Weaponised Uncrewed Aircraft Systems – The Rapid Evolution of Ordnance Application

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AIR WARFARE CENTRE – AIR FORCE

This slide pack contains material up to

OFFICIAL

Outline

- Overview and Problem Statement
- Weapon Danger Areas (WDA) / Range Danger Areas (RDA)
- Extant Policy and Direction
- **Proposal for Weapon Danger Area Development**
  - Overview
  - Individual Phases
  - Risk Management Approach
  - Summary
  - Limitations
- Questions

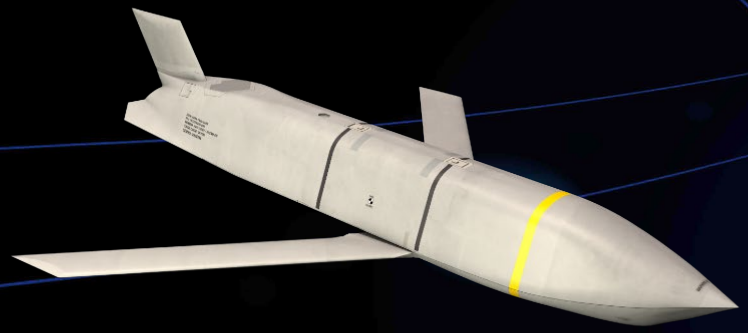
Overview

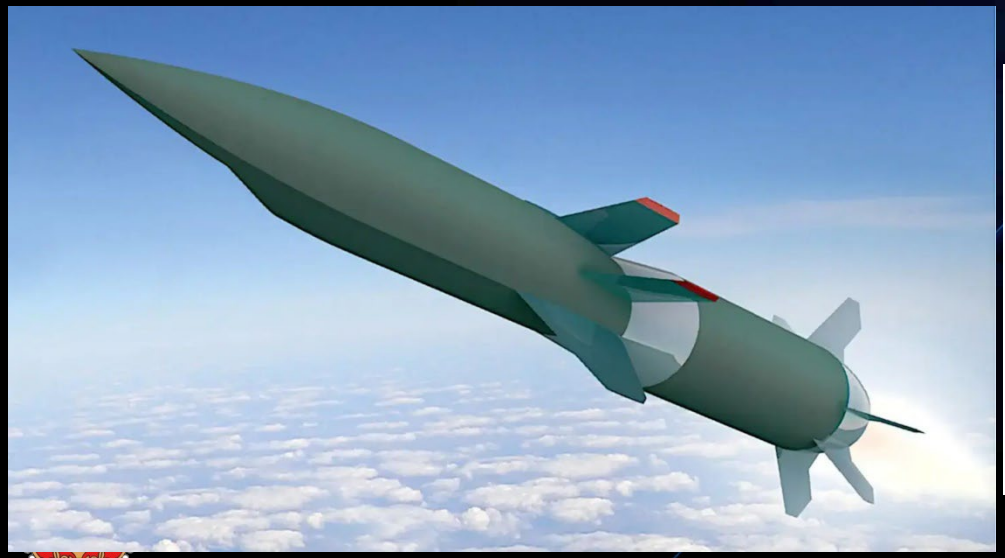
- The rapid evolution of Uncrewed Aircraft Systems (UAS) and the missions that they are expected to perform has seen Defence safety related policy being challenged.
- Weaponisation of UAS has accelerated, capability increasing rapidly
- Experience from active theatres being integrated into programs
- Outstripped safety systems and policy

Problem Statement

- Traditional Weapons
  - Significant Development periods
  - MOTS / Large OEMs / Big $$$
  - Fitted with Flight Termination System (FTS)
- Weaponised UAS
  - Rapid iterations from Small OEMs
  - Focus on costs / time
  - No ‘FTS’

What is the Risk?





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What is the Risk?

- UAS
  - Software not easily/always assessed
  - Hardware not certified to defined standards
- Fitted with kinetic warheads
  - Often developmental or adapting existing ordnance to new role / environment
- Long Ranges
  - Ability to exceed Range Boundaries
  - Use of batteries as primary power

What is the Risk (Continued)?

