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Quantitative Risk Assessment for Regulatory Applications Using IMESAFR

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ACRONYMS

APT	A-P-T Research, Inc.
ATD	American Table of Distances
ATF	Bureau of Alcohol, Tobacco, Firearms and Explosives
CERL	Canadian Explosives Research Laboratory
DCMA	Defense Contract Management Agency
DDESB	Department of Defense Explosives Safety Board
DoD	Department of Defense
ES	Exposed Site
GIS	Geographical Information System
GUI	Graphical User Interface
IME	Institute of Makers of Explosives
IMESAFR	Institute of Makers of Explosives Safety Analysis for Risk
ISP	IMESAFR Science Panel
MSHA	Mine Safety and Health Administration
OSHA	Occupational Safety and Health Administration
PES	Potential Explosion Site
PDF	Probability Density Function
QD	Quantity Distance
QRA	Quantitative Risk Assessment
RBESCT	Risk-Based Explosives Safety Criteria Team
SAFER	Safety Assessment for Explosives Risk
SME	Subject Matter Expert
TP	Technical Paper
UDEA	User-Defined Explosive Article
USCG	United States Coast Guard

Abstract

Both the military and commercial explosives communities have traditionally used Quantity Distance (QD) for explosives safety regulations. However, over the last 25 years, the use of Quantitative Risk Assessments (QRAs) has been growing in acceptance. The U.S. Department of Defense Explosives Safety Board (DDESB) has established an approved QRA methodology for evaluating and accepting risks associated with explosives storage and other activities. The QRA methodology created by DDESB is defined in DDESB Technical Paper (TP) 14. Risk-based siting evaluations use multiple parameters including facility construction, number of exposed individuals, amount of time individuals are present, potential for an explosives accident, direction of the exposed site from the potential explosion site, as well as quantity of explosives and distance to inhabited buildings to assess risk. Risk-based analysis provides a basis for distinguishing between scenarios, even when quantity and distance are the same. The DoD Risk-Based Explosives Safety Criteria Team (RBESCT) was chartered to develop the methodology required and then create a model. This led to the creation of the Safety Assessment for Explosives Risk (SAFER) software tool, which is a semi-empirical QRA model for the DoD. In 2004, APT Research, Inc. (APT), was commissioned to work with a team of industry and regulatory experts to incorporate the SAFER methodologies and algorithms into a tool designed for the commercial explosives industry. The result of this collaborative effort was the QRA software tool IMESAFR© (Institute of Makers of Explosives Safety Analysis for Risk). This tool is owned and maintained by APT, sponsored by an industry consortium, and reviewed by regulators and industry experts. IMESAFR is currently accepted for use in the U.S. and Canada for regulatory applications involving commercial explosives. Criteria have been established for individual and group risk and are used for granting risk-based variances or derogations in the U.S. and Canada, respectively. The IMESAFR tool assists with QRAs, but training is required, as regulators are concerned with the appropriate use of the tool. Regulators around the world are trained on the tool and it is used for regulatory approval in the U.S. and Canada; however, to date there are only limited regulatory uses for QRA in the rest of the world. Based on requests from regulators, improved modeling capabilities such as NATO-based QD tables using AASTP-1 Edition C as a guideline, HD 1.2 explosive article inclusion, improved side-impact debris algorithms for barricades, and updated logic for the Probability Density Function (PDF) parameters used to model debris will be implemented in the next release version of IMESAFR. Another future area of study is the inclusion prompt propagation modeling for QRAs. The software is supported by full-scale field test programs, which were historically funded by the Department of Defense (DoD) and are now funded primarily by the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF), with limited industry funding. In 2024, ATF funded a test program for jet perforating guns (JPGs), which was the first step in anchoring the IMESAFR model for perf guns to test data. Future test programs are anticipated to include overhead bins and small quantities in small commercial storage magazines. Test programs are used to update current debris logic by comparing test data to the existing IMESAFR models and making any corresponding improvements required, or to include new logic for additional test articles or

scenarios. Basing updates to the IMESAFR algorithms on test data improves the software's ability accurately model scenarios, which in turn allows regulators and industry to make informed decisions for reducing risk. Military and commercial personnel can benefit from the use of IMESAFR's risk-based methodology for regulatory purposes and as part of a risk management plan to increase safety at sites.

1.0 Introduction

Over the last 25 years, the use of Quantitative Risk Assessments (QRAs) for explosives safety regulations has been growing in acceptance in not just the U.S. but in many countries around the world. With this growing acceptance, it has been necessary to develop tools that can model scenarios and predict risk values for both the military and commercial explosives communities. One such tool that has been developed to assist with risk-based siting evaluations is the Institute of Makers of Explosives Safety Analysis for Risk (IMESAFR©), which has been in development since 2004.

1.1 QUANTITATIVE RISK ASSESSMENT

QRA is an approach to safety based on evaluating risk as a numerical value. QRA allows a more comprehensive assessment of the overall risk to personnel from explosives facilities, rather than only assessing the quantity and distance from explosives. This approach determines a risk value by quantifying the likelihood of an event, as well as the consequence. Factors, beyond quantity and distance, that are incorporated into the numerical risk value include: facility construction, number of exposed individuals, amount of time individuals are present, probability of an event occurring (P_e), type of explosives present, activity occurring at the facility, and direction of the exposed site relative to the potential explosion site.

