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Smartphones in the Tactical Environment: A Framework for Financial Analysis of U.S. Marine Corps Options

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30 September 2013

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Abstract

The purpose of this analysis is to explore the application of commercial smartphone technology in the United States Marine Corps (USMC) tactical environment. Based on our research and financial analysis, we conclude that the dual-use potential of smartphones makes their economics more attractive than the existing radios the USMC has available, and, therefore, the business case for deploying sleeved smartphones in the tactical environment complements the military rationale for adopting this technology. Because uncertainty exists about what the true productivity benefits of smartphones might or might not be for different kinds of USMC users, we recommend that the USMC adopt a staged investment approach to smartphones, starting with a substantive trial of the technology in order to better understand the potential economic benefits.

Keywords: Smartphone, Tactical Environment, Mobile Device, Telecommunications

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Smartphones in the Tactical Environment: A Framework for Financial Analysis of U.S. Marine Corps Options

Introduction and Background

Introduction

In 2013, the typical U.S. teen sends 3,339 text messages a month (i.e., over 100 per day).

The original proposal on which this report was based started with the premise that smartphones of the kind used by the typical U.S. teen might have tactical utility for the United States Marine Corps (USMC). Some of the same teens mentioned above go on to become newly minted USMC riflemen. So why not take a technology that they use ubiquitously in their personal lives and apply it to improve their warfighting capabilities and their productivity? After all, some Marines already BYOD (bring your own device) when authorized by their commander or acquire mobile cellular capabilities from local providers while deployed. In other words, they are even willing to bring their own gear/stuff to work in order to work faster and better (i.e., more productively). Some of those productivity benefits undoubtedly spill over and are captured by the Department of Defense (DoD).

In our proposal, we posited the potential value of a secure mobile virtual network operator (sMVNO) concept for USMC tactical operations as a way of implementing smartphones over a private cellular network. Since we wrote the proposal, quite a lot has changed in the fast-moving tactical communications environment: The technical options are evolving at a clip, USMC requirements have changed, and—not least of all—the budgetary environment (with sequestration and a likely budget drawdown) has altered considerably with several of the USMC budget priorities cut back significantly, including some in the command and control (C2) area. USMC end strength, currently at 195,000, will almost certainly fall, perhaps by as much as a quarter in the medium term (to around 150,000) depending on future congressional appropriations. Certainly, the prospects of a significant USMC end-strength reduction cannot be ignored.

The good news is that opportunities for deploying smartphones via DoD private cellular networks have increased and offer one potential way of soaking up some of the USMC end-strength reduction by improving the warfighting capabilities and productivity of the individual Marines that remain and, consequently, the Corps as a whole compared to what it would otherwise be. It is the usual story: a smaller fighting force, but one that packs more punch per rifleman/sailor/pilot. Achieving this requires innovation in the way the USMC does things, something that is already high on the strategic agenda at the USMC, as emphasized in Figure 1.

