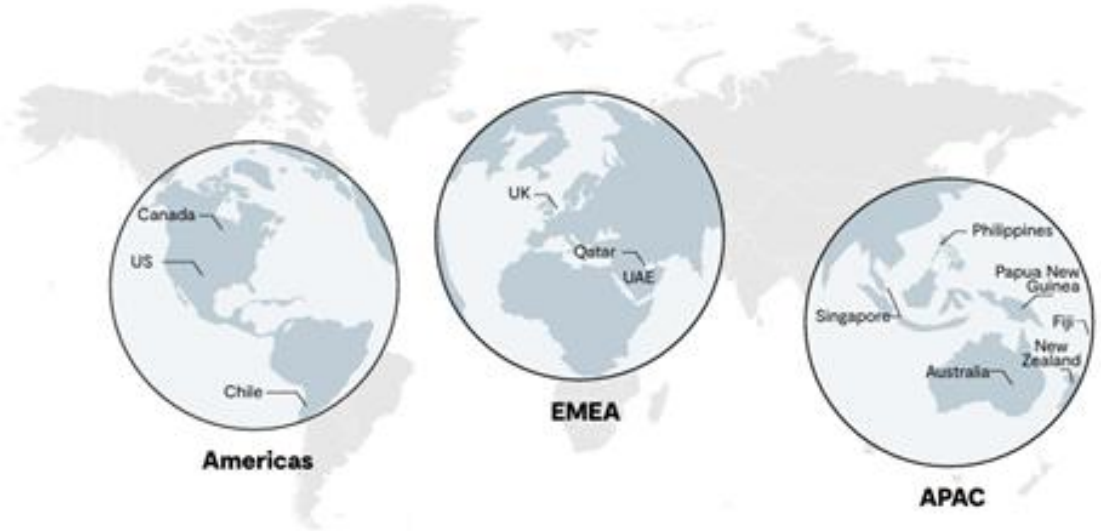
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Explosive Ordnance Storage in Constrained Sites - Challenges and Responses

Welcome

Beyond boundaries

↳ Driven by global knowledge that is delivered proficiently, with agility, to meet your needs.





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Agenda

- Why Explosive Ordnance siting is challenging
- History of siting Explosive Storage Facilities (ESF)
- ESF siting method – current policy
- Other considerations for design
- Qualitative Risk Assessment
- Modelling – technical considerations



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Why EO Siting is now a strategic design problem

- EO demand and larger systems place pressure on existing storage capacity.
- Land scarcity and urban encroachment reduce space previously available
- QD and safeguarding protect people, facilities, public areas and Defence's future licensed capacity.
- Protective structures can improve land-use efficiency, but bring cost, constructability and maintenance consequences.
- The required response is multidisciplinary and through-life, not an EO-planning exercise in isolation.

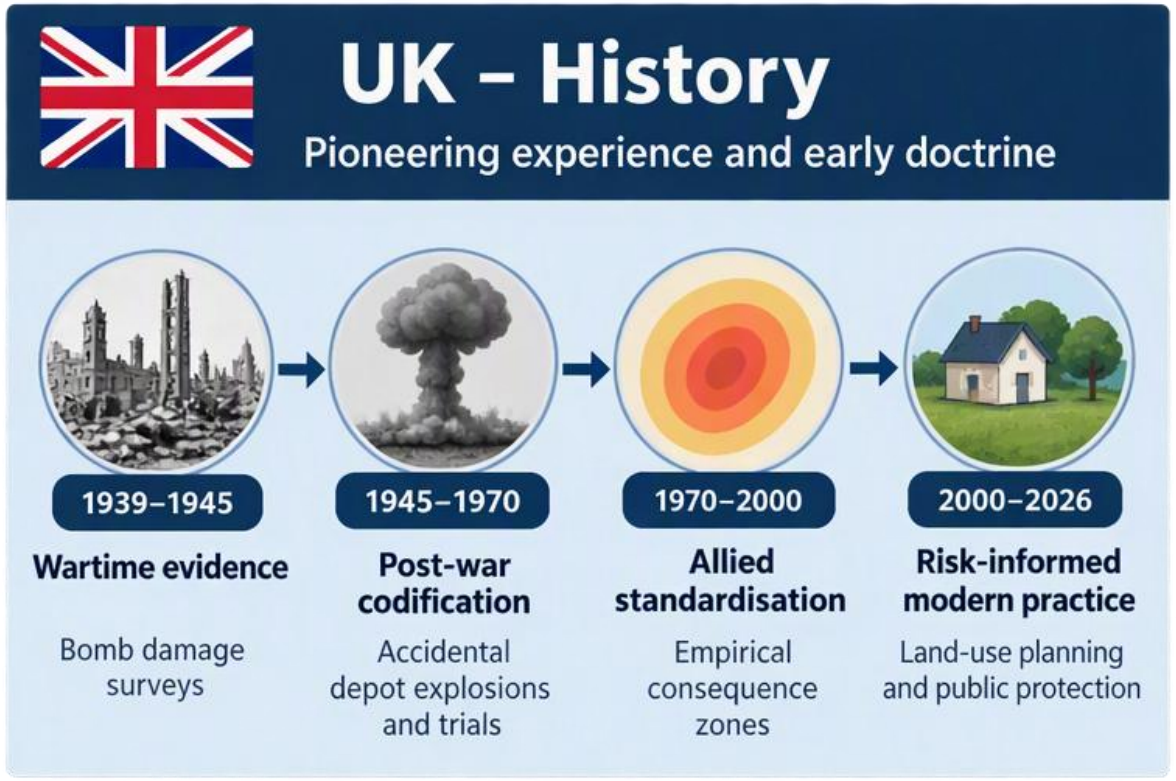
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Challenges in siting EO facilities