1.2 IMESAFR

IMESAFR is a QRA software tool used to calculate risk to personnel from explosives facilities. IMESAFR is available commercially and can be obtained from A-P-T Research, Inc. (APT), who owns and maintains the software. To acquire the program, users are required to attend a training course and pass a basic proficiency exam. After attending training and passing the exam, users can purchase an annual license and use the program freely. It is important to note that IMESAFR is subject to export restrictions based on its EAR99 designation. This means that users from countries or entities on the U.S. State Department's restricted list cannot be provided with the program. Furthermore, IMESAFR may not be provided to any person on the U.S. State Department denied parties list, regardless of location.

2.0 History

Although QRA is commonplace internationally in safety in general, its use has been a more recent development in explosives safety, especially in the U.S., for both the defense sector and the commercial explosives industry.

2.1 RISK-BASED EXPLOSIVES SAFETY CRITERIA TEAM

In 1997, the DoD began developing its approach to implementing QRA for explosives safety. The Risk-Based Explosives Safety Criteria Team (RBESCT) developed the Technical Paper 14 (TP-14) model (Ref. 1), implemented by the Safety Assessment for Explosives Risk (SAFER) tool. The RBESCT comprised representatives from the Department of Defense Explosives Safety Board (DDESB) and Services (Army, Navy, Air Force, Marines, and Coast Guard). Other government entities, including the Defense Contract Management Agency (DCMA), also participated over the years.

APT supported the RBESCT in this effort by providing subject matter experts (SMEs) on QRA and explosives effects/consequences modeling. APT also served as the team secretariat and the software developer for the SAFER tool.

2.2 IMESAFR

Following the development of the SAFER tool, the Institute of Makers of Explosives (IME) felt it would be beneficial to have a similar tool for use in the commercial explosives community. Given APT's role in the development of the SAFER tool, IME contracted APT to develop the IMESAFR tool, using the same DDESB TP-14 approaches. This was facilitated by DDESB's decision to allow a technology transfer for the general QRA methodologies developed for TP-14. The history and relation of APT, IME, RBESCT, SAFER, and IMESAFR is depicted in Figure 1.

Figure 1: IMESAFR Development History and Relationship

2.2.1 Project

As stated previously, the IMESAFR project looked to build upon the work of the RBESCT and develop QRA solutions for use by industry, with an initial focus on the U.S. and Canada. To accomplish this, IME and APT invited regulators to participate in the development of IMESAFR. The Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF), Mine Safety and Health Administration (MSHA), Occupational Safety and Health Administration (OSHA), Natural Resources Canada – Explosives Research Division (NRCan-ERD), and Canadian Explosives Research Laboratory (CERL) were involved from the first meeting. Regulatory participation was vital, as the goal of the IMESAFR project was not only to develop a QRA model, but also to establish the rules and requirements for application of IMESAFR, initially in the U.S. and Canada. To this end, it was essential to have regulatory buy-in on the approach, level of conservatism, and intended applications of IMESAFR. This collaboration between members of industry, regulators, and QRA SMEs (APT) to develop IMESAFR has been referred to as a "Three-Legged Stool" in the past and is depicted in Figure 2.

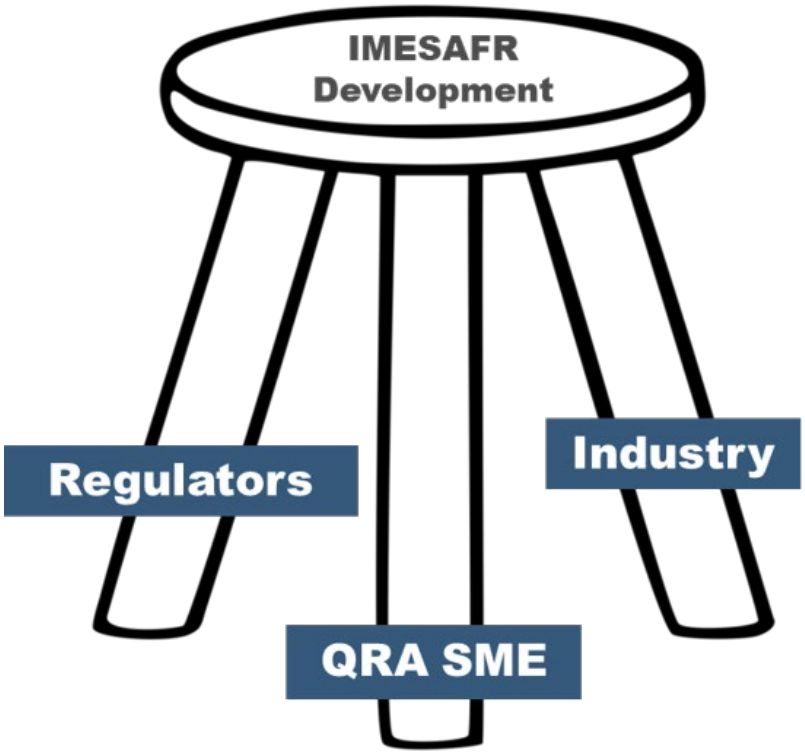

Figure 2: IMESAFR's "Three-Legged Stool" Relationship

The development of IMESAFR was originally sponsored solely by the Institute of Makers of Explosives (IME), who assembled a team of industry and regulatory representatives to provide input on the needs of the commercial explosives world. APT was contracted to develop and deliver the executable version of a QRA software tool, which was eventually known as IMESAFR. This software tool was made commercially available after the initial release to the development team, with APT owning and maintaining the source code. More recently, the sponsor team became a group of five members: Orica, Dyno Nobel, Nelson Brothers, Austin

Powder, and IME. Over the course of the tool's development APT has closely collaborated with regulators and members of industry to develop the models in the software.

