FNGUN

Internal ballistics modelling

FRAZER-NASH CONSULTANCY

In partnership with QinetiQ

SYSTEMS AND ENGINEERING TECHNOLOGY

FNGUN is a validated, easy-to-use, commercially available software suite for the analysis of internal ballistics. The FNGUN software suite has been developed by Frazer-Nash, in partnership with other leading industry experts, to incorporate elements at the forefront of research whilst remaining easy to use.

FNGUN is used by government and industrial R&D facilities worldwide, and has been successfully applied to gun systems ranging from small-calibre firearms, through mortars and grenade launchers, to howitzers and tank guns.

Frazer-Nash provides full training and support for FNGUN and offers consultancy services in internal ballistics analysis.

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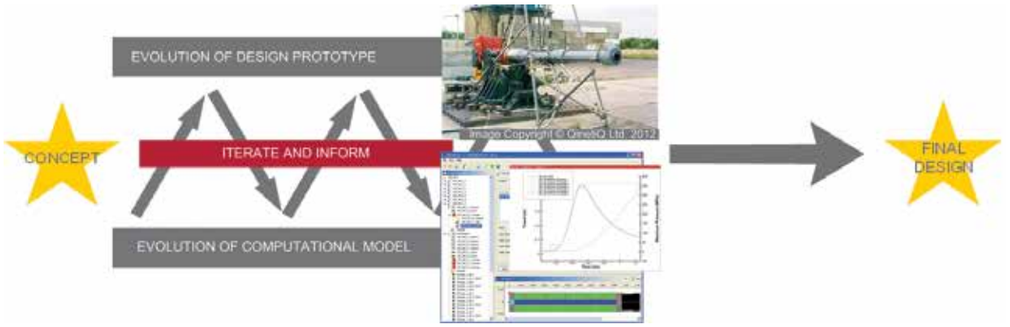
The benefits of internal ballistic modelling

FNGUN2D

Good internal ballistics design requires an intimate understanding of the inner workings of a gun chamber. What happens inside the chamber directly affects the safety, structural integrity, efficiency and performance of a gun system. Without modelling the complex combustion processes inside the chamber using internal ballistics software such as FNGUN, the only sources of information to the designer are test firings and prototype designs.

Computational methods offer greater flexibility in the design process, allowing the ballistician to quickly carry out ‘what if’ analyses, and check the robustness of a design’s performance to variations in structural or loading parameters. Using such methods the design process becomes faster, cheaper and easier.



CAPTURE MORE DATA

With a computational model you can obtain information about the chamber conditions at any location and time – you are not restricted by the limitations of physical measurement devices.

INVESTIGATE ‘WHAT IF’ SCENARIOS

Developing a computational model of your system is an easy way to investigate ‘what if’ scenarios – ‘what if we change the number of charge modules?’; ‘what if ignition fails to occur at the right time?’ Where such investigations may be expensive or even impossible to test with prototypes, a computational model allows you to easily carry out analyses.

MAKE DESIGN CHANGES QUICKLY AND EASILY

Whether you want to see if you can achieve the same performance with a different shape of projectile, or investigate the effect of fluctuations in charge size, making changes to your design in a computational model is quick and easy.

REDUCED TIME-TO-MARKET FOR NEW PRODUCTS

All of these benefits combined will cut your development costs and deliver a reduced time-to-market for new products.

FNGUN – the internal ballistics analysis suite

FNGUN comprises one- and two-dimensional software packages, FNGUN1D and FNGUN2D, both of which enable the user to carry out fast and accurate internal ballistics analyses with validated solvers and a user-friendly interface. These packages are complementary, with FNGUN1D often used in preliminary analysis, and FNGUN2D used for further analysis as the design process develops.

The software is supplied with tailored on-site training, technical support and a library of typical gun system components and examples. This ensures that new users can immediately obtain the maximum benefit from these powerful tools. Both software packages have been developed to international software quality standards – ISO 9001 and TickIT *plus*.

VALIDATED INTERNAL BALLISTICS AND THERMAL SOLVERS

FNGUN has been continually improved over the past 20 years. The current version represents decades of expertise in development and validation, with FNGUN2D incorporating the well-respected QIMIBS solver developed by QinetiQ.

Systems which FNGUN has been successfully validated against firing data include:

- Small and medium-calibre systems
- 81mm and 120mm mortar
- 120mm direct fire
- 105mm and 155mm indirect fire

FNGUN also includes a thermal solver for modelling barrel heating, which has been validated for medium-calibre and mortar systems.