- New safeguarding arcs that may intersect boundaries or future development.
- Existing buildings, roads, services, environmental constraints, terrain and neighbouring land uses constrain new builds
- Competing needs for safety separation, secure access, vehicle movement, utilities and operational efficiency.
- Remote locations may assist separation but increase logistics, maintenance and workforce constraints.

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Historical review – United Kingdom



- WWII created a large observational evidence base: the Bomb Census recorded weapon type, location, casualties and building damage, with selected incidents receiving technical investigations.
- Post-war doctrine formalised donor/acceptor concepts, propagation control, public protection and construction-specific allowances.
- Further post war testing improved understanding of effects
- UK safeguarding extended explosives safety into land-use planning: safeguarding maps trigger consultation on development around licensed military explosives areas
- Current direction is further UK–NATO convergence.

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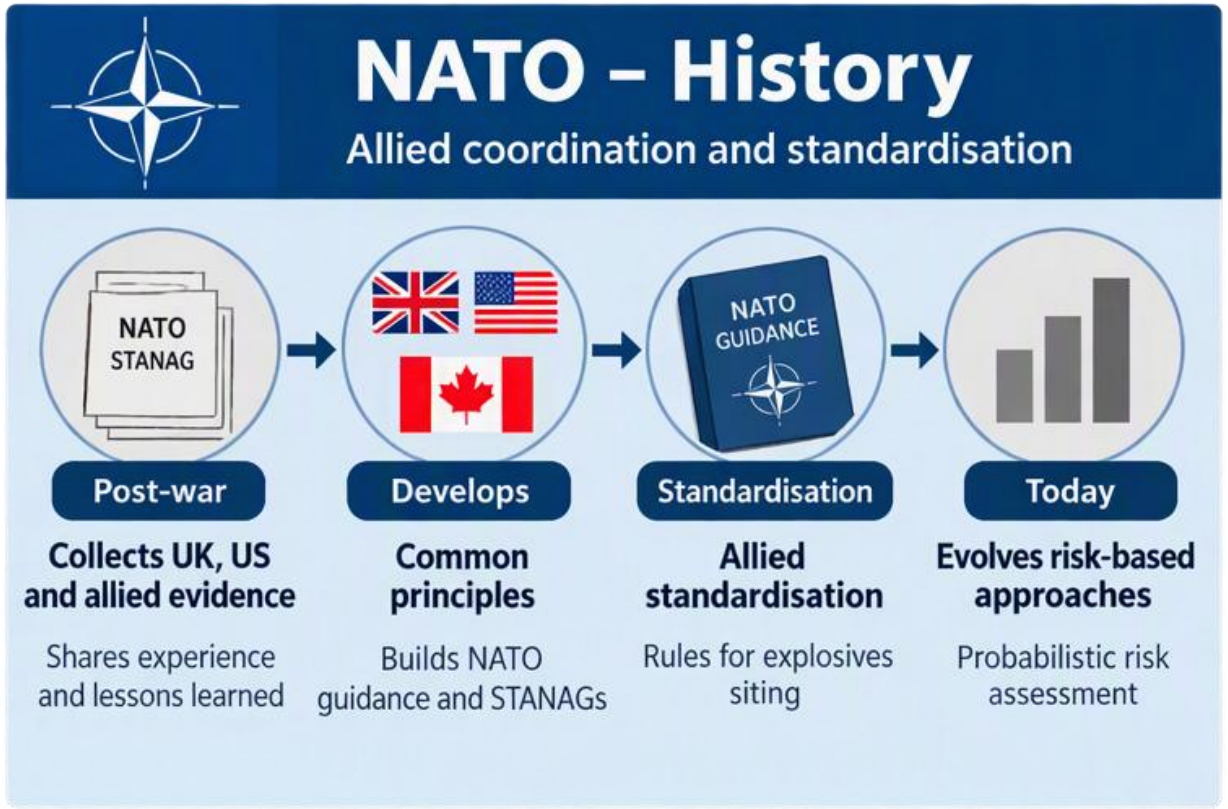
Historical review - Australia



