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Finding a safe place when **airborne weapons head down**

Anyone positioned in close proximity to live firings of missiles and bomb drops is faced by the concern that the point of impact is always somewhat uncertain due to factors such as possible technical malfunction. DSTO is developing a tool called the Range Safety Template Toolkit (RSTT) that quantifies and displays the levels of risk across an area when these kinds of weapons are launched.

Various organisations within the Australian Defence Force (ADF) have produced and used what are called Weapon Danger Areas (WDA) over many years.

WDAs represent the levels of risk to infrastructure and personnel during weapon trials. These are also known as 'templates', 'safety traces' or 'footprints', though WDA is now the internationally recognised term.

The first step in addressing a risk is to quantify it, and a WDA quantifies the stray round impact risk at various locations on the ground. It is accepted that it is impossible to eliminate risk entirely, and so, a risk threshold at some level – for example, 'one in a million' – may be deemed acceptable for members of the general public in the vicinity of a training range.

A problem with the use of WDAs, as DSTO researcher Duncan Fletcher explains, is that "there is no broadly accepted methodology for generating them. Each weapon has been dealt with on an *ad hoc* basis by the organisation responsible for developing and or authorising WDAs for use."

"Furthermore, modern strike weapons fly a long way. When a WDA is produced for these weapons using the older maximum-range-boundary techniques, the area arrived at can be impractically large.

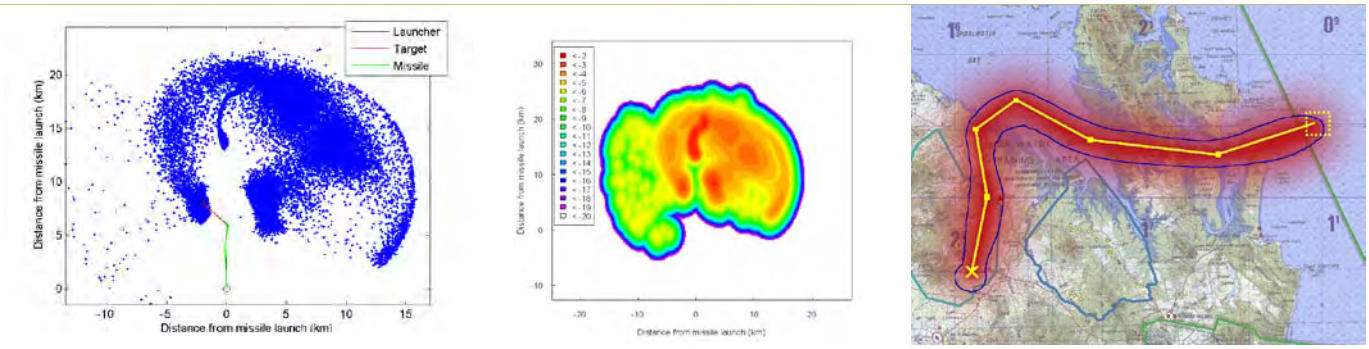
F/A-18 Hornet firing Aim 7 missile.

"We are currently building a simulation-intensive software system that will provide a standardised WDA generation capability, delivering more precise safety threshold boundaries to assist with the ADF's guided air weapon test and evaluation exercises.

"We intend that the system be accepted for general use by the Department of Defence; hence, we are building it in accordance with departmental quality assurance requirements for complex aerospace systems."

The system is being developed by DSTO with the support of RAAF Air Operations Support Group, Australian industry and universities, including Aerospace Concepts Pty Ltd, TRC Mathematical Modelling, the KAZ group, and the University of Adelaide.

Australian army cavalry scouts fire a Javelin anti-armour missile.



Weapon Danger Area plots with ground impact probability shown in different ways.

Devising a WDA or template

The first part of the process, undertaken by weapons experts, involves preparing weapon-specific databases of simulated ground impacts.

This activity includes inputting data provided by the manufacturer about the weapon's performance as well as potential malfunctions; these latter events are given probability weightings of occurrence. Other relevant data added into contention includes historical meteorological data and missile operational envelopes.

Fletcher explains, "The data preparation system uses a medium fidelity Six-Degree-of-Freedom (6DOF) model of the weapon system, which includes models of Failure Response Modes (FRMs), to generate ground impact distributions. Developing this part of the system to support new weapons can take anywhere from three to twelve months.

"Once the model is built, we start the simulations. For specified launch or release conditions and particular target profiles, we do what are called Monte Carlo simulations using the model and other computer software to determine where the weapon might land for each potential FRM occurring at a random time of flight.

"These simulations are run several million times to get a distribution of ground impacts over a large sample of trials, producing a database of ground impacts that can be used to generate WDAs that are valid for a launch event undertaken anywhere in a user-specified envelope."

The second part of the process is undertaken by operations and range managers with a user-friendly software tool. This tool draws on the weapon ground impact database to develop a WDA for a particular set of launch conditions. Additional information taken on board during the process includes on-the-day wind limits, trial scenario data and geospatial (land survey map) data.

The manner of displaying the WDA data can take different forms.

One mode of depiction is as a contour plot, representing different levels of ground impact probability or risk with different colours. Another requires selecting an acceptable-risk threshold to define the boundary between safe-enough and too-dangerous, depicted as an irregularly shaped outline.

These plots can be overlaid on maps of the intended launch area featuring population demographics and high value assets, which are then used to assess the degree of risk the launch poses to people and equipment. This essentially constitutes a risk map for the trial.

Safety conditions for a launch might be selected to limit the risk of debris impacting within 500 metres of any infrastructure, plus limit the individual risk to any personnel and members of the general public to regulated levels.

If it should happen that the risk of debris impacting outside the firing range boundary is unacceptably high, the launch could be re-planned to take place at a lower altitude or at a different location to avert this predicted hazard.

Easy to use with many applications

The hardware used to run the Monte Carlo simulations and generate the WDAs is standard commercial off-the-shelf computing equipment. The high-fidelity simulations that populate the ground impact database run on a 'farm' of more than a hundred rack-mounted servers. Generating WDAs from the database requires only a simple laptop or desktop PC.

The front-end part of the system has been designed to be readily usable by range and operational personnel, and to provide information that is easily understandable by them as well as relevant outside parties, such as legal advisors and public officials.

By presenting 'quick look' results, it enables rapid assessment of options for operational planning, while also delivering more detailed results in other ways that can be used to support technical assessments. The information it provides has a degree of quality assurance such that it can be used with confidence to support safety-of-life decisions that are legally defensible.

Even in the absence of full weapon technical information, the system is able to calculate WDAs, albeit much larger to compensate for the greater degree of uncertainty in the simulations.

One of the first uses for this tool has been to assist with trials for the ASRAAM air-to-air missile. RSTT is currently scoped to include support for longer range weapons such as the Joint Air to Surface Standoff Missile (JASSM), and sounding rocket launches planned for DSTO's hypersonic research program, HIFiRE. With appropriate enhancements made to the 6DOF model, the tool can be applied to in-service weapons, current procurements and those yet to be developed.

RSTT has uses not only for developmental trials and operational training involving guided air weapons, but also the capability development phase of weapons procurement. This could arise when considering whether a weapon needs a flight termination system, and for operational planning, on how a weapon's collateral risks may impact other aspects of an operation.

RSTT has come to be seen by members of the Defence community within Australia and overseas as an invaluable aid for assessment and safe testing of guided air weapon systems.