EASY-TO-USE INTERFACE

FNGUN features easy-to-use graphical user interfaces which run on the Windows® operating system, providing a user-friendly environment in which to build, analyse, compare and improve your gun system designs. Model runtime is in the order of seconds (FNGUN1D) or a few hours (FNGUN2D) on a standard desktop.

Within FNGUN, our component-based approach to gun system design allows the user to easily build up a library of reusable gun system components, vary aspects of their design, and solve a wide range of designs using the FNGUN1D and FNGUN2D solvers. FNGUN also comes with a fully integrated post-processor, employing the powerful features of Tecplot® for FNGUN2D.

FNGUN supports a wide range of built-in propellant geometries, and allows the user to define their own grain geometry and properties.

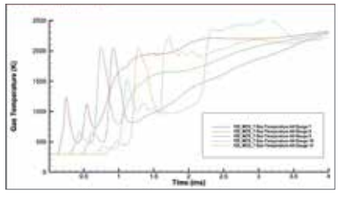
FULL TRAINING AND SUPPORT TAILORED TO YOUR PROGRAMME

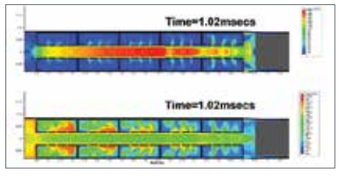
We provide training and support in how to effectively model your system in FNGUN. With over 20 years experience in internal ballistics modelling, our experts can provide bespoke advice on how to make the most of FNGUN software tools through a combination of training and support tailored to your requirements.

Training courses range from 2 days to a full week and can be delivered at your offices in order to engage the maximum number of your staff. We will tailor each course to your project requirements. Course subjects include:

- General principles of internal ballistics modelling
- Modelling best practice
- Use of the FNGUN software to model your systems
- Maximising efficiency and fidelity: using FNGUN1D and FNGUN2D in parallel

In addition, we offer support options ranging from telephone and e-mail support through to regular workshops and development of software upgrades to meet your needs.





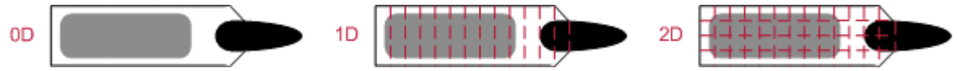
Applications of the FNGUN internal ballistics suite

WHICH SOFTWARE PACKAGE: FNGUN1D OR FNGUN2D?

The choice of when to use FNGUN1D or FNGUN2D depends on both the complexity of the gun system and the features being investigated.

If you are looking for an estimate of muzzle velocity or peak pressure, and your system geometry is relatively simple, then FNGUN1D may be sufficient for your needs. More complex models and analyses require FNGUN2D, particularly when considering complex ignition effects.

Often the best approach is to use a combination of FNGUN1D and FNGUN2D to balance high-fidelity (in 2D) analysis with rapid design iterations (in 1D).



	0D	1D	2D
Overview	0D (or 'lumped parameter') codes such as IBHVG2 give an estimate of muzzle velocity and peak pressure. They assume a uniform propellant bed, and use only mean values for chamber pressure and temperature. Thus they do not model pressure waves or flame spread.	1D codes, such as FNGUN1D, model axial gas flow in the chamber, making the analysis of pressure waves and charge motion possible, for non-uniform charge densities; the muzzle velocity and pressure distributions are more accurate than 0D.	A 2D code, such as FNGUN2D, models both axial and radial gas flows; this results in a more accurate simulation of the system, and permits the high-fidelity analysis of complex processes such as multi-stage ignition in modular charge systems.
Uses	Estimates of muzzle velocity and peak pressure for variations in the total charge or projectile mass.	Modelling axial pressure waves, gas flow constraints, multi-stage ignition, non-uniform or multi-propellant charges.	Complex ignition trains, radial charge layouts, high–low pressure systems, perforated primers (piccolo tubes).

APPLICABLE TO A WIDE RANGE OF GUN SYSTEMS

The FNGUN software can be used to analyse a wide range of weapon calibres and types; systems which can be modelled include:

- Small arms, including Cased Telescoped Ammunition (CTA)
- Medium-calibre weaponry and bayonet primers
- Mortars and other high–low pressure systems
- Modular Charge Systems (MCS)
- Tank guns and major artillery

INTERNAL BALLISTICS CONSULTANCY SERVICES

As well as training and support in using our software, we offer consultancy services in the internal ballistics analysis of gun systems.


