NOVEMBER 24, 2026

A Case Study for Modified Quantitative EO Risk Assessments

Based on Weighting Factors for Operational Risk, Mission Urgency, Personnel and Asset Protection

Rhys Centin
Project Engineer
Thornton Tomasetti Pty Ltd

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PRESENTATION OVERVIEW

1. Background: Introduce Tool used to Expediate Siting Process (FDESLT)
2. Present Case Study for QERA Application
3. Show What the Hypothetical ELL Limits would be
4. Highlight Consequence Assessment Metrics for QERA
5. Introduce Weighting Factors to Modify the Assessment
6. Integrate Consequence Assessments with Weighting Factor Metrics
7. Discuss the Implications of Weighting Factor Application

TT EO SITING TOOL – FDESLT

Day 1 | Day 2 | **Day 3** | Full program

Thursday 26th November, 2026

10:10am - 10:40am	**Session 7A – Risk Modelling** **Room: Royal Theatre** **Chair:** **Physics based modelling of earth covered magazine breakup and consequence using ammunition and explosives consequence analysis tool (AECAT)** *Mr Neil McCormack, Lloyd's Register Advisory, Canada*
10:40am - 11:10am	**Practical application of the ammunition and explosives consequence analysis tool (AECAT)** *Mr Christopher Heron, Canadian Department of National Defence*
11:10am - 11:40am	**Warships in harbour – consequence advice for decision makers** *Dr Michael Netherton, Karagozian & Case Australia*
11:40am - 12:10pm	**The Field Deployable Explosive Siting and Licensing Tool** *Mr Rhys Centin, Thornton Tomasetti Australia*



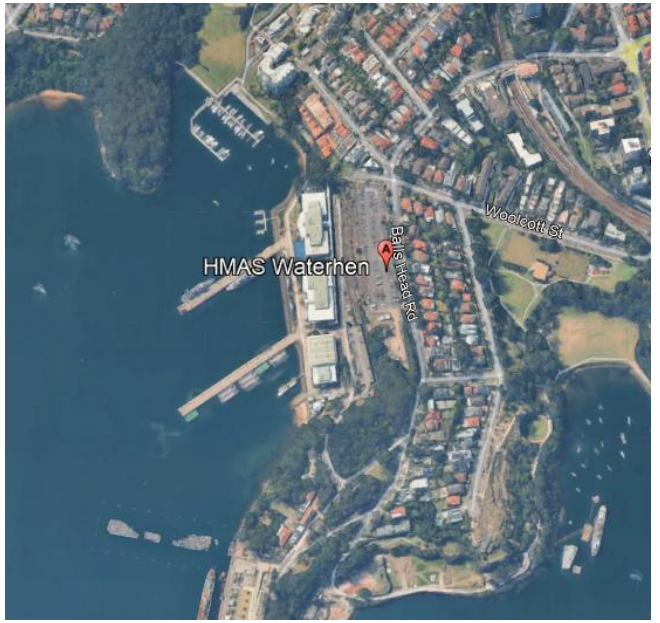
CASE STUDY

MHC at HMAS *Waterhen*

- *Waterhen* is the home port for MHC class
- ~ 1.9 km Northwest of Sydney CBD, urban environment
- EO stock holdings – typically SQF due to location
- What if, mission criticality requires significant uptake of HD 1.1 disposal charge stock-holdings for MHC activities?
- Note this is a fictitious scenario with many assumptions
- We are interested in the *application* of concepts being discussed here to actual EO holdings limits to the ADF



