Evaluation of Munitions Sensitivity to Guarantee the Survivability of Nuclear Aircraft Carrier Charles de Gaulle

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1.0 INTRODUCTION

Systems such as nuclear stoke or nuclear warheads, on board of the Charles de Gaulle aircraft carrier must not suffer from immediate vicinity, which implies stringent safety requirements for all pyrotechnic devices shipped on the platform.

C.E.A. (French Atomic Energy Commission) and SNPE Group, have been asked by the French Ministry of Defence (DGA) to develop a methodology to assess the sensitivity of conventional airborne munitions shipped on the aircraft carrier (missiles, bombs,…).

The aim of this paper is to present the methodology which has been developed to demonstrate the ability of the munitions to fulfil the safety requirements.

2.0 SAFETY REQUIREMENTS ASSIGNED TO MUNITIONS

When on board of the aircraft carrier, munitions have a life profile starting from their shipment up to their set-up on aircraft, with intermediate phases of storage or even of preparation before being set-up on aircraft.

During these phases, they can possibly suffer from accidental aggressions of various nature such as:

- thermal aggressions (fast cook off, slow cook off, …),
- mechanical aggressions (shocks, drops, …),
- electrical or electromagnetic aggressions (electrostatic discharges, lightning, …),
- chemical aggressions (salted water, corrosive products, …).

In addition to these accidental threats, some hostile aggressions like fragments or bullet impact can also occur.

If the ammunition reacts when submitted to one of these stimuli, the response belongs to one of the three following classes of reaction, depending on the violence of the reaction effects:

- combustion (NATO type V),
- explosion (NATO type III, IV and propulsion),
- detonation (NATO type I and II).

Paper presented at the RTO AVT Symposium AVT-087/RSY-012 on "Combat Survivability of Air, Sea and Land Vehicles", held in Aalborg, Denmark, 23-26 September 2002, and published in RTO-MP-090.

Finally, the specifications which the munitions have to comply with, are expressed by a maximum level of "occurrence probability", for each of the three classes of reaction, when the ammunition is submitted to an aggression. The following example illustrates these specifications.

In the case of a drop of the ammunition without container from 12 m high on a flat ground, it must not react with an occurrence probability higher than:

- 10^{-n} if combustion,
- 10^{-p} if explosion,
- 10^{-q} if detonation.

3.0 METHODOLOGY FOR MUNITIONS SENSITIVITY DEMONSTRATION

The demonstration methodology which has been proposed is divided in three separate steps:

- Step 1: identify the scenarios leading to each class of reaction of the ammunition,
- Step 2: characterise the physical mechanisms of the ammunition components which generate these scenarios,
- Step 3: determine the occurrence probability of these mechanisms.

3.1 Scenarios Identification

The purpose is to identify all the combinations of events which lead to the three classes of reactions (combustion, explosion and detonation), also called « feared events ». To do this, the method which is used is the "**Fault Tree Analysis**".

