Department of Defense Explosives Safety Board (DDESB)

Explosives Safety Munitions Risk Management (ESMRM)
Technical Paper 23- “DoD Explosives Safety And Munitions Risk Management: Acquisition Lifecycle Considerations, Risk Assessment Process Framework, And Associated Tools”
August 2018

Training Session Agenda

- Intro Brief
- ESMRM Policy
- **Technical Paper 23 Overview**
- ESMRM Assessment Process
- ESMRM Assessment Examples
- ESS risk based capabilities in ESS 6.1.4

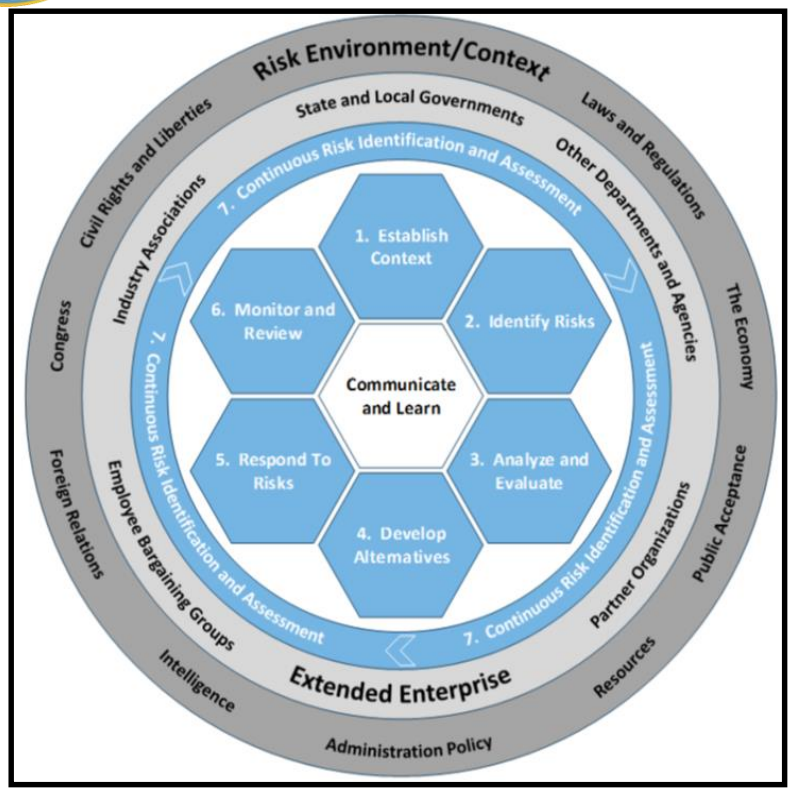
ESMRM Policy Implemented

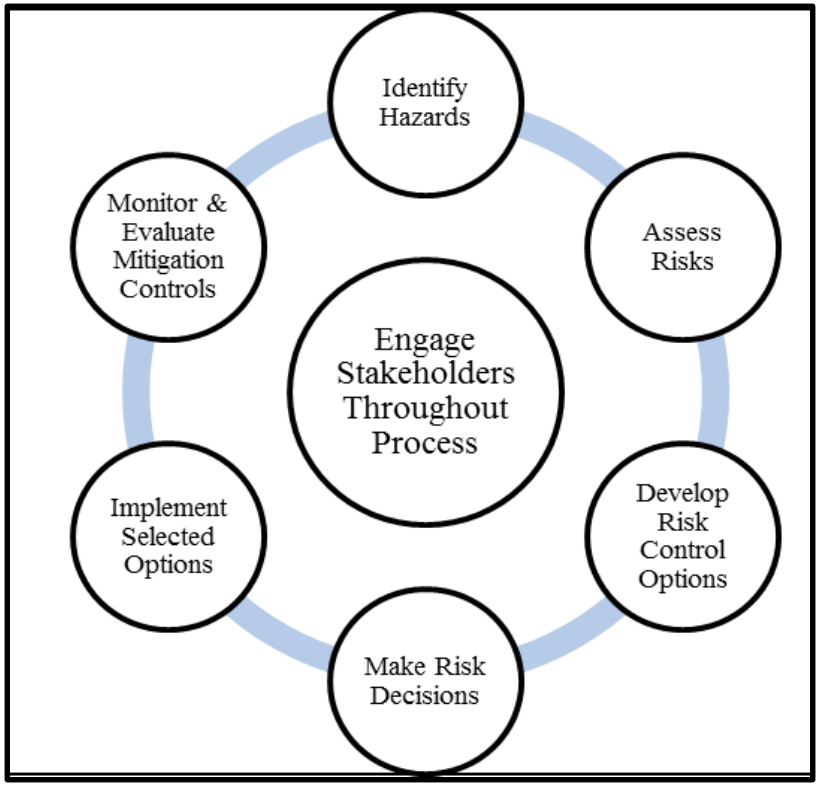
- DoDD 6055.09E *Explosives Safety Management*
- DoDI 6055.16 *Explosives Safety Management Program*
- DoDM 6055.09 *Ammunition and Explosives Safety Standards*
- Joint Staff Policy on ESMRM
- ESMRM Implementation
- DODD 5000 *The Defense Acquisition System*
- Mil-STD 882E *Department of Defense Standard 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.*

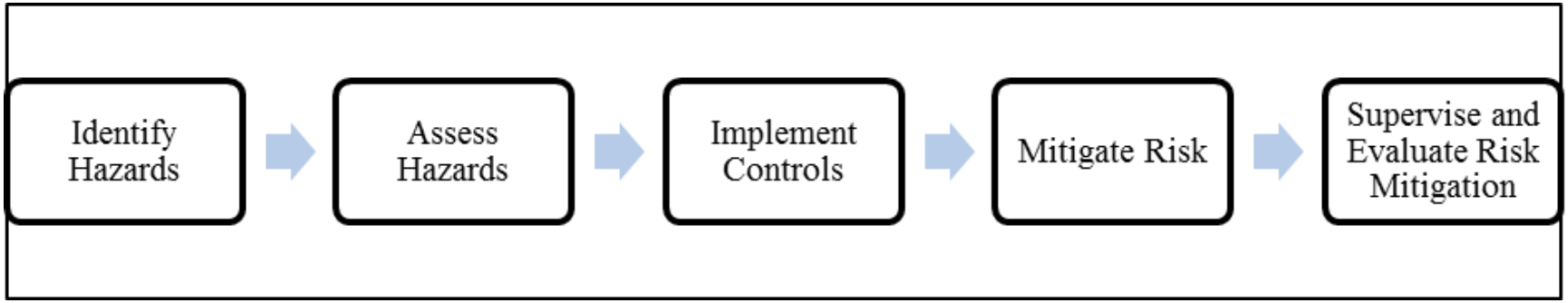
TP-23 General Overview

- Chapter 1, Introduction
  - Applicability– Munition Life Cycle
- Chapter 2, Risk Management Fundamentals
- Chapter 3, Explosives Safety Considerations in Acquisitions
- **Chapter 4, Explosives Safety Risk Assessment Process**
  - Circumstances Requiring ESMRM Assessment
  - Assessment Maintenance and Updated Frequency
  - Tools and Factors for Assessing Explosives Safety Risk
  - ESMRM Assessment Process
  - Review and/or Updating Existing Munitions Risk Management Assessment
- **Chapter 5, Consequence and Probability Matrix**
  - **Risk**
  - **Probability**
  - **Munitions-Related Probabilities**
  - **Severity**
  - **Risk Level**
  - **Deviation**
- **Chapter 6, Risk Assessment Tools**
  - **Software and tools**
  - **ASAP-X**
  - **Fast-SITE**
  - **RBESS**

OMB vs DOD Risk Management Process







Principles for Risk Assessment

1. Agencies should employ the best reasonably obtainable scientific information to assess risks to health, safety, and the environment

2. Characterizations of risks and changes in the nature or magnitude of risks should be both qualitative and quantitative, consistent with available data. The characterizations should be broad enough to inform the range of policies to reduce risks.

3. Judgments used in developing a risk assessment, such as assumptions, defaults, and uncertainties, should be stated explicitly. The rationale for these judgments and their influence on the risk assessment should be articulated.

