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PARARI 2026

A Data-Driven Approach to Missile Captive Carriage Lifing



Photo credit: USAF

Acknowledgments and Ownership

Funding and Ownership

- This work was funded and is owned by the Aerospace Explosive Ordnance Systems Program Office (AEOSPO).

Technical Development

- Technical work developed by QinetiQ Australia under contract to AEOSPO and informed by work published by the UK Ministry of Defence (Edward Hoole, Christopher Mallinson, Steven Wagstaff, Chris Roberts, Ian Carr).

Acknowledgements

- AEOSPO: SQNLDR Nitilaksh Prasad, SQNLDR Brent Thoroughgood and SQNLDR Carlo Oreas.
- QinetiQ: Carl Mouser and Tim Cooper.

Context

Background

- ADF missiles are assigned a defined Captive Carriage (CC) life during certification.
- CC life is established through qualification testing and is tracked using air carriage hours.

Problem Statement

- Different operational scenarios can vary significantly in severity i.e. missiles accumulate damage and life is expended at different rates.
- This is not accounted for in the current lifing approach.
- This can lead to a risk that missile life is not managed optimally (under/over utilised).

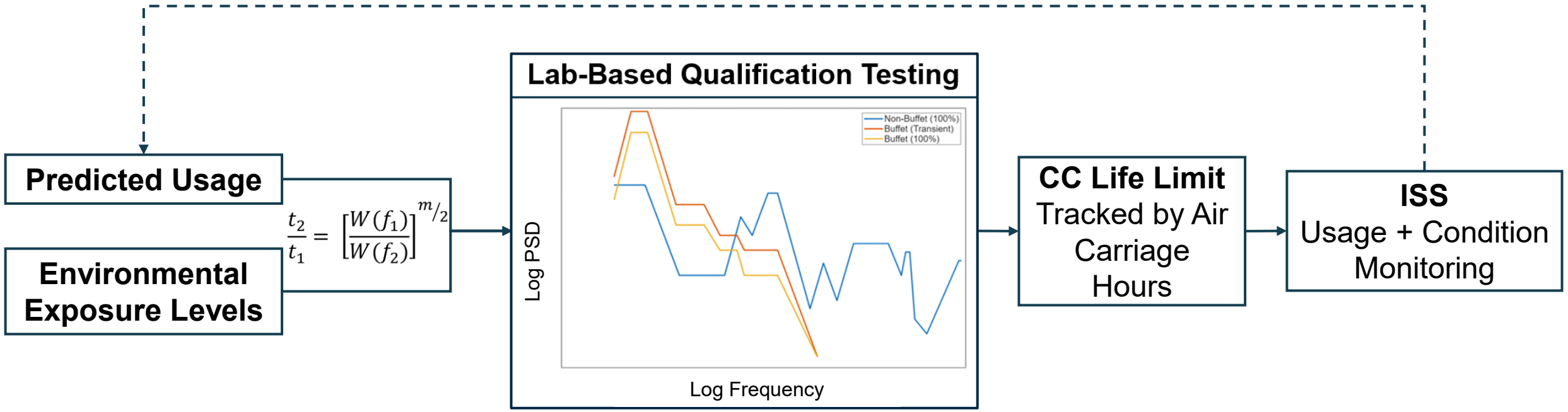
Solution

Munitions Health Management (MHM) – an optimised approach to tracking the consumed CC life of a missile by using actual usage and environmental exposure data to maximise utilisation.

Background

Conventional Qualification and Lifing Approach (ADF)

CC life determined through qualification testing – vibration tests are used to induce an equivalent level of damage as that expected in-service based on predicted usage.



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Background
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CC life determined through qualification testing – vibration tests are used to induce an equivalent level of damage as that expected in-service based on predicted usage.

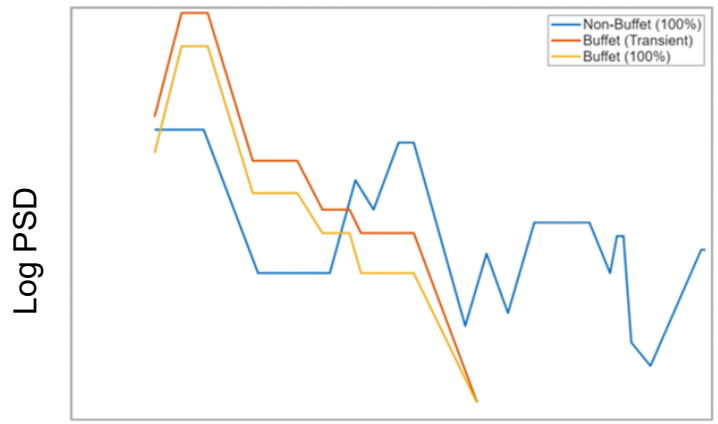
What if operational usage deviates from predicted usage?