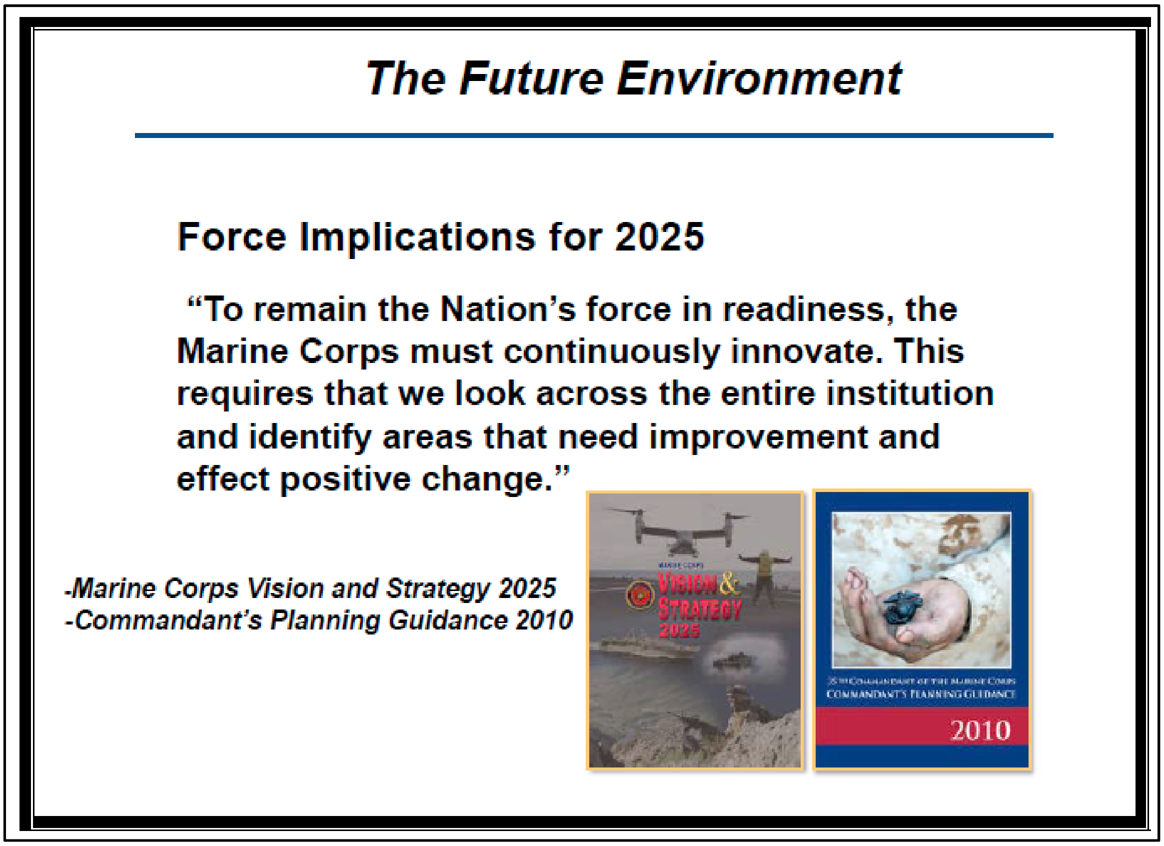

Figure 1. USMC Planning Guidance (Naval Research Advisory Committee [NRAC], 2012)

The analysis we provide in this report is designed with this guidance in mind. We see the combination of commercial off-the-shelf (COTS) smartphones and COTS private cellular networks integrated with military hardware and software as providing innovation potentialities that are well worth further analysis and experimentation. The report reflects the most up-to-date information that is available to us about the directions that the USMC and DoD are following for deploying smartphones and private cellular networks. This looks like it will not include the sMVNO concept we mooted a year ago, so in the report we focus on analyzing two more likely paths of smartphone and cellular network adoption:

- the deployment of a secure H2 smartphone sleeve to increase capabilities at the squad level (a project already initiated by MARCORSYSCOM (Marine Corps systems command) under the MOBILITY JCTD); and

- the deployment of Oceus Networks private cellular systems to increase the capabilities of the company combat operations center (COC; a project similar to one already developed via the JOLTED TACTICS JCTD, of which the U.S. Army has already initiated purchases).

Importantly, the report is designed to be of practical use to USMC stakeholders, specifically staff at MARCORSYSCOM, and potentially also in the U.S. Army, which is considering similar initiatives to the USMC.

Our basic conjecture is that sleeved smartphones may be not just militarily justifiable owing to their tactical utility, but are financially justifiable based on their *dual-use economics*: They may pay for themselves by generating productivity benefits for Marines while dwelling at home station, even if we attribute zero financial benefits for the days the phones are deployed in the field. Or, to put the same point in a different way, if a sleeved smartphone offers similar tactical utility to the PRC-152 and PRC-153 radios currently used, then the tactical benefits are a “wash” in the financial analysis, and we can therefore ignore them. Instead, we can focus on the relative costs of the different alternatives and on their potential for productivity benefits. In fact, there may be a financial case for adopting smartphones without an H2 sleeve for non-tactical use, simply based on their productivity benefits. We explore these alternatives in this report.