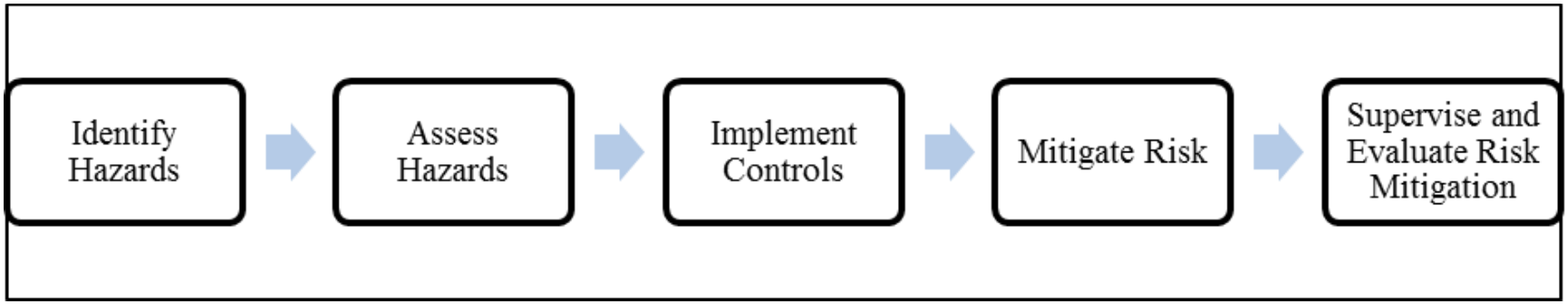
4. Risk assessments should encompass all appropriate hazards (e.g., acute and chronic risks, including cancer and non-cancer risks, to human health and the environment). In addition to considering the full population at risk, attention should be directed to subpopulations that may be particularly susceptible to such risks and/or may be more highly exposed.

5. Peer review of risk assessments can ensure that the highest professional standards are maintained. Therefore, agencies should develop policies to maximize its use.

6. Agencies should strive to adopt consistent approaches to evaluating the risks posed by hazardous agents or events.

ESMRM Considerations Throughout the Acquisition Lifecycle

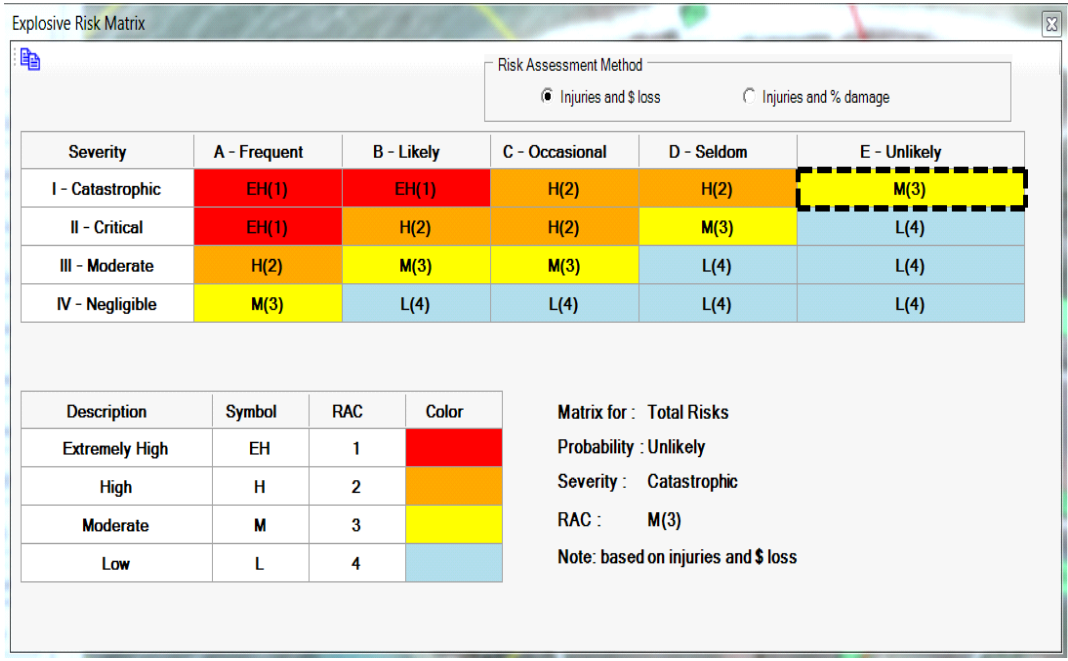
- Materiel Solution Analysis
- Technology Maturation and Risk Reduction
- Production and Deployment
- Operations and Support
- Disposal



Risk Assessment Matrix

Probability	Severity			
	Catastrophic (1)	Critical (2)	Marginal (3)	Negligible (4)
I-Frequent (A)	High	gh	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
* Eliminated (F)	* Eliminated			

Mil-STD 882E



TP-23

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

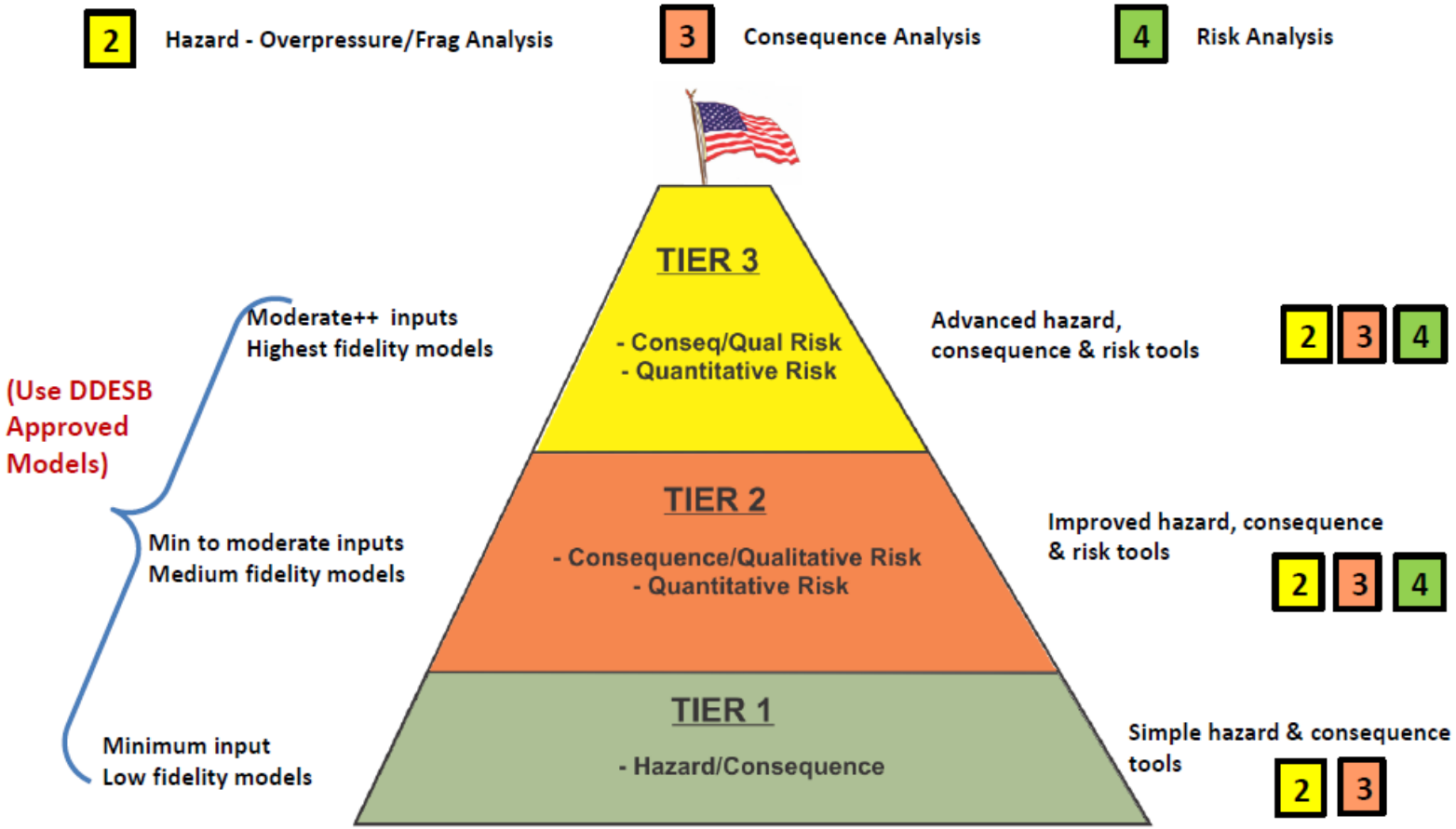
Description	Category	Definition
Catastrophic	**1**	Mission Failure One or more deaths and/or serious injuries of individuals not meeting quantity-distance criteria.
Critical	**2**	Mission Interrupted Multiple serious injuries of individuals not meeting quantity-distance criteria.
Marginal	**3**	Mission 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