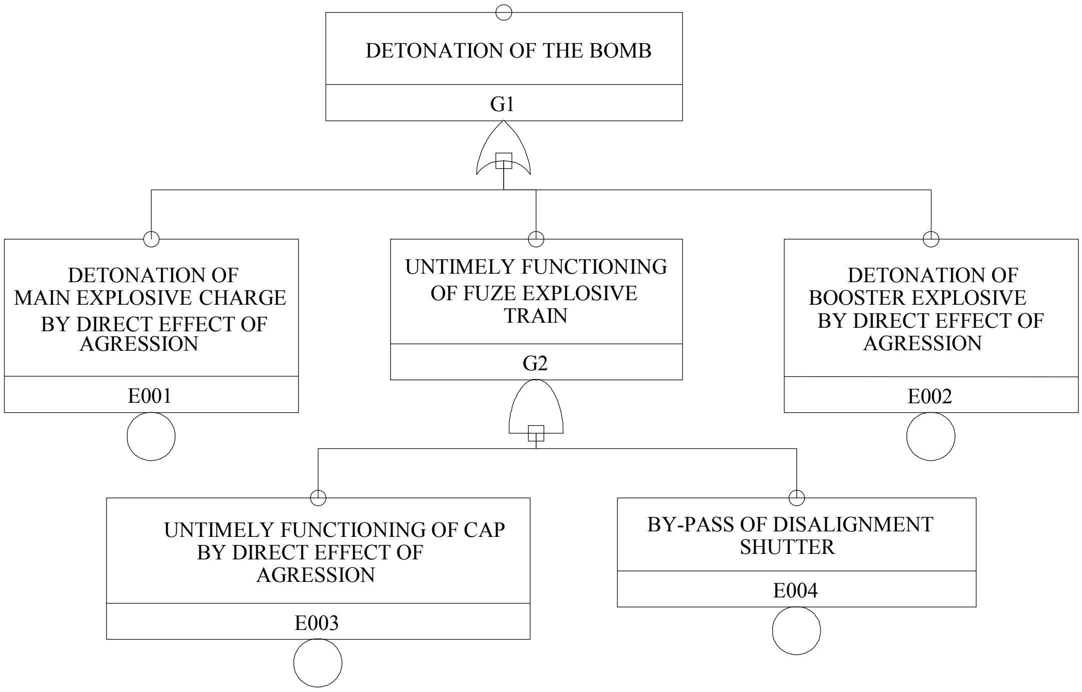
It allows to identify all the ammunition components involved in inducing the feared event. So, using this method, will appear all the sensitive elements of the ammunition, that is to say:

- those which generate the energy: igniter, cap, batteries, propellant and explosive charges,…
- those which constitute safety barriers: disalignment shutter, safety pin, electric shunt, etc…

Thus, in order that the feared events may occur, it is necessary that:

- the first (energy generators) react untimely,
- the second (safety barriers) fail, and do not stop the energy released by the first.

The simplified fault tree hereafter presents the different scenarios which may lead to the detonation of a bomb made of a main explosive charge, a booster and a fuze explosive train including a cap and a disalignment shutter.



It appears that the three scenarios can lead to the detonation of the bomb, the two first by direct action of the aggression on the main explosive charge or on the booster, and the third by untimely functioning of the fuze explosive train.

In this case, the sensitive elements are the main explosive charge, the booster and the cap which generate energy and the disalignment shutter which is a safety barrier.

Moreover, the identification of the scenarios allows to allocate safety objectives to each of them, in order to make easier the demonstration of meeting the requirements.

3.2 Characterisation of Physical Mechanisms of Components

For each event identified in the Fault Tree Analysis, the purpose is to define the physical phenomena which take place when the component, associated to this event, is submitted to the aggressions previously defined. To do so, the method which is used is inspired from the "**Failure Mode and Effects Analysis**".

It allows to list the assessment parameters which are representative of the mechanism involved.

These physical parameters, which are two of them, correspond for the first to the nature of the constraint applied due to the aggression, the second is the resistance of the component submitted to this aggression.

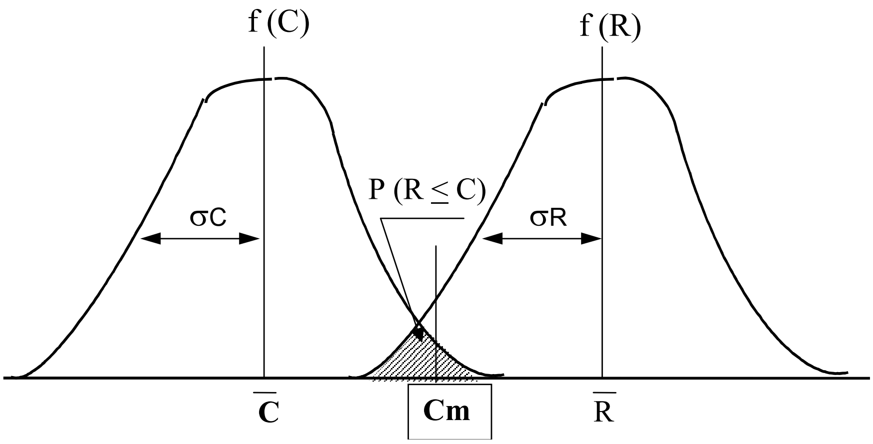
Coming back to the previous example, and in the case of mechanical aggressions, the following table shows the way used to make this analysis.

