Military Robotics and Collateral Damage

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Conflicting Trends?

- Emergence of Combat Robotics: armed robots with a degree of autonomy
- Growing importance of Collateral Damage control
- Is there a conflict between the two trends?

Measures and Questions

- Consider NC/C ratio: C – hostile combatants killed; NC – non-combatant fatalities
- What are typical historical NC/C ratios for representative human conflicts?
- How can one predict an NC/C ratio for a given set of combat robots operating under a particular command, control, and targeting strategy?
- How would the NC/C ratio characteristic of a combat robotic force compare to that of a conventional manned force?
- More broadly: how to model, predict, and *minimize* the NC/C ratio?

Show Me a Combat Robot

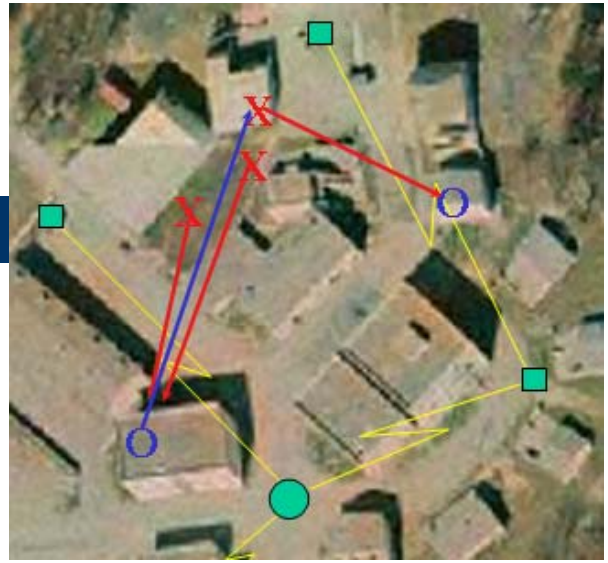
- DF: combat robot – a (partially) autonomous unmanned platform capable (at least in principle) of applying effects
- General capabilities:
  - Persist on the battlespace
  - Plan and execute broad repertoire of actions
  - Identify and approach the enemy target
  - Apply effects, repeatedly
- Would they introduce a greater risk of fratricide and collateral damage?

A Scenario

Is This Realistic in Near Term?

- Autonomous mobility, obstacle detection and avoidance
- Perception of friendly force
- Enemy detection and targeting