RBESS Software

Tiered Approach to Risk-Based Explosives Siting Analysis

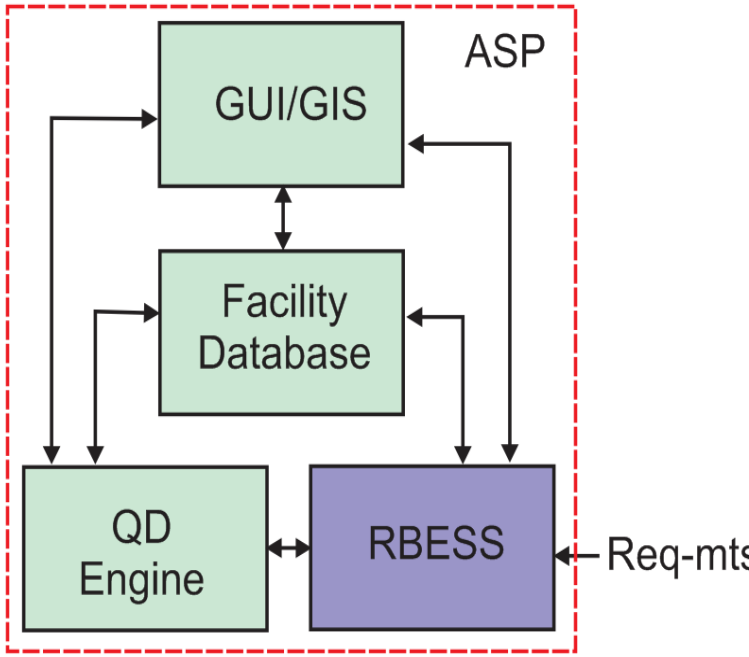


DDESB Risk Tools

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

Integration with Automated Site Planning (ASP)

- Integration with ASP's geospatial data and geographical information system (GIS) databases will greatly improve the DDESB's risk-based explosives siting tool
- From the user's perspective:
  - Distances and orientations are automatically generated
  - PES siting tree for Group Risk calculations is automated
  - Some facility information required for ASP (such as explosives information) removes the need to collect/enter the information twice
- From the perspective of algorithm development:
  - Ability to account for debris density as a function of azimuth (cloverleaf debris pattern)
  - Building damage can be calculated as a function of angle of incidence to the blast wave of each reflecting surface and the aspect ratio of the structure



Description of RBESS (Tier 1) ASAP-X

- Tier 1: hazards/consequences/risks (given an explosion occurs at a PES) are based on the location of an ES within six Hazard Zones and the damage definitions in DoD 6055.9M-STD:
  - Inter-magazine-barricaded distance (IMD-B); K6.
  - Intra-line-barricaded distance (ILD-B): K9.
  - Inter-magazine-unbarricaded distance (IMD-U): K11.
  - Intra-line-unbarricaded distance (ILD-U): K18.
  - Public traffic route distance (PTRD): K24.
  - Inhabited building distance (IBD): K40/K50.

Tier 1 (ASAP-X) Consequence Logic

Building Damage:

Zones 1, 2 and 3 = 100%
Zone 4 = 50% - (0.5(K18-ES distance)/(K18-K11)+0.5)
Zone 5 = 20% - (0.3(PTRD-ES distance)/PTRD-K18)+0.2)
Zone 6 = 5% - (0.15(IBD-ES distance)/(IBD-PTRD)+0.05)

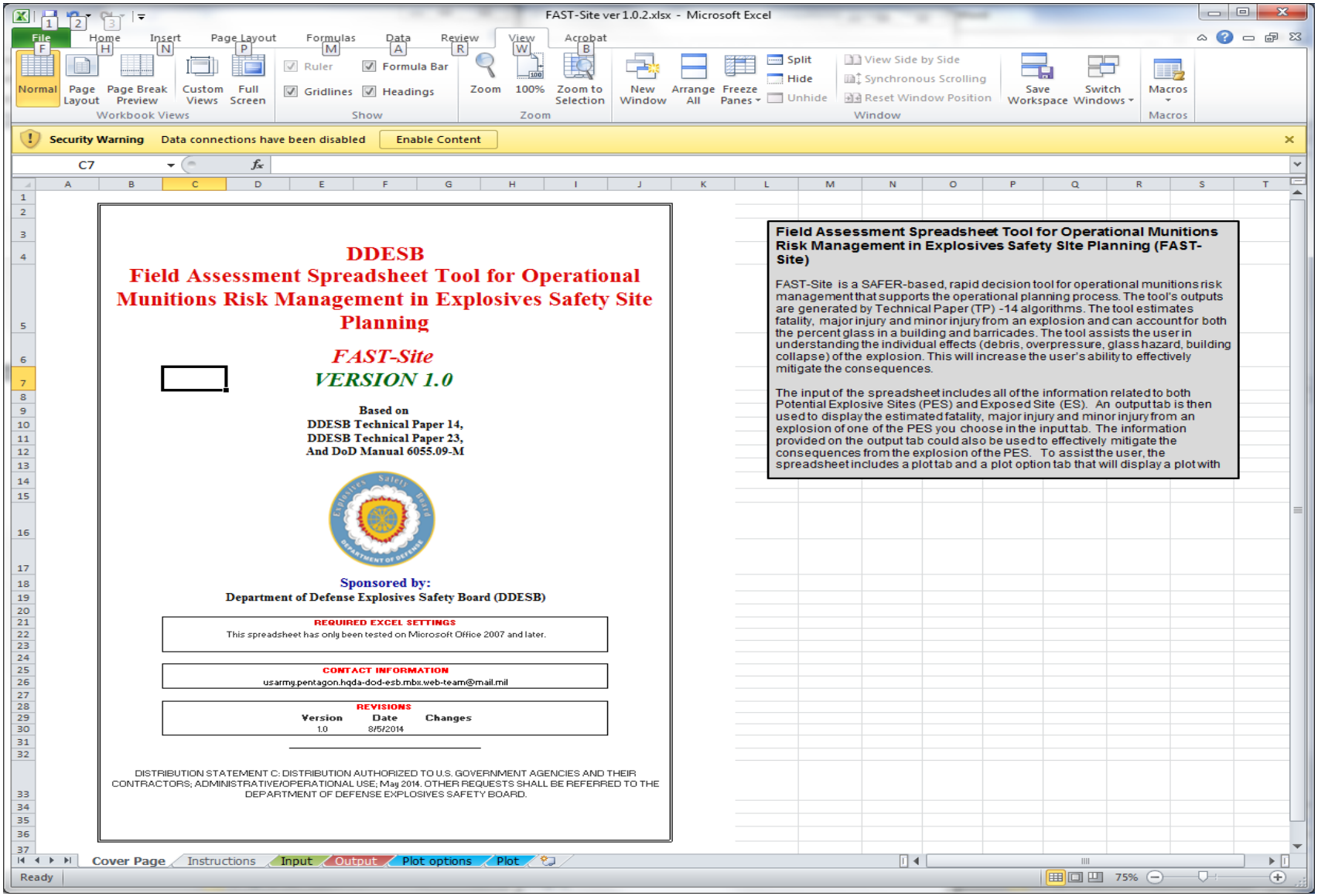
Fatalities:

Zone 1 = 100%
Zone 2 = 90% - (0.1(K9-ES distance)/(K9-K6)+.90)
Zone 3 = 80% - (0.1(K11-ES distance)/(K11-K9)+. 80)
Zone 4 = 20% - (0.6(K18-ES distance)/(K18-K11)+.20)
Zone 5 = 2% - (0.18(PTRD-ES distance)/PTRD-K18)+.02)
Zone 6 = 1% -(0.01(IBD-ES distance)/(IBD-PTRD)+.01)

Injuries:

Zone 1 = All non-fatal are injuries
Zone 2 = All non-fatal are injuries
Zone 3 = All non-fatal are injuries
Zone 4 = Sliding scale from "all non-fatal" to 2 x fatalities
Zone 5 = Twice the # of fatalities
Zone 6 = Twice the # of fatalities