IMESAFR's stakeholders include government regulators and commercial explosives companies across the world, trained participants, and licensed users. Another key stakeholder is the IMESAFR Science Panel (ISP), a group co-chaired by the ATF and industry, to review scientific integrity of the models and algorithms used in IMESAFR.

2.2.2 Software Development

Periodically, a new version of the software is released after it has been reviewed internally and all algorithm changes have been approved by the ISP. The following subsections describe the versions of IMESAFR that have been developed.

2.2.2.1 Released Versions

Beginning in 2005, the IMESAFR Development Team developed a list of adaptations and additions necessary to create a software tool for industry, using SAFER as a starting point. Released in January 2007, IMESAFR v1.0 shared algorithms with SAFER v3.0. While similar, IMESAFR contained differences including explosives, activities, environmental factors, and available potential explosion site (PES) types (Ref. 2, 3).

IMESAFR was updated to IMESAFR v1.1, which was released February 2009. This version included algorithm updates provided in SAFER v3.1, as well as updates to create a more intuitive graphical user interface (GUI).

In February 2011, IMESAFR v1.2 was released to the public with bug fixes, additional updates from SAFER v3.1, and other enhancement features. This version allowed the importing of User-Defined Explosive Articles (UDEAs) and allowed pressure-reduction credit for an exposed site (ES) due to the presence of barricades, under certain conditions (Ref. 4).

IMESAFR v2.0 was released to the public in January 2013. This version included major updates to the interface, including an interface based on a Geographical Information System (GIS) (i.e., a map-based GUI). Users now had the ability to place structures and roads on a map, visualize risk, and generate other informative details, such as debris contours.

In April 2018, IMESAFR v2.1 was released to the public. This version included a full development platform update, algorithm updates, and additional new features. These features included updates to barricades, user-friendly keyboard shortcuts, parametric studies, and user-defined risk color-coding.

IMESAFR was updated to v2.2, in October 2022, and released to the public with algorithm updates and additional new features. These features included the ability to toggle structures on/off, generate a risk contour of the entire site, and add/remove barricades to all ESs. This version also implemented a revised probability of event approach, which is based on hazard

division rather than compatibility group. This change was spurred by a similar development planned for inclusion in TP-14 Revision 5 (Ref. 5).

In September 2025, IMESAFR v2.3 was publicly released. This version included bug fixes, algorithm updates, and additional new features. These features include the implementation of a NATO-Based QD system, the inclusion of hazard division (HD) 1.2 items, barricade improvements, and ease-of-use features. More information on features IMESAFR v2.3 is provided in Section 3.1.

2.2.2.2 Ammonium Nitrate (AN) Module

APT was contracted by IME to work with an IME AN Working Group to develop the AN Module for IMESAFR v2.0. Research used for the development of the module includes data provided by IME members which ensured a thorough understanding of the blast wave characteristics of AN explosions and the effect AN explosions have on donor structures. Where adequate experimental and test data were not available, the model is "physics-based" (and also uses numerical modeling to provide "synthetic empirical data" to supplement the available data). The AN Module also included two additional PES models associated with the storage of AN: overhead silos and railcars (Ref. 6).

This AN Module was originally developed as a separate tool (IMESAFR v2.0N) but was eventually incorporated into future versions of IMESAFR when IME decided that releasing the tool outside of their member companies would be acceptable. As of IMESAFR 2.1, this AN module is included in the publicly available software, but an additional training certification is required to access it.

2.3 TESTING

As stated in Section 2.2.1, collaboration between members of industry, regulators, and QRA subject matter experts has played a major role in the development of IMESAFR. This collaboration extends past the software itself and includes several testing programs as well. In 2011, APT worked with members of industry, regulators, and QRA subject matter experts to develop a "maturity matrix" for IMESAFR, which was intended to identify areas within the model that are in the most need of additional empirical data anchor points. Three key areas were identified: elevated ammonium nitrate/ammonium nitrate emulsions (AN/ANE) storage bins, jet perforating guns (used in oil and gas operations), and relatively low quantities in smaller commercial storage magazines.

At this point in time numerous tests have been performed, with their results analyzed and implemented into IMESAFR. In addition to Explosives Safety Knowledge Improvement Operation (ESKIMORE) testing (Ref. 7), tests conducted so far include two large debris recovery efforts that were supported by IME and ATF to supply anchor data to IMESAFR models: National Ground Intelligence Center (NGIC) Iron Warrior 4 (IV4) (conducted by U.S.

Army Engineer Research and Development Center (ERDC) at Dugway Proving Ground (DPG)) (Ref. 8), and Combating Terrorism Technical Support Office's (CTTSO) Minimum Booster Test (MBT) series (conducted by Sandia at DPG) (Ref. 9). Additionally, the first jet perforating gun test series was completed in July-August 2024. This test series provided empirical data that will be used to improve the perforating gun model in IMESAFR and is described in detail in the *2024 ATF Perforating Gun Test Series to Support QRA* (Ref. 10).

