The Lazy Person's Guide to Command and Control

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Command: To give orders to.
Control: To exercise authority or influence over.

Command and Control (C2): Together, these two words represent the foundation of the military environment. Without C2 a large mass of armed people is simply a mindless mob. In this article we will look at the process of C2, some of the ways technology has affected command and control over the years, and a view of what it might become in the future.

As is my habit, this article will cover the social aspects of C2 as much or more than the technical side. There are many people who can describe the intricacies of the Global Information Grid, or the Navy's Common Operating Environment far better than I can. What I would like to do here is give you some history and insight into how we got where we are and where we might want to go with C2 as a system that includes humans as the key component.

C2: The Basics

The basic unit of force, military or otherwise, has always been a single person. Pretty much every human activity can be measured against what one person can do with their bare hands. So, at its core, C2 begins with a single person's ability to observe, orient, decide, and act (known as the OODA loop). You see a threat or opportunity and respond to it. At the next level is cooperative action between two or more people. A group must reach a consensus of some type as a prerequisite for successful action. This can either be by conscious agreement or conditioned reflex. In the case of the best performing teams, be they military units or basketball players, they do both. Effective C2 systems facilitate cooperation.

Another key principle of C2 is simplicity. First, this means that the people should only have to deal with the minimum amount of information they need to get the job done. The challenge here is that the amount and type of information a task force commander needs is radically different than that needed by a Marine platoon leader or a fighter pilot. Some part of the C2 system, either human or automatic, has to sort and aggregate information appropriately for every participant.

Second, people in the middle of battle have a limited attention span for anything that is not directly related to shooting and not being shot. The signals sent need to be simple, clear and direct. Anything that distracts frontline troops for more than a few seconds is likely to get them killed.

Here is one last piece of philosophy before we get into a more specific discussion of C2. According to an old Warren Zevon song, the three sources of power in the world are "Lawyers, Guns and Money." While that may seem the case in today's news, I am inclined to a more generic description of these three factors. In his book, *Powershift: Knowledge, Wealth and Violence at the Edge of the 21st Century*, Alvin Toffler proposes three basic types of power: knowledge, force and wealth. All three of these play a role in the effectiveness of projecting power.

Force is what people provide, enhanced by whatever technology they have. A rifle shot does more damage than a fist, and a bomb more than a rifle. However, a human still has to initiate the action. A horse can carry more than a person, a truck more than a horse, and a C-17 can carry about 85 tons of all of them. But a person has to tell them where to go and decide what they carry. The rifle, bomb, truck, ship and airplane are all simply extensions of someone's ability to project force in their environment. Wealth is what we have that we can apply to a task. How many trucks, ships, or planes are available? Can we get more? Add in food, munitions, and yes, even people, and you have the assets that allow you to project force. Knowledge is what directs the employment of force and wealth. Without it, you are like Bruce Lee fighting blindfolded. Unless you can see your opponents and where to apply your assets, your luck will eventually run out no matter how good you are.

Simply having force, wealth, or knowledge, however, doesn't guarantee a successful operation. That's where C2 comes in, to monitor and control your environment and operations. But C2 is more than just a communications system tied to big databases. Effective C2 requires three things: reliable sources of data, a means to communicate, and a sense of community and trust.

Reliable data, either from sensors, databases or personal observation is the lifeblood of operations. However, this data is generally a passive part of the system until someone starts culling and applying it to answer questions and solve problems. Automated systems can provide greater amounts of data in less time than human observers, but automated systems usually aren't that good at distinguishing useless data from useful data. They just collect everything. Data entered by people, while it can be of a higher quality, may also be subject to the limits or biases of the person involved. The goal is to make data collection as objective and comprehensive as possible and then develop effective and efficient methods of extracting what you need.