FAST-Site-Tier 2A Spreadsheet tool



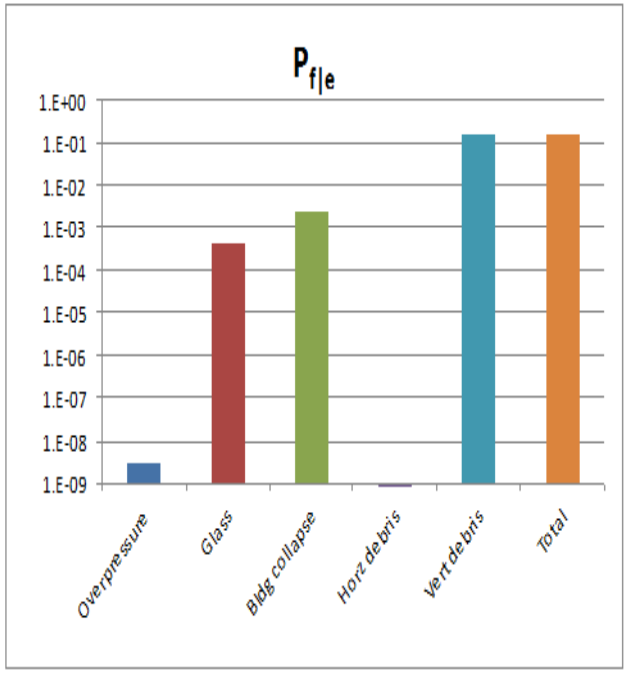
Description of FAST-Site

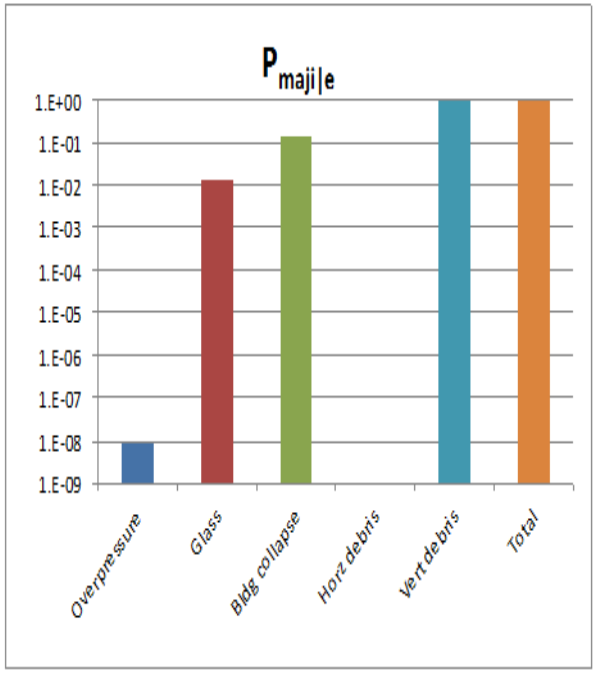
- FAST-Site -Field Assessment Spreadsheet Tool for Operational Munitions Risk Management in Explosive Safety Site Planning
- A Microsoft Excel spreadsheet designed to provide decision support information on the consequences from an explosives event at a PES and the protection afforded (or hazards posed) by various ES types.
- The tool enhances the capabilities of the ASAP-X spreadsheet tool by utilizing TP-14 algorithms currently in SAFER v 3.1.
- The input worksheet is used for assessing all PES and ES related explosives safety consequences using the basic parameters described in TP-14 Revision 4.
- Can also be used to support deviations involving ESQD related risk.
- Provides consequence values that can be used in the DARAD in support of a deviation.
- Estimates fatalities, major injuries, minor injuries and building damage losses.
- FAST-Site is not designed to assess deviations for lightning protection systems, chemical agent hazards, or vegetation control. Nor does it estimate the loss of equipment inside a structure or mission loss due to structural damage.
- Fast-Site does not check for IMD violations
- FAST-Site does not invoke the mixing

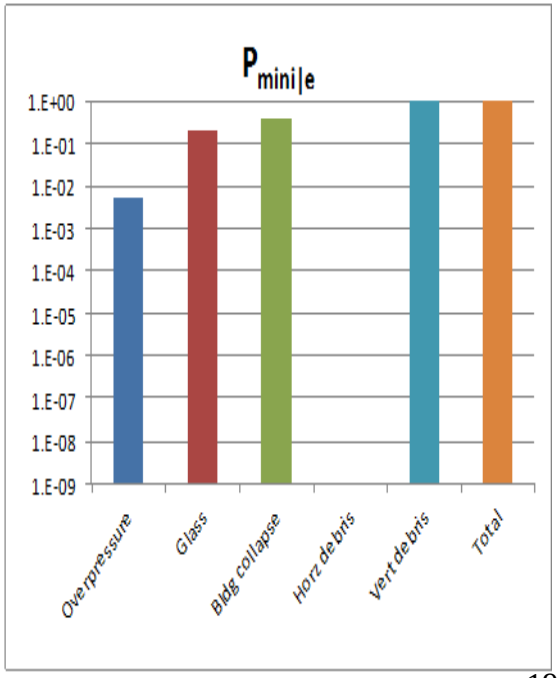
Tier 2A: FAST-Site Results

PES-ES Combination Consequence Results									
Select ES results to plot		Overpressure	Glass	Bldg collapse	Horz debris	Vert debris	Total	People affected	Percentage
Warehouse	$P_{f|e}$	2.96E-09	4.26E-04	2.31E-03	0.00E+00	1.61E-01	1.63E-01	4.1	16.3%
	$P_{maj|e}$	8.91E-09	1.28E-02	1.40E-01	0.00E+00	1.00E+00	1.00E+00	20.9	83.7%
	$P_{min|e}$	5.16E-03	2.13E-01	4.03E-01	0.00E+00	1.00E+00	1.00E+00	0.0	0.0%
	People unhurt						0.00E+00	0.0	0.0%

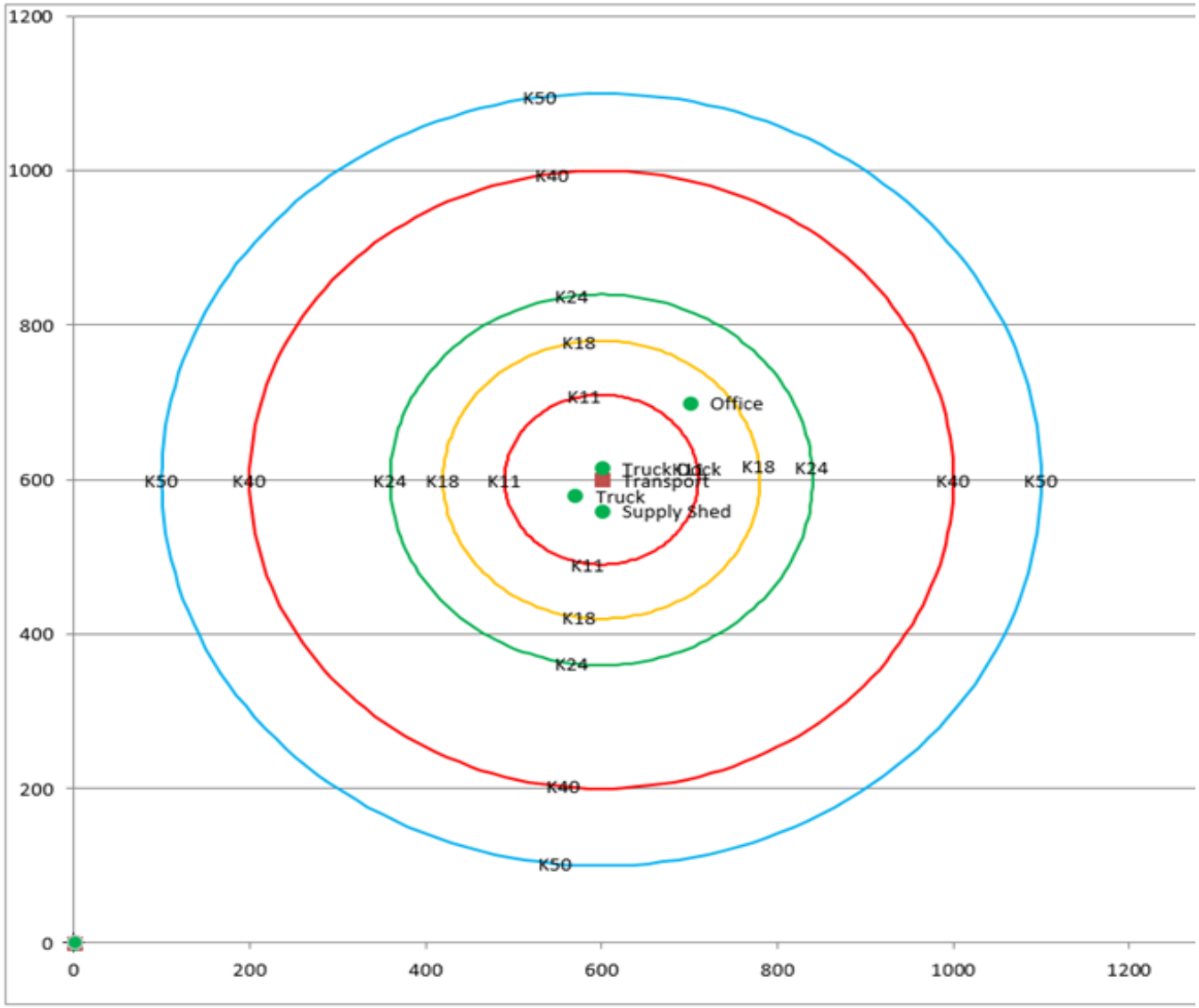
% Building Damage	32.0%	Considerable damage