Predicted Usage

Environmental Exposure Levels

$$\frac{t_2}{t_1} = \left[\frac{W(f_1)}{W(f_2)}\right]^{m/2}$$

Lab-Based Qualification Testing



CC Life Limit
Tracked by Air Carriage Hours

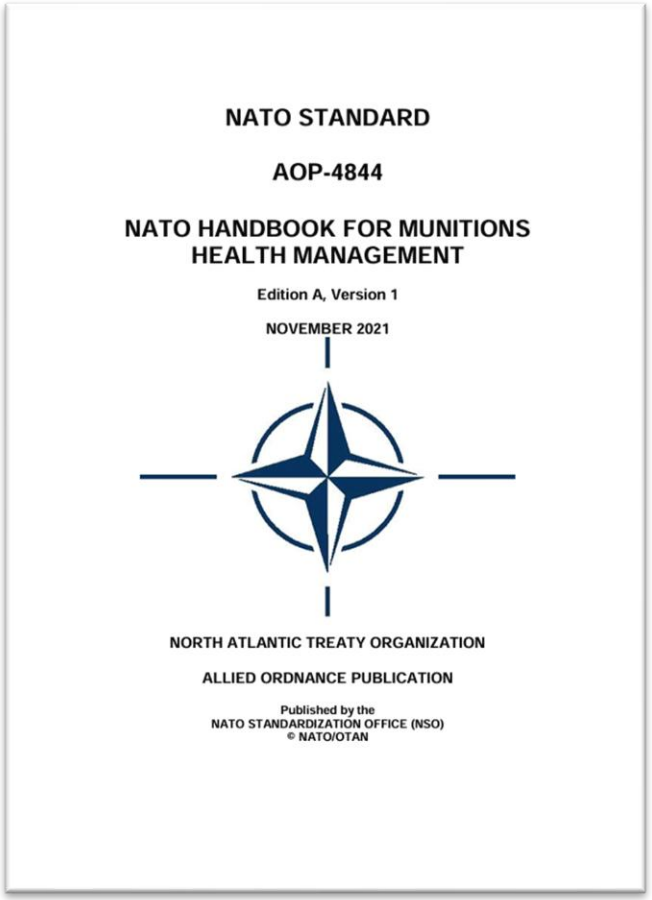
ISS
Usage + Condition Monitoring

What if conservative qualification spectra are used in place of specific platform and weapon assumptions?

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AOP-4844: NATO Handbook For Munitions Health Management (MHM)

In-Service Surveillance vs Munition Health Management


NATO STANDARD

AOP-4844

NATO HANDBOOK FOR MUNITIONS HEALTH MANAGEMENT

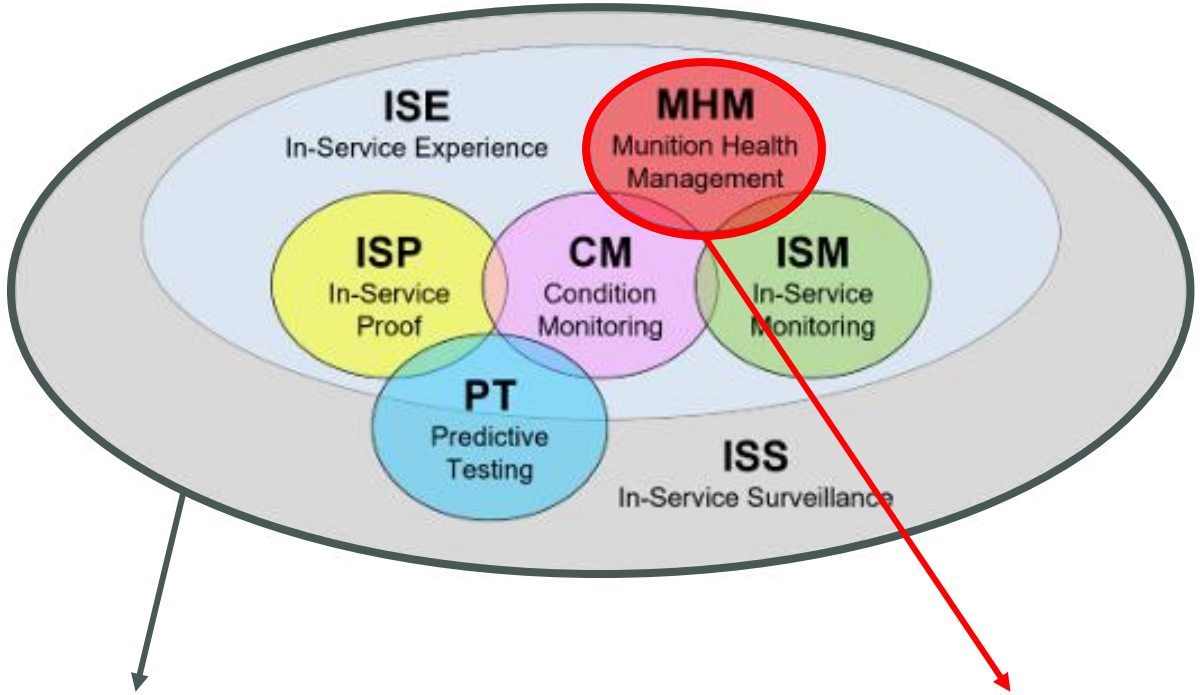
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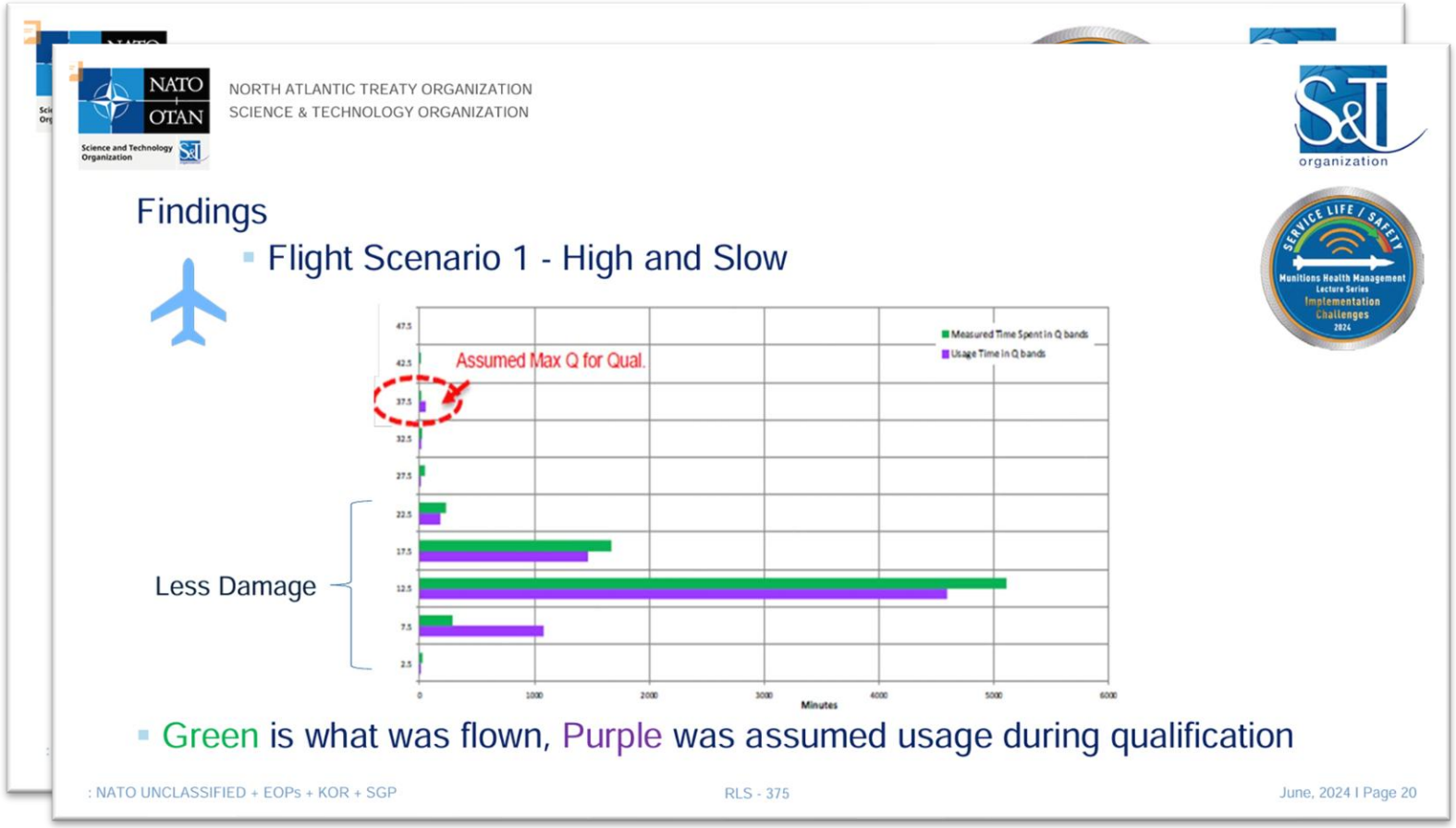