Communication is absolutely vital when giving orders. There are both technical and social aspects to this, but for most of human history the sound of a leader's voice

has been the principal method of C2. I believe this is still largely true today. However, one voice can only carry so far, so there have been many enhancements that have allowed a leader's commands to reach larger and larger forces. In *The Art of War*, Sun Tzu described the basics of managing larger forces on a battlefield 3,500 years ago in the following passages:

- *The control of a large force is the same principle as the control of a few men: it is merely a question of dividing up their numbers. (V-1)*
- *Fighting with a large army under your command is in nowise different from fighting with a small one: it is merely a question of instituting signs and signals. (V-2)*
- *The Book of Army Management says: On the field of battle, the spoken word does not carry far enough: hence the institution of gongs and drums. Nor can ordinary objects be seen clearly enough: hence the institution of banners and flags. (VII-23)*
- *Gongs and drums, banners and flags, are means whereby the ears and eyes of the host may be focused on one particular point. (VII-24)*
- *In nightfighting, then, make much use of signal-fires and drums, and in fighting by day, of flags and banners, as a means of influencing the ears and eyes of your army. (VII-26)*

Communication also requires a common frame of reference and that's where the community aspect of C2 comes in. The participants have to know the language, signs and signals being used to understand and act upon the message. It's also helpful if the enemy does not, thus the use of codes, encryption, and other forms of obfuscation used to make sure that only your team gets the message.

The community also prescribes the boundaries that the C2 system can affect. There are many ways of describing communities, but for C2 I will narrow it down to a group of people with common goals and interests. This can be anything from eight people in a squad trying to secure a building to 100,000 people invading another country. Community is a social rather than a technical issue, but it is a linchpin of C2. If the people receiving orders do not feel themselves bound to the larger community, they may not follow these orders.

Ultimately, though, it all comes down to trust. You can have all the force, wealth, knowledge, community and communication you want, but if the person receiving the order does not trust its source, C2 will fail. Trust becomes more of an issue the farther away we get from direct, face-to-face conversation with someone we know well and respect. There is a huge difference between receiving a telegram telling you to move an army 150 miles in 19 hours and General George S. Patton personally telling you to move an army 150 miles under heavy-fire to relieve Bastogne in 19 hours. Wars have been won or lost on such differences.

C2: The Electronic Age

Flags, trumpets and lights served C2 well for most of human history, but the introduction of electronic communications brought a whole new dimension to commanding and controlling. For the first-time ever, humans had a reliable way of communicating beyond line-of-sight. Early use of electronic communications was limited by the requirement for a wired connection. The telegraph saw some use during the Civil War, but tactical C2 still depended primarily on more traditional signaling devices like flags and bugle calls. The first real impact from electronic communications came with the introduction of the radio. Portability and the range of early field radios were issues, but by WWII radio played a significant role in C2.

During my research I found a wonderfully comprehensive article about the development of C2 capabilities and doctrine in the first part of the 20th century: "History of Communications-Electronics in the United States Navy" (http://earlyradiohistory.us/1963hw.htm), by retired Captain Linwood S. Howeth, USN. Howeth describes the early development of radio technology and the development of radio use in the Navy. I invite you to read through the entire work. If you only read one part of it, however, read the introduction by Fleet Admiral Chester Nimitz. If that doesn't inspire you to read at least some of the rest of the article, nothing will. Some of the things I found most interesting in Howeth's article were the stories about the reactions and opinions of the Naval officers involved with early trials of wireless equipment 100 years ago. There was apparently great resistance to the first attempts to introduce radios into Naval operations. Among the arguments used against employing radios were:

- Using it would give away your ship's position.
- The enemy might break your codes and steal your plans.
- Even if the enemy couldn't understand your signals, they could jam your frequencies and render your radios useless.

While all of these were (and still are) potential problems, Howeth suggests that captains and admirals may have also resisted because they were used to having considerable autonomy. They may not have relished the idea of having someone on shore calling up and interfering with their command while they were out at sea. Howeth notes 1911 as a low point in the history of Naval radio use. The first major tactical tests under battle conditions were apparently a complete failure. What was noteworthy was that very few of the problems were related to the technology, rather the problem was with the *people* struggling to use something new and unfamiliar. Equipment was not installed properly and training was weak — if it was done at all.

It may be easy to look back knowing what we do today about frequency management, radio discipline, and radio-based C2 and congratulate ourselves on how smart we are. But please understand that we are currently attempting to integrate technologies into today's C2 that are as radical to us as radio was 100 years ago. There are some important lessons to be learned from their experiences about how to adapt and evolve C2 based on a new communications environment. First, don't assume everyone will automatically embrace new technology. This is usually more a function of habit than conscious resistance. People trust what they know, particularly where it involves life or death situations

like combat. Second, beware of people who embrace new technology too enthusiastically. Uninformed optimists can wreak far greater havoc and chaos than stick-in-the-mud pessimists. At least the pessimists won't make things any worse than they already are. Third, not all technologies can be applied equally across the board. What works at home may not work deployed. What works deployed may cost too much to install at home. The trick is finding a balance so you get one, seamless system. Finally, take into account how your target audience wants to work, because if the system does not match their style, they will likely try to bypass it.