- Mass Effects
  - Swarming / Storming (failures / collisions expected?)
- Human in the Loop Guidance
- AI…
- New Launch Methods
  - UAS launching armed UAS
- T&E vs RTS Environment
- Woomera Test Range is big but not unpopulated
- All other Ranges are subject to harsher constraints

Extant Policy / Direction

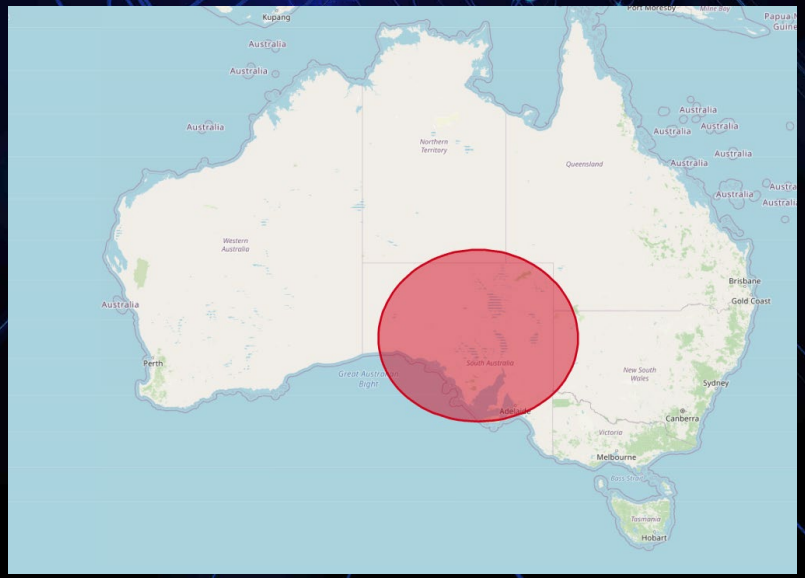
- WHS Act
- DASR UAS
  - DASR.UAS.50 (being rewritten)
- Defence Training Area Management Manual (DTAMM)
  - Rewrite inbound…
- Air Force Air Weapons Practice Manual (AFAWPMAN)
- Explosive Safety Regulatory Framework
- AWC Internal Processes
- Not a lot of information identified from Foreign Forces
- No single Authority responsible for Post Launch Weapon Safety

So where does that leave us?

- Users want to test weaponised UAS
- Ranges want to safely support testing
- Traditionally have three WDA/RDA options
  - Max Energy, Deterministic, and Probabilistic
- Cobble together solutions
  - Use smaller or discharged batteries
  - Restrictive flight envelopes
- What happens when these don't work…
- Handing over to WGCDR Ricciardi

Maximum Energy Boundary

- Maximum possible area
- Includes all reasonable failures
- A true total energy area that represents Zero Risk outside boundary
- Risk inside not quantified / managed
- Limited assumptions
- Least amount of computation
- Used whenever practicable