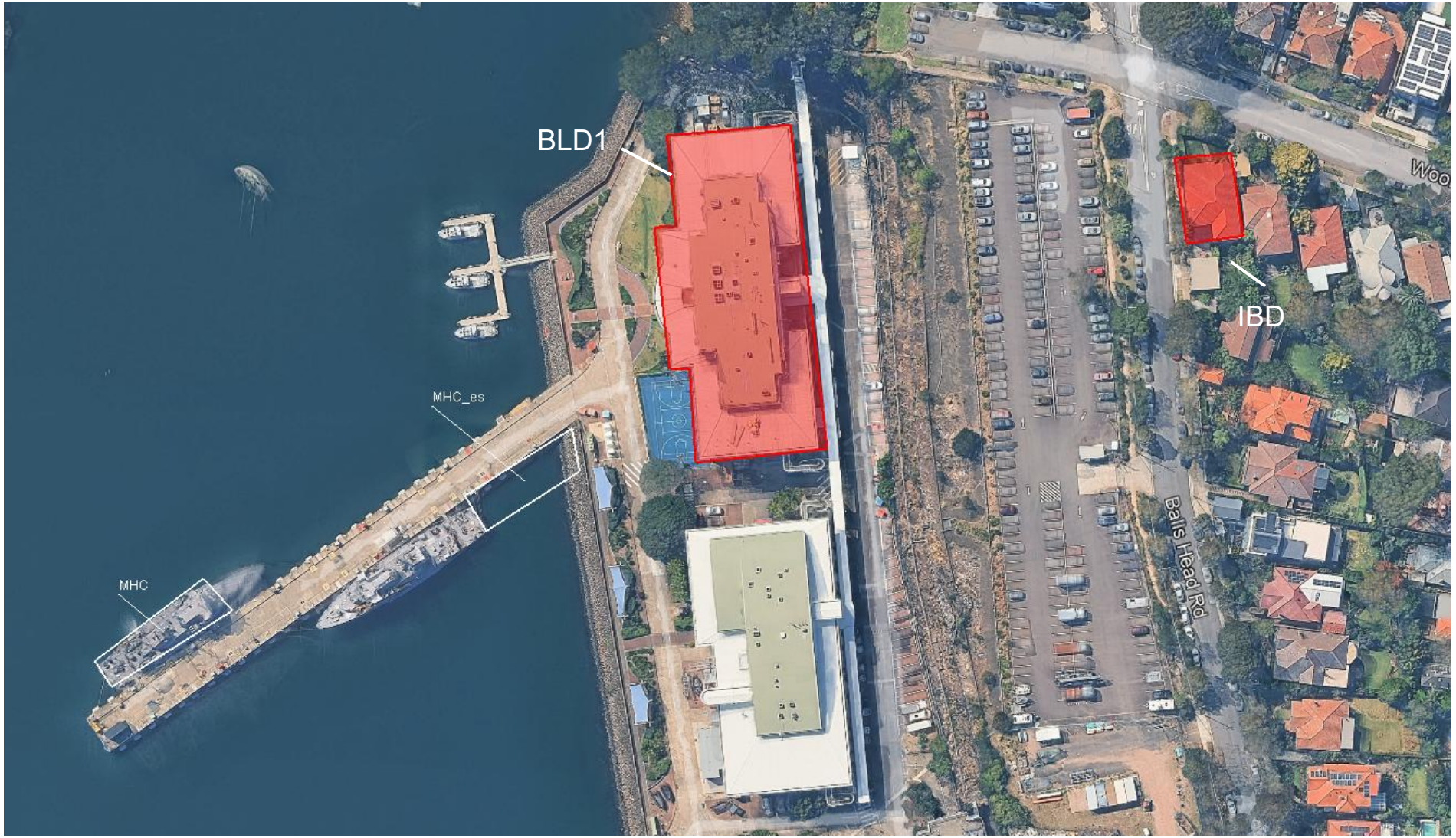
HMAS *Diamantina* anchored in Vanuatu from RAN Website [1]



HMAS *Waterhen* from Google Earth [2]

[1] – RAN Website
[2] – Google Earth Pro

THE PROBLEM SPACE



Google Earth, HMAS *Waterhen* Top-Down View [2]

[2] – *Google Earth Pro*

PES-ES INTERACTIONS

PES = MHC (Western)

- Lightweight Building of Construction
- Barricaded for *some* interactions

ES of Consideration

- MHC as an ES @ ~ 70 m
- BLD1 as a ‘Low Occupancy’ Admin Bldg. @ 130 m
- IBD as our Public / Inhabited Bldg. @ ~ 270 m