Tier 2A: FAST-Site Results

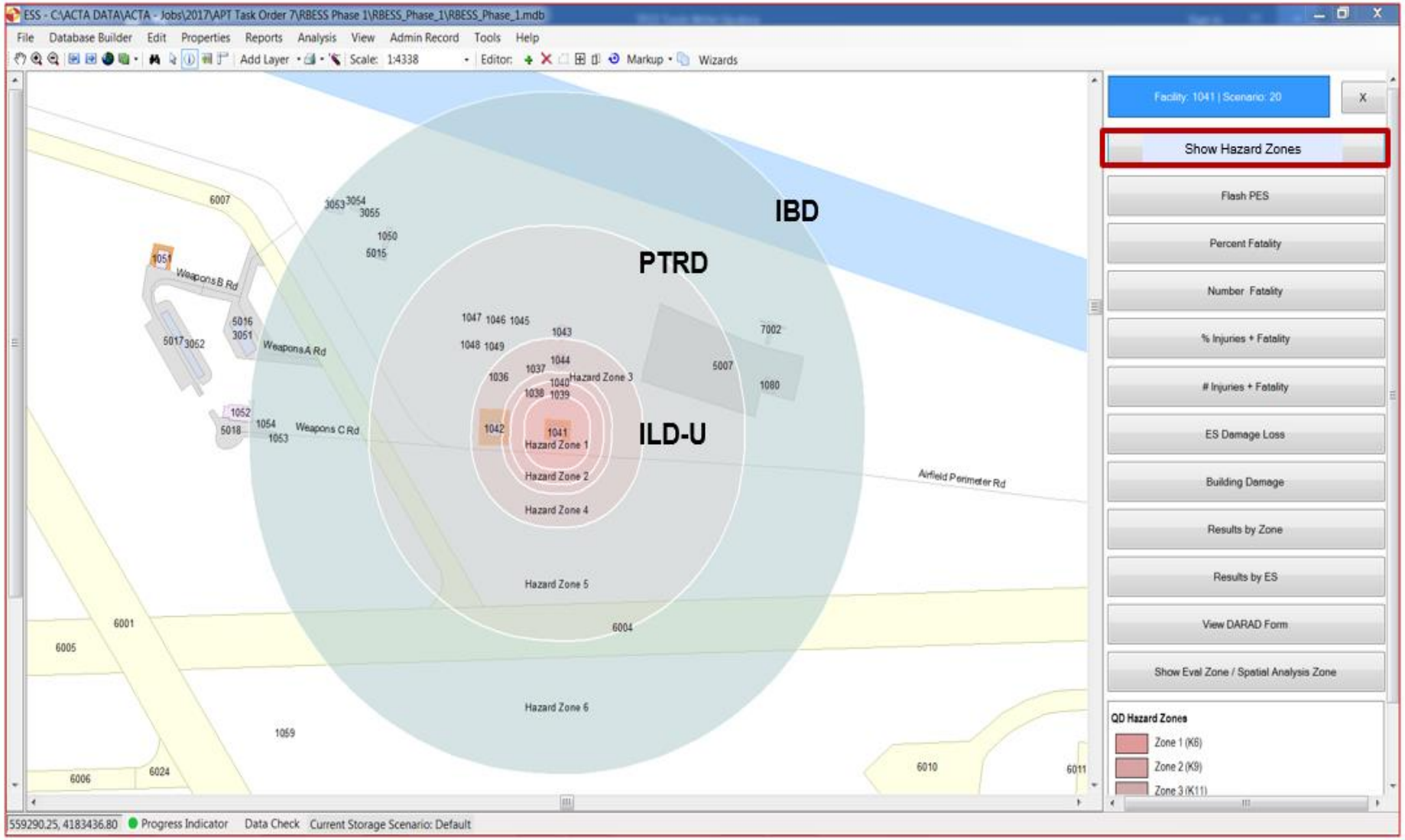


Description of RBESS (Tier 2)

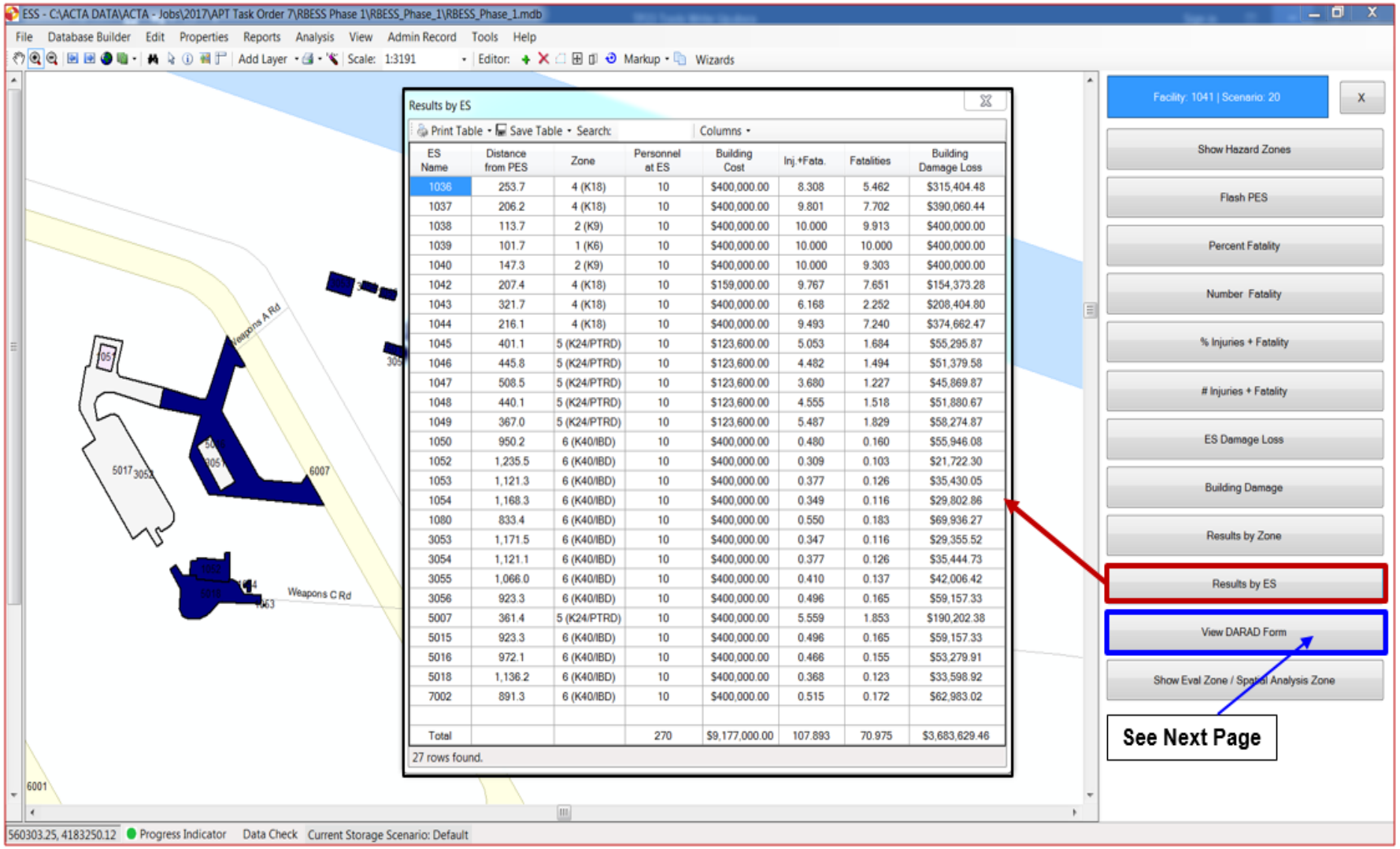
- **Tier 2:** hazards/consequences/risks are based on the PES-ES distance and the physics-based air blast, fragment/debris and thermal consequence models documented in DDESB Technical Paper No. 14 (Revision 4).
- **Tier 2a (Qualitative Risk):** the explosion at a selected PES is assumed to occur and the qualitative accident probability (unlikely, seldom, occasional, likely, frequent) and consequence severity (catastrophic, critical, moderate, negligible) are used to generate a risk matrix and DARAD if utilized.
- **Tier 2b (Quantitative Risk):** the quantitative accident probability (e.g., 1.5E-5/year) and fatality consequences are used to compute the: a) Maximum Probability of an Individual Fatality, P_f, and b) Expected Number of Fatalities, E_f, which are compared to DDESB risk acceptance criteria for unrelated and related personnel.