Robots Could Perceive Hostile Shooters Fast and Accurate

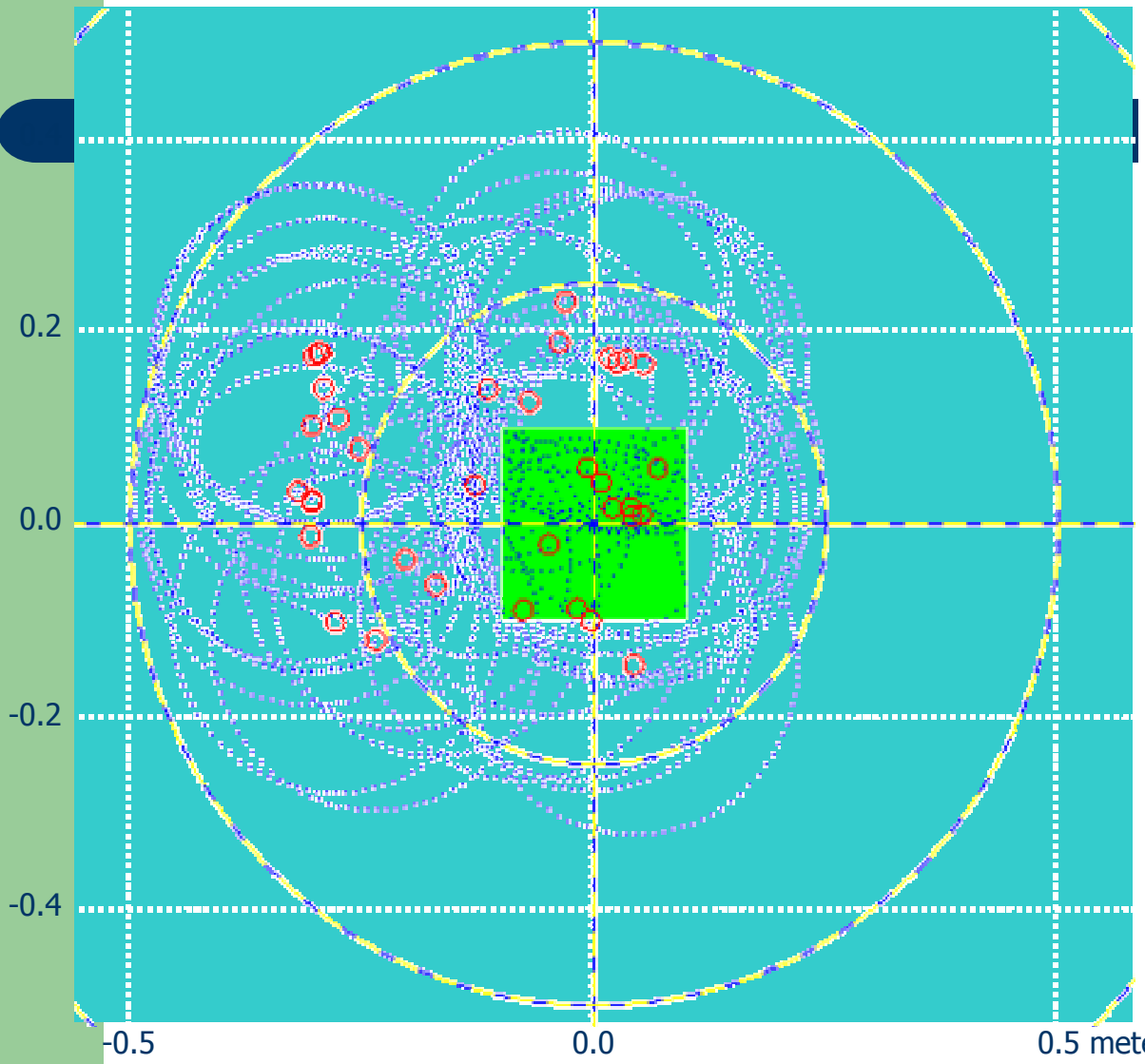


- Perception is considered the greatest challenge of robotics
- Can be overcome by not attempting to duplicate human perception
- Shooter detection -- the most effective way of identifying hostiles
- Far more reliable than human visual
- Difficult for humans: “Took fire many times - never could pin-point the source.” (MG Garrett)
- Shock-wave sensors can be accurate