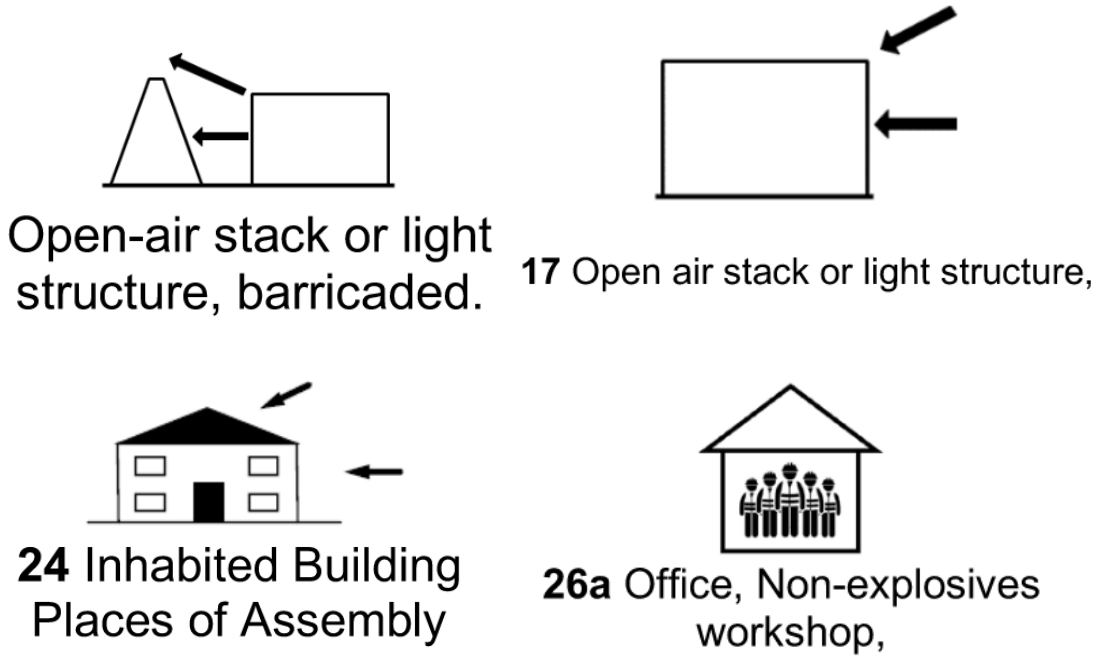
Google Earth, HMAS *Waterhen* Isometric View of Elevation [2]

[2] – Google Earth Pro

WHY THESE ES OF INTEREST?

Different ‘Categories’ for Weighting Factors

- Cat 17, MHC_{ES} = Internal Asset
- Cat 26a = Internal Asset + Personnel
- Cat 24 = Public Asset + Personnel
- ‘Closest’ Bldg. of each category



PES-ES Types, Taken from AASTP-1 [3]

[3] – MSIAC, 2025, AASTP-1, ed D, ver 1

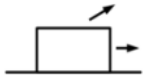
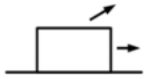
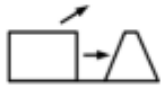
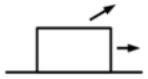
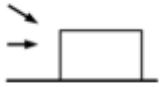
SAFEGUARDING INDICATION



Google Earth, HMAS *Waterhen* Top-Down View with Safeguarding Arcs [2]

[2] – *Google Earth Pro*

PROBLEM SPACE CURRENT ELL LIMITS

PES				
HD 1.1 NEQ (kg)	500			
ES				Min Limits
Name	MHC(es)	BLD1	IBD	-
Dist [m]	70	130	270	-
HD 1.1	BD30	DFD18	DFD7	DFD18
	30	17	1,378	17
HD 1.2.1	BD30* (MCE)	DFD18* (MCE)	P1D4	DFD18* (MCE)
	0	0	1,359	0
HD 1.2.2	-	P2D3	P2D4	P2D3
	250,000	59,895	250,000	59,895
HD 1.2.3	BD30* (MCE)	DFD18* (MCE)	TD4	DFD18
	0	0	76,827	0
HD 1.3.1	TD1	TD3	TD4	TD3
	98,440	27,174	76,827	27,174
HD 1.3.2	TD1(<60)	TD3	TD4	TD3
	250,000	27,174	76,827	27,174

NOTE:

For HD1.1 BD14 @ 70 m = 3,101 kg

For HD1.1 BD26 @ 130 m = 1,482 kg

Debris & Frag driven requirement for HD 1.1

GP5	DFD6
Purple Line	192
GP4	DFD6
Yellow Line	192
GP3	DFD18
Green Line	130

CONSEQUENCE ANALYSIS APPROACH

- Problem space – mission critical to store more HD 1.1
- We therefore need to assess blast and debris/frag consequences
- This approach could be tweaked and applied to other HDs – beyond scope of study

PES → / E S ↓	EFFECT	Open-air stack or light structure, barricaded. Truck, trailer, rail-car or freight container loaded with munitions, barricaded. (i)	Open-air stack or light structure, unbarricaded. Truck, trailer, rail-car or freight container loaded with munitions, unbarricaded. (j)	See introduction for full instructions and calculation tables for full formula. 1. Select correct PES/ES interaction. 2. Use HD/SsD table to determine applicable calculations 3. Use HD/SsD table to determine quantity, either NEQ or MCE 4. Use associated formula for min Distance or max Quantity.						
				HD/SsD						
				1.1	1.2.1	1.2.2	1.2.3	1.3.1	1.3.2	1.6
24 Inhabited Building Places of Assembly	BLAST	BD31	BD31	NEQ	MCE		MCE			MCE
	DEBRIS & FRAG	DFD7	DFD6	NEQ	MCE		MCE			MCE
	PROG' 1.2.1	P1D4	P1D4		NEQ					
	PROG' 1.2.2	P2D4	P2D4			NEQ				
	THERMAL 1.3.1	TD4	TD4					NEQ		
	THERMAL 1.3.2	TD4	TD4				NEQ		NEQ	NEQ