"The primary purpose of ISS is to monitor the condition of in-service munitions and to demonstrate that the munitions will still function safely and reliably after exposure to the service environment." AOP-46

"An intelligent process to capture and analyse ***data regarding real exposure*** of munitions to lifecycle threats in order to ***optimise the assessment of their remaining safe life*** with a view to achieving improved safety, reduced cost and sustained capability." AOP-4844

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UK Ministry of Defence MHM Capability
Munition Environmental Lifing Programme (MELP)



Slide reproduced from NATO STO EN-AVT-375-01 presentation

g-Q trend used to support increase in life of 10-20% for 8 missiles

New equivalent exposure time

Grms level at assumed max Q

$$\frac{t_2}{t_1} = \left[\frac{S_1}{S_2}\right]^m$$

Assumed time spent at max Q

Grms level at actual max Q

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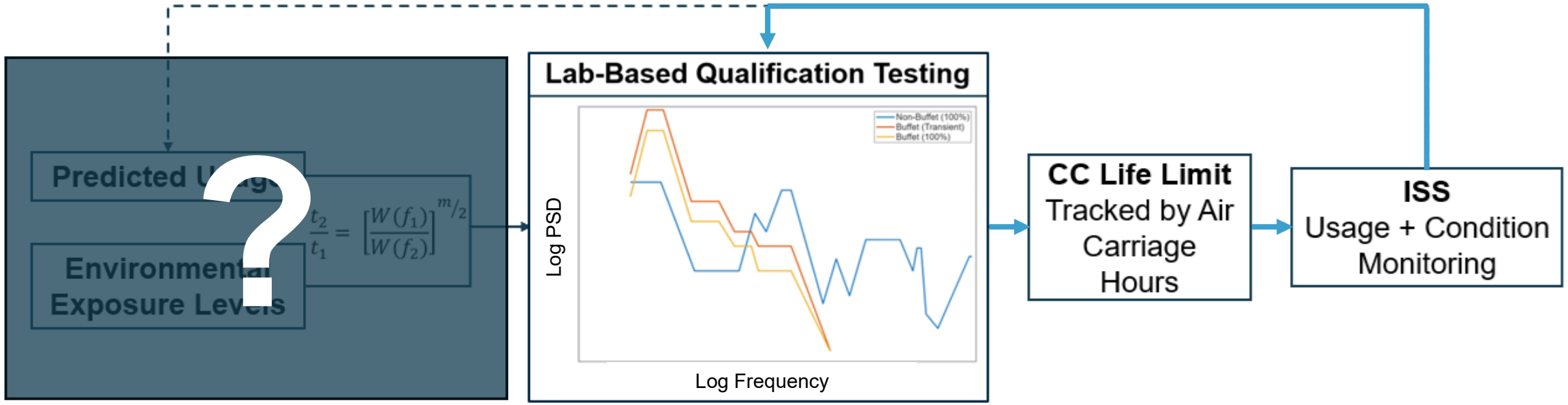
QinetiQ Tasking by AEOSPO

QinetiQ tasked by AEOSPO to investigate the feasibility of adopting the UK MELP approach.