- Wartime Australian depots visibly used dispersion and earth traverses as safety measures.
- Post-war practice increasingly drew on NATO concepts and joint UK–Australian Woomera trials addressing blast, debris and structural response.
- Continual updating of Defence Explosive Ordnance Publication 101 as the Australian Defence policy – standardisation with NATO standards
- Defence's thematic review of Commonwealth explosive regulations with movement towards a principles-based framework focused on individuals, community and environment.
- Australian decision-making has a strong estate/community interface where safeguarded areas interact with land outside Defence control.

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Historical review - NATO



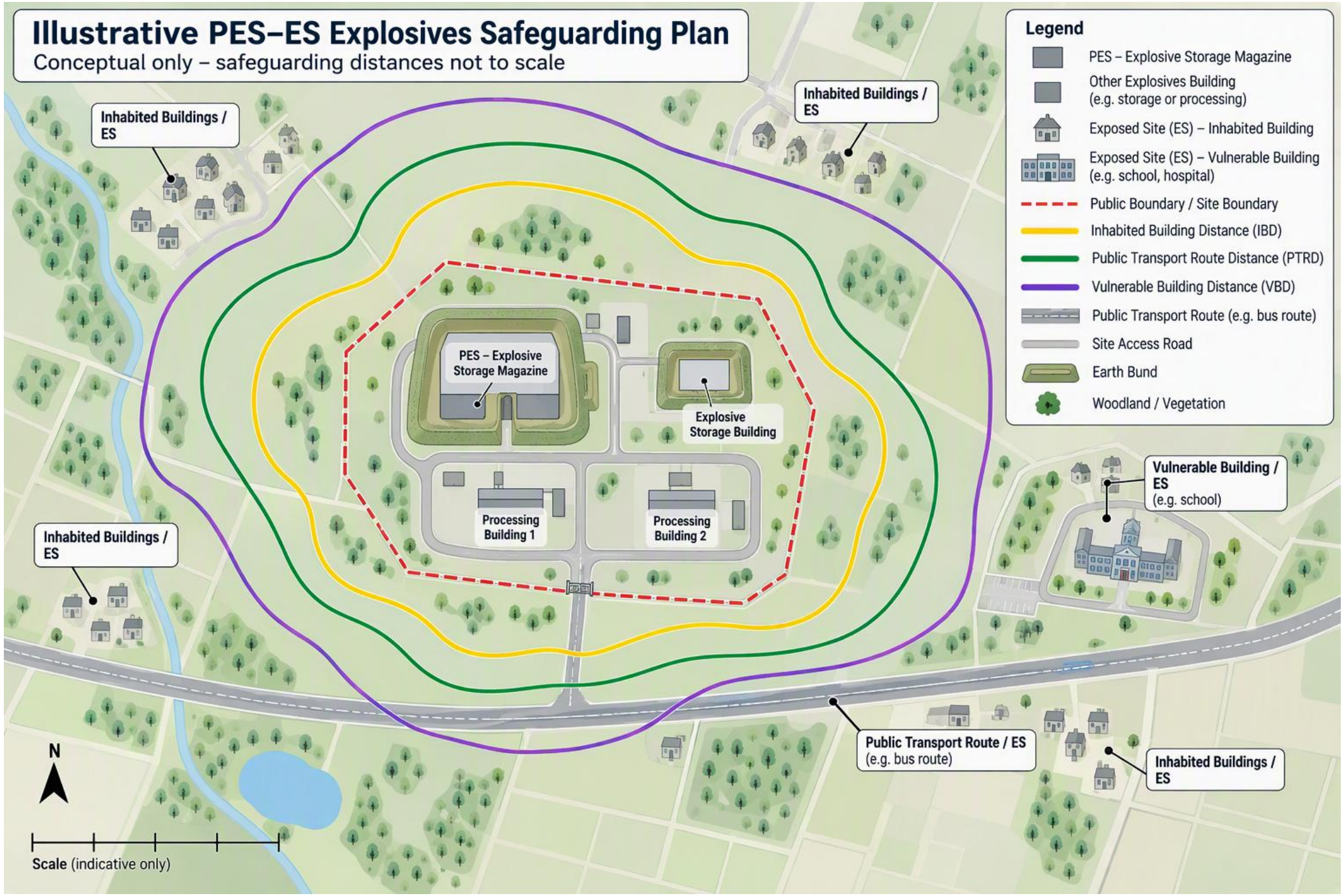
- NATO standardised terminology, donor–acceptor relationships and allied protection objectives.
- AASTP-1 addresses storage guidance; the currently listed AASTP-1 Edition D / STANAG 4440 Revision 4 was promulgated on 4 November 2025.
- NATO QDs aim to provide an acceptable protection level at an ES following an accidental event at a PES—not guaranteed absence of damage or injury.
- Effect-specific logic considers blast, fragments, structural debris and thermal hazards.
- When AASTP-1 or AASTP-5 requirements cannot be met, NATO policy calls for the ESMRM risk-assessment/risk-management process described in ALP-16