3.0 Current Status

The following subsections will provide an update on the status of the IMESAFR software, regulatory acceptance of QRA using IMESAFR, training, and the IMESAFR user base as of January 2026.

3.1 SOFTWARE

As stated in Section 2.2.2.1, IMESAFR v2.3 was released to the public in September of 2025. With the release of v2.3, the decision was made to begin sunsetting older versions of IMESAFR. At this point in time, only v2.3 is available for purchase, however v2.2 is still used by a large number of users across the world. IMESAFR v2.1 is still in use as well, although primarily only in Australia.

In IMESAFR v2.3, several new features have been implemented, based on user and sponsor feedback. These features can be broken down into two major groups: updates to the interface and updates to the algorithms. The interface updates include features such as the new Risk Results Panel, undo and redo buttons, and NATO-Based QD rulesets. The algorithm revisions include features such as updated mass distributions and debris logic parameters for some PES models, an updated P_e matrix, and improvements to the pressure and impulse calculations when the blast wave reaches the ES. Table 1 provides a full list of all the new features and a brief description of each feature. Information on the planned additions for future versions of IMESAFR is described in Section 4.3.

Table 1: IMESAFR v2.3 New Features

	Feature	Description
Interface Updates	Risk Results Panel	A new side panel that summarizes the individual and group risk results and compares them to definable criteria.
	Undo and Redo Buttons	New buttons have been added to allow users to undo and/or redo certain actions
	Side-Impact % Blocked Report	A new report that users can choose to generate, which will provide an estimation for the percentage of side-impact debris that is blocked by a barricade.
	Barricade Structure	Users can now draw barricades directly onto the map-based portion of the GUI.
	NATO-Based QD	NATO-Based QD logic derived from AASTP-1 Edition C has been implemented into the tool and can be used when running scenarios in SI units.
Algorithm Updates	Debris Logic Parameter Updates	Updated the parameters used by one of the probability density functions in IMESAFR.
	Mass Bin Distribution Updates	Updated the mass distribution for the Standard Concrete and ISO models.
	Building Updates	Added a new Small Concrete Building type, the old Concrete Building types were all increased by one size (e.g. small to medium).
	P_e Matrix Updates	Updated the probability of event for Storage activities based on a recent IME study and added in values for HD 1.2.
	HD 1.2	HD 1.2 is now an option to be modeled in IMESAFR.
	Pressure and Impulse Calculation Updates	Updated the methodology used for calculating the pressure and impulse at the ES after finding inconsistences in the TP-14 Rev 5 methodology.

3.2 REGULATORY

As stated in Section 2.2.1, IMESAFR was developed with input from regulators from the beginning of the project. As this software tool has matured, and acceptance of QRA-based methods has expanded, regulatory usage has increased. This increase achieves the project goal of

making explosives safety software models available to regulators that provide a much better picture of risk, and therefore safety, than previously available. Moving forward, regulations need to be evaluated and, in some cases, modernized.

3.2.1 United States

3.2.1.1 ATF

In the U.S. storage of commercial explosives is regulated by ATF. As participants in the development of IMESAFR, ATF has been heavily involved with determining how the existing standards can be modified, or how exceptions can be made, based on QRA. ATF grants "variances" from traditional QD siting requirements, similar to waivers in DoD vernacular. However, unlike waivers in the DoD, the industry cannot choose to have a variance – they must be granted one by ATF.

The initial approach used by ATF for granting risk-based variances was the "Risk Bank" method. Rather than comparing the numerical risk values from IMESAFR against numerical criteria, the industry applicant would demonstrate that the risks associated with their desired scenario were no greater than the risks associated with the "equivalent" QD-compliant scenario (i.e., the scenario with either the quantity lowered or the distance increased to meet the American Table of Distances (ATD)). However, there was no guarantee that the risk from a Risk Bank-approved scenario was tolerably low when judged numerically.

On August 26, 2013, ATF hosted an explosives QRA workshop sponsored by IME. This workshop covered the advantages and disadvantages of using QRA, the methodology behind establishing a QRA program, and introduced IMESAFR to members of the explosives industry, foreign representatives from NATO countries, and several Federal agencies (Ref. 11).

In 2014, ATF announced that they would accept risk-based variances based on IMESAFR. Then in 2015, ATF accepted the first IMESAFR variance submitted. The approval of this variance was based on the Risk Bank method. This milestone approval was especially noteworthy in that all parties involved – including ATF – thought the solution was an improvement in safety compared to alternative solutions that met ATD requirements.

In 2022, ATF accepted and published the numerical criteria they use to evaluate risk-based variances. Individual Annual Public Risk is evaluated against a criterion of 1E-06, and Group Annual Public Risk is evaluated against a criterion of 1E-05. With the publication of these criteria, ATF officially ended the use of the Risk Bank approach.

In 2025, ATF announced that it would begin accepting variances based upon IMESAFR without the requirement to try to meet ATD first. This is an important step in ATF's efforts to modernize their approaches and standards.

3.2.1.2 USCG

In order to load/unload explosive material at a port in the U.S., a permit is required from the U.S. Coast Guard (USCG). Traditionally, this permit is granted based on passing QD rules for operations at a port. However, USCG Captains of the Ports (COTPs) have policy and precedence available to approve/disapprove requested quantities of explosives that do not meet QD requirements. To obtain approval from a COTP, IMESAFR can be used to submit a waiver request. Part of this process is to inform affected parties of the risks involved and obtain buy-in from them. USCG Headquarters also encourages USCG COTPs to use IMESAFR when incoming shipments do not meet QD.