Risk Based Explosives Safety Siting In ESS

RBESS Tier 1 Analysis Results – Hazard Zone Display



RBESS Tier 1 Analysis Results – ES Consequence Summary Report



RBESS Tier 1 Analysis Results –DARAD – Page 3

AMMUNITION AND EXPLOSIVES WORKSHEET

Deviation #:	Effective Date:	Expiration Date:

INFORMATION ON THE POTENTIAL EXPLOSION SITE (PES)

29a. PES Name/#: 1041	29b. PES Function:	30. PES # People: 9
31. PES Equip/Fac (Value) $: $159,000.00	32. Required Blast Distance: 727	33. Required Fragment Distance: 1250
34a. Hazard Division: 1.1: NEW: 6,000	34b. Hazard Division: 1.2.1: NEW: 4,800	34c. Hazard Division: 1.2.2: NEW: 3,500
34d. Hazard Division: 1.2.3: NEW: 16,000	34e. Hazard Division: 1.3: NEW: 17,000	34f. Hazard Division: 1.4: NEW/MEQ:

35a. QD arcs exceed the installation boundary? YES ☐ NO ☐ Are other Services affected? YES ☐ NO ☐ Was coordination made? YES ☐ NO ☐ Provide other coordination documentation, as necessary.

Why coordination was/was not made:

Coordination paperwork attached? ☐

35b. Is this deviation associated with a hybrid or risk-base safety submission?

35c. If YES, provide site plan #:

Only ES's w/ QD Violations are shown

INFORMATION ON THE EXPOSED SITES (ES)

36. EXPOSED SITES

FACILITY	DISTANCE: Feet REQUIRED	DISTANCE: Feet ACTUAL	# PEOPLE	EQUIP/FAC (VALUE) $	EXPOSURE TYPE	ON/OFF INSTALLATION	At Required Distance FATALITIES	At Required Distance INJURIES	At Required Distance EQUIP/FAC (LOSS) $	At Requested Distances FATALITIES	At Requested Distances INJURIES	At Requested Distances EQUIP/FAC (LOSS) $	(Attachment?) VIOLATION?
1037	327	206.2	10	400,000.00	ILD(U)	ON	2	4	199,968.15	7.7	2.1	390,060.44	YES
1038	1,250	113.7	10	400,000.00	IBD	ON	0	0	0.00	9.91	0.087	400,000.00	YES
1039	1,250	101.7	10	400,000.00	IBD	ON	0	0	0.00	10	0	400,000.00	YES
1040	1,250	147.3	10	400,000.00	IBD	ON	0	0	0.00	9.3	0.7	400,000.00	YES
1043	1,250	321.7	10	400,000.00	IBD	ON	0	0	0.00	2.25	3.92	208,404.80	YES
1044	1,250	216.1	10	400,000.00	IBD	ON	0	0	0.00	7.24	2.23	374,662.47	YES
1050	1,250	950.2	10	400,000.00	IBD	ON	0	0	0.00	0.16	0.32	55,946.08	YES
1052	1,250	1,235.5	10	400,000.00	IBD	ON	0	0	0.00	0.1	0.21	21,722.30	YES
1053	1,250	1,121.3	10	400,000.00	IBD	ON	0	0	0.00	0.13	0.25	35,430.05	YES
1054	1,250	1,168.3	10	400,000.00	IBD	ON	0	0	0.00	0.12	0.23	29,802.86	YES
1080	1,250	833.4	10	400,000.00	IBD	ON	0	0	0.00	0.18	0.37	69,936.27	YES
7002	1,250	891.3	10	400,000.00	IBD	ON	0	0	0.00	0.17	0.34	62,983.02	YES
													NO

EXPECTED POTENTIAL CONSEQUENCES

37. Potential Explosion Site:	a. Fatalities:	9	b. Injuries:	c. Equip/Fac $:	$ 159,000.00
38. Potential Losses for Exposed Sites (ES) Meeting Criteria:	a. Fatalities:	2	b. Injuries: 4	c. Equip/Fac $	$ 199,968.15
39. Potential Loss Being Accepted for Deviating from Approved Standards:	a. Fatalities:	47.27	b. Injuries: 10.77	c. Equip/Fac $	$ 2,448,948.30
40. Total Potential Loss (#/$):	a. Fatalities:	58.27	b. Injuries: 14.77	c. Equip/Fac $	$ 2,807,916.45

