Part I/Risk-Based Siting Criteria – Current and Future Efforts in Risk Management and Siting Applications

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PART II: Will go into further details on the future development of Risk Methodology for Siting

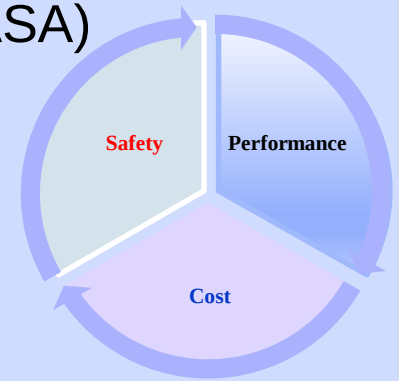
Other papers in this Symposium will discuss science improvements

Background

- Quantity-Distance (QD) criteria have been used as the primary means for the safe siting of facilities for more than 70 years.

- 20+ years of DDESB involvement in Risk-Base for Explosives Safety

- Other governing and policy setting entities that are continuing to collaborate with the DDESB:
  - Range Commanders Council (RCC)
  - Institute of Maker of Explosives (IME)
  - North Atlantic Treaty Organization (NATO)
  - National Aeronautics and Space Administration (NASA)
  - The Bureau of Alcohol, Tobacco
  - Firearms and Explosives (ATF)
  - Coast Guards and even in the United Nations
  - The Department of Homeland Security

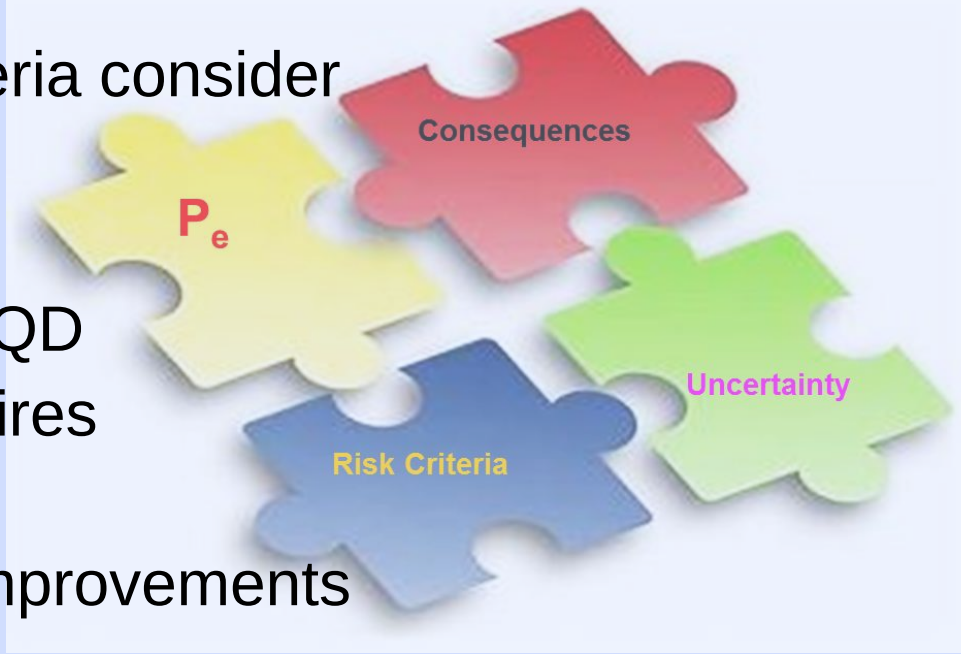


ESMRM Policy Implemented

- DoDD 6055.09E *Explosives Safety Management*
- DoDI 6055.16 *Explosives Safety Management Program*
- DoDM 6055.09 *Ammunition and Explosives Safety Standards*
- Joint Staff Policy on ESMRM
- ESMRM Implementation
- DODD 5000 *The Defense Acquisition System*
- Mil-STD 882E *Department of Defense Standard Practice – System Safety*
- Office of Management and Budget, Circular No. A-123, *Management's Responsibility for Enterprise Risk Management and Internal Control,15 July 2016.*
- DoD Instruction 6055.01, *DoD Safety and Occupational Health (SOH) Program,14 October, 2014*
- OSHA *29 CFR 1910 Process Risk Management*
- *NFPA 495- : Explosives Materials Code, 2016.*

Considerations of QD and Risk-Base for Siting

- Quantity Distance (QD) criteria consider
  - Explosives quantity
  - Hazard Division (HD), and
  - Facility type to determine QD
  - Risk-Base for Siting-Requires
    - more input and the
    - answer is a significant improvements