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Explosive Storage – Terms

- **PES (Potential Explosive Site):** the location capable of generating the credible accidental explosive event.
- **ES (Exposed Site):** a facility, building, route, person group, public area or infrastructure exposed to its effects.
- **QD (Quantity Distance):** a standardised separation relationship intended to achieve a defined protection outcome for a PES–ES pairing.
- **Propagation prevention:** reducing the prospect that an event at one location promptly affects adjacent EO (prevent cascading events).
- **Protection level:** the intended consequence outcome; it is not synonymous with “no damage”.
- **Safeguarding:** preserving the storage capacity on a site over time by controlling or consulting on incompatible development

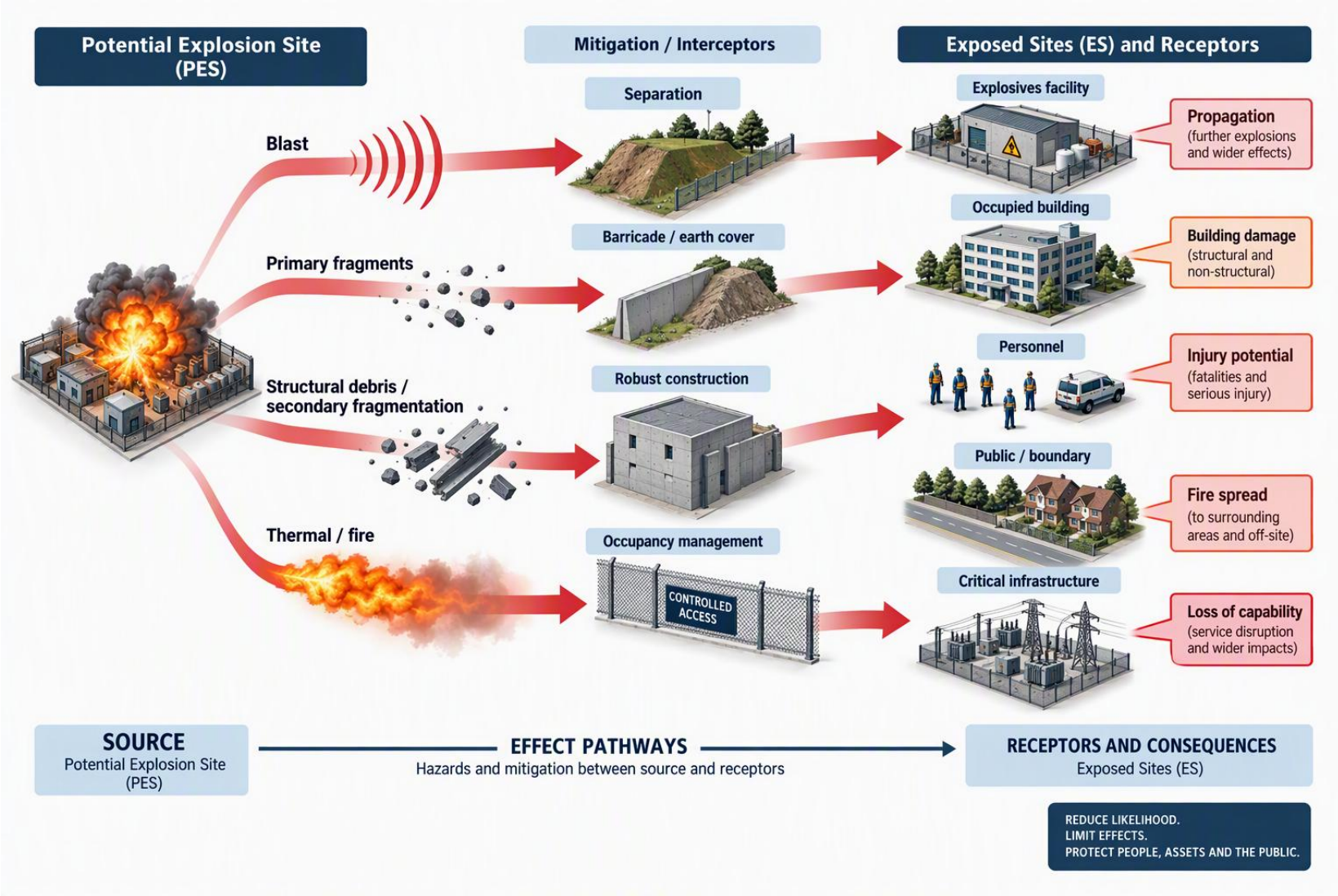
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Illustrative PES–ES Explosives Safeguarding Plan
Conceptual only – safeguarding distances not to scale
Legend
PES – Explosive Storage Magazine
Other Explosives Building (e.g. storage or processing)
Exposed Site (ES) – Inhabited Building
Exposed Site (ES) – Vulnerable Building (e.g. school, hospital)
Public Boundary / Site Boundary
Inhabited Building Distance (IBD)
Public Transport Route Distance (PTRD)
Vulnerable Building Distance (VBD)
Public Transport Route (e.g. bus route)
Site Access Road
Earth Bund
Woodland / Vegetation
Inhabited Buildings / ES
Inhabited Buildings / ES
PES – Explosive Storage Magazine
Explosive Storage Building
Processing Building 1
Processing Building 2
Vulnerable Building / ES (e.g. school)
Inhabited Buildings / ES
Public Transport Route / ES (e.g. bus route)
Inhabited Buildings / ES
N
Scale (indicative only)

Consequence of PES explosion

High-level PES-to-ES consequence pathways:

– explosion effects reach different exposed sites, while separation, protective construction and exposure controls affect risk



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Factors implied in QD siting at exposed sites

- Blast generation at PES
- Primary fragments and secondary debris that can cause injury.
- Number of people, duration of occupancy and tolerance of risk of occupants.
- Protection provided by ES
- Explicit risk analysis requires an understanding of likelihood, occupancy, vulnerability, aggregation and uncertainty

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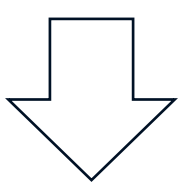
Direct Qualitative Risk Assessment compared to Quantity Distance Tables