Additionally, given that the largest percentage of U.S. manufacturing states do not have ports, safe entry of explosives at any given port likely has a nationwide economic impact, which is a cost-benefit factor directed to be considered by USCG policy (Ref. 12).

IMESAFR-based QRA solutions have been implemented at specific ports by individual COTPs (Ref. 13), and USCG Headquarters encourages the use of QRA, but they have stated that they look to ATF to establish policies related to commercial explosives.

3.2.2 Canada

NRCan-ERD was the first commercial explosives regulator to grant a QD derogation (the equivalent to an ATF variance) based on an IMESAFR-supported QRA. ERD had been granting derogations based on QRAs since the 1990s, but the advent of IMESAFR made the generation of such QRAs easier for the explosives companies, as well as much more rigorous, consistent, and easy to review from the regulatory perspective.

Canadian regulators quickly recognized the value/potential for a commercial explosives equivalent to SAFER and had people on the IMESAFR Development Team from early in the process. ERD and CERL (as well as ATF) have provided great assistance in the development of IMESAFR and have all been strong proponents of removing over-conservatism from the model.

ERD has referenced IMESAFR in both regulations and guidelines for many years and requires IMESAFR, or equivalent, analyses to support QRAs for QD derogations[1]. ERD recognizes that there is no equivalent to IMESAFR available but for obvious reasons cannot mandate the use of a single program or product for any purpose.

The newest of these requirements is for QRAs for ports and wharves using new guidelines written by ERD. G09-*02 Guidelines for quantified risk assessments at Ports and Wharves* (Ref. 14) references IMESAFR as an acceptable tool and requires the use of a tool such as IMESAFR to quantify the risk. These guidelines also refer to the IME Safety Library Publication (SLP) 24 (Ref. 15) and detail the specific considerations required for conducting a risk assessment using

[1] A derogation is now known as an “equivalent level of safety” in Canadian regulations.

the IMESAFR software. But most importantly, the guidelines provide numerical targets for both individual and group risk. These are the "standard," so far as that exists: 1E-06 for Public Individual Risk and 1E-05 for Public Group Risk. These are the same values used by the ATF, as described in Section 3.2.1.1. ERD will also consider other preventative or mitigative factors (e.g., the presence of a well-defined and established Emergency Response Action Plan) included in a QRA. It is expected that these numerical risk criteria for ports and wharves will become the de facto risk targets for all applications; ERD had traditionally (but unofficially) used the 1.0E-06 value for individual risk, however they had not (even unofficially) provided a group risk criterion. These criteria will also become a useful tool in discussions with other regulators in potentially setting numerical risk targets in other jurisdictions.

3.2.3 Other

3.2.3.1 Australia

Australian commercial explosives regulations are largely handled at the state level, and use of QRA currently varies across the different states. Regulators from Queensland have been active participants in the development of IMESAFR and the ISP. Australian industry is actively using IMESAFR when risk assessments are required by state regulators, but there currently is no regulatory equivalent to the risk-based variances now used by ATF. There are also numerous Australian users in the defense sector, including government representatives (e.g., the Directorate Ordnance Safety, Explosive Ordnance Branch).

3.2.3.2 Europe

Europe is an obvious candidate for the adoption of IMESAFR. The continent is densely populated, making QD a potential issue. Many of the regulatory agencies are technically sophisticated and most of the countries use risk tools for the management of other hazardous goods. IMESAFR has been used to demonstrate compliance with Seveso III Directive requirements when transporting explosives from one European Union country to another, and Belgian regulators have adopted IMESAFR for use in some domestic scenarios. Numerous other European counties have trained regulators using IMESAFR, but an official process (akin to the ATF variance) is still evolving.

3.3 TRAINING

The IMESAFR training class is held several times a year at the APT Safety Engineering and Analysis Center (SEAC) headquarters in Huntsville, AL. APT also offers at least one class per year in Canada, Australia, and Europe. Additional training options are available as demand warrants. If a new version of the program is released and a user is trained on the most recent version of IMESAFR then they are not required to attend another full training class. Instead, APT offers users the option to attend an online virtual upgrade training to gain their certification for the newest version. More information on IMESAFR training classes is available on APT's website.

3.4 USER BASE

IMESAFR has a large user base made up of members of industry and governmental regulators, both foreign and domestic. Between December 2022 and December 2025, a total of 262 users were trained on IMESAFR v2.2 and v2.3, not including APT personnel that also use the program. Figure 3 shows how many users have been trained on v2.2 versus v2.3, with the v2.3 training starting in August 2025 for the ISP and September 2025 for everyone else.

