



The Coming Swarm: *The Cost-Imposing Value of Mass*

By Paul Scharre

A SHIFTING STRATEGIC LANDSCAPE

In the 1970s, the United States adopted an “offset” strategy to counter Soviet numerical superiority with qualitatively superior

Coming this Fall

“Robotics on the Battlefield Part II: The Coming Swarm” will explore how the robotics revolution will enable new ways of bringing mass back on the battlefield, and the advantages of swarming.

weapons. Enabled by information technology, the U.S. fielded precision-guided weapons, advanced sensors and command and control links with the intention of allowing an outnumbered but

qualitatively superior force to decisively defeat a numerically superior foe. The effect of these technologies was most vividly seen in the Gulf War, when U.S. forces defeated Saddam’s Soviet-equipped military in a 100-

hour war that saw an outsized casualty ratio of 30-to-1.

The proliferation of information technology and precision-guided weapons is turning the tables on the United States, however, as other nations will have access to the same technologies that enabled a smaller force to target a larger one with high precision. Numbers may once again matter in warfare in a way they have not since World War II, when the U.S. and its allies overwhelmed the Axis powers through greater mass. Qualitative superiority will still be important, but may not be sufficient alone to guarantee victory. Uninhabited systems in particular have the potential to bring mass back to the fight in a significant way by enabling the development of swarms of low-cost platforms.

MASS CAN BE USED TO IMPOSE COSTS ON ADVERSARIES

Overwhelming adversaries through greater numbers is a viable strategy for technology competition, and was used successfully by the United States in World War II. One of the chief advantages of this strategy is that it can be used to *impose costs* on adversaries because it forces one's adversary to counter large numbers of systems. The value of mass in a cost-imposing strategy can be best illustrated with a simple vignette:

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Two adversaries, Red and Blue, are engaged in a technological competition of innovation and countermeasures. In an unguided munitions regime, both seek to maximize the rate of fire of their weapons and the density of the barrage landing on enemy positions. Because the unguided munitions are inaccurate, large numbers are needed to maximize the odds of a successful hit on an enemy target. Blue develops guided munitions first, however, and has a game-changing advantage.

With guided munitions, Blue is able to trade large numbers of unguided weapons for smaller numbers of higher-cost guided munitions, and this tradeoff is a winning strategy because the guided munitions have a high probability of kill (Pk) of hitting their target. Rather than pour thousands of unguided munitions at Red, Blue can invest scarce defense dollars into a mere handful of guided munitions that home in on Red and strike their target. Red is powerless against this approach.

This works great for Blue until Red develops guided munitions as well. Now Red can counter both Blue

munitions and, more importantly, Blue's power projection platforms that launch the munitions with Red's own guided munitions. This is a winning strategy for Red because – in this vignette – there is a fundamental asymmetry between Red's and Blue's strategic approaches. Blue is a naval power attempting to project power around the globe far from its home, while Red is a land power with a large land mass within which Red can hide mobile missile launchers and build scores of dispersed airfields. Blue has many targets to engage and Red has few.

Now Blue has two approaches to counter this new challenge from Red. Blue can continue to invest in fewer numbers of ever-higher quality assets or buy larger numbers of lower-cost and therefore lower-quality assets. Blue has a fixed amount of money, so every dollar spent on one type of platform or munition is a dollar robbed from another. Let's consider the value of each approach:

HIGH-QUALITY

Let's assume that for its money Blue can buy, for every given Red target, **1** high-cost, high-quality asset, with a Pk of 0.9. That is, this asset has a **90%** probability of achieving a kill against a Red target.

HIGH-QUANTITY

Alternatively, for the same amount of money Blue can invest in **20** lower-cost and lower-quality assets, each with a Pk of 0.11. Each individual weapon has only an **11%** chance of killing a Red target, but the aggregate odds of one of them killing a target if 20 are fired is 90%.¹

From Blue's perspective, both strategies are equal. They cost the same and achieve the same effect. In one, all of Blue's investment dollars go to a single high-quality asset. In the other, Blue resources are spread over a larger number of lower-cost assets which, in aggregate, achieve the same capability. Both are viable strategies for Blue, but how do they look from Red's perspective?