Δ_Risk Losses due to QD violations

DA FORM 7632, APR 2015

Click to Add Continuation Page

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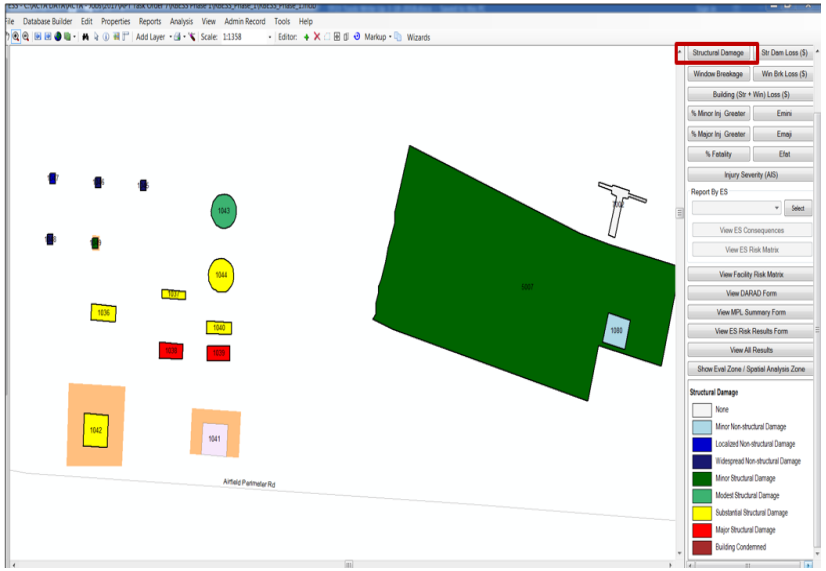
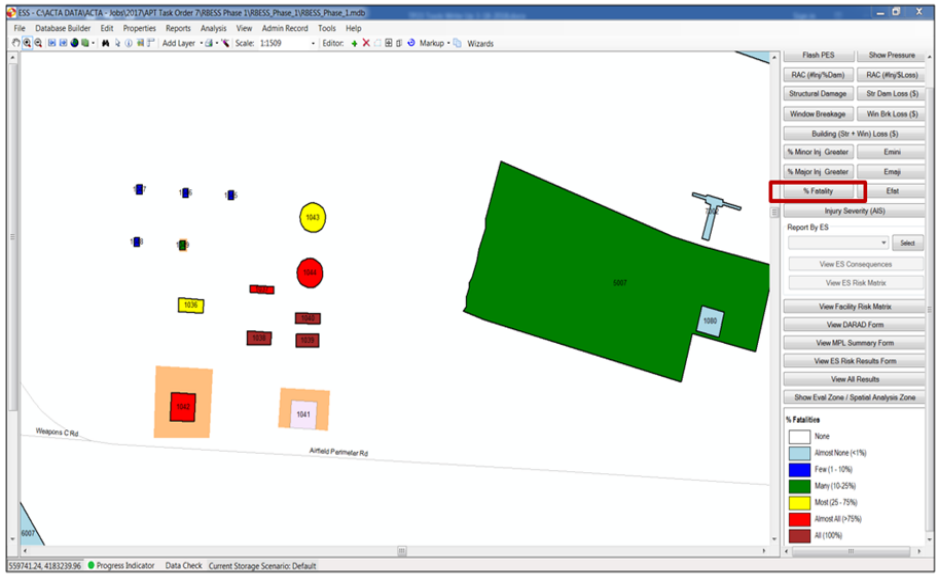
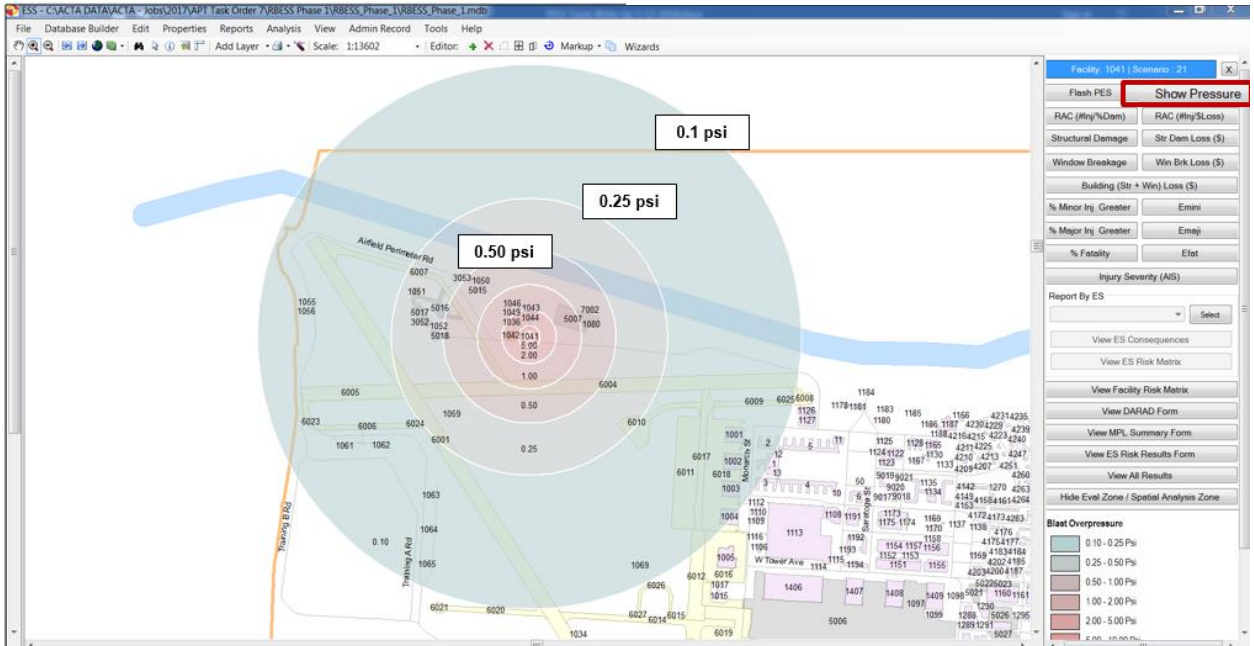
APD LC v1.00ES

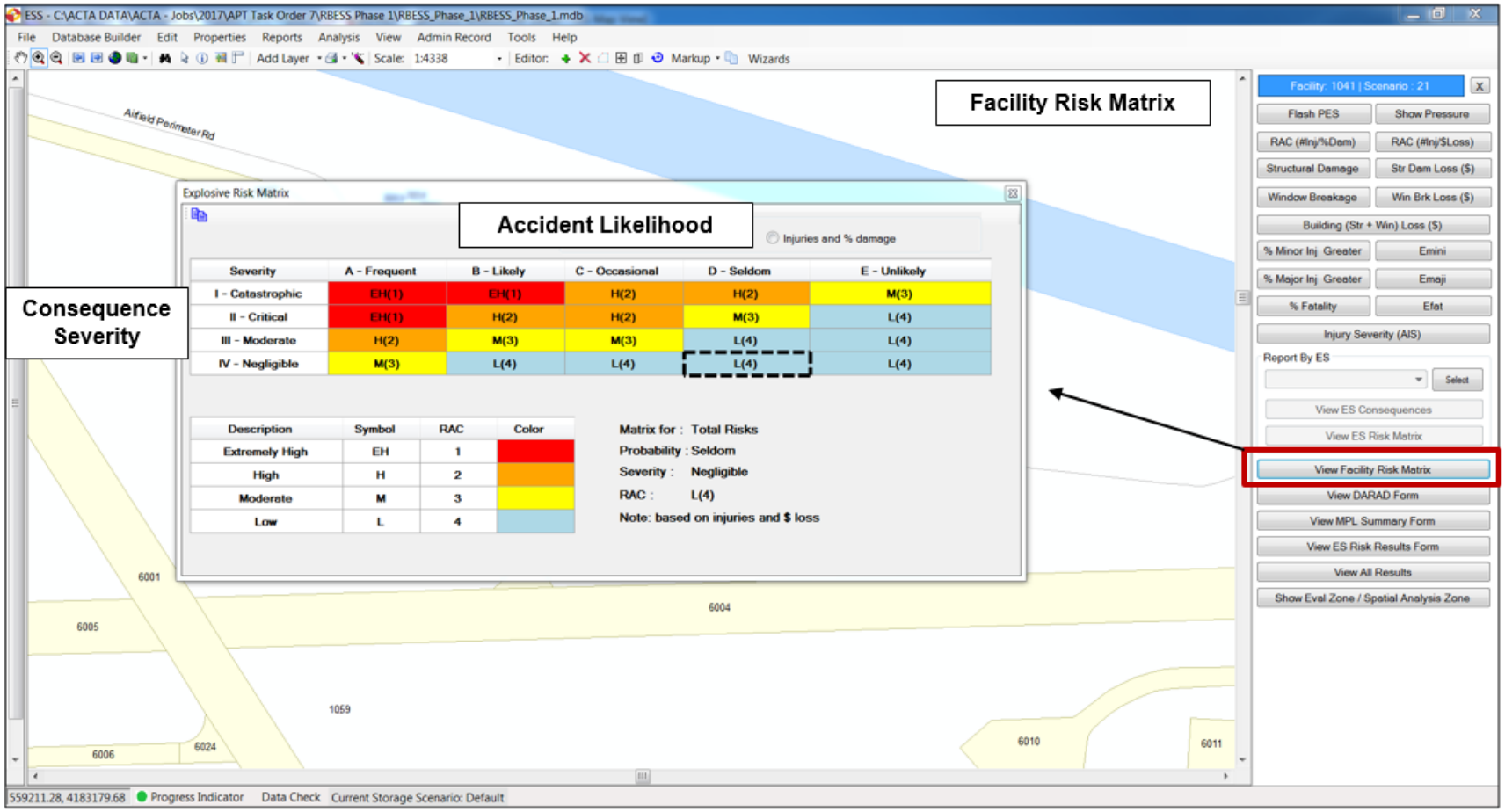
Tier 2a Analysis Results (Overpressure Contours and Percent Fatality)







Tier 2a Analysis Results (Risk Matrix)



Conversion of Consequence to Severity Level and Results

Conversion of Computed Consequences to Severity Level

Severity Level	Severity Description	Expected # Fatalities	Expected # Major Injuries	Expected # Minor Injuries	Expected % Damage
I	Catastrophic	? 1	? 10	? 200	> 75
II	Critical	0.1 - 1	5 – 10	50 - 200	40 - 75
III	Moderate	10^{-6} – 0.1	1 - 5	5 -50	15 - 40
IV	Negligible	< 10^{-6}	< 1	< 5	< 15

Tier 2a Analysis Results (View MPL Summary Form)

Maximum Probable Loss (MPL)

Print Table | Save Table | Search: | Columns

Receptor Type	No. of People	Equip/Fac Value ($)	Fatalities	Major Inj.+Fata.	Any Inj.+Fata.	Equip/Fac Loss ($)
Buildings	300	$7,977,600	70.12	92.25	115.52	$1,378,010
Moving Vehicles	327	$4,356,543	2.08	3.17	4.25	$5,686
Open Areas						
Total	627	$12,334,143	72.2	95.42	119.77	$1,383,696

5 rows found.