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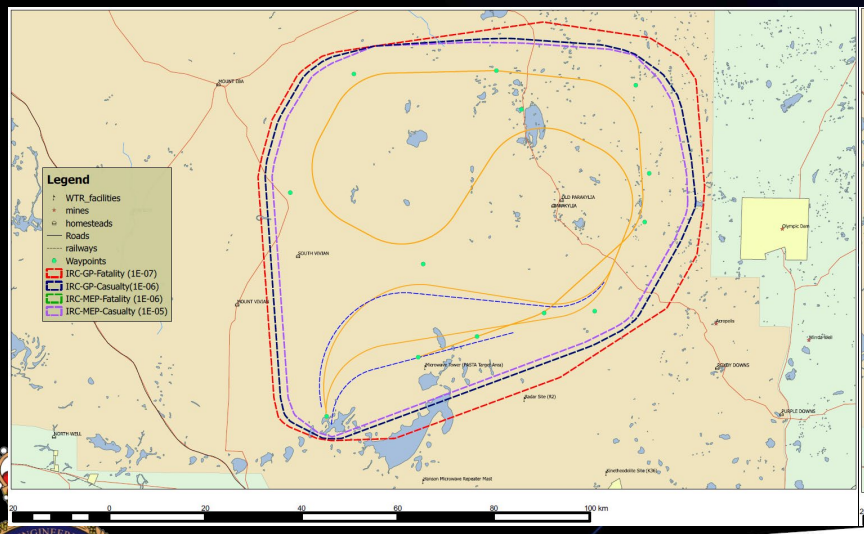
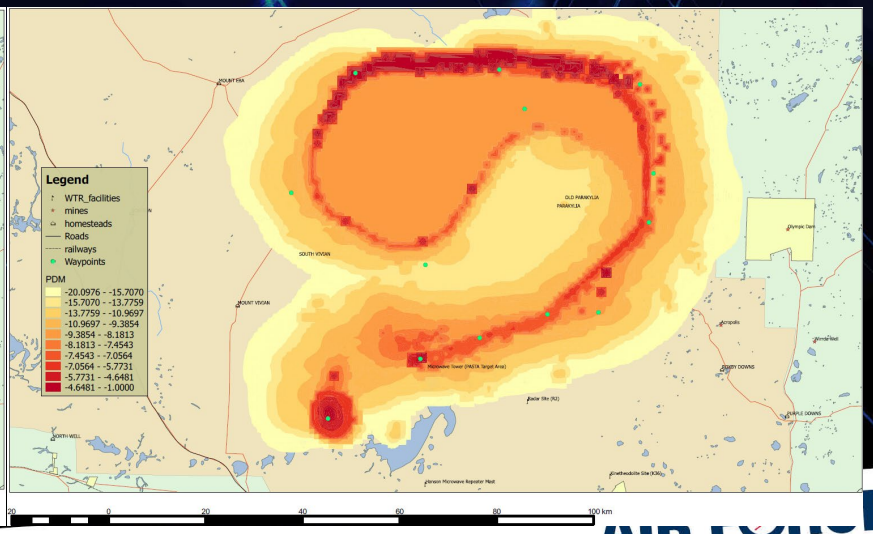
Probabilistic RDA Output

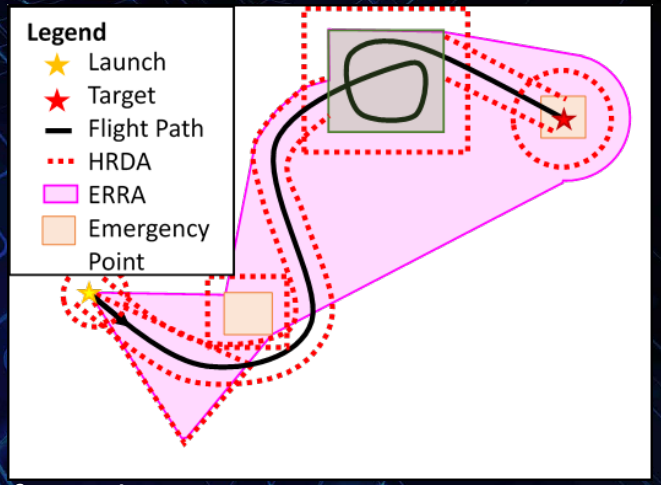
- Pro's: Generally produces the smallest possible danger area
  - Calculates Collective Risk for MEP and GP.
  - Individual Risk for GP and MEP satisfied through evacuation of blue dotted lines (i.e. RDA)
  - If required, heatmap can be used to **place or assess risk to MEP** within the RDA (e.g. JTACs)
- Con's: Requires a 6-DOF model (releasability issues)
  - 600k simulations and 2 million ground impacts for the example below
  - Considers Hardware failures only, Separate Software Risk Assessment required