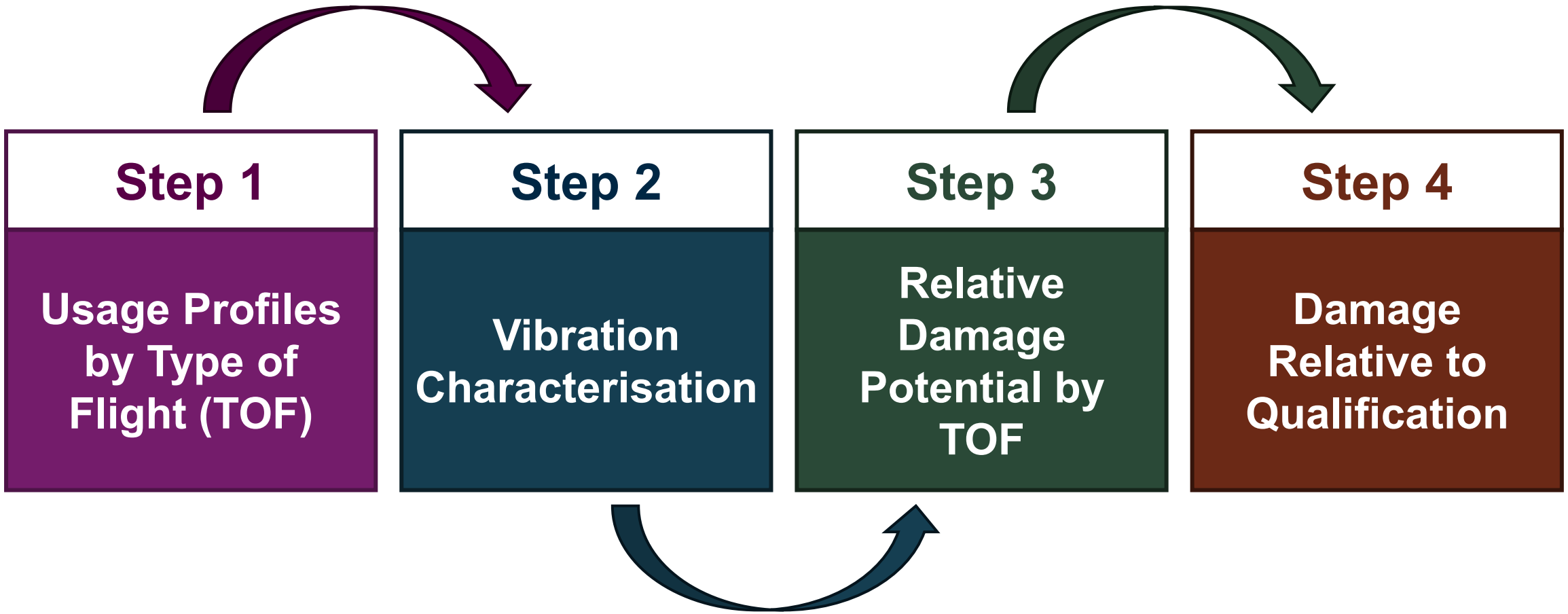
Key limitation identified for direct adoption in the Australian context:

- Conservative test spectra used for qualification (not explicitly tied to usage/environmental exposure assumptions).

An alternative approach was developed and tailored to available Australian datasets.



Methodology
QinetiQ developed MHM Methodology



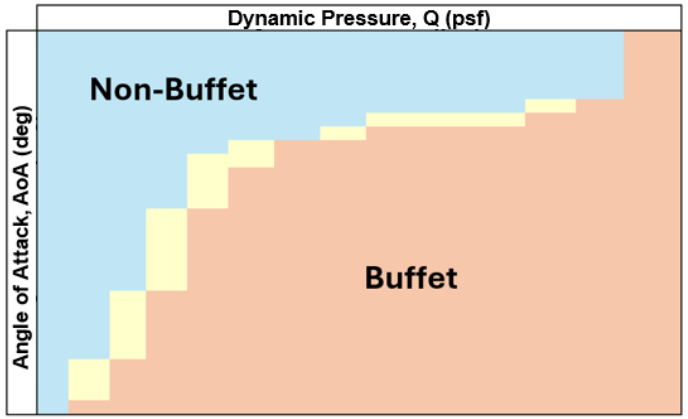
Methodology

Step 1: Usage Profiles by Type of Flight (TOF)

