Center for a New American Security

The Coming Swarm: *The Quality of Quantity*
By Paul Scharre and James Marshall

During the Cold War, faced with the reality of a significant numerical advantage by the Soviet Union, the United States focused on developing qualitatively superior weapons. A side effect of this approach, however, has been more complex weapon systems with ever-rising costs and, as a result, even further diminishing numbers of U.S. systems.[1]

> **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.

In 1984, Norm Augustine observed as one of "Augustine's Laws" that the cost of military aircraft was growing exponentially, while the defense budget was only growing linearly. He humorously noted:

> In the year 2054, the entire defense budget will purchase just one tactical aircraft. This aircraft will have to be shared by the Air Force and Navy 3½ days each per week except for leap year, when it will be made available to the Marines for the extra day.[2]

Of course, such a trend becomes a problem long before the Department of Defense gets down to only one aircraft. That time is now.

AUGUSTINE'S LAW: RISING AIRCRAFT COSTS OVER TIME
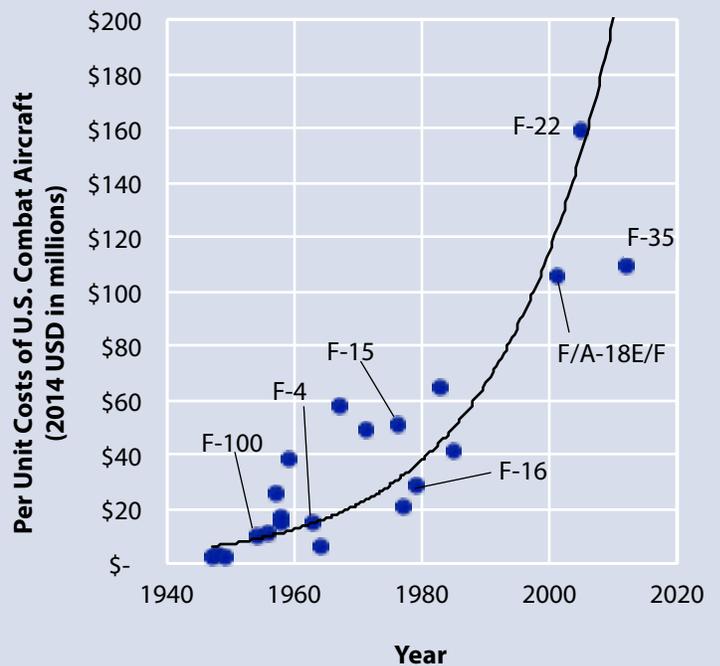
Sources: Marcelle Knaack, *Encyclopedia of USAF Aircraft & Missile Systems;* Congressional Budget Office, *Total Quantities and Costs of Major Weapon Systems Procured, 1974-1993;* and DoD: F/A-18E/F SAR (2012), Air Force FY 2011 Budget Estimate and F-35 SAR (2013).

RISING COSTS, SHRINKING QUANTITES

Rising costs have pushed down procurement quantities for not only aircraft but also ships. Furthermore, shrinking procurement quantities have the pernicious cyclical effect of further driving up per-unit procurement costs, as developmental costs are spread over fewer and fewer units. This can lead to more cuts in production numbers.

From 2001 to 2008, the base (non-war) budgets of the Navy and Air Force grew 22% and 27%, respectively, adjusted for inflation.[3] Meanwhile, the

> **Shrinking procurement quantities have the pernicious cyclical effect of further driving up per-unit procurement costs, as developmental costs are spread over fewer and fewer units.**

number of combat ships and aircraft in the U.S. inventory *declined* by 10% for ships and nearly 20% for aircraft over the same period.[4] A number of factors contributed to this decrease in numbers despite an overall budget rise, and this was in part due to a deliberate choice by the Navy and Air Force to emphasize quality over quantity. But better quality can only compensate so much.