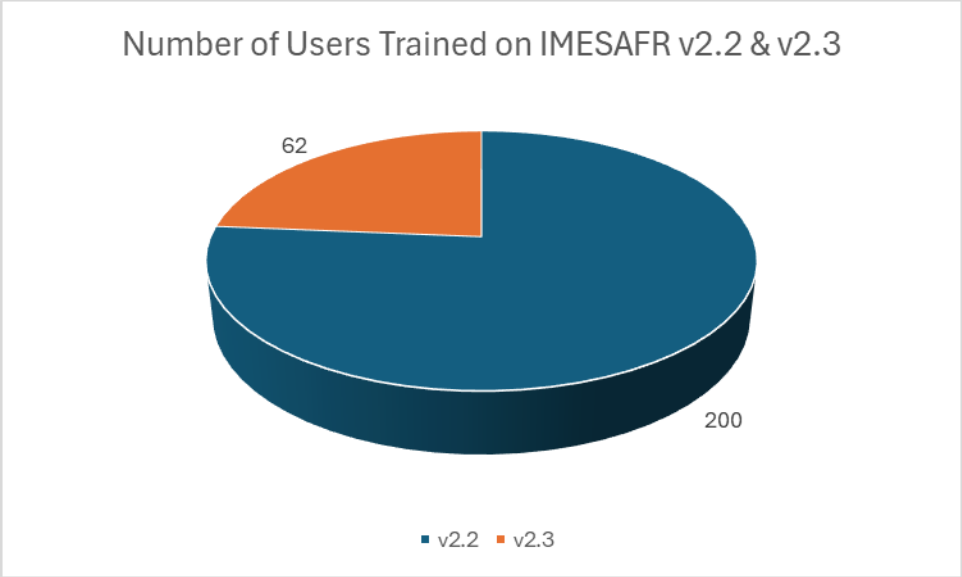

Figure 3: Number of Users Trained on IMESAFR v2.2 & v2.3

As shown in Figure 4, of the 200 people that have been trained on IMESAFR v2.2, 63% of them were from countries other than the U.S., such as Canada, Australia, Belgium, and Latvia.

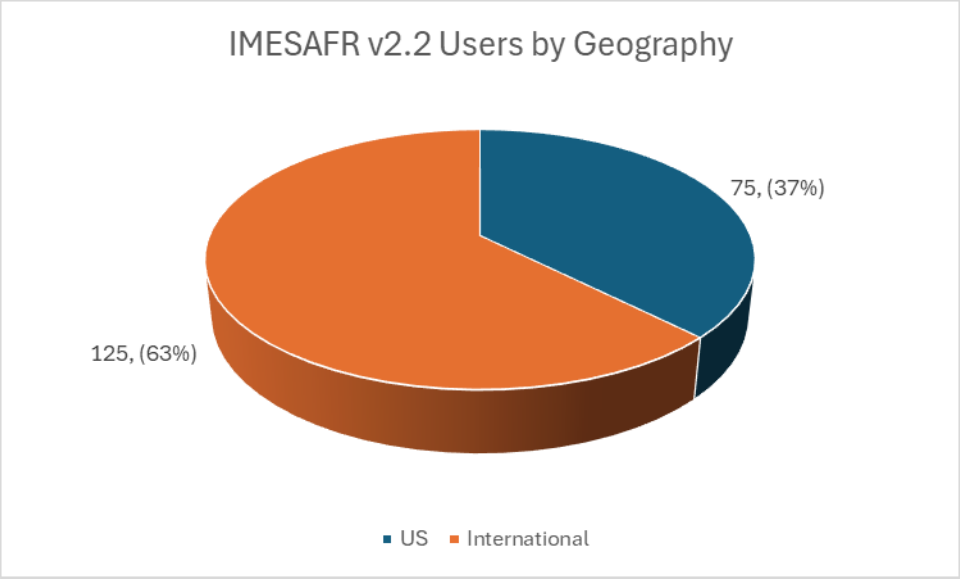

Figure 4: IMESAFR v2.2 Users by Geography

Notably, for IMESAFR v2.2, 54% of the people trained were commercial explosives regulators, and another 12% were people in the defense sector, as shown in Figure 5.

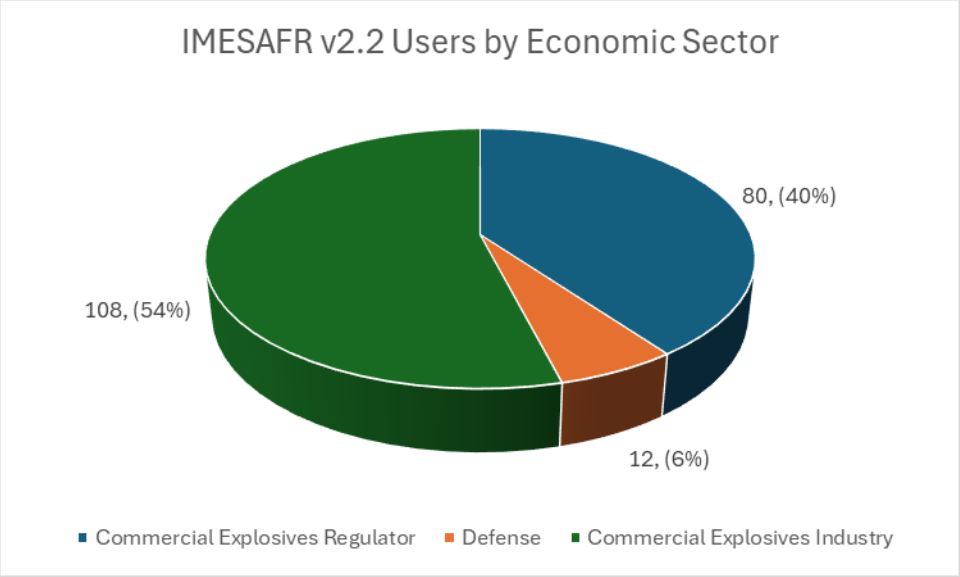

Figure 5: IMESAFR v2.2 Users by Economic Sector

Since its public release in September 2025, 62 people have been trained on IMESAFR v2.3, most of which have been foreign individuals, as shown in Figure 6.