NEST experiments: shooter located within 1m accuracy, at 100m distance

Shooter detection – the silver bullet for the perception challenge

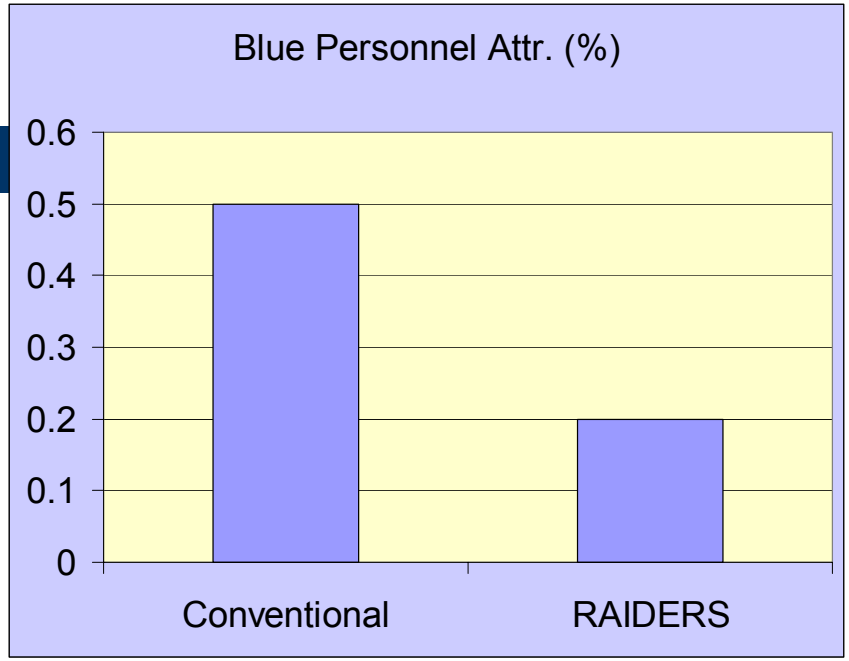
Robots Could Aim and Shoot Well



- Strike pattern at 100m from a randomly rotating shooting platform
- Red circles are laser hit locations
- Dotted blue circles are actual laser beam size at 100 meters away (0.003 radian divergence)
- Bright green is actual size of the reflective target
- Courtesy of Dr. Omead Amidi, CMU

CEP 34 cm – Firing on the move at 100m

Robots Could Save Lives of Blue Warriors



Reduced blue human losses due to:

- **Robots can bring fire support much faster, closer**
- **No need to rescue the crew of a downed robot**

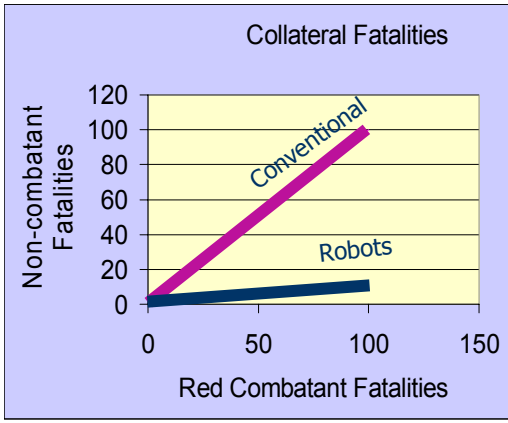
Scenario of the wargame:

- **Dense environment: agricultural and suburban**
- **Red irregulars and civilians**
- **Blue dismounted Co attacks along 2 AAs**
- **Conventional: 6 teams of 2 Apaches**
- **Robots: 7 teams of 2 armed robo-helos**

But what will such robots do to non-combatants?

Robots Could Minimize Collateral Damage

- Non-humanoid tactics and C2 can make a difference
- Robots can use restrictive "sacrificial" ROEs (too dangerous for human soldier):
  - Draw fire, detect shooter location, then return fire
  - Use exchange of data on dynamically changing no-fire locations
- Robots can come closer, use smaller weapon