DECLINING AIR COMBAT POWER FROM 2001-2014
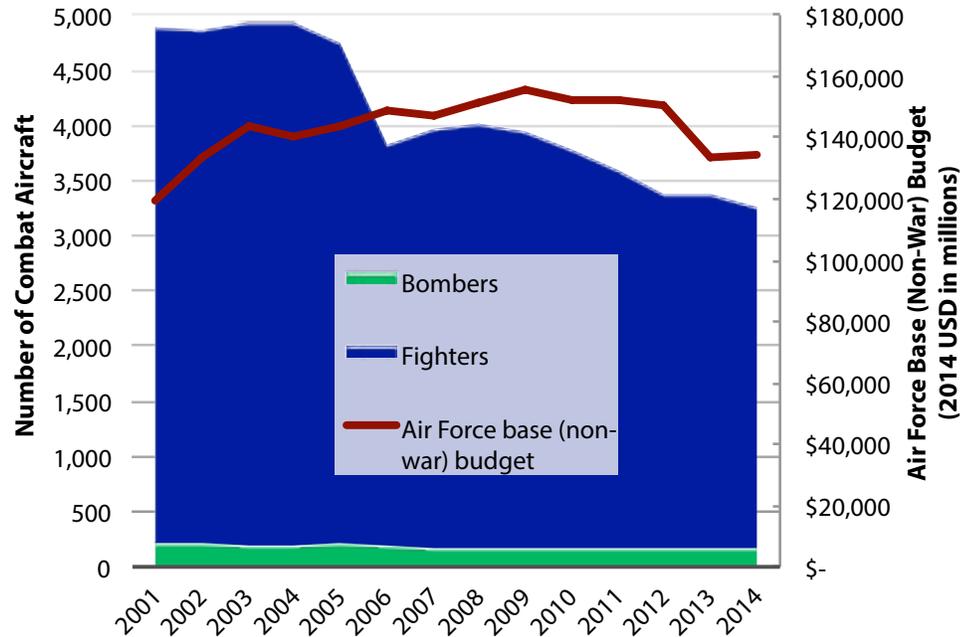
Source: International Institute for Strategic Studies. Includes aircraft in store. Budget data from U.S. Department of Defense.

DECLINING NAVAL COMBAT POWER FROM 2001-2014
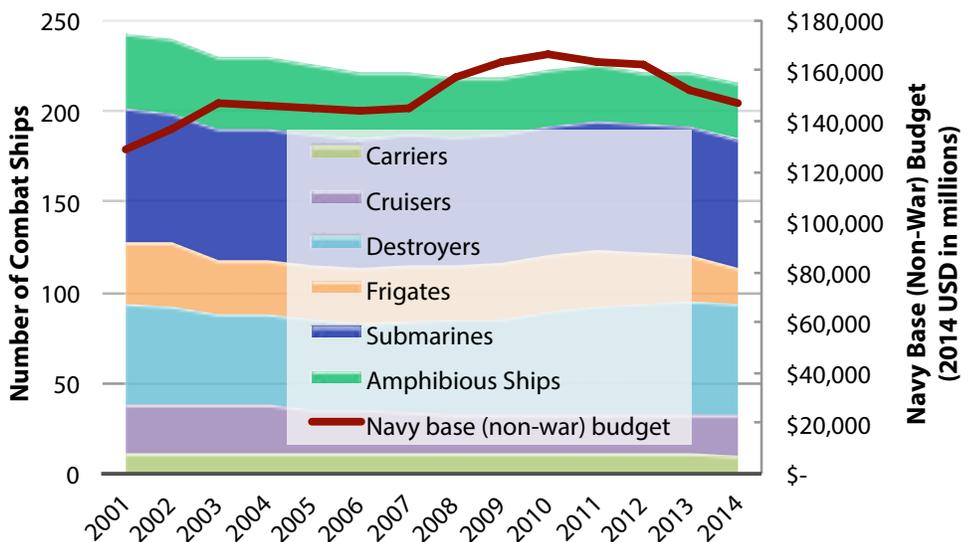
Source: International Institute for Strategic Studies. Includes ships in reserve. Budget data from U.S. Department of Defense.

NUMBERS MATTER

A standard rule-of-thumb for the advantage of quantity vs. quality in military engagements is Lanchester's Square Law. Lanchester's Square Law states that, all things being equal,

Twice as many units in the fight actually translates to a fourfold increase in combat power for units with aimed-fire weapons.

having twice as many units in the fight actually translates to a fourfold increase in combat power for units with aimed-fire weapons. This is because the numerically superior force can double up on attacking enemy units, while the numerically inferior force can only attack half of the opposing force at one time. This is in contrast to hand-to-hand combat, where combatants can only attack one person at a time, and a twofold increase in numbers translates to only a twofold increase in combat effectiveness.
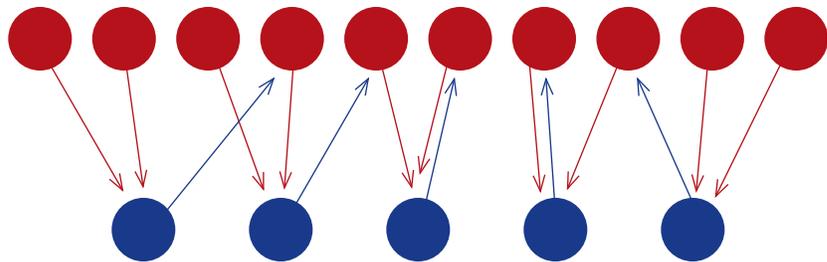
A numerically inferior force can compensate with greater qualitative superiority, but a force that is outnumbered by its opponent 2-to-1 must therefore be *four times better* in quality in order to simply match its opponent. There is, in essence, a limit to how much qualitative superiority can compensate for greater numbers.[5]