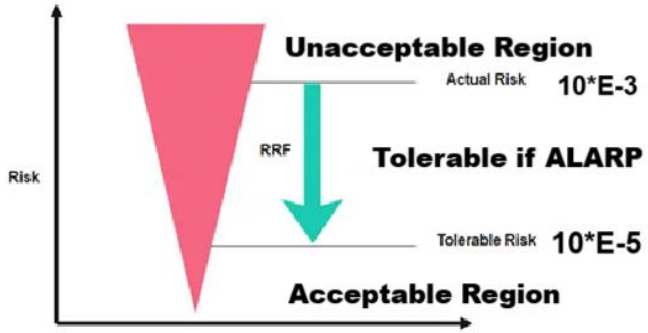
$$\text{Prob fatality}_{\text{indiv}}\ (Pf_i) = P_{\text{explosion}} \times (Pf_{\text{blast|exp}} + Pf_{\text{primary frag|exp}} + Pf_{\text{secondary frag|exp}} + Pf_{\text{thermal|exp}}) \times P_{\text{exposure}}$$

$$\mathbf{Pf_{blast|exp} = Pf(P_s, I_s)\ ;\ Pf_{frag|exp} = Pf(\text{density fragments}, KE_{frag})\ \text{etc}}$$

Prob fatality site (P_f) = $\sum_0^i P$

OR





QD = aNEQ^b where a and b are functions of PES / ES combination

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Design elements that mitigate risk

- **Separation:** arrange PES and ES relationships to interrupt escalation and reduce effects.
- **Prevention/propagation control:** reduce likelihood of initiation and sympathetic involvement through appropriate safety, compartmentation and system controls.
- **Resistance:** improve the response of exposed buildings, façades, openings, services and critical equipment.
- **Exposure management:** reduce the number of people present and cumulative time in higher-consequence areas.
- **Operations:** Maintain access, egress, handling, emergency response and operational usability. Manage storage requirements with operational needs.

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Other design considerations

→ Interoperability and global requirements

EEUM requirements

- Confirm applicable transfer agreements and item-specific requirements early; do not assume one generic EEUM standard.
- Translate requirements into facility needs for physical security, controlled access, accountability and record interfaces.
- Provide safe and practical arrangements for authorised inspection and inventory verification.
- Coordinate security zoning with EO safety, operations, fire response and maintainability.
- Preserve auditable configuration and responsibilities through design, commissioning and use.

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Explosive Risk Assessment Workflow

1 Plan & Define



- Define needs and functional requirements
- Identify site, constraints and access
- Use existing information and lessons learned

OUTPUT
Design brief and site context

2 Develop Concept



- Create layout and zoning options
- Consider safety, security, MHE and access
- Engage key disciplines (structural, services, etc.)

OUTPUT
Preferred concept and layout

3 Engineer & Refine



- Develop structural, modular and services design
- Assess constructability, risk and compliance
- Optimise options and confirm design

OUTPUT
Developed design ready for review

4 Review & Approve



- Internal technical review
- Safety, quality and independent assurance
- Confirm compliance with EEUM and relevant standards
- Approve prototype design

OUTPUT
Approved CDR design

5 Build Prototype



- Construct prototype outside CDR stage
- Test and validate design
- Capture outcomes for future bulids

OUTPUT
Prototype complete and lessons learned

Key outcomes

- Safe and compliant design
- Deliverable and cost-effective
- Evidence-based decisions
- Repeatable for future projects

Building safer explosive storage for tomorrow.

