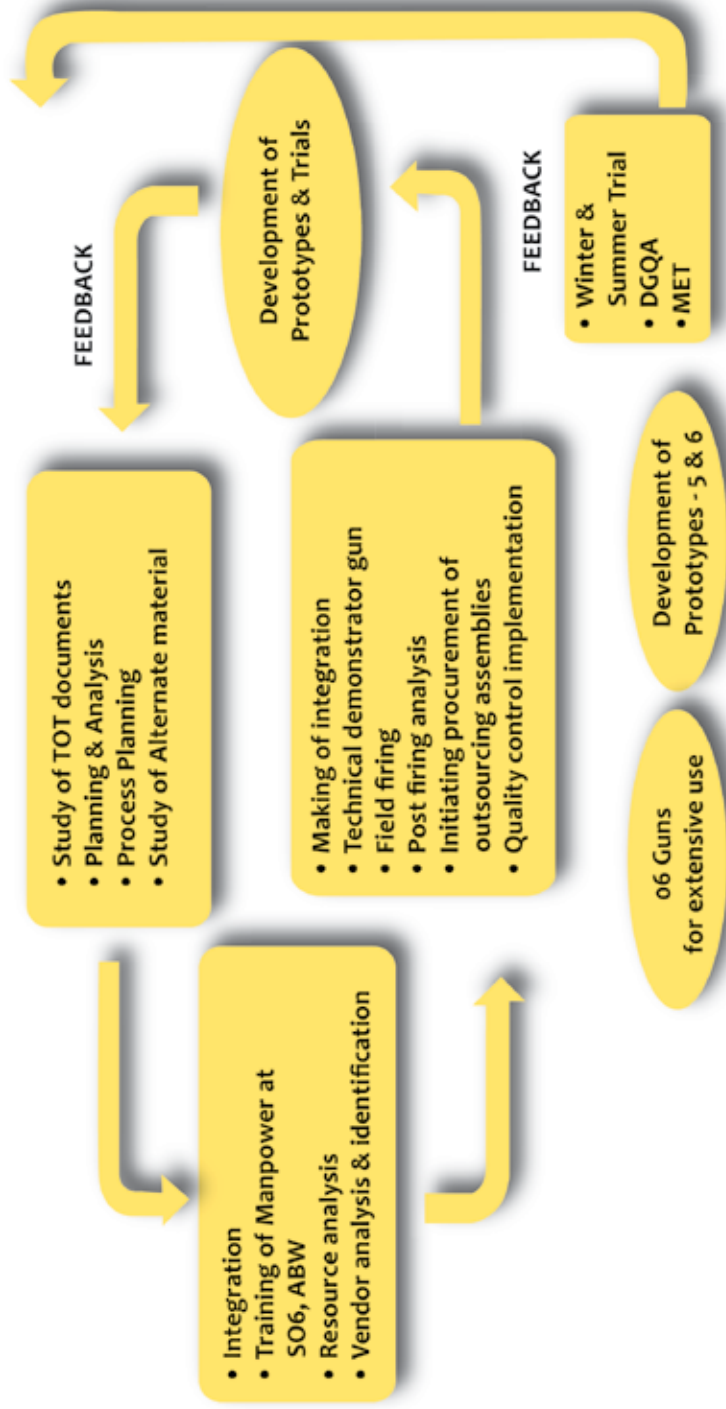


45 CAL BRL

**MODIFIED
LOADING
TROUGH FOR
BMCS**

**MODIFIED
HIGH
EFFICIENCY
MUZZLE
BRAKE**

DEVELOPMENTAL CYCLE



Progressive Indigenization

- Ordnance
- Electronics Upgrade
- Electrical System
- Recoil Buffer

21%
GUN NO 1

- Cradle
- Chassis
- Trails
- Power Plant
- Wheel Assy

51%
GUN NO 3

- Mounting Body
- Hydraulic System (80%),
- Braking System (85%)

69%
GUN NO 4

- Loading Device,
- Complete Hydraulic
- Complete Braking System

75%
GUN NO 5

- Rammer
- Wire race Roller Bearing
- Back Up Sight

80.5%
GUN NO 6

Loading Tray

81%
GUN NO 7-12

DHANUSH ELECTRONIC SUITE