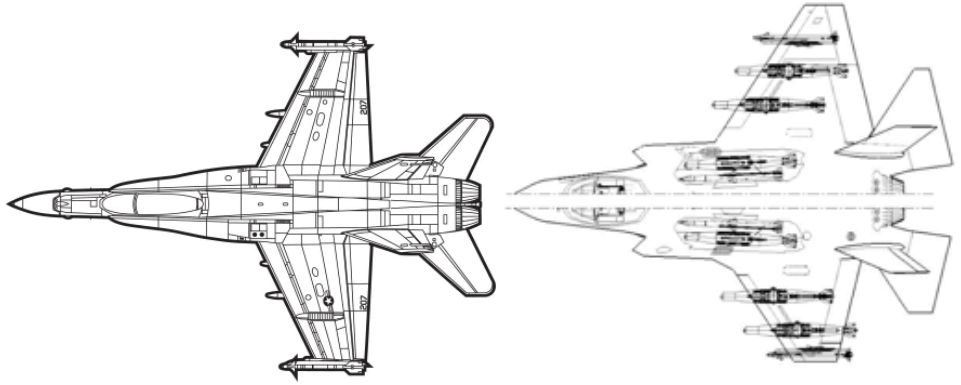
Applicable TOFs for Missile Carriage

Aircraft Usage Monitoring System

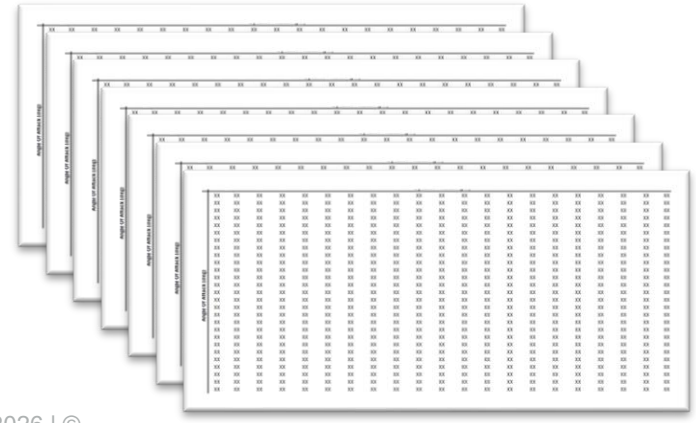
Usage Times by Flight Conditions



Weapon Loadout and Aircraft Station Usage



Usage Profiles per TOF



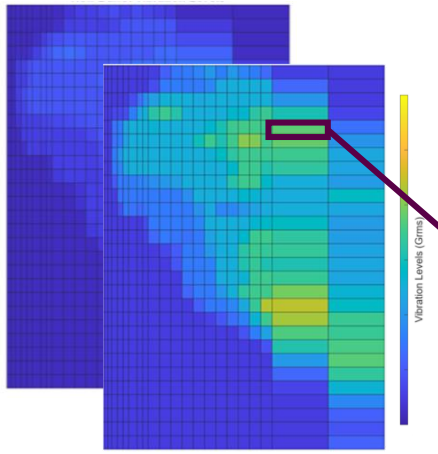
Take-Off, Buffet, Non-Buffet

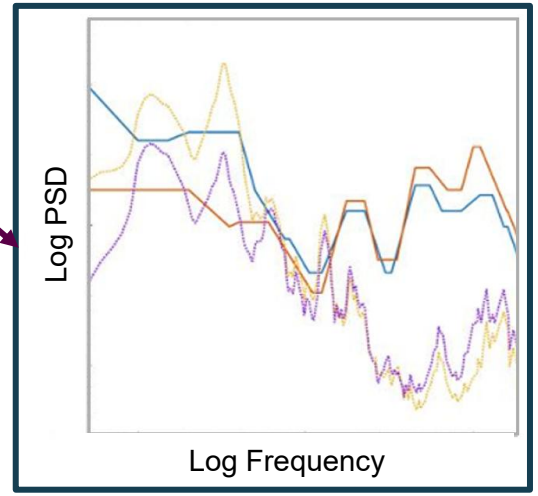
- Dirty weapon loadout + wing carriage
- Dirty weapon loadout + fuselage carriage
- Clean weapon loadout + wing carriage
- Clean weapon loadout + fuselage carriage

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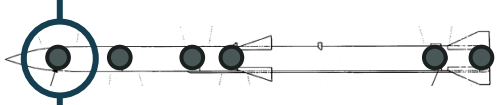
Methodology
Step 2: Vibration Characterisation

Buffet and non-buffet vibration levels as a f(AoA,Q) and PSD shapes

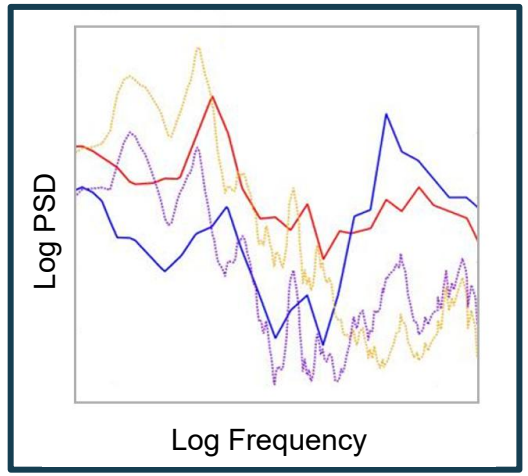




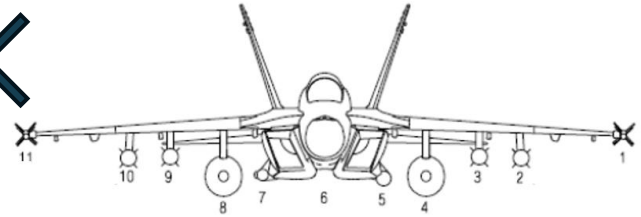
Vibration levels at different missile stations/axis



Take-off vibration levels



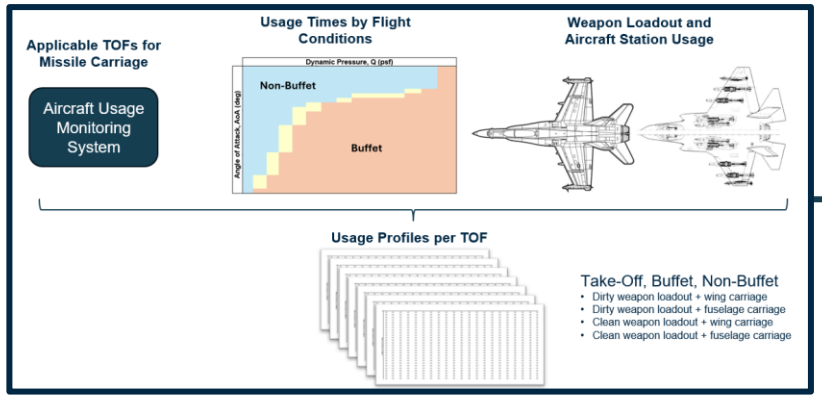
Vibration multipliers for different weapon load outs and aircraft stations