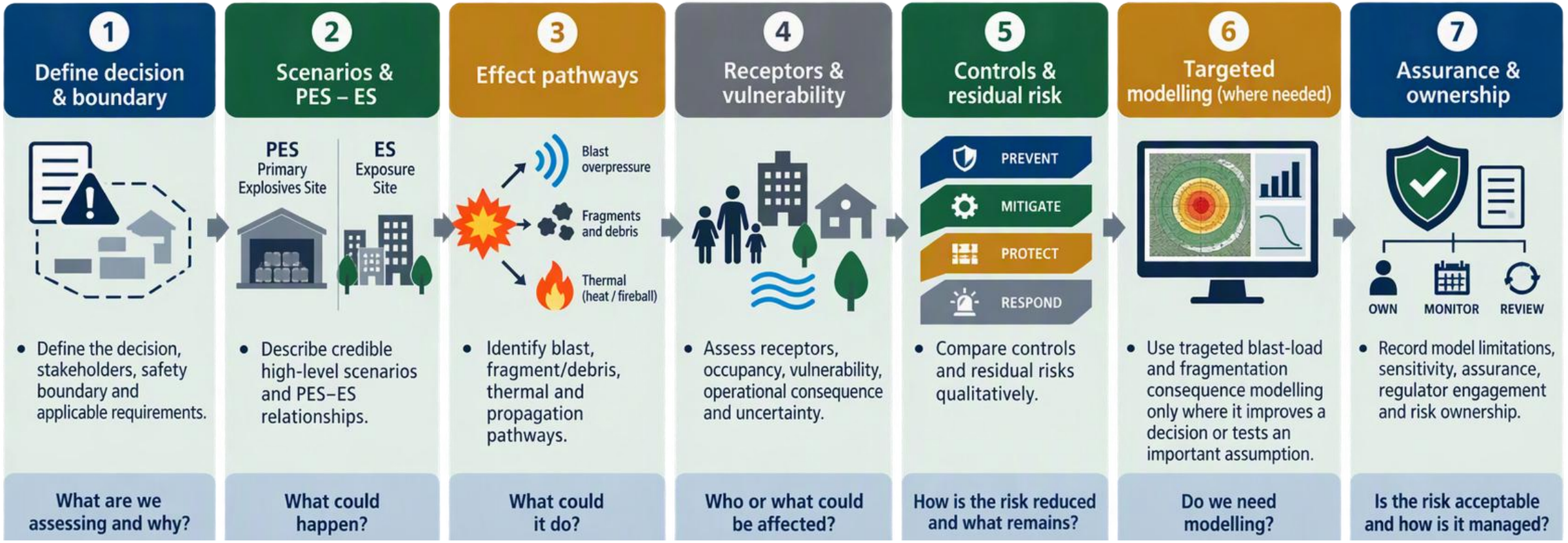
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Whole of Life and Operational value

- Capital cost
- Maintenance cost
- Surge capacity
- Operational use
- Constructability and program
- Resilience

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Explosive Risk Assessment Workflow



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Modelling

- Modelling Blast
- Primary and Secondary fragments
- Modelling effects of fragments



Modelling Blast Effects on Buildings

Method	Best used for	Strengths	Limitations
Engineering / simplified methods	Initial screening and relatively simple blast environments	Fast, transparent and efficient for comparing options	Limited representation of complex geometry, shielding and multiple reflections
Computational Fluid Dynamics (CFD)	Blast propagation around buildings, barriers and complex sites	Captures reflections, diffraction, shielding, channelling and complex geometric interactions	Computationally intensive; sensitive to geometry, mesh, boundaries and assumptions
Finite Element Analysis (FEA)	Dynamic response of buildings and structural components	Models deformation, nonlinear behaviour, connections, local damage and potential failure	Requires reliable material and boundary models; detailed failure analysis can be demanding

CFD predicts the blast load • FEA predicts the structural response

Primary Fragmentation and Secondary Building Debris

Characteristic	Primary Fragments	Secondary Building Debris
Origin	Fragments associated directly with the EO event	Walls, roofs, doors, glazing, fittings and other building elements affected by the event
Source model	Approved test evidence or validated fragment-source characterisation	Structural response and failure predicted using FEA or validated engineering methods
Propagation	Particle / trajectory modelling	Debris trajectory or rigid-body modelling following debris generation
Key influences	Directionality, shielding, terrain and intervening structures	Structural failure mode, debris generation, shielding and building configuration
Typical output	Relative fragment exposure and affected receptor areas	Debris distribution and potential consequences at exposed sites