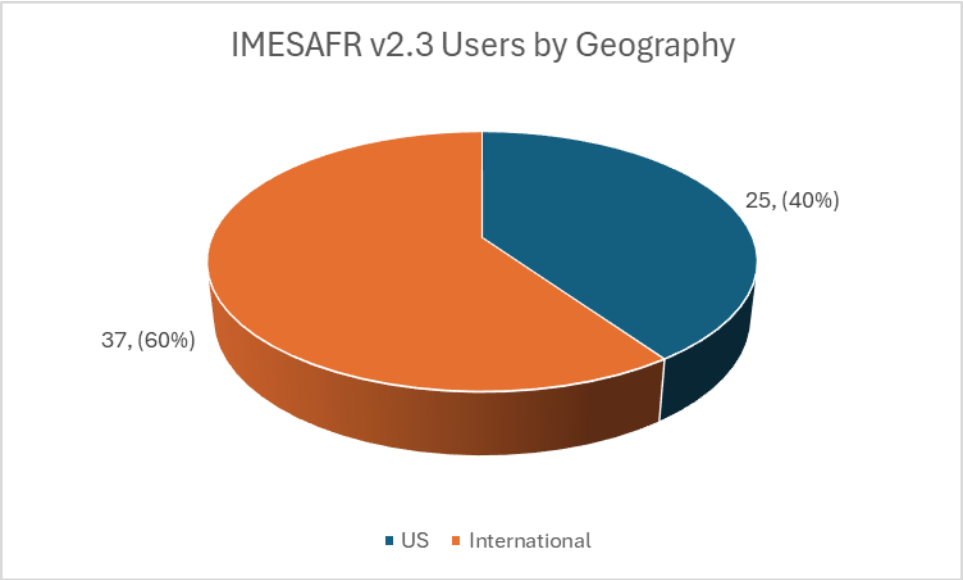

Figure 6: IMESAFR v2.3 Users by Geography

At this point in time, most of the people trained on IMESAFR v2.3 were from the commercial explosives industry, with 23% of trained people being commercial explosives regulators and 6% from the defense sector, as shown in Figure 7.

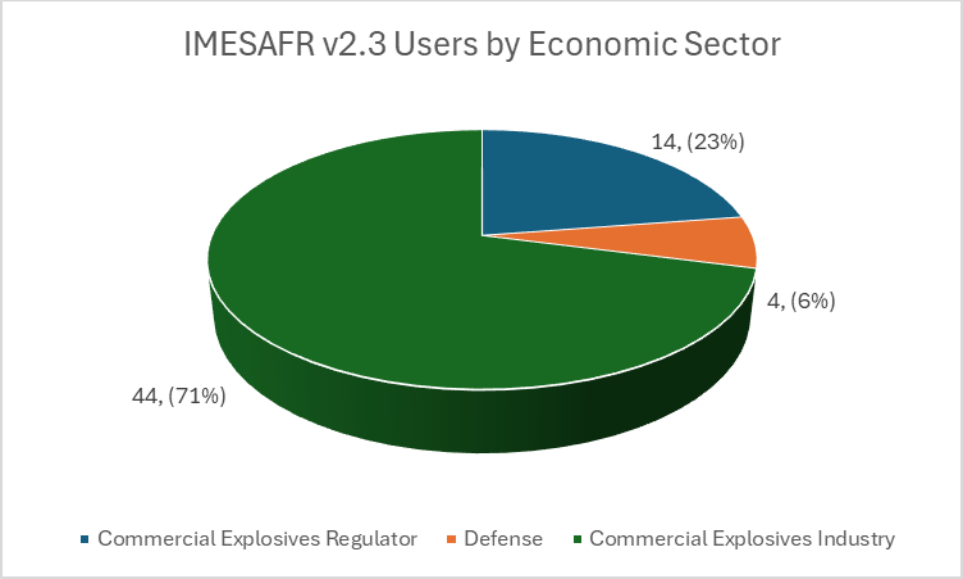

Figure 7: IMESAFR v2.3 Users by Economic Sector

4.0 Future Plans

As shown in Section 3.4, the use of QRA (specifically via IMESAFR) is on both sides of the approval process: regulators and industry. This increased acceptance of QRA is not just limited to the commercial explosives industry but has also been seen in the defense sector. Going forward, the goal of improving the modeling capabilities of IMESAFR is to increase the acceptance of QRA from regulators, which in turn will lead to more members of the commercial explosives industry and defense sector using QRA. Ideally, this increased use of QRA will be not only for approval scenarios, but also in general to manage risk.

4.1 TESTING

As described in Section 2.3, numerous tests have been completed in order to generate the empirical data needed to support IMESAFR's current capabilities. However, in order to implement the new models/capabilities that are desired for IMESAFR, more test data will be required to anchor the science behind these features. To support this acquisition of further test data, APT, IME, and ATF hope to jointly conduct tests on AN in overhead bins and small quantities in small ATF magazines. Furthermore, there will likely be additional jet perforating gun testing performed in the future pending further discussion and analysis of the results from the first perforating gun test series. ATF has also recently expressed a desire to perform testing on pyrotechnics in the future.