Tier 2a Analysis Results (DARAD Form)

AMMUNITION AND EXPLOSIVES WORKSHEET

Deviation #:	Effective Date:	Expiration Date:

INFORMATION ON THE POTENTIAL EXPLOSION SITE (PES)

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31. PES Equip/Fac (Value) $: $159,000.00	32. Required Blast Distance: 0	33. Required Fragment Distance: 0
34a. Hazard Division: 1.1: NEW: 6,000	34b. Hazard Division: 1.2.1: NEW: 4,800	34c. Hazard Division: 1.2.2: NEW: 3,500
34d. Hazard Division: 1.2.3: NEW: 16,000	34e. Hazard Division: 1.3: NEW: 17,000	34f. Hazard Division: 1.4: NEW/MEQ: 500000

35a. QD arcs exceed the installation boundary? YES ☐ NO ☐ | Are other Services affected? YES ☐ NO ☐ | Was coordination made? YES ☐ NO ☐ | Provide other coordination documentation, as necessary.

Why coordination was/was not made: | Coordination paperwork attached? ☐

35b. Is this deviation associated with a hybrid or risk-base safety submission? | 35c. If YES, provide site plan #:

INFORMATION ON THE EXPOSED SITES (ES)

36. EXPOSED SITES

FACILITY	DISTANCE: Feet REQUIRED	DISTANCE: Feet ACTUAL	# PEOPLE	EQUIP/FAC (VALUE) $	EXPOSURE TYPE	ON/OFF INSTALLATION	At Required Distance FATALITIES	At Required Distance INJURIES	At Required Distance EQUIP/FAC (LOSS) $	At Requested Distances FATALITIES	At Requested Distances INJURIES	At Requested Distances EQUIP/FAC (LOSS) $	(Attachment?) VIOLATION?
1037	436	206.2	10	400,000.00	ILD(U)	ON	0.82	2.3	59,980.00	9.28	0.72	152,000.00	YES
1038	1,250	113.7	10	400,000.00	IBD	ON	0.00019	0.00056	526.40	10	0	207,300.00	YES
1039	1,250	101.7	10	400,000.00	IBD	ON	0.00019	0.00056	515.30	10	0	220,400.00	YES
1040	1,250	147.3	10	400,000.00	IBD	ON	0.00019	0.00056	478.50	10	0	192,200.00	YES
1043	1,250	321.7	10	400,000.00	IBD	ON	0.00019	0.00056	720.30	2.77	5.11	94,730.00	YES
1044	1,250	216.1	10	400,000.00	IBD	ON	0.00019	0.00056	720.50	9.15	0.85	150,800.00	YES
1052	1,250	1,235.5	10	100.00	IBD	ON	0.00017	0.00049	0.69	0.00017	0.00049	0.69	YES
1053	1,250	1,121.3	10	400,000.00	IBD	ON	0.00019	0.00053	73.22	0.00034	0.00096	83.14	YES
1054	1,250	1,168.3	10	100.00	IBD	ON	0.00019	0.00053	0.70	0.00026	0.00074	0.74	YES
1080	1,250	833.4	10	400,000.00	IBD	ON	0.00019	0.00056	728.80	0.0019	0.0056	4,059.00	YES
3051	1,284.4	1,252.4	10	400,000.00		ON	0.00012	0.00035	1,191.00	0.00012	0.00035	1,191.00	YES
3052	1,478.1	1,448.3	10	400,000.00		ON	0.000039	0.00011	1,006.00	0.000039	0.00011	1,006.00	YES
5007	398.8	361.4	10	400,000.00		ON	1.23	3.34	78,340.00	1.23	3.34	78,340.00	YES

EXPECTED POTENTIAL CONSEQUENCES

37. Potential Explosion Site:	a. Fatalities:	9	b. Injuries:		c. Equip/Fac $:	$ 159,000.00
38. Potential Losses for Exposed Sites (ES) Meeting Criteria:	a. Fatalities:	2.12	b. Injuries:	5.83	c. Equip/Fac $	$ 147,095.84
39. Potential Loss Being Accepted for Deviating from Approved Standards:	a. Fatalities:	54.53	b. Injuries:	11.13	c. Equip/Fac $	$ 1,112,653.41
40. Total Potential Loss (#/$):	a. Fatalities:	65.65	b. Injuries:	16.96	c. Equip/Fac $	$ 1,418,749.25

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APD LC v1.00ES

Safety Assessment for Explosives Risk (TP-14 Rev 4)

- The TP-14 Rev 4 (SAFER Version 3.1) tool may be used for risk-based explosives safety siting as allowed per DODM 6055.09-M
- The tool may also be used for risk management purposes
- TP-14 provides DDESB- approved methodologies for calculating the risk associated with explosives operations and storage through use of the SAFER tool
- Current tools not designed to assess deviations for lightning protection systems, HERO hazards, chemical agent hazards, or vegetation control.
- Current tools do not estimate the loss of equipment inside a structure or mission loss due to structural damage.
- All of the tools can be obtained via the DDESB

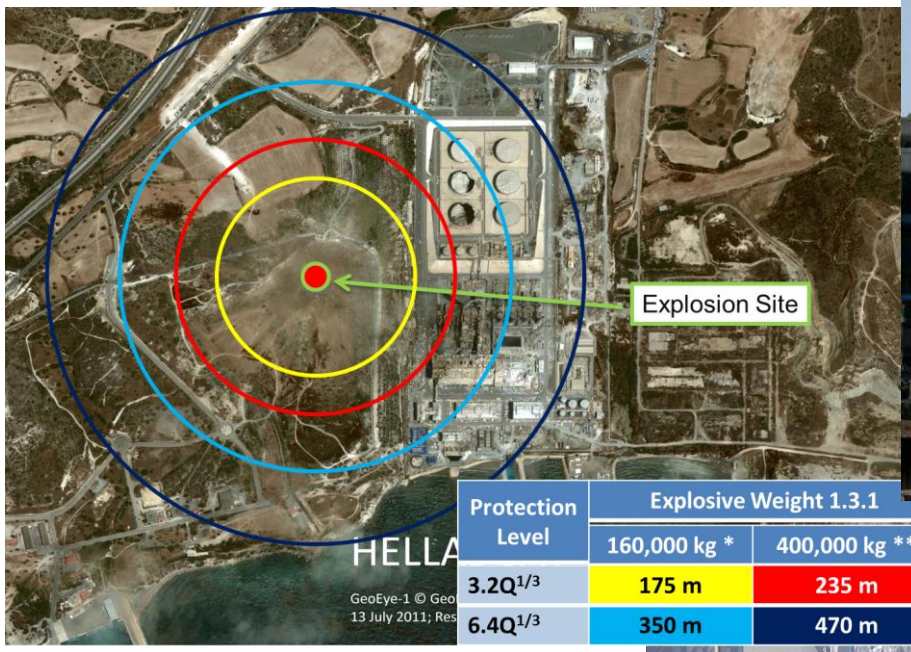
https://www.ddesb.pentagon.mil/

Summary and Conclusions

- These tools align with all of US government AND NATO requirement for Risk assessments
- RBESS tools are modular
- Level of fidelity increases as you go from a Tier 1 tool to a Tier 3 tool.
  - Qualitative ➡ Quantitative with specific analysis results (what caused the injury, fatality or building damage.
- Can be modified and improved
- Give you an easy to use DARAD print out for reporting the risk to leadership
- One needs to know how to use the tools otherwise

Garbage IN = Garbage OUT

Questions / Comments / Discussion



Protection Level	Explosive Weight 1.3.1	
	160,000 kg *	400,000 kg **
$3.2Q^{1/3}$	175 m	235 m
$6.4Q^{1/3}$	350 m	470 m

Evangelos Florakis Naval Base explosion, Cyprus July 2011. The incident occurred on 11 July 2011, when 98 containers of explosives that had been stored for 2½ years in the sun self-detonated. It is ranked as the fifth largest non-nuclear human-induced explosion in history with a yield of approximately 2 to 3.2 kilotons. The resulting explosion killed 13 people, 12 of them immediately, the Commander of the. The explosion severely damaged hundreds of nearby buildings including all of the buildings in Zygi and the island's largest power station, responsible for supplying over half of Cyprus' electricity. As a result, much of Cyprus was without power in the immediate aftermath of the incident and were initiated in order to conserve supplies.