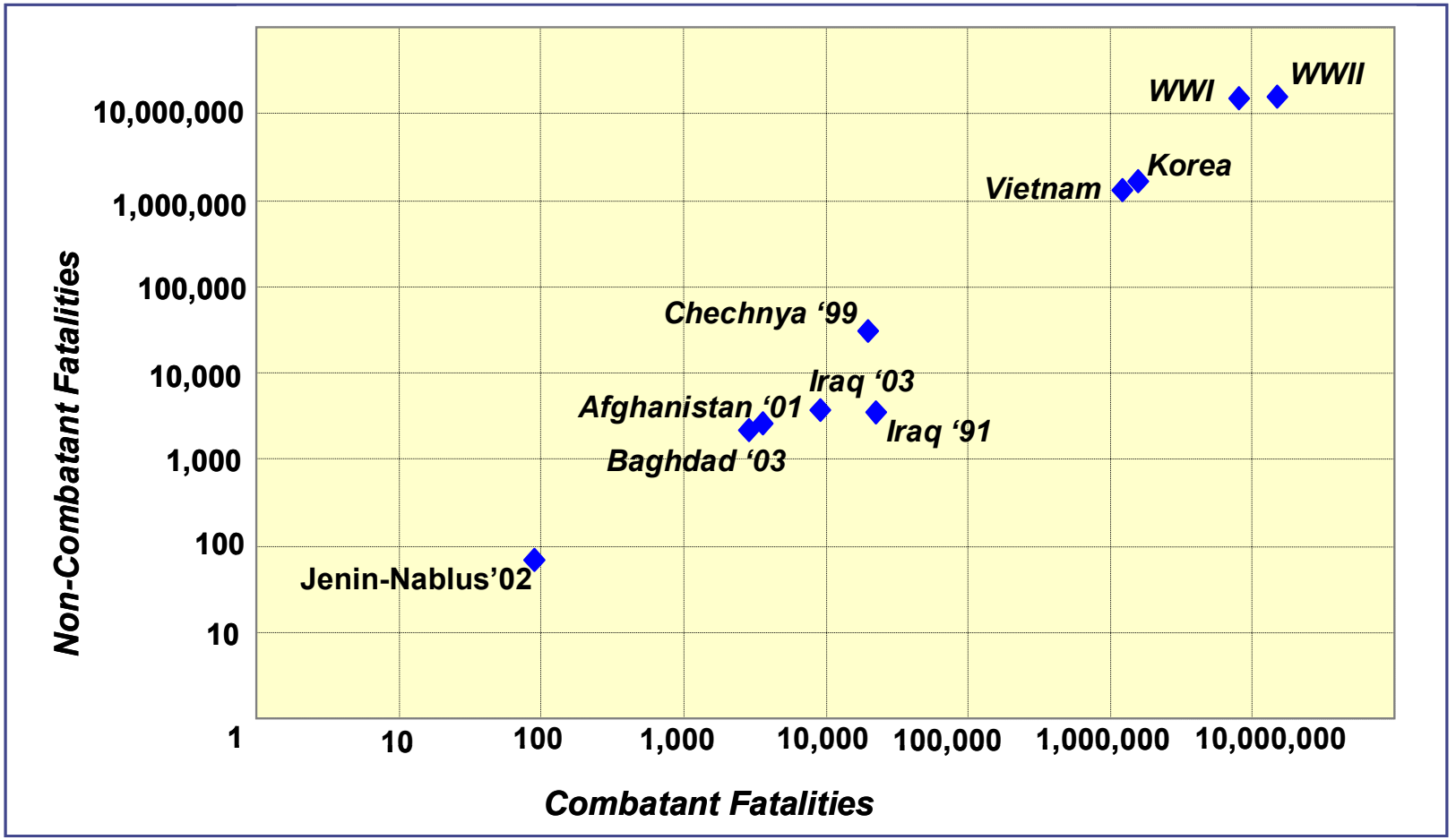


Robots can reduce collateral damage, as compared to human forces

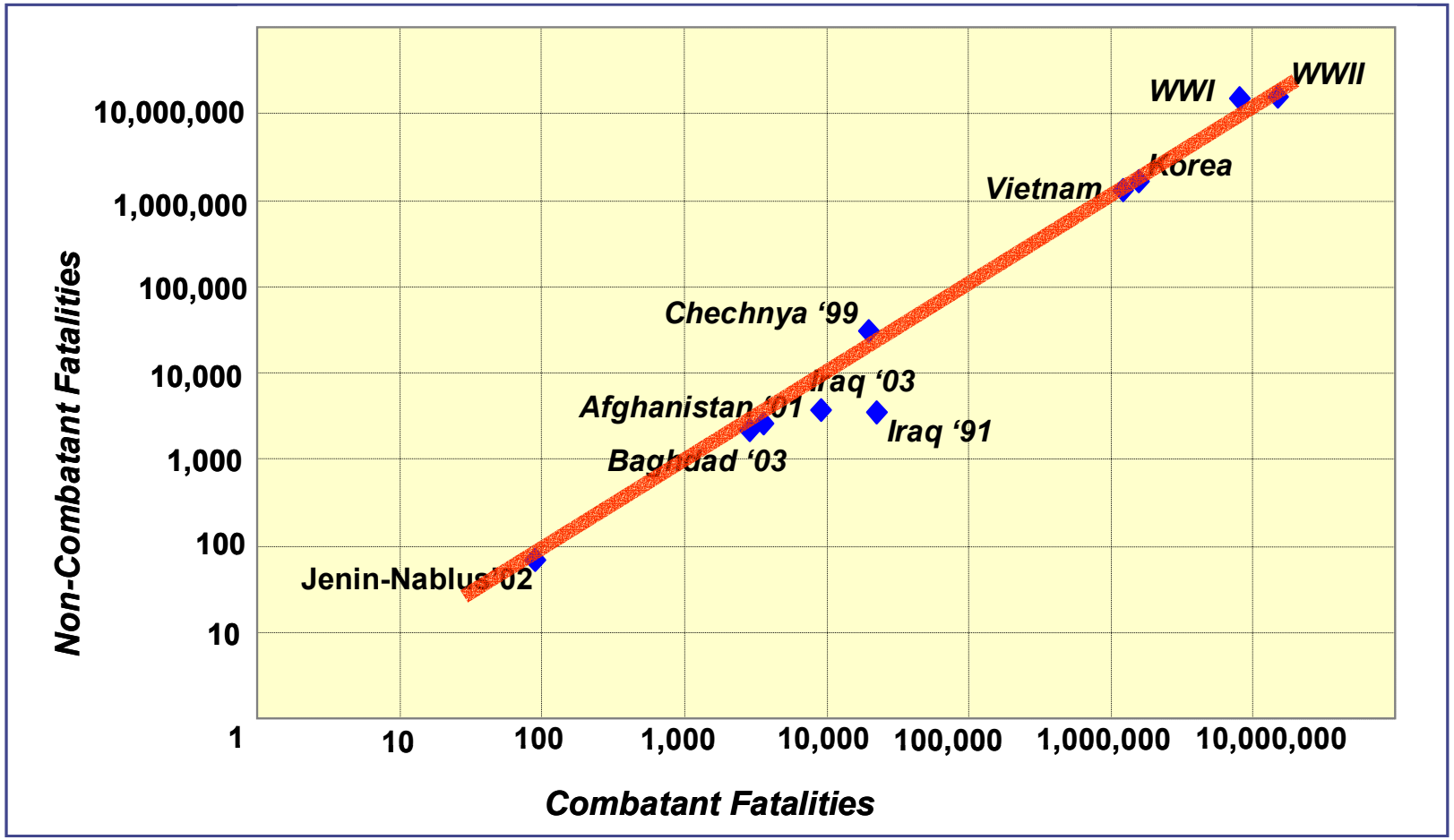
Some Historical Data

Conflict	Dates	NC-Low	NC-Hi	NC-Mean	C-Low	C-Hi	C-Mean	Source
WW1	1914-1919			**13,000,000**				13
							8,500,000	10
							7,734,300	6
	Overall Mean			13,000,000			8,117,150	
WWII	1939-1945						12,948,300	6
				13,000,000			20,000,000	13
				13,000,000			**15,164,300**	10
Korea	1950-1953			1,633,000			1,890,000	10
		400,000	3,000,000	1,700,000	582,000	2,000,000	1,291,000	8
	Overall Mean			**1,666,500**			**1,590,500**	
Vietnam	1960-1975	486,000	840,000	**1,330,000**	663,000	1,140,000	**1,235,000**	8
Iraq-Gulf War	1991		3,664	**3,500**	20,000	26,000	**23,000**	1
		2,500	3,000	2,750				5
Chechnya-Russia	1999-2002			**30,000**	17,817	22,117	**19,967**	7
Kosovo	1999	500						2
Afghanistan	Oct-Dec 2001	3,073	3,597	3,335				4
		1,000	1,300	1,150			**3,602**	2
				3,500				7
	Overall Mean			**2,662**				
Jenin and Nablis	Apr-02	64	76	**70**	73	105	**89**	11
Iraq-OIF	Mar-May2003	3,200	4,300	**3,750**	7,600	10,800	**9,200**	1
		5,951	7,590	6,771				12
Baghdad	Mar-May2003				1,700	2,120	1,910	1
		1,990	2,357	**2,174**	2,224	3,531	**2,878**	1