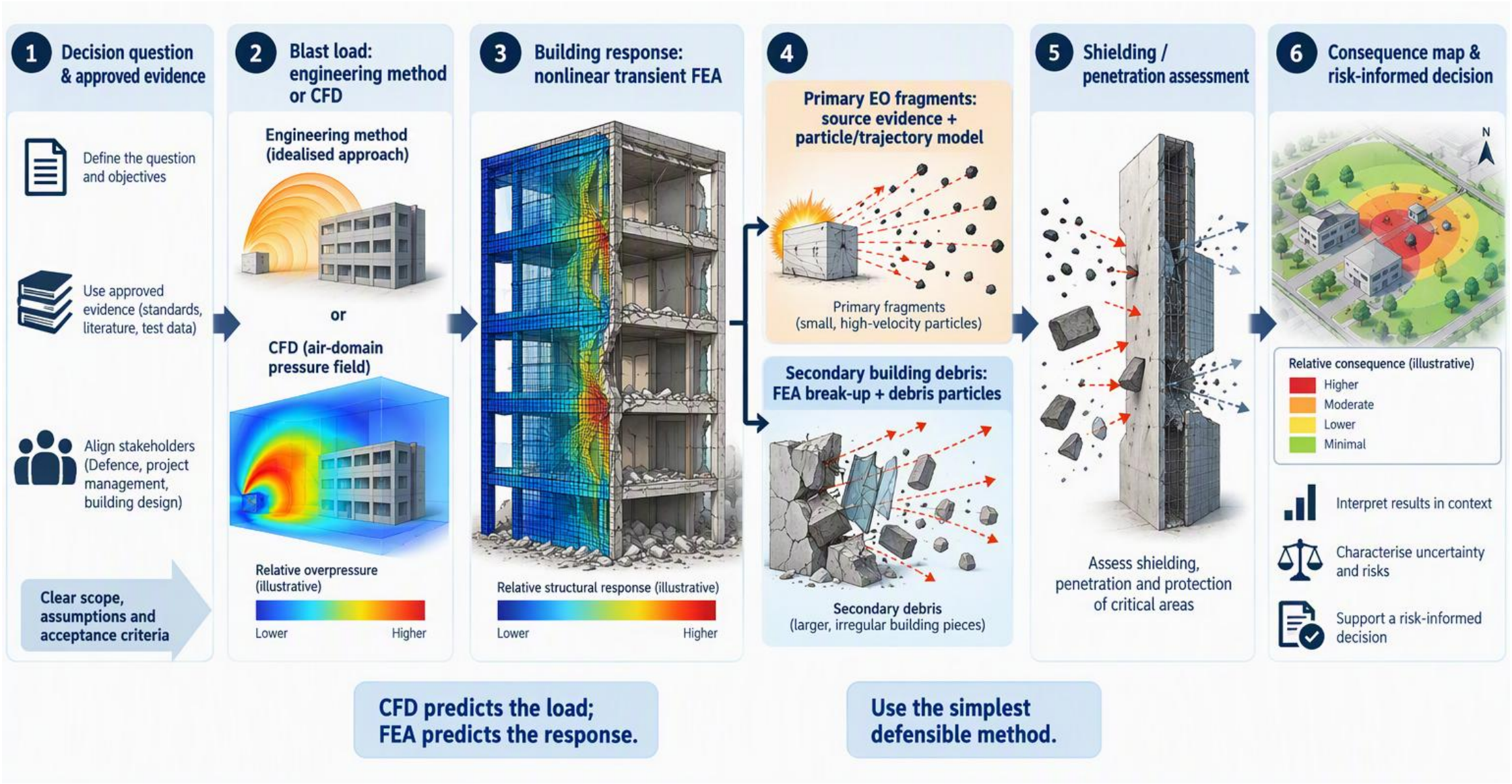
Model and report primary fragments and secondary debris separately — their origins, uncertainties and controls differ.

Modelling Fragment Penetration into Structures

Approach	Appropriate use	Strengths	Limitations
Empirical / semi-empirical methods	Initial penetration or perforation screening	Fast and grounded in applicable test evidence	Limited to the material, geometry and failure regimes represented by the supporting evidence
Analytical resistance models	Concept comparison and sensitivity assessment	Transparent and computationally efficient	Simplifies complex material, interface and local failure behaviour
Nonlinear explicit FEA	Important barriers or unusual structural configurations	Represents contact, deformation, local damage and material failure mechanisms	Computationally demanding and sensitive to material, failure, contact and mesh assumptions
Meshfree / particle methods	Severe deformation and material breakup	Handles large deformation and material separation	Greater computational and validation demands than simplified approaches
Hybrid FE–particle methods	Detailed local impact within a larger structural model	Combines efficient structural analysis with detailed local impact modelling	Transition between modelling approaches requires careful verification and validation

Screen first → identify governing cases → apply detailed modelling selectively → validate

Modelling chain for accidental explosions



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Summary

- EO storage planning and design is becoming more complex
- QD method (empirical) is well understood and accepted BUT
- Important designers understand the risks implied in this method AND
- Requirements other than siting need to be considered
- Qualitative Risk Assessments are possible – but complicated
- Modelling will require agreed methodology and assumptions

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Thank you

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