Hybrid-Probabilistic RDA

- Deterministic exclusion zone (launch/flight/terminal phases):
- Considers three FRMs through the vehicle's flight path
  - Deterministic Glide Profile (i.e. best glide ratio)
  - Ballistic Descent Profile (i.e. simple point mass ballistic model)
  - Emergency/Recovery Risk Area (ERRA)
- Probabilistic Casualty Expectation
  - Assumes vehicle fly's to its Maximum Energy Boundary (MEB)
  - Leverages elements of the Annex F SORA casualty expectation formula
  - Quantifies risk to each population centre within the MEB
- Pros:
  - Does not require a HPC and 6DOF model, 1-3 weeks to generate (with all data available)
  - Software failures??? – (work in progress with DASA)
- Cons:
  - It assumes uniform probability of crashing at any point in space
  - Produces a collective risk value only, risk inside exclusion zone not quantified
- Larger than probabilistic



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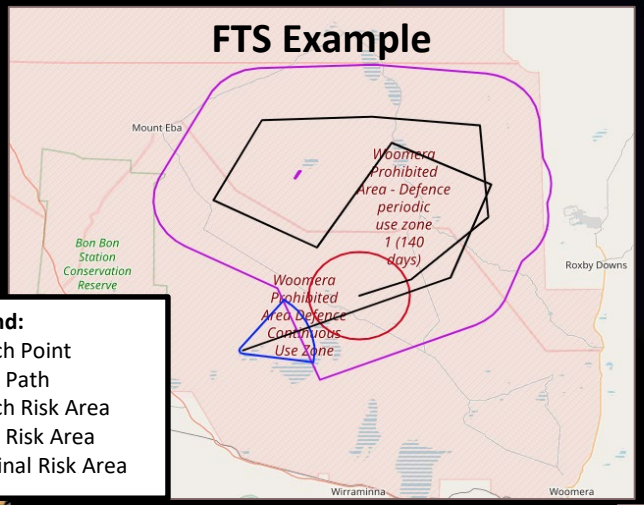
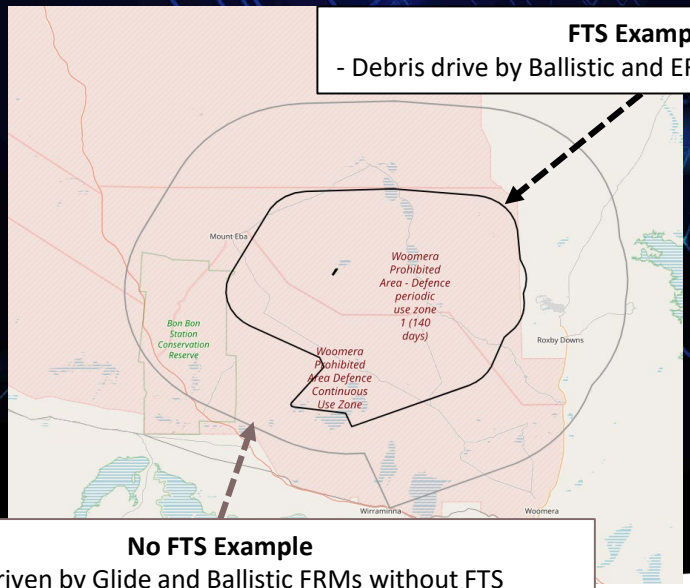
Hybrid RDA - Exclusion Zone Output

- HRDA Exclusion Zone must be fully evacuated (GP and MEP) and must lie within the Defence Practice Area (DPA) for use
  - If MEP are within the HRDA, the Risk Management Authority (RMA) must retain this risk and ensure sufficient protection is provided SFARP



Legend:
- Launch Point
- Flight Path
- Launch Risk Area
- Flight Risk Area
- Terminal Risk Area



FTS Example
- Debris drive by Ballistic and ERRA FRMs due to FTS

No FTS Example
- Debris driven by Glide and Ballistic FRMs without FTS
- this may also be interpreted as FTS failure