Event	Mechanism of event appearance	Origin of event	Assessment parameters	
			Constraint	Resistance
Detonation of main explosive charge by direct effect	Shock Detonation Transition (SDT)	Violent shock on main explosive charge	Shock pressure generated on explosive	Detonation pressure of explosive (French Gap test)
	Deflagration to Detonation Transition (DDT)	Combustion of explosive damaged by shock	Energy due to the combustion of the main explosive charge	Friability of the explosive
By-pass of disalignment shutter	Mechanical rupture of shutter	Shock on shutter	Mechanical stress	Failure stress

3.3 Assessment of the Occurrence Probability of Scenarios

The purpose is to estimate the occurrence probability of each event which has been identified in the Fault Tree and then, to infer the probability of the feared event. The computation is made using the "Resistance - constraint" probabilist method.

This method enables to compare the assessment parameters (Constraint and Resistance) supposed to be random variables following a "normal law" (Gauss distribution), and thus defined by a mean and a standard deviation as shown on the diagram hereafter.



The occurrence probability is given by : $P = \text{Prob}\left(U \leq \dfrac{\overline{R} - \overline{C}}{\sqrt{\sigma R^2 + \sigma C^2}} \right)$

where U is the reduced centred normal variable (mean = 0 and $\sigma = 1$).

Generally, the resistance parameter is determined experimentally by a series of tests, which gives all the data of the normal law. For the constraint, resulting from a single numerical computation, the normal use is to make an over-evaluation and determine the maximum constraint (Cm) applied to the component.

Finally, the probability is expressed by: $P = \text{Prob}\left(U \leq \frac{\overline{R} - Cm}{\sigma R} \right)$.

Coming back to the example of the bomb detonation after a violent shock like an impact of a several hundreds grams fragment at a very high velocity:

- the maximum shock pressure in every point of the ammunition has been computerised using DYNA code,
- the shock wave sensitivity of explosive (main charge and booster) has been measured experimentally using the French Card Gap Test (STANAG 4488).

This test has been performed many times in order to obtain the statistic distribution of the sensitivity level of pyrotechnic materials.

Using the probabilist “Constraint - Resistance” method gives the occurrence probability of each event of the Fault Tree. The treatment of the minimum scenarios of the Fault Tree enables then to calculate the probability of the feared event and to verify that the ammunition complies with the specified requirement.

4.0 CONCLUSIONS

This methodology, coming from dependability analysis methods, allows to assess the hazards of pyrotechnic reaction of the munitions shipped on board of the aircraft carrier Charles de Gaulle. Within the framework of a system consideration, this method is using both the knowledge of the physical mechanisms which induce the response of materials and especially energetic materials, submitted to a given stress and numerical and experimental means of assessment.

SYMPOSIA DISCUSSION – PAPER NO: 14E

Discusser's Name: Less

Question:
Please explain the "French Gap Test".

Author's Name: Gaudin

Author's Response:
The French Gap Test is used to determine the sensitivity of energetic materials to shock wave (see STANAG 4488). A barrier made of cellulose acetate cards (o 40 mm, 0.19 mm thickness) is placed between a donor explosive (RDX/Wax) and the substance to be tested (confirmed in a stell tube (0 40 mm, 4 mm thick). The aim is to determine the minimum number of cards which attenuate sufficiently the donor shock wave pressure to prevent the substance to detonate.

Discusser's Name: May

Question:
Is there a reason why "fratricide" or sympathetic initiation is not treated in your probabilistic evaluation?

Author's Name: Gaudin

Author's Response:
The methodology was developed to assess the sensitivity of munitions exposed to a list of insults potentially encountered on an aircraft carrier. This list, established by the French DGA, does not include "sympathetic detonation".

Nevertheless, the main scenario involved in sympathetic detonation is the detonation of "receiver" due to the impact of fragments from "donor" ammunition. Such effects are included in the analyses.