Artist depiction of Chinese DF-21D anti-ship missile widely circulated on Chinese defense-related web forums.

RED'S RESPONSE

From Red's perspective, countering Blue's high-quantity approach is much more difficult if Red's preferred method of countermeasure is hit-to-kill interception. If Blue adopts a high-quality approach, Red only needs to find a way to hit Blue's single asset. If Blue adopts a higher-quantity approach, Red needs to hit and kill *all of Blue's assets*, even though most of them will not actually succeed in killing the Red target.² From Red's perspective, this is a nightmare. Even though most of Blue's assets are not a threat, Red can't know which will miss and which will hit, making the problem of intercepting Blue's assets twenty times harder. Blue's choice to disperse combat power among a large number of assets is very cost-imposing to Red because Blue's assets effectively act as decoys for the ones that get through.

WHAT IF RED TRIED A DIFFERENT APPROACH?

The challenges involved in getting a kinetic hit-to-kill on all of Blue's assets might drive Red to adopt a different approach, instead focusing on reducing the Pk of all of Blue's assets across the board through the use of decoys or some kind of wide-area spoofing attack. What is the effect of such an approach on Blue?

Let's assume that Red adopts a countermeasure that reduces the effectiveness of Blue's assets by 50%.

For the high-quantity approach, Blue's Pk drops from 0.11 to **0.055** for each asset. In order to get back up to a 90% probability of a hit, Blue must launch **41** assets at Red instead of 20, or just over *double* what was required before Red degraded Blue's munitions' effectiveness.

For the high-quality approach, Blue's Pk drops from 0.9 to **0.45** for each asset. In order to get the total probability of a hit back up to 90%, Blue must now field **4** assets instead of one, an increase of *fourfold* over its original approach.

Again, numbers matter. Red's countermeasure that reduces the Pk of any given Blue asset by 50% is much more cost-imposing to Blue when Blue relies on high-quality assets. This makes sense, because when Blue was adopting a low-cost, high-quantity approach, Blue wasn't relying heavily on the quality of its assets individually for getting a kill anyway. Blue's approach favored mass and Blue can counter degraded quality by simply throwing more mass at the problem.

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"FLOODING THE ZONE" WITH UNINHABITED SYSTEMS

Are larger numbers of low-cost assets always the answer? Of course not. The merits of any given approach in a specific exchange depend heavily on the particular assets at play, their cost, actual Pk, the cost of countermeasures and counter-countermeasures and the cost of any platforms to get them into the fight. The example of trading twenty lower-cost assets with a Pk of 0.11 for one high-cost asset with a Pk of 0.9 is notional and used only to illustrate the value of mass. It is not necessarily indicative of any specific cost-quantity-Pk tradeoff. All things being equal, however, dispersing one's combat power imposes significant costs on the enemy by forcing the enemy to counter many threats, even if individually each of those threats is less capable.

Even if the cost-quantity-Pk tradeoff for a particular asset favors mass, the ability to get additional mass to the fight is essential to the success of this strategy. If Blue relies on \$1 billion power-projection platforms that can carry only four missiles each, then Blue ought to go with the higher-quality munitions. If Blue can field large numbers of low-cost arsenal ships and missile trucks to get more assets into the fight ... Well, then it is another matter entirely. Uninhabited arsenal ships in the form of missile barges at sea, large "pods" underwater, or uninhabited missile-carrying aircraft can be used to bring large numbers of low-cost swarming systems into the fight in a cost-effective manner. These could impose severe costs on adversaries, effectively "flooding the zone" with U.S. systems, saturating and overwhelming enemy defenses.

The advantages of swarming uninhabited systems will be explored in a forthcoming new report from CNAS this fall, "Robotics on the Battlefield Part II: The Coming Swarm."

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Previous 20YY Reports

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ENDNOTES

1. Total probability of a hit for a salvo is given by the following formula: Probability of hit = $1 - (1 - Pk)^N$ where Pk is the probability of kill for a single munition and N is the number of munitions fired in a salvo.
2. Of course, reducing the number of Blue's assets has some value for Red, even if Red does not eliminate all of them. Partially reducing Blue's salvo reduces the likelihood of Red's target being taken out, even if it does not eliminate it entirely.