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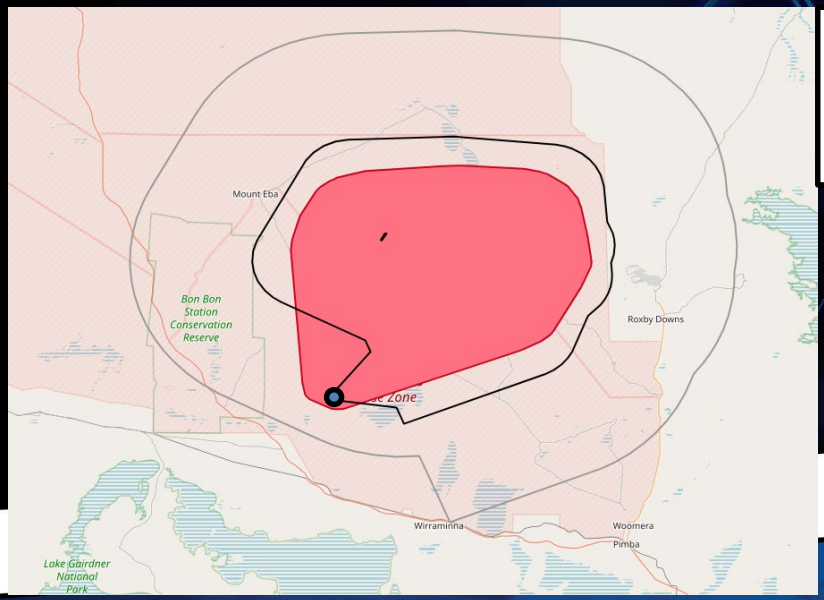
Comparison of PRDA and HRDA Exclusion Zones

- Key Differences:
  - Although the HRDA Exclusion Zone (FTS) does not contain the PRDA entirely, it has captured majority of the PRDA exclusion zone. This is due to the differing methodology in capturing ground impacts/risk.
  - HRDA Exclusion Zone (No FTS) captures the PRDA exclusion zone as it considers the failure of FTS activating
    - Note: PRDA consider FTS failure within modelling