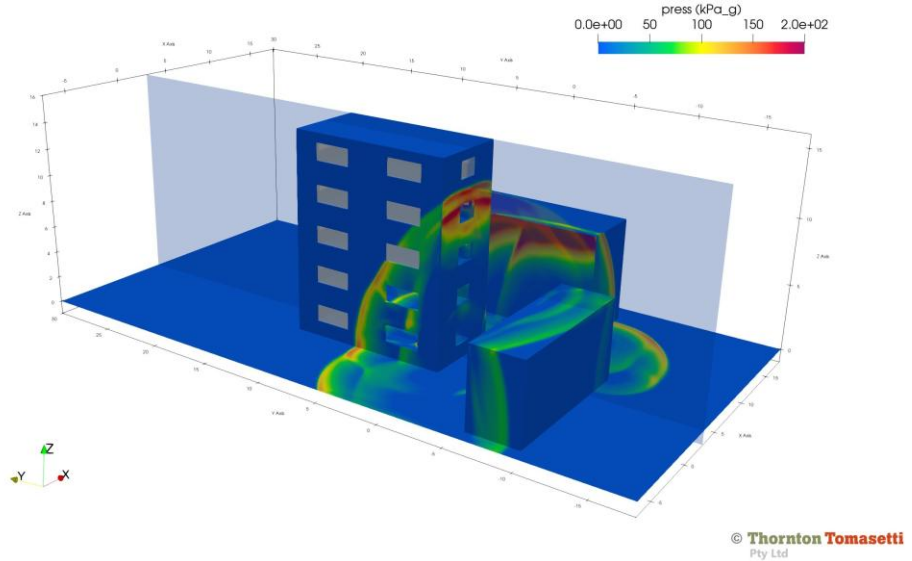
Light Walled Buildings and Open Stacks, Taken from AASTP-1 [3]

[3] – MSIAC, 2025, AASTP-1, ed D, ver 1

BLAST BASED CONSEQUENCES

Multi-Step Process

1. Define peak incident overpressure and impulse from AASTP-4 Vol II [4]
2. Define asset-based consequence via PI damage curves
3. Define personnel-based consequence via injury metrics



Sample External Airblast CFD Analysis Using WALAIR ++

[4] – MSIAC, 2024, AASTP-4 Vol 2, ed B, ver 1

ASSET CONSEQUENCES FROM PI

Two commonly used models for asset consequences from blast (damage)

1. WWII bomb damage against terraced brick houses (Gilbert, Lees, Scilly criteria taken from L-229)
   Note: damage level Ca is precursor to IBD criteria used commonly in QD siting rules.

2. Medium RC building SDOF model (taken from AASTP-4)

Both models have associated personnel consequences (sheltering in place)

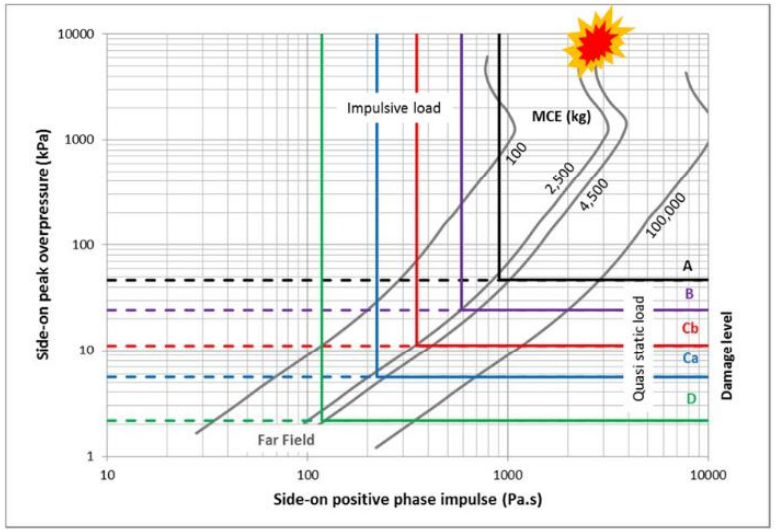


Figure 11 From L-229 [5] – P-I curves for the various damage levels based on Gilbert, Lees, and Scilly.