NC/C Ratio


Non-Combatant Fatalities
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
10
100
1,000
10,000
100,000
1,000,000
10,000,000
Combatant Fatalities
WWI
WWII
Korea
Vietnam
Chechnya '99
Iraq '03
Afghanistan '01
Iraq '91
Baghdad '03
Jenin-Nablus'02

A Near Constant NC/C Ratio?



Can We Estimate Collateral Damage?

	Robotic	Unmanned 1	Unmanned 2
Range To Target (m)	106	300	300
Pd	0.8	0.3	0.3
Pfa	0.0016	0.006	0.006
Target Location Error (m)	1	3	3
Weapon	small rocket	medium missile	small rocket
Blast Radius (m)	3	6	3
CEP of weapon (m)	1	1	1
Density of NC (NC/Km^2)	175	175	175
Prob. Kill ($P_{k)}$	0.69	0.28	0.15
Prob. Collateral Dmg (P_{knc})	0.05	0.68	0.05
NC/C Ratio	0.07	2.45	0.34

Outline of the Model

Number of munitions required (N_w) to achieve C: $N_w = C / P_k$

Then: $NC = N_w * P_{knc} = C * P_{kn} / P_k$

$P_k = Pd * (0.5 * P_{kcep} + 0.45 * P_{\overline{kcep}})$

The values for killing a target in the CEP:

$$P_{kcep} = P_s \approx 1.0 \qquad \text{if } W_b \geq CEP_{50}$$
$$= P_s * (W_b / CEP_{50})^2 + (1 - (W / CEP_{50})^2) * (1 + P_s(CEP_{50})) / 2 \qquad \text{if } W_b < CEP_{50}$$

The function $P_s(R)$ is the probability of kill as a function of range, R, from the weapon impact point.

The probability of killing a target outside the CEP_{50}:

$$P_{\overline{kcep}} = (P_s(CEP_{50}) + P_s(CEP_{95})) / 2 \qquad \text{if } W_b < CEP_{95}$$
$$= P_s \approx 1.0 \qquad \text{if } W_b \geq CEP_{95}$$