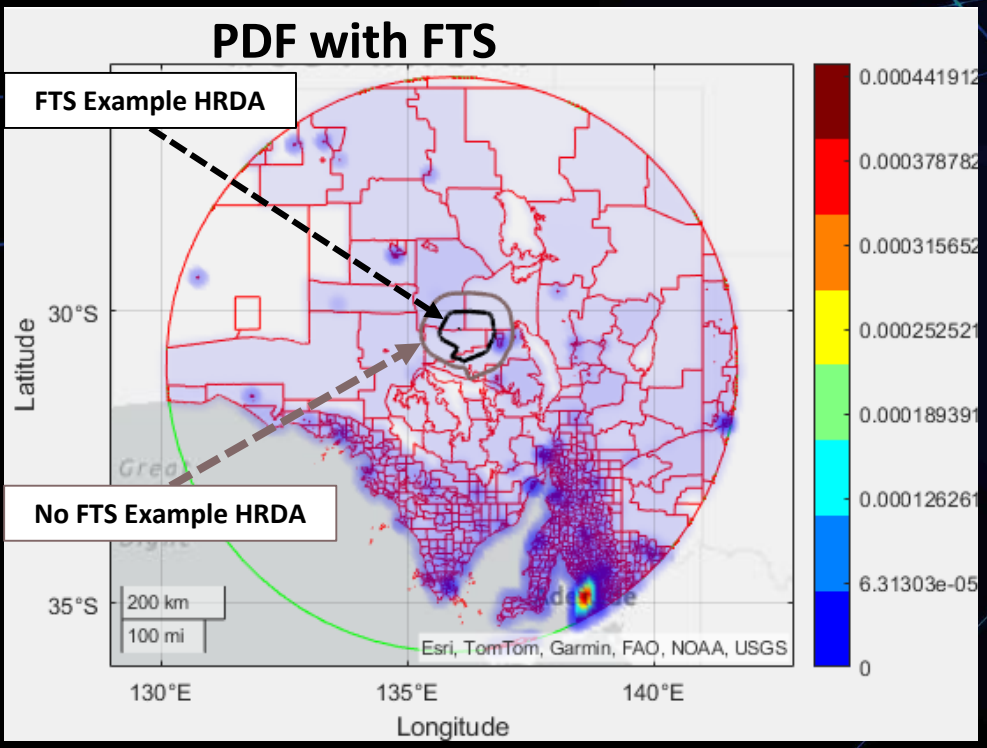


Calculating Casualty Expectation

- $EC = \lambda_{Fatality} = \lambda_{GI} \cdot \mathrm{D_{Pop}} \cdot F_{exp} \cdot A_C \cdot P(fatality|collision, LOC_{GI}) \cdot f_{containment} \cdot P_{warhead_f}$
- In this instance:
  - $\lambda_{Fatality}$ = Casualty Expectation,
  - λ_{GI} = Probably of loss of control leading to ground impact per flight hour,
  - $\mathrm{D_{Pop}}$ = Population Density per square km (considered across the MEB),
  - F_{exp} = fraction of people exposed to harm (1- shelter factor),
  - A_C = Critical Area (includes ricochet and fragmentation and explosions),
  - $P(fatality|collision, LOC_{GI})$ = probability of UAS causing a fatality,
  - $f_{containment}$ = percentage of failures to occur outside of the exclusion zone,
  - $P_{warhead_f}$ = likelihood of explosion due to fuze/warhead malfunction.

  - NB: this methodology usually assumes that a crash = warhead explosion

Hybrid RDA - Risk Calculation Output



- For our worked example:
- 24,906 population centres exposed to Maximum Energy Boundary (MEB)
- **With FTS system,** 294 population centres exceed the GP Collective Risk value
- Primarily the red hot spot of Adelaide
- **Without FTS system,** 18,973 population centres exceeds risk threshold

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Decision-to-Proceed Authorities

	Current	Proposed in AFAWPM	
Residual Risk	Authority	Residual Risk Level	Authority
Potential weapon effects extend beyond a DA with the probability of third-party casualty or damage to critical public infrastructure exceeding the safety criteria thresholds.	Minister for Defence (MINDEF)	Very High	Chief of Air Force (3*)
Potential weapon effects extend beyond a DA with the probability of third-party casualty equal or below the safety criteria thresholds. The probability of casualty for MEP and damage to critical assets may exceed the safety criteria thresholds provided a defensible training requirement and suitable SFARP judgement exists. Overflight of non-Defence land or sea is planned.	Service Chiefs (CA/CAF/CN)	High	ACAUST (2*)
Potential weapon effects extend beyond a DA with the probability of casualty or damage to critical assets equal or below the safety criteria thresholds. No planned overflight.	Training Area Operational Authority (TAOA)	Medium	(1*)
Potential weapon effects are either wholly contained within a DA or so low as not to present a credible hazard to third-parties, MEP or critical assets.	Range Control Officer (RCO)	Low	Range Control Officer not below O-5
As per Low		Very Low	Range Control Officer not below O-5

Additional Risk Mitigations

- Relocate launch point and/or waypoints
- Reduce the operational altitude and ToF
- Targeted evacuations
- Establish a sheltering plan
  - an agreement with industry (e.g. mining industry) located within the area of interest to be adequately sheltered during an activity
- Certification of warhead/insensitive munition
- Certification of Independent FTS
- Parachute FTS

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Are we SFARP?

- International Standards exist for Deterministic / Probabilistic methodologies
- No collective agreement on ‘other methods’ as yet
  - JARUS Specific Operational Risk Assessment/ RCC-323 address Range Safety for UAS but not weaponised

- Maximum Energy Boundary/Deterministic = risk eliminated
- Probabilistic Danger Area= risk quantified/mitigated
- To be SFARP we have to show that both of these options are not reasonably implementable before we consider the Hybrid probabilistic approach

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QUESTIONS?

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