LANCHESTER'S SQUARE LAW

5 vs. 5
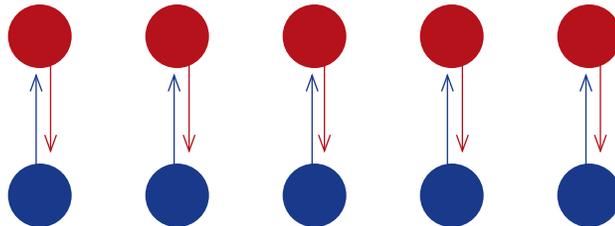
5 vs. 10

Relative combat power is proportional to the square of the relative sizes of opposing forces. A two-fold numerical advantage leads to a four-fold increase in combat power.

Hypothetical U.S.-China Air War

A 2009 RAND study on a hypothetical U.S.-China air war over Taiwan highlighted the value of numbers and the limits of qualitative superiority alone. Even though U.S. fighters were assessed to be far more capable than Chinese fighters – 27 times better in the case of the U.S. F-22 – China was able to launch nearly 800 sorties in the first day of fighting and won the battle.

Source: David A. Shlapak et al., *A Question of Balance*.

20YY WARFARE INITIATIVE

20YY Warfare is an ambitious, multi-year initiative to examine how rapid advances in robotics, autonomy, networking and computer processing will shape the future of warfare. 20YY Warfare will explore the impact of these and other emerging technologies on future concepts of operation, policy and strategy.

The 20YY Warfare Initiative will convene experts from the operational, policy, legislative, private sector and academic communities to tackle tough operational, policy and strategy issues on the future of warfare. 20YY Warfare will focus on publishing groundbreaking research and growing the community of interest on these issues, with the aim of delivering actionable recommendations to stakeholders today.

20YY Team

Paul Scharre
Fellow and Director of the 20YY
Warfare Initiative
pscharre@cnas.org

James Marshall
Research Intern

Shawn Brimley
Executive Vice President and
Director of Studies
sbrimley@cnas.org

Daniel Burg
Adjunct Senior Fellow
dburg@cnas.org

SWARMS OF LOW-COST SYSTEMS

Low-cost uninhabited systems offer a way to bring mass back to the fight. With no human onboard, they can take greater risk. Survivability can be balanced against cost, with swarm resiliency taking the place of platform survivability. Swarms of low-cost uninhabited systems can be used to saturate and overwhelm enemy defenses.

The robotics revolution will enable new ways of bringing mass back on the battlefield, and the advantages of swarming will be explored in a forthcoming new report from CNAS this fall, "Robotics on the Battlefield Part II: The Coming Swarm."

Previous 20YY Reports

MAY 2014
"Robotics on the Battlefield Part I: Range, Persistence and Daring"

JANUARY 2014
"20YY: Preparing for War in the Robotic Age"

Acknowledgements

We would like to thank Russell Rumbaugh of the Stimson Center for his valuable insights on defense accounting. Any errors of analysis, fact or omission are ours alone. CNAS does not take institutional positions.

ENDNOTES

1. For more insight on the sources behind this cost growth, see Mark V. Arena et al, *Why Has the Cost of Fixed-Wing Aircraft Risen?* (Washington: The RAND Corporation), 2008; and Mark V. Arena et al, *Why Has the Cost of Navy Ships Risen?* (Washington: The RAND Corporation), 2006.

2 Norman R. Augustine, *Augustine's Laws* (American Institute of Aeronautics, 1984).

3 U.S. Department of Defense, *National Defense Budget Estimates for FY 2015,* Table 2-1, available at http://comptroller.defense.gov/budgetmaterials.aspx.

4 International Institute for Strategic Studies, *The Military Balance (2001)* and International Institute for Strategic Studies, *The Military Balance (2008).*

5 Lanchester's Law is a very rough rule of thumb given for illustrative purposes. In a precision-guided weapons exchange, models focusing on the probability of kill are more accurate. Nevertheless, the overall point about a limit on how much better quality can compensate for reduced quantity remains valid.