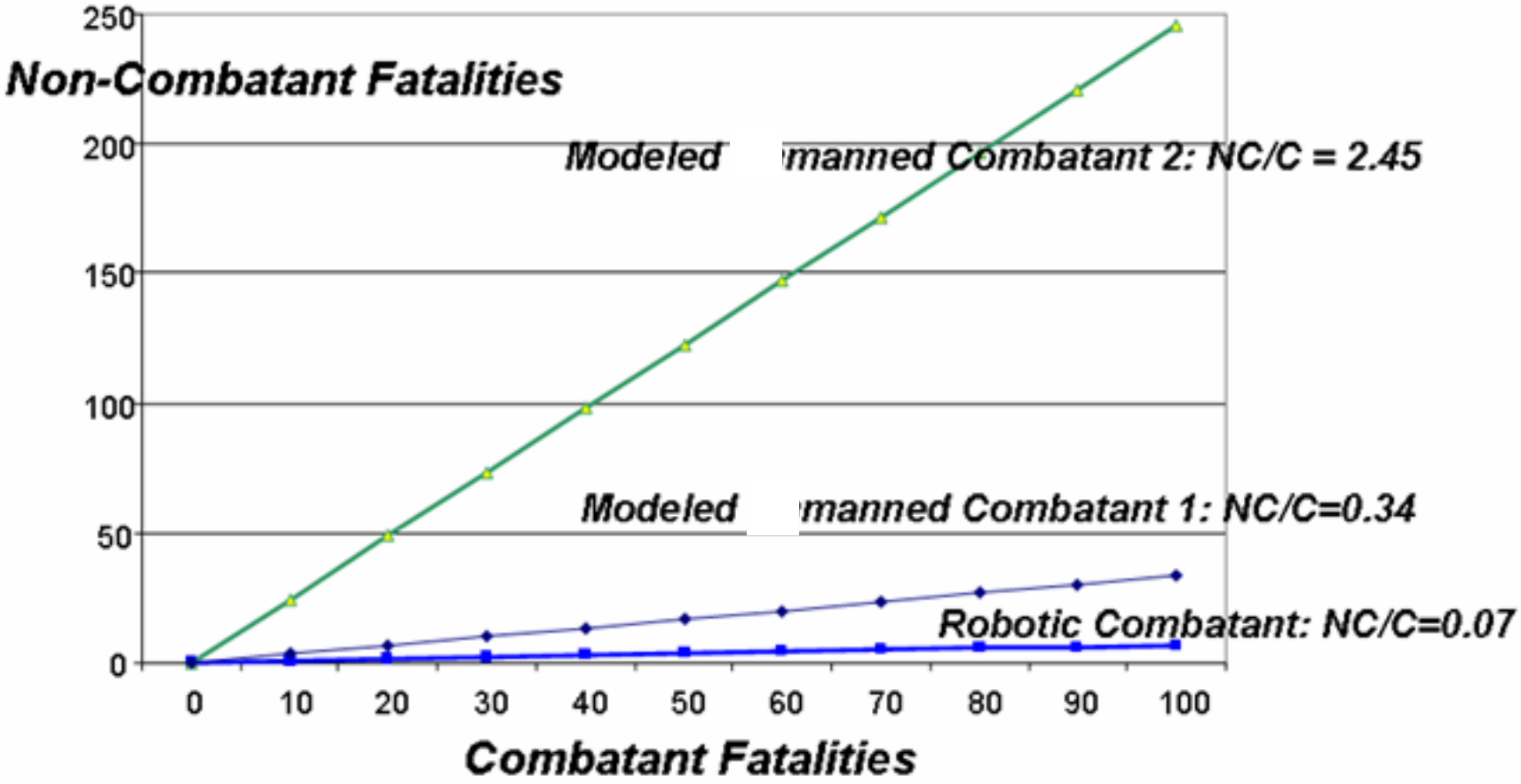
CEP_{95} is calculated using a Gaussian fit to the CEP_{50} values.

CEP_{50} – function of the flight accuracy of the weapon, the target location accuracy, the weapon's platform's pointing accuracy, and the weapon's platform's own location accuracy including both INS and GPS errors.