$$Risk = Probability\ of\ Event \times Consequences \times Exposure$$

$$Risk = P_f = P_e \times P_{f|e} \times E_p$$

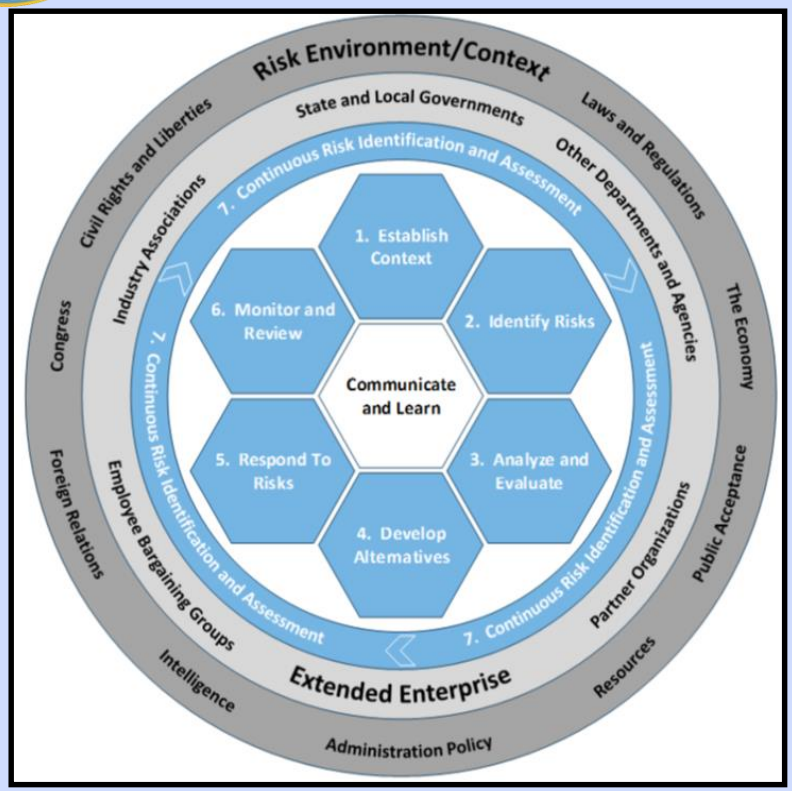
P_e =probability that an explosives mishap will occur at a potential explosion site (PES) in a year

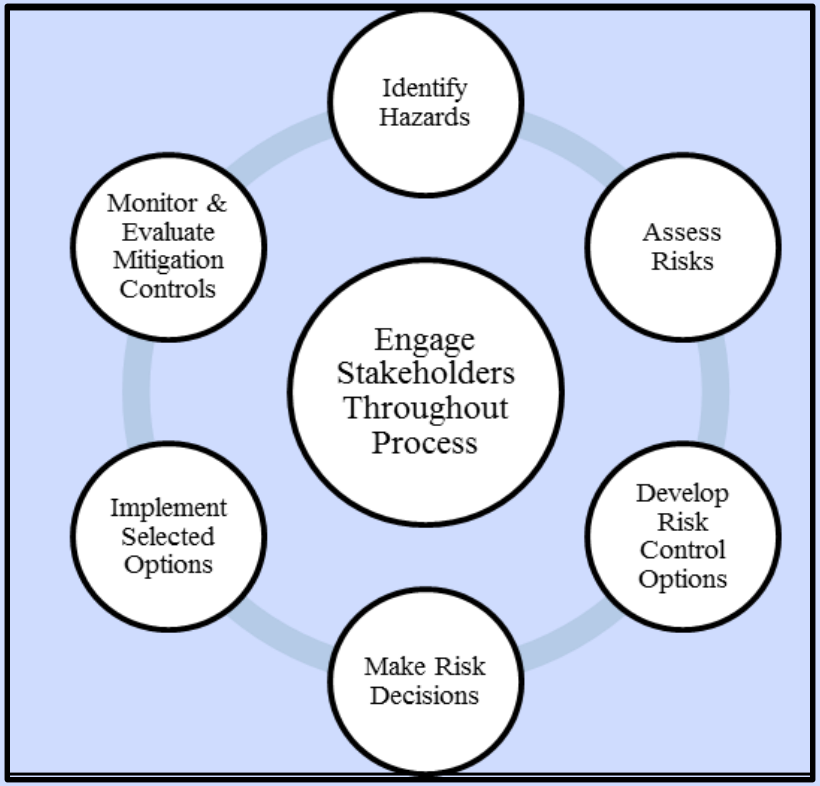
$P_{f|e}$ = probability of fatality given an explosives event and the presence of a person

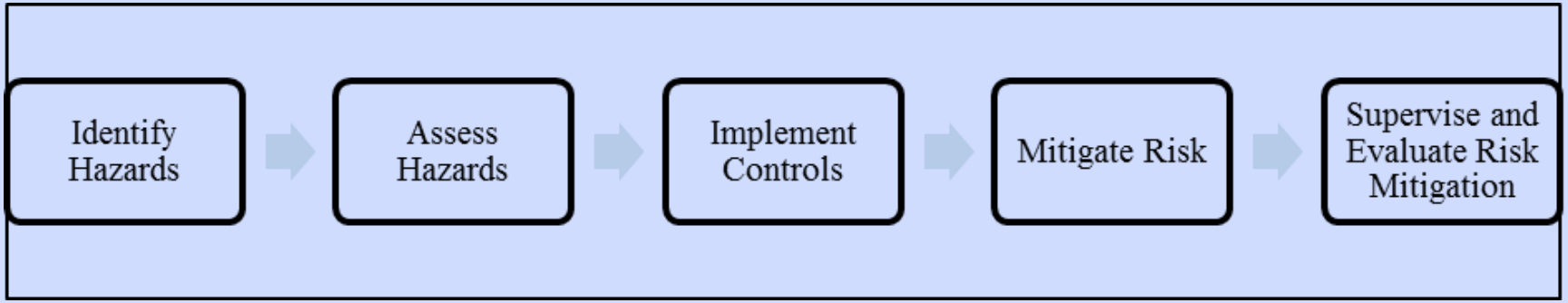
E_p = the exposure of one person (as a fraction of a year) to a PES on an annual basis