Mortars


Major artillery


Direct fire


CTA & Small arms

FNGUN internal ballistics suite – technical overview

FNGUN1D

FNGUN1D is a one-dimensional two-phase flow CFD solver which offers greatly increased capability over lumped parameter codes. Its features include:

- Modelling of axial pressure waves in the chamber
- Charge designs consisting of many different types and make-up of propellant can be modelled
- Modelling of complex ignition processes with separate igniter and propellant components
- Modelling of moving charges
- Many supported propellant geometries (including slotted tube and 7- or 19-hole tube)
- User-defined grain geometries for novel or non-ideal grains
- User-defined propellant properties vs. regression distance for retardants
- Erosive burning and implicit ignition of grains by heat transfer for improved flame-front modelling
- Runtimes of around 1 minute on a standard desktop

FNGUN1D has been successfully applied to the analysis of a wide variety of gun systems, including small-calibre ammunition, tank ammunition and simple mortar models and Modular Charge Systems.

FNGUN THERMAL MODULE

A thermal module for analysing heat transfer to the barrel is available as part of the FNGUN suite. The thermal model can be used to assess:

- Impact of battlefield day on barrel durability
- Cook-off limits
- Gun tube heating and cooling rates
- The effect of different propellant composition

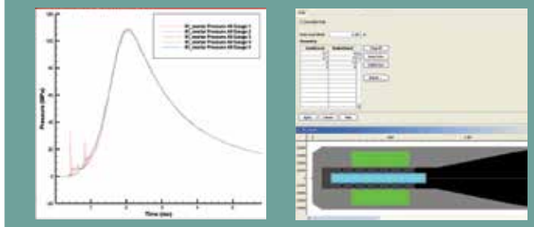
The thermal model has been validated for medium-calibre and mortar systems.

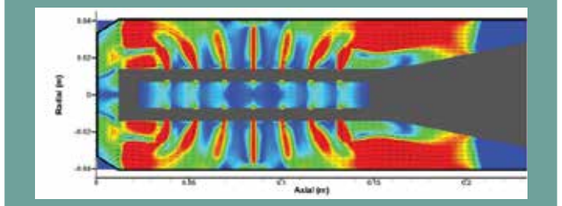
FNGUN2D

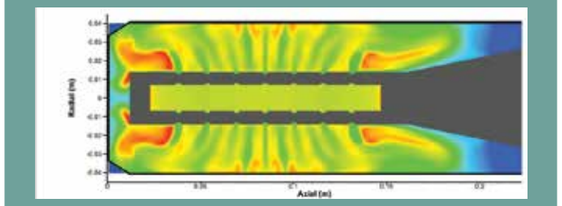
FNGUN2D is especially well suited to modelling the complex ignition trains in mortar and Modular Charge Systems (MCS), and those incorporating radial venting features such as piccolo tubes; it has been successfully applied to the analysis of Cased Telescoped Ammunition (CTA).

FNGUN2D includes the well-respected QIMIBS solver developed by QinetiQ; its features expand on those of FNGUN1D and include:

- A two-dimensional, two-phase flow FCD solver
- (QIMIBS), for modelling radial flow (see below)
- More complex ignition models, such as Piccolo tubes
- and MCS
- Improved modelling of propellant bed movement and compaction
- Runtimes of just a few hours on a standard desktop







RESEARCH AND COLLABORATION

FNGUN has been used in the research and development of a variety of gun systems. Papers resulting from this research have been presented at all but one of the International Ballistics Symposia since 1998. The list below includes some of the key publications:

An Alternative Method for the Derivation of Propellant Burn Rate Data From Closed Vessel Tests.
M. D. Pocock[1] & C. C. Guyott[1], (1999). Proceedings of the 18th International Symposium and Exhibition on Ballistics. San Antonio, Texas, USA 15–19 November 1999. USA: Taylor & Francis Group.
1. Frazer-Nash Consultancy Ltd

An Investigation of Inaccuracies in Grain Shape on the Derivation of Propellant Burn Rate Data From Closed Vessel Tests.
M. D. Pocock[1] & C. C. Guyott[1], (2000). Proceedings of the European Forum on Ballistics of Projectiles – EFBP2000. ISL, French-German Research Institute of Saint Louis, France 11–14 April, 2000. Saint-Louis, France: ISL.
1. Frazer-Nash Consultancy Ltd

Factors Affecting the Accuracy of Internal Ballistics, Including the Simulation of Propellant Motion.
M. D. Pocock[1], J. O. O'Neill[1] & C. C. Guyott[1], (2001). Proceedings of the 19th International Symposium on Ballistics, 1: 81–88. Interlaken, Switzerland 7–11 May 2001. Switzerland: Vetter Druck AG, Thun.
1. Frazer-Nash Consultancy Ltd