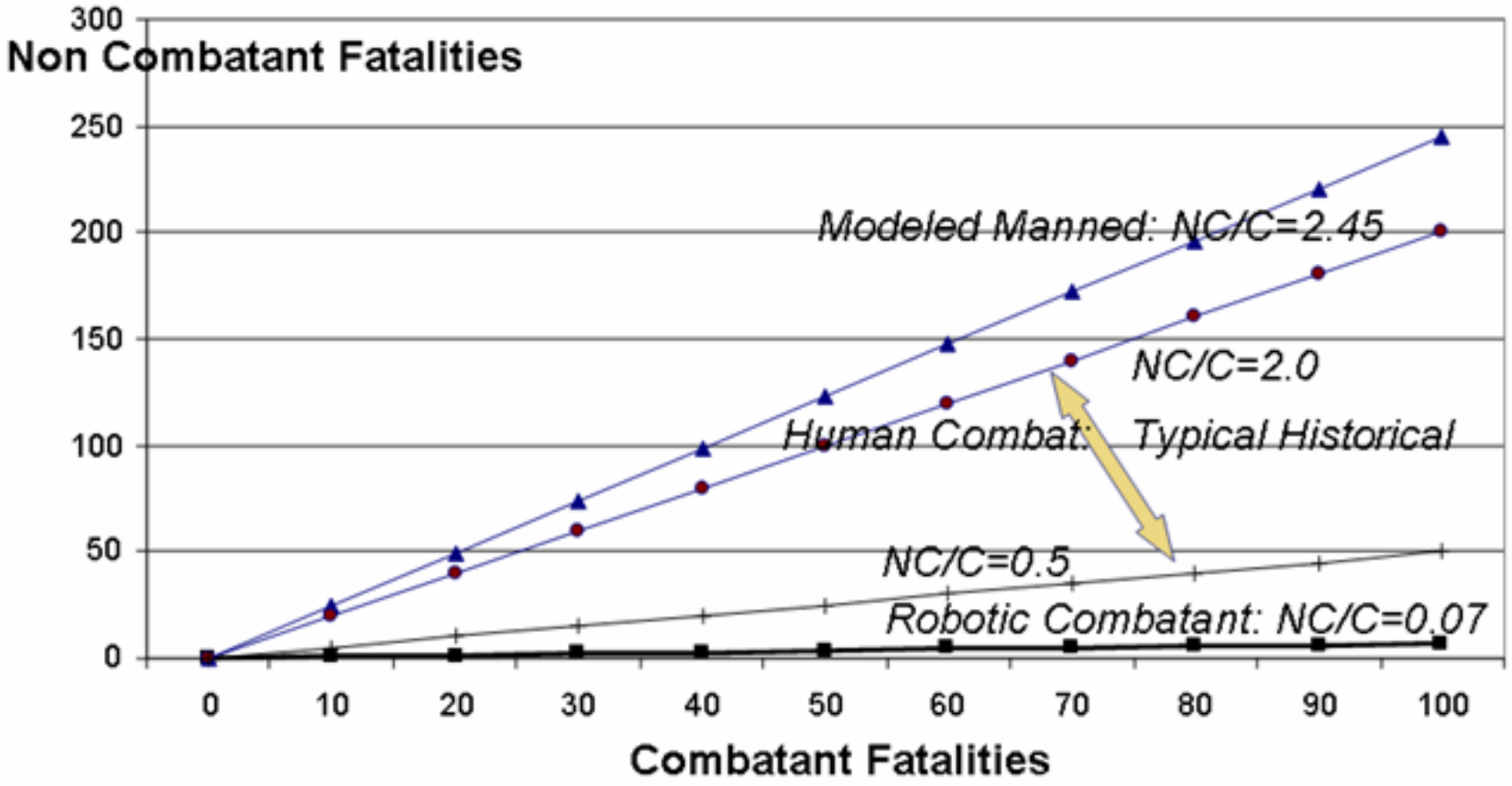
The probability of killing a non-combatant:

$$P_{knc} = P_k * P_{fa} / P_d + P_s * W^2 * \pi * D + P_{ks} * W_{max}\text{^}2 * \pi * D$$

Risk of Non-Combatant Fatalities Robots vs. Manned



Historical Range vs. Model-based Estimates



Robots vs. Manned Warriors: Critical Assumptions

- Robots can afford to come closer to the enemy:
  - more accurate fires and smaller weapons (with smaller blast radius)
  - with less risk of affecting nearby non-combatants.
- Robotic ROE is the revenge fire:
  - locate the sources of hostile fire more accurately and rapidly
  - reduces the probability of fire at a misidentified non-combatant

Summary

- Combat robots are coming
- With the right ROEs and C2, robots could be great fighters
- Robots could save lives of Blue humans
- Robots could also save non-combatants!
- NC/C ratio is useful and historically stable metrics
- NC/C can be modeled, estimated
- Robots could affect dramatically lower NC/C than humans!