Table 11 From L-229 [5] – Building Damage Levels, RB Ratio… an excerpt

Damage level	RB ratio	P (kPa)	I (Pa.s)	Description
A	0.675	47	905	almost complete demolition
B	1.00	24	588	50-75% external brickwork destroyed or rendered unsafe and requiring demolition
Cb	1.74	11	350	houses uninhabitable – partial or total collapse of roof, partial demolition of one or two external walls, severe damage to load-bearing partitions requiring replacement
Ca	3.0	5.6	222	not exceeding minor structural damage, and partitions and joining wrenched from fittings
D	6.0	2.2	118	remaining inhabitable after repair – some damage to ceilings and tiling, more than 10% window panes broken

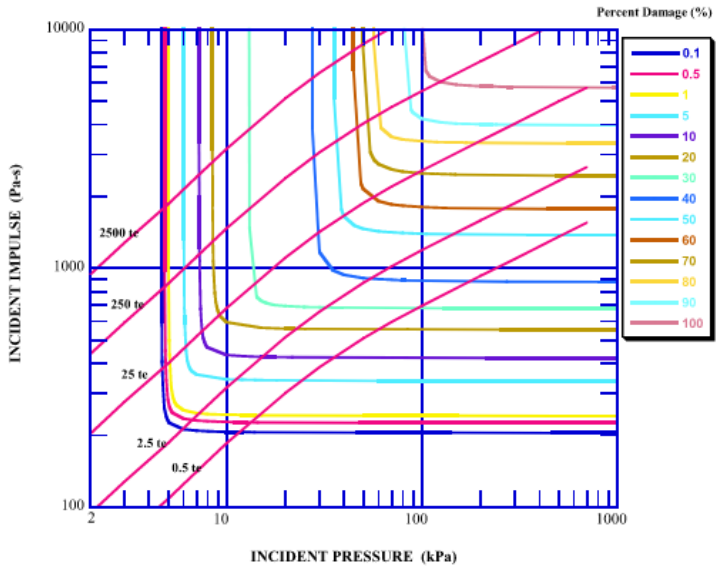


Figure A-5 From AASTP-4 [4] – Medium RC Building Structural Damage PI Curve

[4] – MSIAC, 2024, AASTP-4 Vol 2, ed B, ver 1
[5] – MSIAC, 2022, L-229: Experimental and Theoretical Basis of NATO Standards for Safe Storage of Ammunition and Explosives.

PROPOSED WEIGHTING FACTOR APPROACH

Before we progress with consequences analysis, let's define the following mission criticality ratings, as they pertain to EO stowage:

- Alpha = EO holdings are mission critical
- Bravo = EO holdings are mission essential
- Charlie = EO holdings are mission support
- Delta = Peacetime / no mission criticality, defer to default approach



QUANTITATIVE METRICS FOR CRITICALITY RATINGS

Define acceptable quantitative metrics for criticality ratings

- Examples given below, which will be used throughout case study
- Sample only, in practice would require more categories for greater granularity, situational adaptability, etc.
- To not exceed values would require significant rigor and peer review to implement in practice

Most Critical



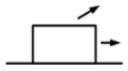
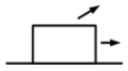
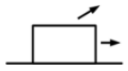
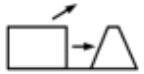
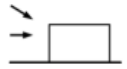
Least Critical

Criticality Rating	EO Holdings Criticality	Mission Asset Damage not to Exceed (%)	Public Asset Damage not to Exceed (%)	Mission Personnel Lethality not to Exceed (%)	Public Personnel Lethality not to Exceed (%)
Alpha	Critical	50%	20%	20%	5%
Bravo	Essentional	20%	10%	10%	2%
Charlie	Support	10%	1%	5%	1%
Delta	None	-	-	-	-

ASSET BLAST CONSEQUENCES IN CASE STUDY

Let's apply mission criticality rating Bravo in our case study:

- New maximum permissible NEQ^ = 4,100 kg based on criticality driven by MHC_{ES}
- This is only for assets + personnel sheltering in place from blast consequences
- Need to map out other consequences from HD 1.1 material and find the new minimum
- Key drawback: see IBD ES, using different PI damage / vulnerability criteria yields higher than expected NEQ^

PES					
ES					
Name	MHC(es)	BLD1	BLD1	IBD	IBD
Mission or Public	Mission	Mission	Mission	Public	Public
Asset Type	Asset	Asset	Personnel	Asset	Personnel
Tolerance	20%	20%	5%	10% / Cat B	2% / Cat B
Dist [m]	70	130	130	270	270
NEQ^ (kg)	4,100	9,500	15,000	75,000	75,000
Z (m/kg^1/3)	4.37	6.14	5.27	6.40	6.40
Structure	RC	RC	RC-Personnel	Brick	Brick-Personnel
Pi (kPa)	35.5	9.3	11.2	21.7	21.7
Ii (Pa.s)	552.3	322.9	420.2	1077.0	1077.0

PERSONNEL IN THE OPEN

PI Curves from UFC 3-340-02 [6] as human vulnerability metrics for personnel in the open

- Lung Damage as lethality metric
- Hearing Damage as injury metric
- Typically, higher PI combination / threshold than building damage metrics – not applied here
- Apply these in a similar manner based on criticality.