For Risk-base siting see Technical Paper 14 DDESB web site https://ddesb.altess.army.mil/

OMB vs DOD Risk Management Process



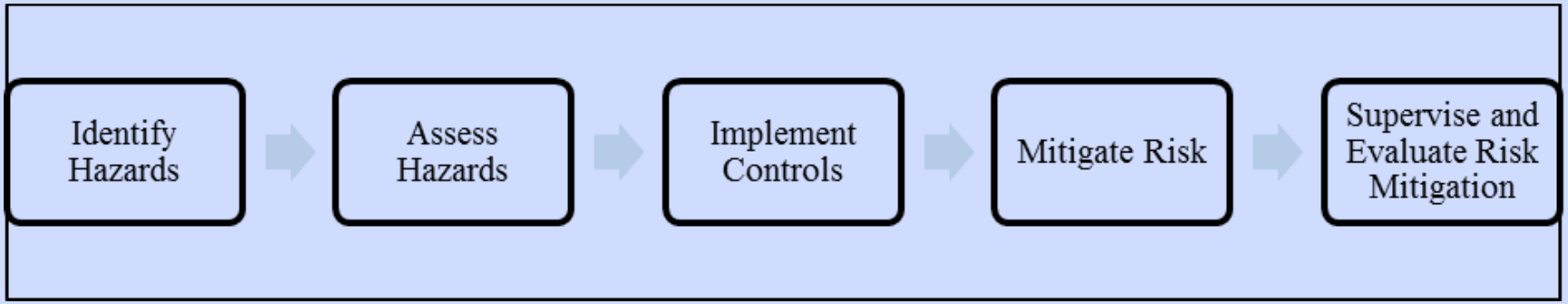




ESMRM Considerations Throughout the Acquisition Lifecycle

- Materiel Solution Analysis
- Technology Maturation and Risk Reduction- Siting
- Production and Deployment
- Operations and Support
- Disposal

Siting Facilities TP-14 ⟺ Risk Management TP-23



Risk Assessment Matrix

TP-23

Risk Assessment Method

(•) Injuries and $ loss ( ) Injuries and % damage

Severity	A - Frequent	B - Likely	C - Occasional	D - Seldom	E - Unlikely
I - Catastrophic	EH(1)	EH(1)	H(2)	H(2)	M(3)
II - Critical	EH(1)	H(2)	H(2)	M(3)	L(4)
III - Moderate	H(2)	M(3)	M(3)	L(4)	L(4)
IV - Negligible	M(3)	L(4)	L(4)	L(4)	L(4)

Description	Symbol	RAC	Color
Extremely High	EH	1	
High	H	2	
Moderate	M	3	
Low	L	4	

Matrix for : Total Risks
Probability : Unlikely
Severity : Catastrophic
RAC : M(3)
Note: based on injuries and $ loss

Probability	SEVERITY			
	Catastrophic (1)	Critical (2)	Marginal (3)	Negligible (4)
Frequent (A)	High	High	Serious	Medium
Probable (B)	High	High	Serious	Medium
Occasional (C)	High	Serious	Medium	Low
Remote (D)	Serious	Medium	Medium	Low
Improbable (E)	Medium	Medium	Medium	Low
Eliminate (F)	Eliminate			