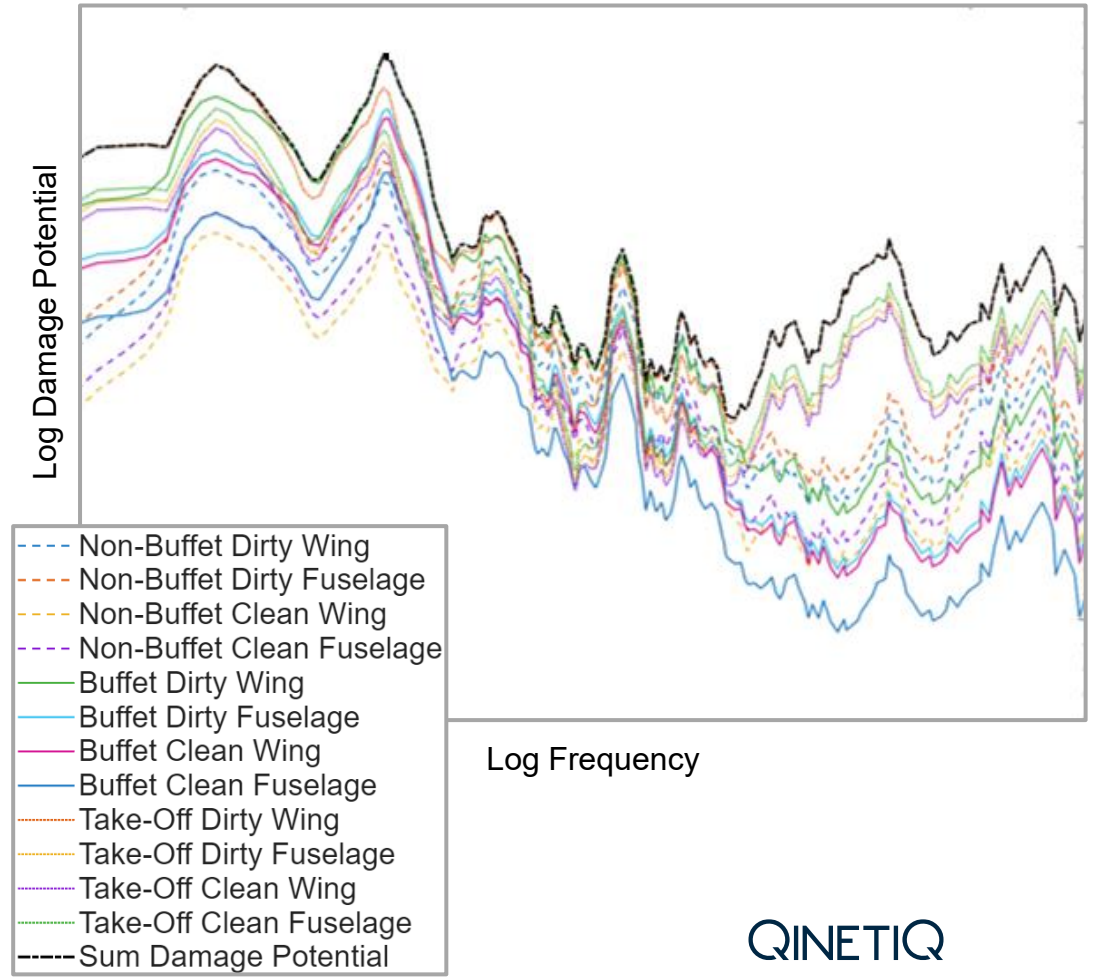
Methodology

Step 3: Relative Damage Potential by Type of Flight (TOF)

Damage potential curves provide a relative means of comparing the severity of different vibration environments. ***They do NOT represent an estimate of actual damage to the missiles and do NOT consider the susceptibility of the missile to the environment.***