Investigation of Gas Leakage on Mortar Rounds: Comparison Between Experiment and Numerical Modelling.
M. D. Pocock[1], A. Makkonen[2] & C. C. Guyott[1], (2002). Proceedings of the 20th International Symposium on Ballistics, 1: 291–297. Orlando, Florida, USA 23–27 September 2002. Pennsylvania, USA: DEStech Publications, Inc.
1. Frazer-Nash Consultancy Ltd
2. Patria Weapon Systems Oy, P. O. Box 18, Vammaksentie, FIN-38201 Vammala, Finland

Effect of Statistical Variation in Grain Geometry on Internal Ballistics Modelling.
M. D. Pocock[1], P. M. Locking[2] & C. C. Guyott[1], (2004). Proceedings of the 21st International Symposium on Ballistics, 2: 610 615. Adelaide, Australia, 19–23 April 2004. Australia: Defence Science and Technology Organisation.
1. Frazer-Nash Consultancy Ltd
2. BAE Systems, RO Defence, Shrivenham, Swindon, UK

Improved Mortar Barrel Thermal Model.
M. D. Pocock[1], P. M. Locking[2] & C. C. Guyott[1], (2005). Proceedings of the 22nd International Symposium on Ballistics, 2: 1187. Vancouver, BC, Canada 14–18 November 2005. Pennsylvania, USA: DEStech Publications, Inc.
1. Frazer-Nash Consultancy Ltd
2. BAE Systems, RO Defence, Shrivenham, Swindon, UK

Challenges of Internal Ballistics Modelling of Novel Propellants and Propellant Geometry.
M. D. Pocock[1], S. Einstein[2], C. C. Guyott[1], K. Ng[1], D. Carlucci[2], K. Klingaman[2] & K. B. Moran[3], (2007). Proceedings of the 23rd International Symposium on Ballistics, 1: 337–342. Tarragona, Spain, 16–20 April 2007. Madrid, Spain: Francisco Gálvez.
1. Frazer-Nash Consultancy Ltd
2. US Armament, Research and Development Center, Picatinny Arsenal, Dover, NJ 07871, USA
3. ATK Energetic Systems Division, Radford Army Ammunition Plant, Radford, VA 24143-0001, USA

Matching Internal Ballistics Code Fidelity to Gun System and Analysis Complexity.
M. D. Pocock[1], T. Melvin[2], I. Robertson[1], C. Woodley[3] & C. C. Guyott[1], (2008). Proceedings of the 24th International Symposium on Ballistics, 1: 329–335. New Orleans, Louisiana, USA 22–26 September 2008. Pennsylvania, USA: DEStech Publications, Inc.
1. Frazer-Nash Consultancy Ltd
2. University of Bristol, Engineering Mathematics Department, Bristol, UK
3. QinetiQ, Fort Halstead, Sevenoaks, Kent, UK

Benefits of Two Dimensional Internal Ballistics Modelling for Small Calibre Cased Telescoped Ammunition.
S. Georgi[1], M. D. Pocock[1], I. Robertson[1], C. Woodley[2], R. Threlfall[3] & C. C. Guyott[1], (2011). Proceedings of the 26th International Symposium on Ballistics, 1: 830–836. Miami, FL, USA 12–16 September 2011. Pennsylvania, USA: DEStech Publications, Inc.
1. Frazer-Nash Consultancy Ltd
2. QinetiQ, Fort Halstead, Sevenoaks, Kent, UK
3. Oxford University, Engineering Department, Oxford, UK

A Linked Internal Ballistics and Finite Element Analysis.
S. Georgi[1], M. D. Pocock[1], J. Jones[1] & C. Watt[1], (2013). Proceedings of the 27th International Symposium on Ballistics, 1:124–134. Freiburg, Germany. 22–26 April 2013. Pennsylvania, USA: DEStech Publications, Inc.
1. Frazer-Nash Consultancy Ltd

Linking two- and one-dimensional internal ballistics analyses.
S. Georgi[1], M. Pocock[1], C. Woodley[2] & C. Turpie[1]. Proceedings of the 28th International Symposium on Ballistics, Atlanta, Georgia, USA 22–26 September 2014.
1. Frazer-Nash Consultancy Ltd
2. QinetiQ, Fort Halstead, Sevenoaks, Kent, UK

MORE INFORMATION

For more information about our products and services, or to request a quote for FNGUN internal ballistics software, please contact fngun@fnc.co.uk.

FNGUN is subject to UK export approval.

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To find out more about our work and how we can add value to your business, email fngun@fnc.co.uk or visit our website:

www.fnc.co.uk