Once the Navy got past some initial hurdles, the effects of radio on C2 were profound. At first, the radio was only used to duplicate orders issued by flags and other visual signals. Over time, however, as Sailors became more familiar with it, radio eventually became a primary means of transmitting orders between units ashore and at sea. By World War II, radio was an integral part of C2 for all U.S. military forces. Today, radio transmissions blanket the globe and the medium serves as a backbone of modern analog and digital communications. It is hard to imagine operating today without radio in some form, but as with many of the technologies used in modern warfare, radio has been part of C2 for less than 100 years.

C2: Sensors

Radio gave us a way to control modern forces and direct them to where they need to be. But how do you know where you need them? Locating targets, or even your own position relative to a target, is a function of sensors, the eyes and ears of the command function. While we are in historical mode, it is important to note the development of two other technologies during WWII that also have a key role in C2: radar and sonar.

Radar is short for "radio detecting and ranging." It locates objects by beaming pulses of radio waves and reading the echoes that bounce back off the objects in the path of the waves. Direction is determined by sweeping pulses around the antenna transmission arc and then seeing which ones will come back. Distance is determined by timing how long it took a pulse to return. The radar systems used in WWII could locate targets at a distance of 33 miles and distinguish between multiple targets at around 26 miles. This gave U.S. forces, particularly in the Pacific, a tremendous advantage in conventional Naval combat and anti-aircraft operations, particularly at night and in bad weather.

Sonar is short for "sound navigation ranging." Its importance as a sensor can be seen by the progress made by Allied anti-submarine operations in the Atlantic from 1940-1944. In 1940, Axis submarines were sinking an average of 80 Allied ships per month. When the Germans began their "wolf pack" operations 1941, that average went up to 93 Allied ships per month. However, thanks to improvements to both sonar apparatus and anti-submarine tactics, the tide began to turn. In November 1942, the Allies lost only 23 ships to Axis submarines out of 1,065 assorted Allied vessels that traveled from the United States and United Kingdom as part of the North African invasion. In 1943, the Allies were dropping sonobuoys from aircraft, increasing their detection ability. That year, the number of Allied losses dropped. During the winter of 1944, the Allies sank more submarines than the Axis sank ships. The final proof of the value of electronic sensors came during the D-Day invasion. Due to tight radar and sonar screens, the Allies did not lose a single vessel to submarines for over three weeks. The Germans never regained the upper hand.

Today, we have high altitude reconnaissance and satellites that can give us a detailed view of the entire planet. Our sensor technology has become so sensitive that we can tell how many living creatures are crossing a particular patch of ground and whether they are walking on four legs or two. They are all sources of data, but each new advance adds more complexity to the system. Life is still full of little trade-offs.

C2 Today

Much of modern C2 doctrine was developed during WWII and the basic principles remain the same: observe, orient, decide and act, the OODA loop I mentioned earlier. The force that accomplishes this faster will have the advantage in battle. Improvements in our sensor systems, communications gear and tactics have improved the speed with which we complete this loop. Increased trust, both in new systems and in cooperating forces, also help the OODA cycle. More than one submarine commander in WWII, for example, plotted his torpedo bearings manually for every shot instead of using the analog target data computer containing prefigured firing solutions provided to every submarine in the fleet. Eventually, we came to trust computers enough to calculate firing solutions for us.

But there are two things that distinguish modern C2 systems from their predecessors. The first is the sheer volume of data they can convey. Field and task force commanders have access to huge, detailed stores of information related to every aspect of their operations and logistical support. The challenge today isn't so much getting information to commanders, but reducing or aggregating it to usable size. Also, we are developing systems capable of linking everyone right down to the basic infantryman in the field. They also need to know a piece, but only their piece, of the battlefield. As the principal function of a C2 system is to deliver trustworthy, useful information, a large part of that process will be how the system handles and presents information to all the individual participants.