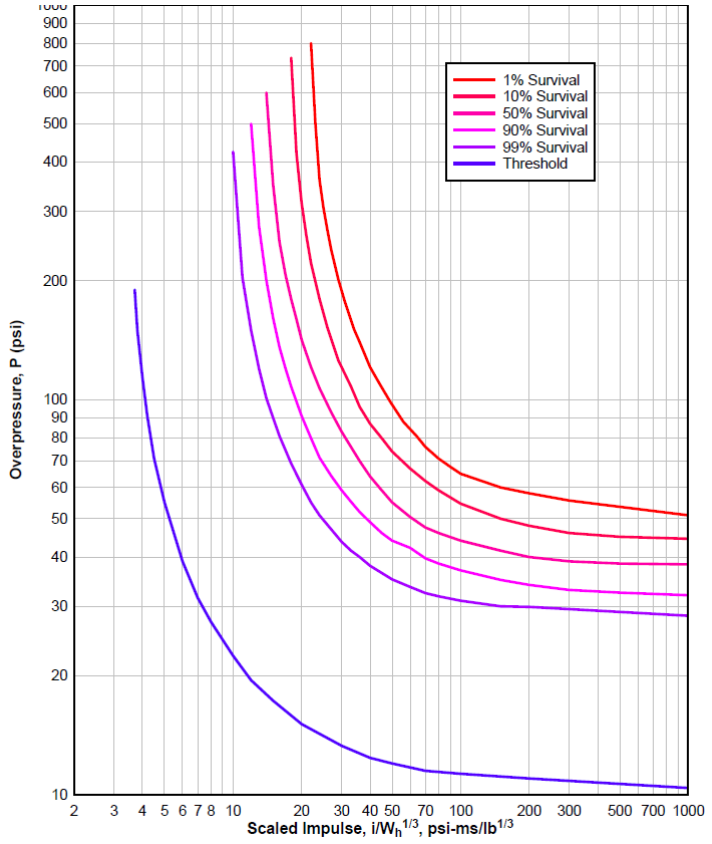


Figure 1-2 from UFC from 3-340-02 [6] – Survival Curves for Lung Damage…

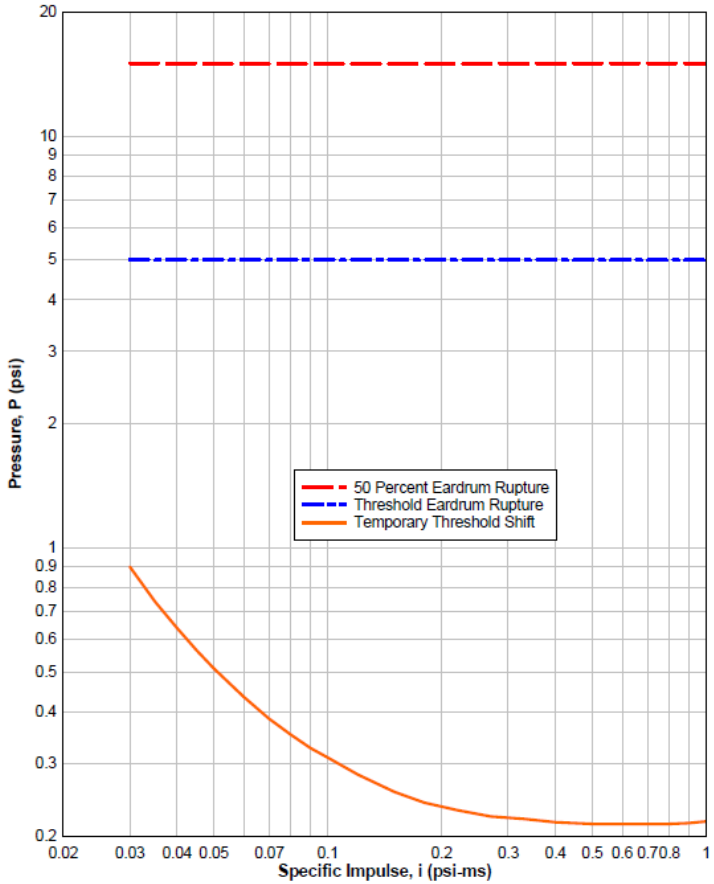


Figure 1-3 from UFC from 3-340-02 [6] – Human Ear Damage Due to Blast Pressure

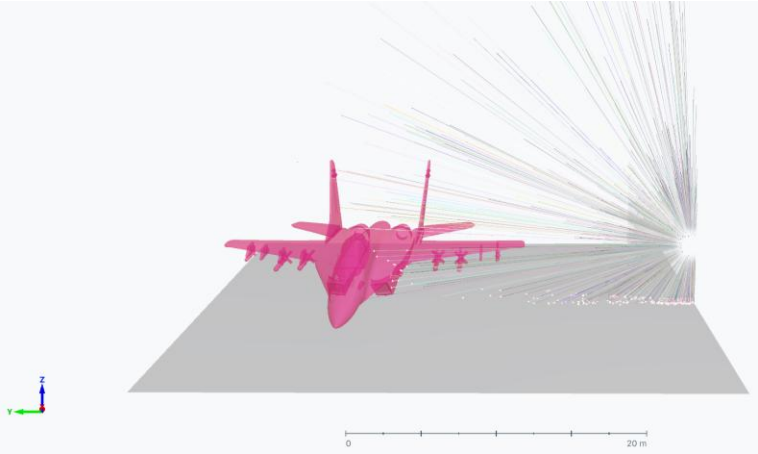
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[6] – UFC 3-340-02,2008.

FRAGMENTATION / DEBRIS BASED CONSEQUENCES

Multiple Considerations

1. Asset damage from fragmentation and debris
    - Not covered in this presentation as methods are lengthy – see TP-14 [7] / SAFER for detail
2. Personnel vulnerability from fragmentation:
    - Whilst sheltering in place
    - Whilst in the open



Sample of Fragmentation Vulnerability Model using IMPETUS

[7] – DDESB, 2009, TP-14 Rev 4.

PERSONNEL VULNERABILITY FROM DEBRIS

L-252 defines a method for debris-based consequences for personnel:

- ‘a’ value is when normalised distance function changes over
- For our case study:
  - PES ~ ISO Container
  - BLD1 – consider people in open, and shelter in place (for comparison purposes)
  - IBD – consider people in open only, cannot control public personnel movement.

Table 19 from L-252 [8] – Parameter ‘a’ for PES Types

PES type	a
Aboveground Reinforced Concrete	0.55
Aboveground Brick	0.65
ISO Containers	0.35
ECM / HAS	0.65 (preliminary)
Generic value for MQDCAT	0.5

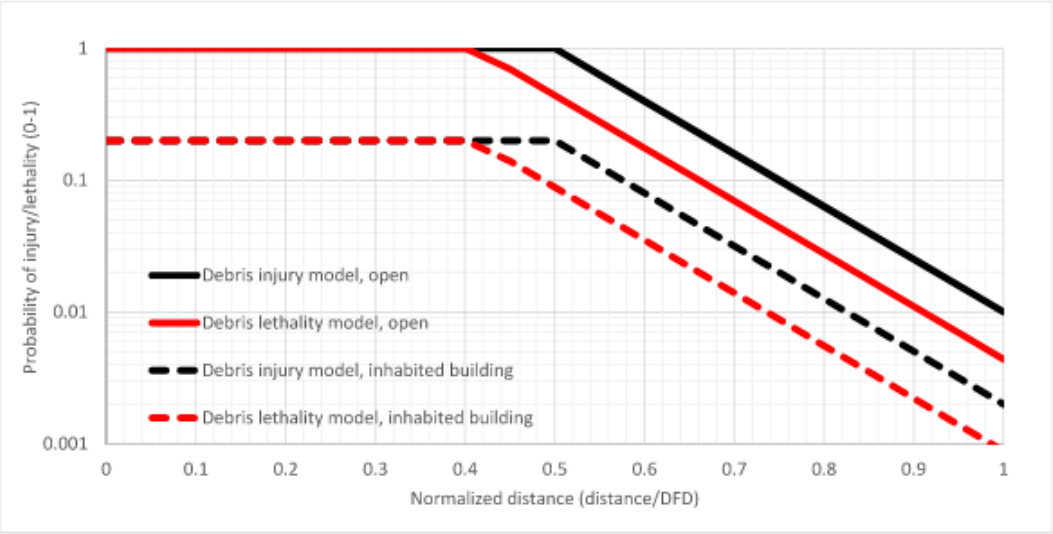


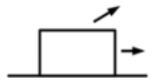
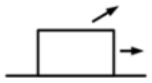
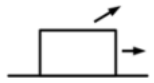
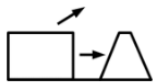
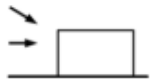
Figure 23 from L-252 [8] – Pr Injury and Lethality versus normalized distance (distance divided by DFD)…

[4] – DDESB, 2009, TP-14 Rev 4.