Mil-STD 882E

Risk Management --Munition Specific Risk Categories

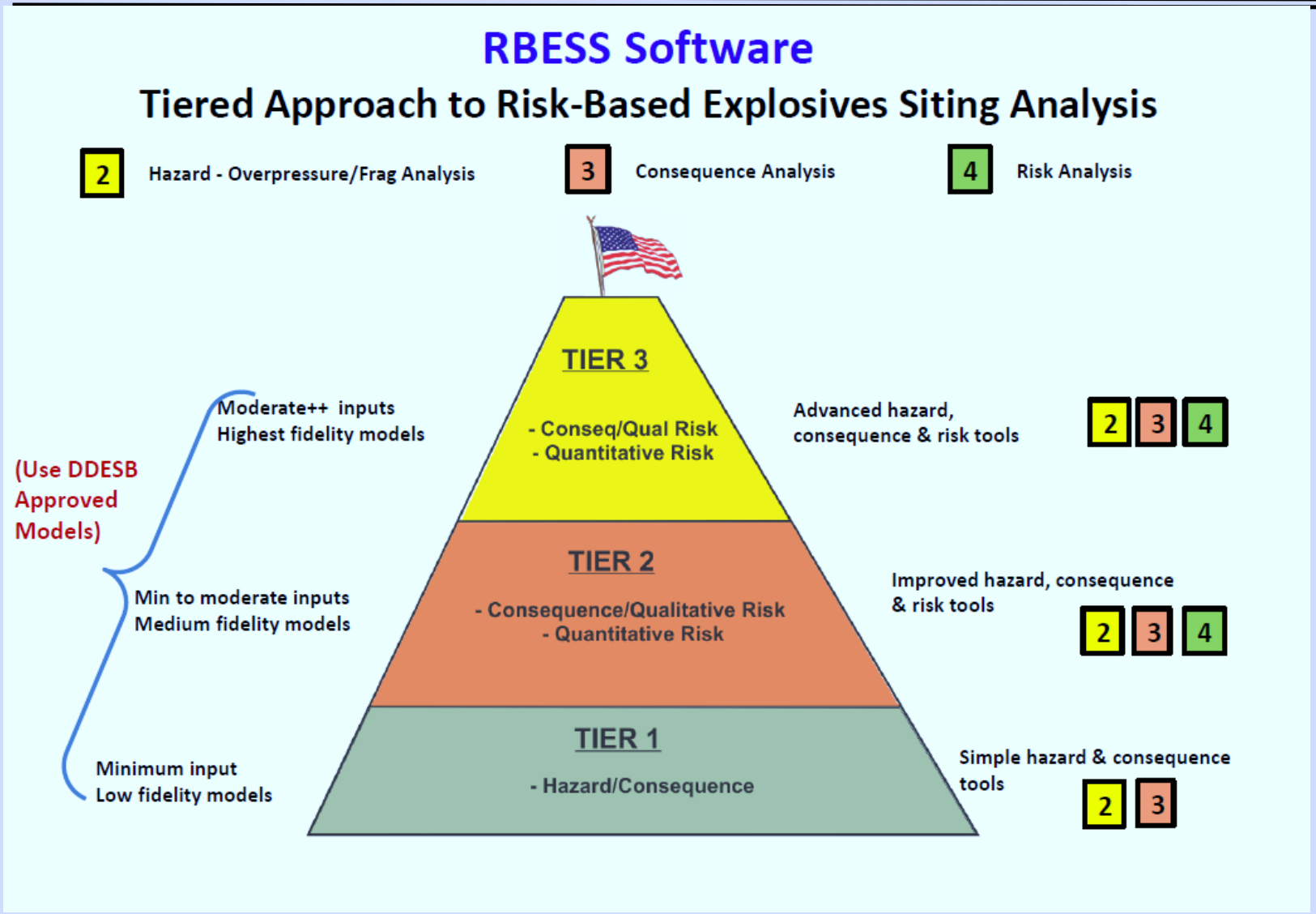
Probability Levels Specific for Munition Related Mishaps

PES Used Primarily For:	* Probability:
Burning Ground / Demilitarization / Demolition / Disposal/EOD	OCCASIONAL
Assembly / Disassembly / LAP / Maintenance / Renovation	REMOTE
Lab / Test /RDTE	REMOTE
Training	REMOTE
Missile System in Static Mode	IMPROBABLE
Manufacturing/Production	IMPROBABLE
Inspection / Painting / Packing/	IMPROBABLE
Loading / Unloading/ Handling (Ships, Aircraft, Vehicles, Container Stuffing/Unstuffing)	REMOTE
Short Term Storage (hrs – few days)	IMPROBABLE
Temporary Storage (1 day - 1 month)	IMPROBABLE
Deep Storage (1 month - year)	IMPROBABLE
Munitions and Explosives of Concern	OCCASIONAL

Description	Category	Definition
Catastrophic	**1**	Mission Failure One or more deaths and/or serious injuries of individuals not meeting quantity-distance criteria.
Critical	**2**	Mission Interrupted Multiple serious injuries of individuals not meeting quantity-distance criteria.
Marginal	**3**	Mission Degraded Minor injuries of individuals not meeting quantity-distance criteria.
Negligible	**4**	Mission Unaffected No anticipated injuries and/or other effects for individuals not meeting quantity-distance criteria.