The second difference is an increased use of autonomous C2 systems that can "OODA" far faster than a human can aspire to. I'm sure anyone reading this article is aware of cases where anti-

aircraft systems set on automatic have, unfortunately, fired on friendly aircraft. It's a difficult dilemma. Modern combat happens so fast that humans simply can't react to some threats fast enough. On the other hand, setting a weapon system on automatic without an ironclad way to have it identify friend from foe carries a certain amount of risk.

Today's "sensor to shooter" C2 systems are global webs of interconnected observers (radar, sonar, satellites, people), communications systems (wired and wireless), content (voice, data, video and images) and people. They include projects like the Global Information Grid, Force XXI, and the Army's Future Combat Systems. There are probably a lot of very bright people with an opinion about how to go about successfully integrating all the different C2 systems and components under development. Here are my two cents on the subject.

Replicating Human Cognition

Evolving our C2 systems beyond what we had in the 20th century will require a certain amount of autonomy. What I believe we need are large-scale cognitive systems that have the ability to solve all the small everyday problems that we mere humans handle without a second thought. We will need systems that do not just act on sensor data, but are capable of assessing the results of their actions and learning from them.

Impossible? Well, a few years ago cognitive experts claimed that a computer would never be capable of beating the best human chess grandmasters. In the last three matches with the world's top chess champions, though, computers have earned two draws and a win. We are not quite to the point of a HAL 9000 or Mr. Data from *Star Trek*, but computers are demonstrating increasingly sophisticated capabilities and behavior.

What kind of behaviors will automated C2 systems require? There are inherent differences between organic and machine behaviors. An aircraft, for example, does not flap its wings to fly like a bird does. They are two very different solutions to the same challenge: taking flight. However, when you are conserving energy while gliding through the air, the design solutions between bird and plane are, as Leonardo da Vinci illustrated, remarkably similar.

Developing the autonomous control systems of the future will depend on adapting our systems to operate in an environment that is currently suited primarily for human cognition and behavior. The best solutions will include design strategies that we already know work in our environment. An automated anti-aircraft system, for example, should be able to distinguish between hostile and friendly aircraft. It should also be able to make a decision on what battery should fire and whether it should use a heat-seeking or radar-guided missile to take out a hostile aircraft based on the target's type and knowledge of what munitions it has available. Humans have developed doctrine and tactics to deal with this over many years of experimentation. What we know can be programmed into a system.

However, it may be a bit like a bird trying to teach an aerospace engineer how to fly. Humans make value judgments and decisions every day, but try to diagram how we arrived at a decision that took two seconds and it can take days to describe all the parameters. It is probably why it took us so long to get into the air with the birds. Until we figured out a way to get airborne without flapping our arms, we were stumped, and even then it took us a few centuries before the Wright brothers made da Vinci's plans work.

A key challenge for 21st century C2 is to develop all of these individual sensor and control systems to cooperate together automatically when they come in proximity to each other, like the automatic wireless peer networking you can get from some 802.11b wireless Ethernet systems. Let's make these systems smart enough so that when a squadron of Air Force A-10s is attacking the same target as a squadron of carrier-based A-6s near a Marine armored assault force, the C2 system automatically groups them, gives them common radio frequencies, and provides a fused picture of the battlespace, even if the participants didn't know ahead of time that they would be operating in the same space.

In short, I want what I used to see on the *Star Trek* television series: a system that knows where everyone is and can put me in touch with them simply by saying my name and theirs. We can buy a $100 cellular telephone that will call Pete Hess when I push a button and say, "call Pete Hess." Why not do the same thing with C2 and have a system that automatically sets up a secure voice circuit when a task force commander says, "Task Force One to Abraham Lincoln?" While it may be labor-intensive programming everyone into the system, it should be no more complex than the one your Web browser uses to locate one IP address out of the millions on the Internet.

Final Words

If we compare this point in our history with the development of the signs and signals codified by Sun Tzu, we are at roughly 2400 B.C. as far as electronic C2 is concerned. We have a long way to go and a lot of potential to work with. We will probably pull a few "Zippys" along the way. But as long as we keep our focus on operational goals and don't become obsessed with technology for its own sake, someday we will get that *Star Trek* C2 system.

Until then, Happy Networking!

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