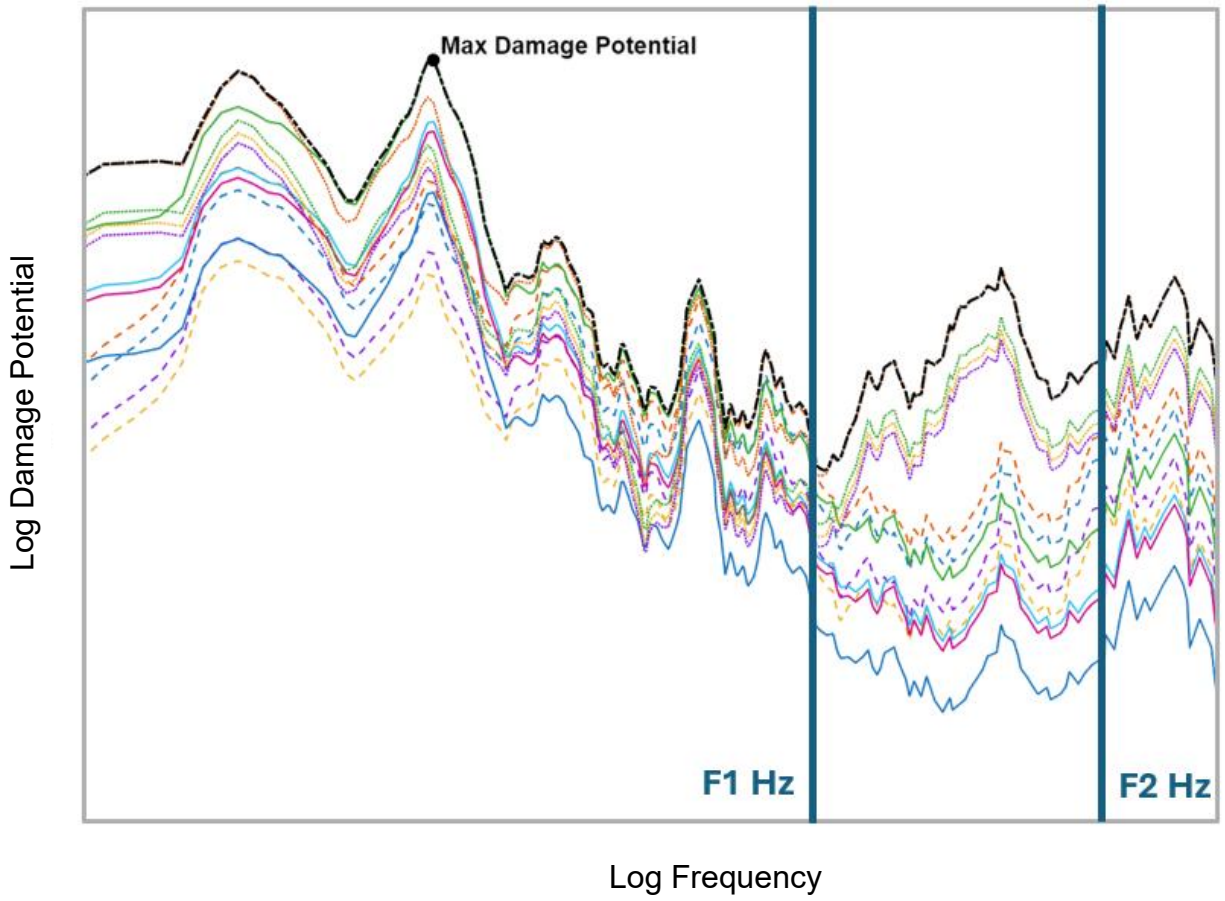
$$\frac{t_2}{t_1} = \left[\frac{W(f_1)}{W(f_2)}\right]^{m/2}$$



Methodology

Step 3: Relative Damage Potential by Type of Flight (TOF)

To determine the effect of a given environment on a particular store, an understanding of its critical failure modes and life-limiting components is required.

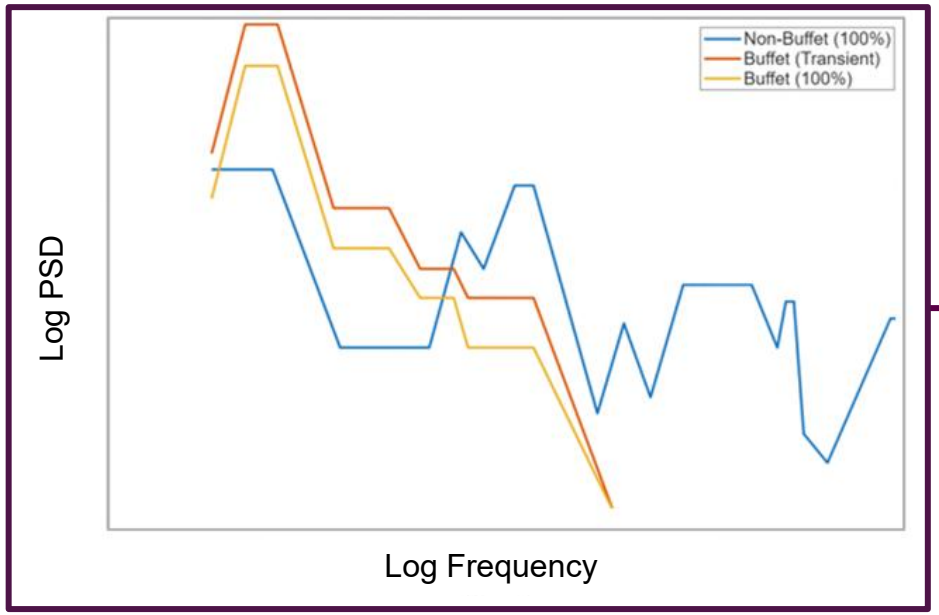


Electronics susceptible to high frequencies (F1 – F2 Hz)

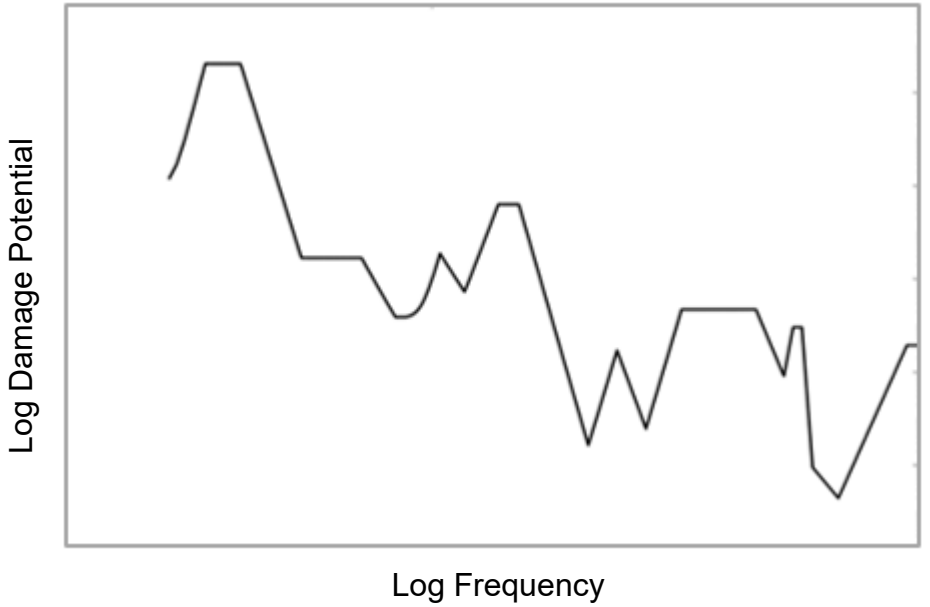
TOF	Max Damage Potential (F1 – F2 Hz)	Relative Damage Ratio	Equivalent Hrs
A	…	1	1
B	…	<1	>1
C	…	<1	>1