Severity Categories

Risk Base Explosives Safety Siting (RBESS) Software



Siting Facilities TP-14 ⟷ **Risk Management TP-23**

DDESB Risk Tools

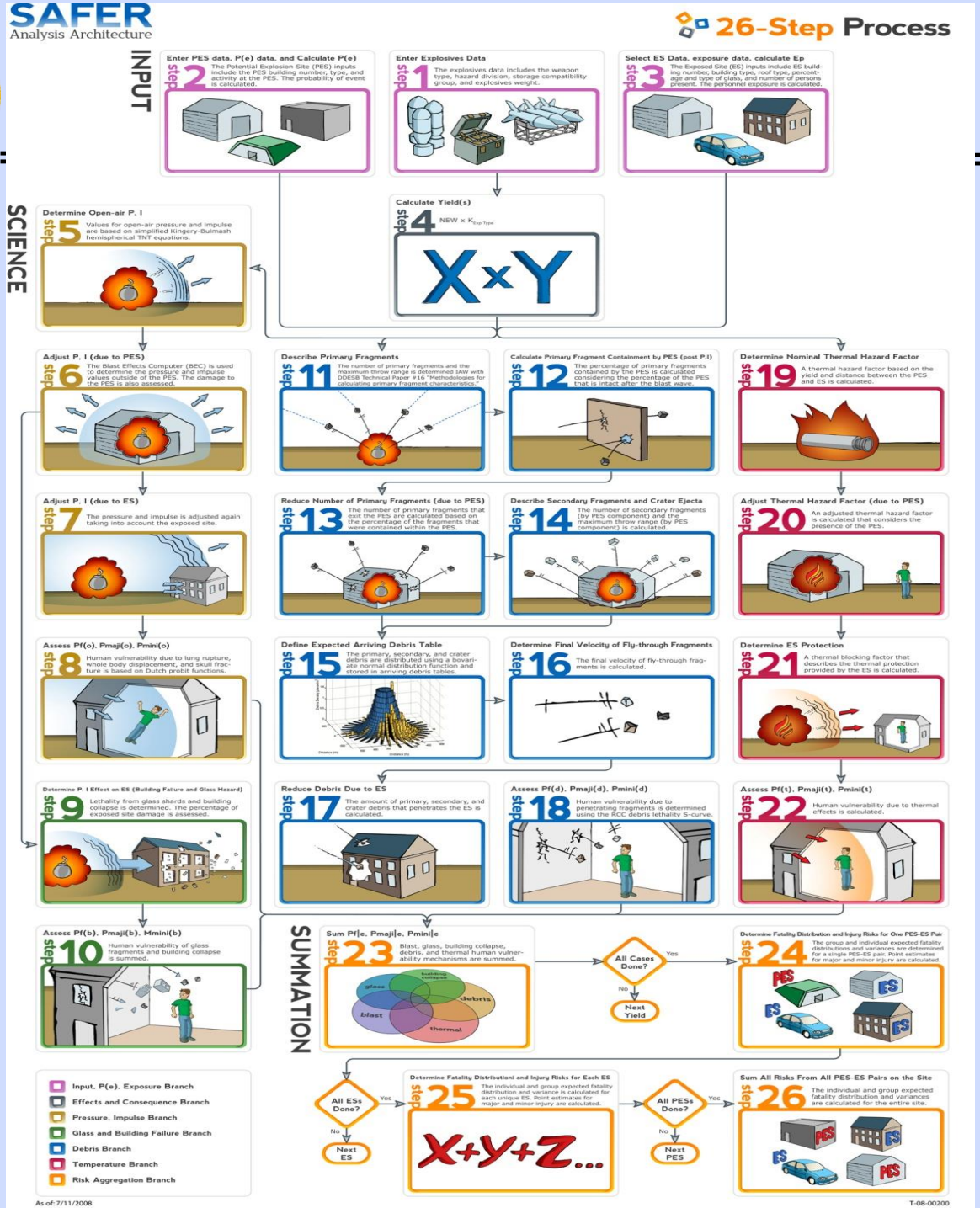
Analysis Level	Tool	App Type	Resp Org	Documentation	Analysis Results
Tier 1					
Consequences based on 6055.9M damage descriptions	ASAP-X	Spreadsheet	DDESB	TP23	$loss, #injuries/fatalities
	CNRI	Spreadsheet	DDESB	???	$loss, #injuries/fatalities
	S/CNRI	GUI/Spreadsheet	???	???	$loss, #injuries/fatalities
	HAZX/ASAP-X	GUI/GIS	ACTA	Users Guide with tech info	%damage, $loss,%/# minor/major injuries, DARAD, various GIS
	RBESS/ASAP-X	GUI/GIS	EXWC	RBESS Draft?	%damage, $loss,%/# minor/major injuries, DARAD, various GIS
	RBESS/MRAS/ASAP-X	GUI/GIS	EXWC	RBESS Draft?	%damage, $loss,%/# minor/major injuries, DARAD, various GIS
Tier 2a					
Consequences based on DDESB TP14	HAZX/TP14	GUI/GIS	ACTA	Users Guide with tech info	%damage, $loss,%/# minor/major injuries, DARAD, Risk Matrix/RAC, various GIS displays
	RBESS/TP14	GUI/GIS	EXWC	RBESS Draft?	%damage, $loss,%/# minor/major injuries, DARAD, Risk Matrix/RAC, various GIS displays
	FASTSITE	Spreadsheet	APT	Users Guide	%damage, $loss,%/# minor/major injuries, other graphic displays
	SAFER V3.2	GUI/GIS	APT	TP19	%damage, $loss,%/# minor/major injuries, other graphic displays
Tier 2b					
Consequences based on DDESB TP14	SAFER V3.2	GUI/GIS	APT	TP19	%damage, $loss,%/# minor/major injuries, other graphic displays
	HAZX	GUI/GIS	ACTA	Users Guide with tech info	%damage, $loss,%/# minor/major injuries, other graphic displays
Tier 3					
Consequences based on PES/Weapon specific data	HAZX	GUI/GIS	ACTA	Users Guide with tech info	%damage, $loss,%/# minor/major injuries, other graphic displays