4.2 RESEARCH

A number of the features and capabilities that are desired for future versions of IMESAFR require further research before they can be implemented into the program. Examples of such features include the unique models/engines for pyrotechnics and underground storage of explosives. Some features, such as the implementation of prompt propagation logic, have already been researched and are ready for implementation in a future version of IMESAFR. More details on the research that was done for prompt propagation can be found in *Implementation of Prompt Propagation Logic in a QRA Tool* (Ref. 16).

4.3 SOFTWARE

There are numerous features and capabilities that are planned for IMESAFR in the future. In addition to the prompt propagation model, other features that are planned for future versions of IMESAFR include updating the jet perforating gun model, adding in a live, cloud-based GIS interface, a 3D user interface, and further optimizing the software to reduce run times.

5.0 Summary

QRA has become an increasingly accepted framework for explosives safety regulation over the past few decades, providing a more comprehensive evaluation of risk than traditional QD criteria alone. IMESAFR is a QRA tool developed and owned by APT for the commercial explosives community, and uses methodologies derived from DDESB TP-14 to quantify the risk to both

individual persons and groups of people, considering factors such as facility construction, operational activities, personnel exposure, explosives type, and site layout.

Since the initial release of IMESAFR in 2007, the program has undergone numerous updates informed by empirical test results, regulator engagement, and scientific review. The most recent version of the program to be released was IMESAFR v2.3, which introduced several new features and updates. The new features and updates include but are not limited to: NATO-based QD logic, updated debris logic, the addition of HD 1.2, and updated pressure and impulse calculations. Furthermore, IMESAFR is used internationally by both regulators and members of the commercial explosives community to support risk-based approaches to site planning and better understand the risk associated with their operations; use by the international defense sector is also growing Ongoing development efforts are focused on improving the models in IMESAFR or through further testing and research, implementing new capabilities such as prompt propagation, and improved computational efficiency, all with the goal of further advancing the acceptance and use of QRA in explosives safety regulation.

6.0 References

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16. Tatom, J., Murray, L. “Implementation of Prompt Propagation Logic in a QRA Tool,” 2025 Internation Explosives Safety Summit and Exposition, Phoenix, AZ, January 2026.

Appendix A: Previously Presented Papers

Numerous IMESAFR papers have been previously presented, including the following:

- "IMESAFR Overview" National Defense Industrial Association (NDIA), International Explosives Safety Symposium & Exposition, San Diego, CA, August 2018; J. Tatom, B. Evans, J. Hoffman, C. Fritz, M. Duncan, M. Robinson.
- "Development and Application of Quantitative Risk Assessment Methodology," SAFEX Topical Papers Series, Paper No. 09/15, L. Santis, M. Swisdak, J. Tatom.
- "IMESAFR Version 2.0: A Next Generation Tool for Managing Risk Associated with Commercial Explosives Operations – 2014 Update," Visfotak Explosives Safety & Technology Society Journal, Volume 9, 2015; J. Tatom, M. Swisdak, L. Santis, T. Ross.
- "IMESAFR Sensitivity Studies," Proceedings of the 40th Annual Conference on Explosives and Blasting Technique (ISEE), Denver, CO, February 2014, T-14-00400; T. Ross, J. Tatom, L. Santis.
- "A New Way of Looking at Risk and QD Compliance," Proceedings of the 38th Annual Conference on Explosives and Blasting Technique (ISEE), Nashville, TN, February 2013; L. Santis, J. Tatom, M. Swisdak.
- "Features of IMESAFR V2.0," Chief Inspectors of Explosives (CIE) Conference 2013; J. Tatom.
- "A Proposed Test Program to Improve Explosive Risk Management," Proceedings of the 38th Annual Conference on Explosives and Blasting Technique (ISEE), Nashville, TN, February 2013; M. Swisdak, J. Tatom, L. Santis, D. Leidel.
- "IMESAFR Version 2.0: A Next Generation Tool for Managing Risk Associated with Commercial Explosives Operations," Parari 2011; J. Tatom, M. Swisdak, L. Santis.
- "An Updated Comparison of the Quin Site Explosive Event Results to IMESAFR Consequence Predictions," Parari 2011; J. Tatom, M. Swisdak, L. Santis.
- "A Comparison of the Quin Site Explosive Event Results to IMESAFR Consequence Predictions," SAFEX 2011; Proceedings from the 33rd DDESB Explosives Safety Seminar, Palm Springs, CA, August 2008; J. Tatom, M. Swisdak, L. Santis.
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- "A New Tool for Managing Risk with Commercial Explosive Operations," Proceedings of the 33rd Annual Conference on Explosives and Blasting Technique (ISEE), Nashville, TN, January 2007; L. Santis, M. Hardwick, D. Leidel, J. Tatom.

- "The Science and Testing Behind Quantitative Risk Assessment Models," Proceedings of the 33rd Annual Conference on Explosives and Blasting Technique (ISEE), Nashville, TN, January 2007; J. Tatom, M. Swisdak.

- "IMESAFR – A Tool for Managing Risk from Commercial Explosives Operations," Proceedings from the 32nd DDESB Explosives Safety Seminar, Philadelphia, PA, August 2006; L. Santis, M. Hardwick, D. Leidel, J. Tatom.

- "A Comparison of SAFER and IMESAFR Methods, Features, and Models," Proceedings from the 32nd DDESB Explosives Safety Seminar, Philadelphia, PA, August 2006; J. Tatom, M. Hardwick, L. Santis.