Trade-off between TOFs

Methodology
Step 4: Damage Relative to Qualification



$$\frac{t_2}{t_1} = \left[\frac{W(f_1)}{W(f_2)}\right]^{m/2}$$



Test times provided for each environment.

Distribution of time and vibration factors provided for different aircraft carriage station

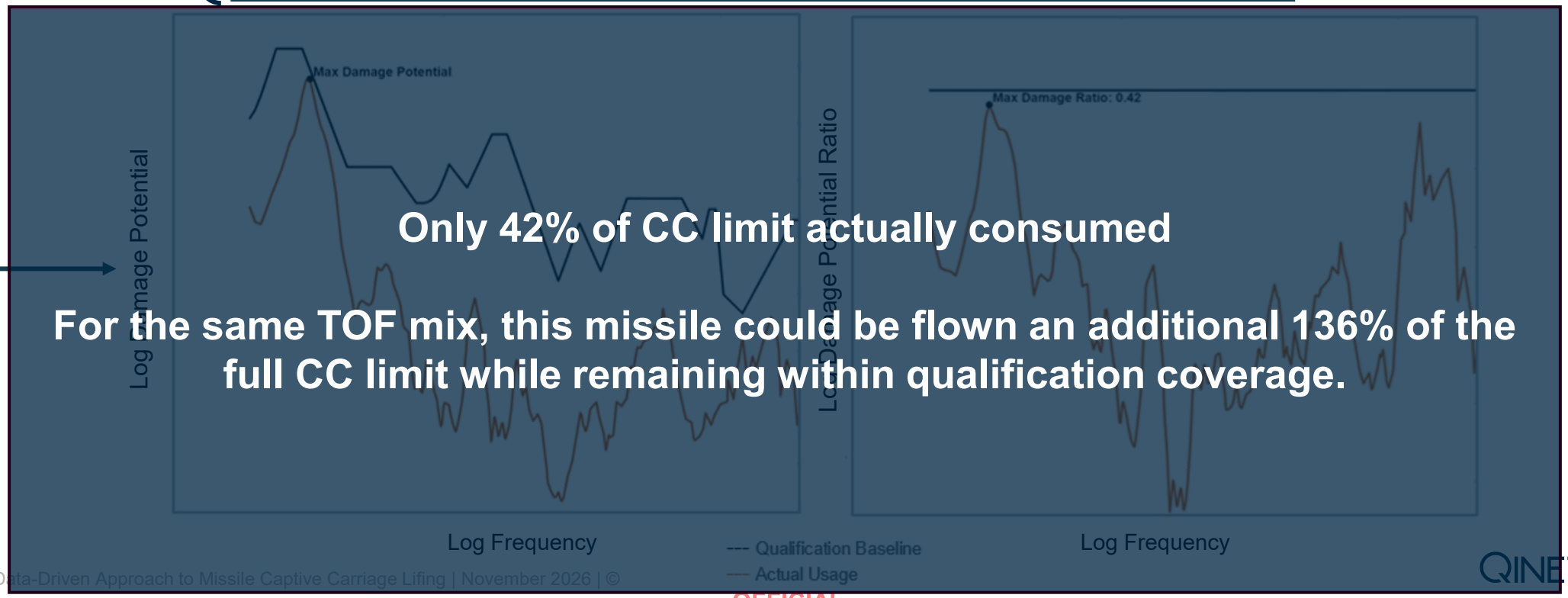
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Methodology

Step 4: Damage Relative to Qualification

Flight history (by TOF) for full CC limit

Role	Profile	TOF ID	CC Limit Breakdown
Role A	Profile A	A	AA%
Role B	Profile B	B	BB%
Role C	Profile C	C	CC%
Role D	Profile D	D	DD%
Role E	Profile E	E	EE%
…	…	…	…
			Sum: 100%



Only 42% of CC limit actually consumed

For the same TOF mix, this missile could be flown an additional 136% of the full CC limit while remaining within qualification coverage.

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Conclusions

- The results produced from the developed methodology reflect the rate at which different Types of Flight (TOFs) consume the CC life (based on actual usage and exposure data)
- This represents an improvement to the current approach to missile lifing which assumes that each air carriage hour is equal in terms of damage to the weapon.
- This methodology can be used to recommend revised lifing estimates based on damage equivalencing between qualification testing and actual usage and exposure.

Limitations

- This is not a traditional life-extension assessment. It relies on a data-driven approach to improve the estimate of the actual consumed CC life which can, *with further assessments*, be used to establish revised lifing estimates that can extend weapon utilisation.

- This method addresses degradation mechanisms related to high cycle, mechanical fatigue. It does not consider the potential relevance of thermochemical or thermomechanical degradation mechanisms as well as low cycle fatigue.

- Recommendations provided to AEOSPO outlining potential improvements to missile tracking and ISS policy, for consideration as part of any future implementation decisions.

Questions?



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