Risk-Based Explosives Safety Siting (RBESS) Module

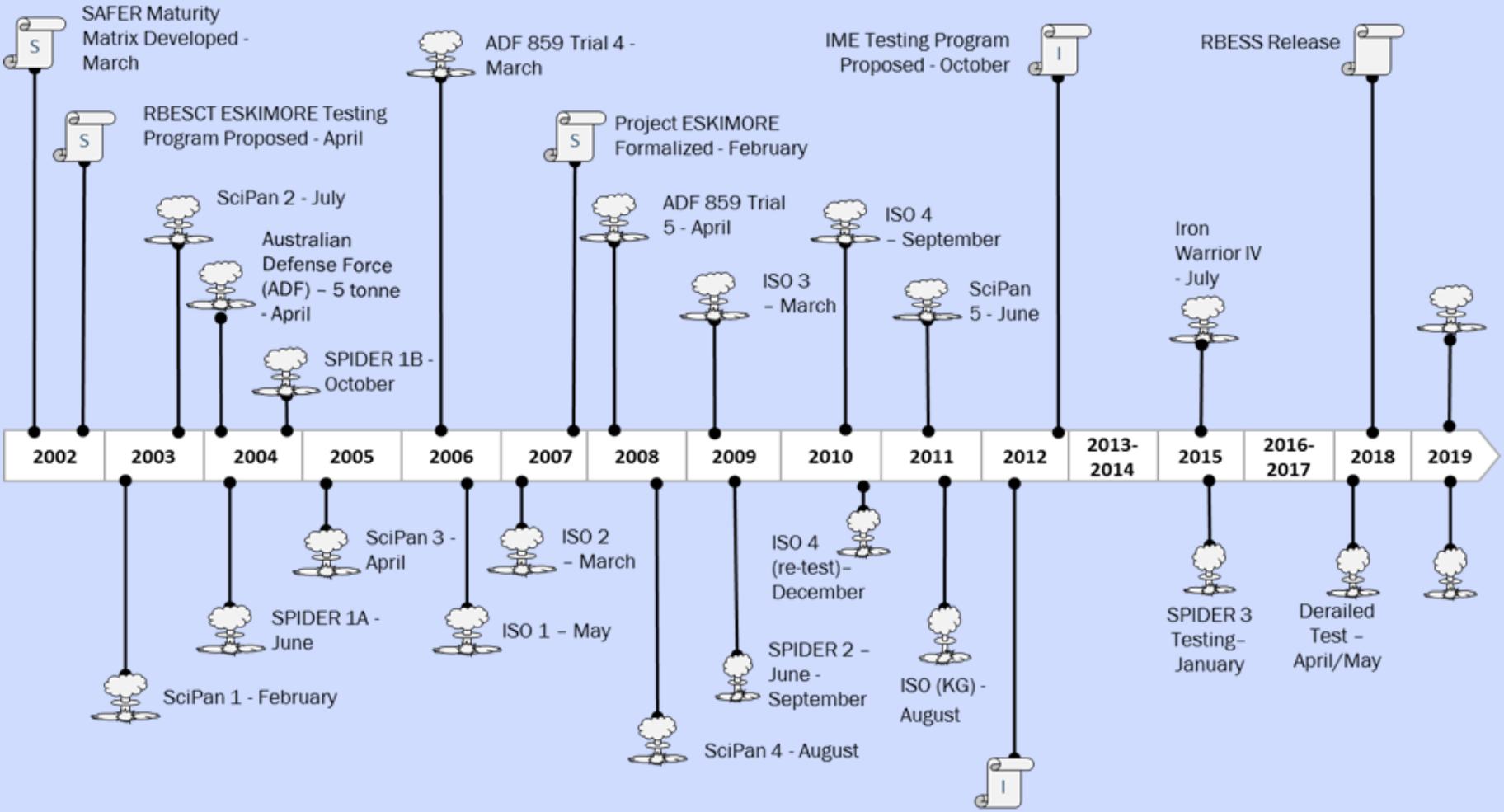
- QD engine modules
- ASAP-X (Tier 1),
- MRAS (Tier 1),
- Fast-Site (Tier 1),
- TP-14 type tool (Tier 2a) HAZX Risk Tool (Tier 2a),
- **Quantitative Risk Analysis TP14-based – SAFER**

TP-14 Six Functional Groups

Group 1	Steps 1-4	Situation Definition, Event and Exposure Analyses Includes user inputs that describe the situation (PES and ES) and calculates Pe, exposure, and yield
Group 2	Steps 5-8	Pressure and Impulse Branch Calculates the magnitude of the fatality mechanisms of pressure and impulse
Group 3	Steps 9-10	Structural Response Branch Calculates the magnitude of the fatality mechanisms of building collapse and broken windows (overall building damage)
Group 4	Steps 11-18	Debris Branch Calculates the magnitude of the fatality mechanisms for multiple types of flying debris
Group 5	Steps 19-22	Thermal Branch Calculates the magnitude of the fatality mechanism heat for HD 1.3 scenarios only
Group 6	Steps 23-26	Aggregation and Summation Aggregates the total magnitude and risks of all fatality mechanisms, calculates the desired measures of risk, and assesses overall uncertainty