ASSET DEBRIS CONSEQUENCES IN CASE STUDY

Let's again, apply mission criticality rating Bravo in our case study for debris:

- Assumed MHC_{ES} has no personnel
- BLD1 – significant difference in DFD requirement and NEQ permissible if personnel forced to shelter in place
    - 196 kg permissible vs 2,414 kg. Note: IBD requirement 1,713 kg would take over here.

PES				
ES				
Name	MHC(es)	BLD1	BLD1	IBD
Mission or Public	Mission	Mission	Mission	Public
Asset Type	N/A	Personnel	Personnel: Shelter-in-Place	Personnel
Tolerance	N/A	10%	10%	2%
Dist [m]	70	130	130	270
DFD	BD30	DFD18	DFD18	DFD7
Normalised DFD	N/A	0.68	0.45	0.90
DFD_target	N/A	192.59	290.83	299.33
NEQ^ (kg)	N/A	196	2,414	1713*

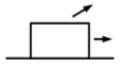
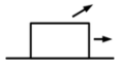
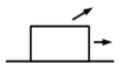
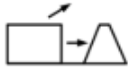
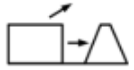
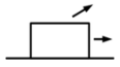
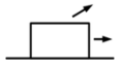
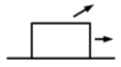
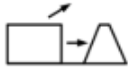
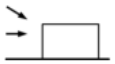
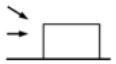
WEIGHTED CONSEQUENCES SUMMARY

Blast Consequences:

- Protection of MHC_{ES} @ 70 m standoff is limit
- Care to be taken where damage models come from multiple sources (See IBD)

Debris Consequences:

- Personnel in open, critical factor
- Is crowd control / fractional exposure applicable?
- Limit 196 kg or 1,713 kg; accordingly

	Blast Consequences						Fragmentation/Debris Consequences			
PES						**PES**				
ES						**ES**				
Name	MHC(es)	BLD1	BLD1	IBD	IBD	**Name**	MHC(es)	BLD1	BLD1	IBD
Mission or Public	Mission	Mission	Mission	Public	Public	**Mission or Public**	Mission	Mission	Mission	Public
Asset Type	Asset	Asset	Personnel	Asset	Personnel	**Asset Type**	N/A	Personnel	Personnel: Shelter-in-Place	Personnel
Tolerance	20%	20%	5%	10% / Cat B	2% / Cat B	**Tolerance**	N/A	10%	10%	2%
Dist [m]	70	130	130	270	270	**Dist [m]**	70	130	130	270
NEQ^ (kg)	4,100	9,500	15,000	75,000	75,000	**NEQ^ (kg)**	N/A	196	2,414	1713*

SUMMARY CONTINUED

- Initial QD-based siting approach yielded max permissible NEQ of ~17 kg HD 1.1
- A mission need was established for storing more HD 1.1 material at the PES in question
- Criticality ratings were established and assigned quantitative ‘not to exceed’ values for blast and fragmentation consequences
- Appropriate literature was applied to calculate the blast and fragmentation consequences arising from the PES at the ES of interest stand-off.
- Based on criticality rating ‘Bravo’, a risk-based justification for raising NEQ holdings of HD 1.1 to ~ 196 kg or ~ 1,713 kg depending fractional exposure.

CONCLUSIONS

- Where operational risk and mission urgency are emerging factors in ADF EO stowage and handling management, mission criticality weighting factors can be used to modify requirements
- These weighting factors should be used in conjunction with quantitative metrics to ensure the process is repeatable and decision makes are informed.
- Key shortcomings and drawbacks with the process aligned here include:

    1. Only HD 1.1 was considered, progressive event and thermal frameworks require investigating.
    2. When combining multiple quantitative consequence models (i.e., building damage from blast) discrepancies in results can arise
    3. The method presented was not exhaustive – (i.e., no debris-based building damage assessed)
    4. The acceptance criteria in this presentation is not proposed for use – it acts only as an example for the case study. Any application of weighting factors requires robust peer review and scrutiny from key relevant stakeholders in the EO safety community.

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THANK YOU



Rhys Centin

Project Engineer
RCentin@ThorntonTomasetti.com
+61.3.9724.3705