SAFER
Analysis Architecture
26-Step Process
INPUT
SCIENCE
SUMMATION
step 1 Enter Explosives Data
The explosives data includes the weapon type, hazard division, storage compatibility group, and explosives weight.
step 2 Enter PES data, P(e) data, and Calculate P(e)
The Potential Explosion Site (PES) inputs include the PES building number, type, and activity at the PES. The probability of event is calculated.
step 3 Select ES Data, exposure data, calculate Ep
The Exposed Site (ES) inputs include ES building number, building type, roof type, percentage and type of glass, and number of persons present. The personnel exposure is calculated.
step 4 Calculate Yield(s)
NEW x K Exp Type
X x Y
step 5 Determine Open-air P, I
Values for open-air pressure and impulse are based on simplified Kingery-Bulmash hemispherical TNT equations.
step 6 Adjust P, I (due to PES)
The Blast Effects Computer (BEC) is used to determine the pressure and impulse values outside of the PES. The damage to the PES is also assessed.
step 7 Adjust P, I (due to ES)
The pressure and impulse is adjusted again taking into account the exposed site.
step 8 Assess Pf(o), Pmaji(o), Pmini(o)
Human vulnerability due to lung rupture, whole body displacement, and skull fracture is based on Dutch probit functions.
step 9 Determine P, I Effect on ES (Building Failure and Glass Hazard)
Lethality from glass shards and building collapse is determined. The percentage of exposed site damage is assessed.
step 10 Assess Pf(b), Pmaji(b), Mmini(b)
Human vulnerability of glass fragments and building collapse is summed.
step 11 Describe Primary Fragments
The number of primary fragments and the maximum throw range is determined IAW with DDESB Technical Paper #16 "Methodologies for calculating primary fragment characteristics."
step 12 Calculate Primary Fragment Containment by PES (post P,I)
The percentage of primary fragments contained by the PES is calculated considering the percentage of the PES that is intact after the blast wave.
step 13 Reduce Number of Primary Fragments (due to PES)
The number of primary fragments that exit the PES are calculated based on the percentage of the fragments that were contained within the PES.
step 14 Describe Secondary Fragments and Crater Ejecta
The number of secondary fragments (by PES component) and the maximum throw range (by PES component) is calculated.
step 15 Define Expected Arriving Debris Table
The primary, secondary, and crater debris are distributed using a bovariate normal distribution function and stored in arriving debris tables.
step 16 Determine Final Velocity of Fly-through Fragments
The final velocity of fly-through fragments is calculated.
step 17 Reduce Debris Due to ES
The amount of primary, secondary, and crater debris that penetrates the ES is calculated.
step 18 Assess Pf(d), Pmaji(d), Pmini(d)
Human vulnerability due to penetrating fragments is determined using the RCC debris lethality S-curve.
step 19 Determine Nominal Thermal Hazard Factor
A thermal hazard factor based on the yield and distance between the PES and ES is calculated.
step 20 Adjust Thermal Hazard Factor (due to PES)
An adjusted thermal hazard factor is calculated that considers the presence of the PES.
step 21 Determine ES Protection
A thermal blocking factor that describes the thermal protection provided by the ES is calculated.
step 22 Assess Pf(t), Pmaji(t), Pmini(t)
Human vulnerability due to thermal effects is calculated.
step 23 Sum Pf|e, Pmaji|e, Pmini|e
Blast, glass, building collapse, debris, and thermal human vulnerability mechanisms are summed.
glass
building collapse
debris
blast
thermal
All Cases Done?
Yes
No
Next Yield
step 24 Determine Fatality Distribution and Injury Risks for One PES-ES Pair
The group and individual expected fatality distributions and variances are determined for a single PES-ES pair. Point estimates for major and minor injury are calculated.
PES
ES
All ESs Done?
Yes
No
Next ES
step 25 Determine Fatality Distributionl and Injury Risks for Each ES
The individual and group expected fatality distribution and variance is calculated for each unique ES. Point estimates for major and minor injury are calculated.
X+Y+Z...
All PESs Done?
Yes
No
Next PES
step 26 Sum All Risks From All PES-ES Pairs on the Site
The individual and group expected fatality distribution and variances are calculated for the entire site.
Input, P(e), Exposure Branch
Effects and Consequence Branch
Pressure, Impulse Branch
Glass and Building Failure Branch
Debris Branch
Temperature Branch
Risk Aggregation Branch
As of: 7/11/2008
T-08-00200

Time Line for Science Improvements for TP-14

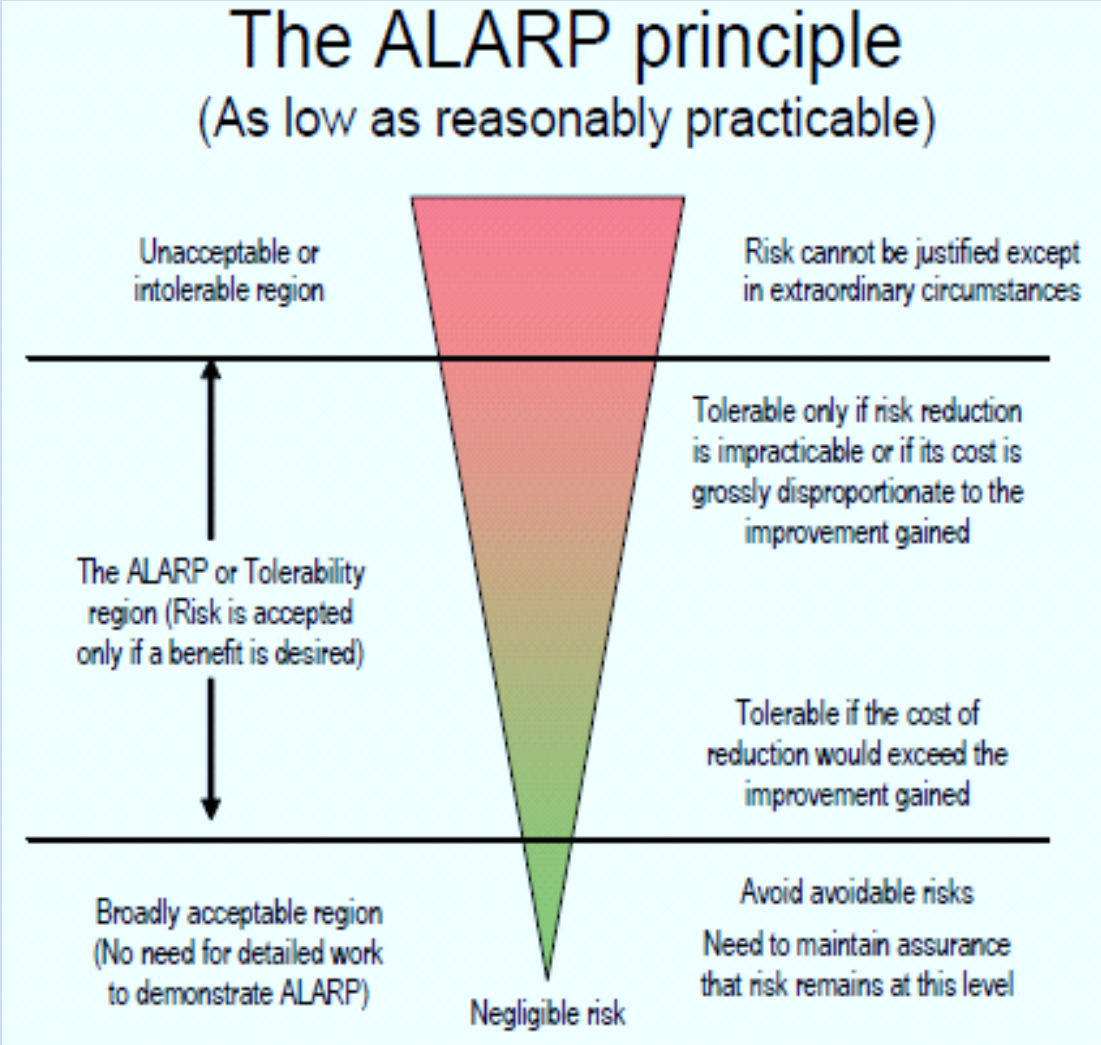


Risk Criteria Per DODM 6055.09-M

Risk to:	DDESB Criteria	Service Guidance
Any 1 worker[a] (Annual P_f)	Risks below 1×10^{-4} are acceptable	
All workers (Annual E_f)	Risks below 1×10^{-3} are acceptable (advisory)	If risks are above 1×10^{-3} apply ALARP principle[c] Accept above 1×10^{-2} with significant national need only[c]
Any 1 person (Annual P_f)	Risks below 1×10^{-6} are acceptable	
All public[b] (Annual E_f)	Risks below 1×10^{-5} are acceptable (advisory)	If risks are above 1×10^{-5} apply ALARP principle[c] Accept above 1×10^{-3} with significant national need only[c]

a) Worker criteria apply to people that are associated with the explosives activity, but not directly involved (hands-on).
b) Public criteria apply to government employees working on the installation but not related to the explosives activity, and the general public.
c) For Service's waivers and exemptions ALARP is the safety principle whereby risks are reduced "as low as reasonably practicable."

Moving Forward-Possible Modification of Criteria



Risk-Base Program Improvement - Short Term

- Updating the probability of event (Pe) used in TP-14 methodology
- Implementing a “warning system” as the criteria for a TP-14 QRA analysis
- Updating the Universal Risk Scale (URS)
- Updating the uncertainty methodology used in TP-14 methodology
- Removing undue conservatism in TP 14 methodology to create a more realistic model
- Creation of RBESS v1.0 for incorporation into Explosive Safety Siting (ESS) to be released in late 2018.

Risk-Base Program Improvements - Long Term

- Implement an “As Low as Reasonably Possible” (ALARP) methodology into the criteria used for a TP-14 QRA analysis
- Implement an F/N process to consider catastrophic risk criteria for a TP-14 QRA analysis
- Remove undue conservatism in TP-14 methodology
- Make tools easy to use
- Continue to support future versions of RBESS and web based RBESS
- Assist DoD Components in utilizing Risk Analysis and Risk Management principles thought-out a munition system lifecycle.
- Develop practical tools in support of DoD Components ESMRM process and life cycle management.
- Incorporate new science to include new test data
- Continue to socialize with DoD Components

Conclusion

- Move into ESS and become Web Based – Allows for switching between conventional QD and Risk Base
  - Improves risk management
  - Increases visibility of critical facilities
  - Improve informed risk decision process– inform key decision makers
  - Quantify the risks at QD
- Continue to improve Risk Analysis tools and methods for explosives safety
  - Risk management in operations
  - Munition lifecycle
  - Combustion processes
- Share findings with national and international communities of interests.