Our approach is to examine the business-case analysis (BCA) for sleeved smartphone and private cellular network adoption by analyzing a reasonable set of assumptions around this issue, but we acknowledge that we have made many simplifications in our approach. Partly, this is owing to constraints (i.e., data incompleteness). But, just as importantly, these simplifications are a choice. For example, we know that salaries vary among riflemen according to the exact rank make up in a particular squad, platoon, or company. However, for the most part, we use an E1 salary as a benchmark for evaluating the BCA. This is not because we don’t know better; it is because it reduces the number of assumptions we make in the analysis, keeps the math more simple and therefore more transparent, and makes it easier for others to replicate or test and alter. Also, it means we have made some choices about what we think are the key drivers of the analysis, the factors that really make a difference in producing the main results. Because our approach is high level (we make some very general assumptions), our analysis is in fact best thought of as a “first cut” that will be useful in helping to frame the business case for/against smartphone and cellular network adoption and to point to where some more detailed analyses might be worth doing.

As a preview of our findings, the main conclusion we draw is that the dual-use potential of smartphone technology makes the economics more attractive than the existing radios USMC has available. Hence, the business case for deploying tactical sleeved smartphones complements the military rationale for adoption. The big economic benefit of smartphones will be in how they enable Marines to work smarter when at their home base as well as fighting better when deployed (if that in fact proves to be the case).

We draw a second important conclusion concerning the implementation of smartphones in light of uncertainty about exactly what their productivity benefits might be. The key point is that there is no substitute for actually trialing the technology to find out more about the benefits case. Therefore, it would make a lot of sense for the USMC to adopt a staged investment plan where it deploys, for example, 1,000 smartphones across a wide variety of users and then collects data on the actual productivity benefits that accrue. A larger scale roll-out of smartphones would be contingent on the results of the test stage.

The Context for Tactical Smartphone Adoption

Smartphone Diffusion Is Happening at a Rapid Clip

People like having a mobile computer in their pockets. The market penetration of mobile phones is already over 100% in the United States (102% in 2012), which trails Europe, where diffusion averages 126% in the six biggest European countries (Germany, the United Kingdom, France, Italy, Poland, and Spain). In many ways, this tells its own story: Households obviously find mobile phones a compelling proposition whose value to the household (or individual) significantly outstrips what they have to pay to acquire mobile service.

Consumers are quickly transitioning from mobile phones to smartphones, which are experiencing a tremendous growth in sales (see Figure 2). In the United States, Nielson research reported that smartphone penetration of the mobile phone market is 75% among 18–24-year-olds, 78% among 25–34-year-olds, and 61% in the total market (Mashable, 2013). The United States is among six countries globally with smartphone penetration rates greater than 50%.

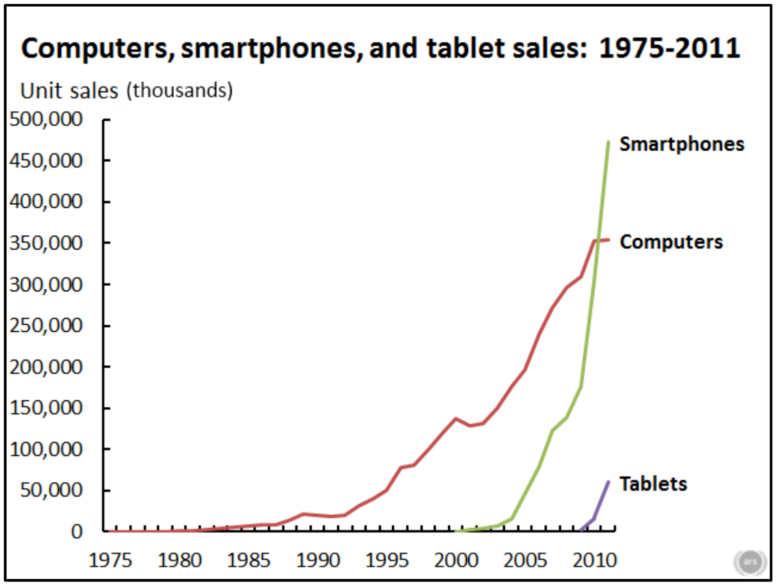

Figure 2. World-Wide Computing and Smartphone Diffusion

The Emerging Gap Between Tactical and Commercial Mobile Communication Technologies

Figure 3 shows a slide offered by General Peter Chiarelli at the Institute for Defense and Government Advancement (IDGA) conference at the Navy War College (NWC) on January 28, 2009. Using peak data rate as a key metric, the slide shows that commercial mobile technologies have been outstripping tactical mobile technology development, opening up a gap (the light blue area) between the capabilities on offer. The general's message was that the DoD should start leveraging COTS mobile technologies more effectively.

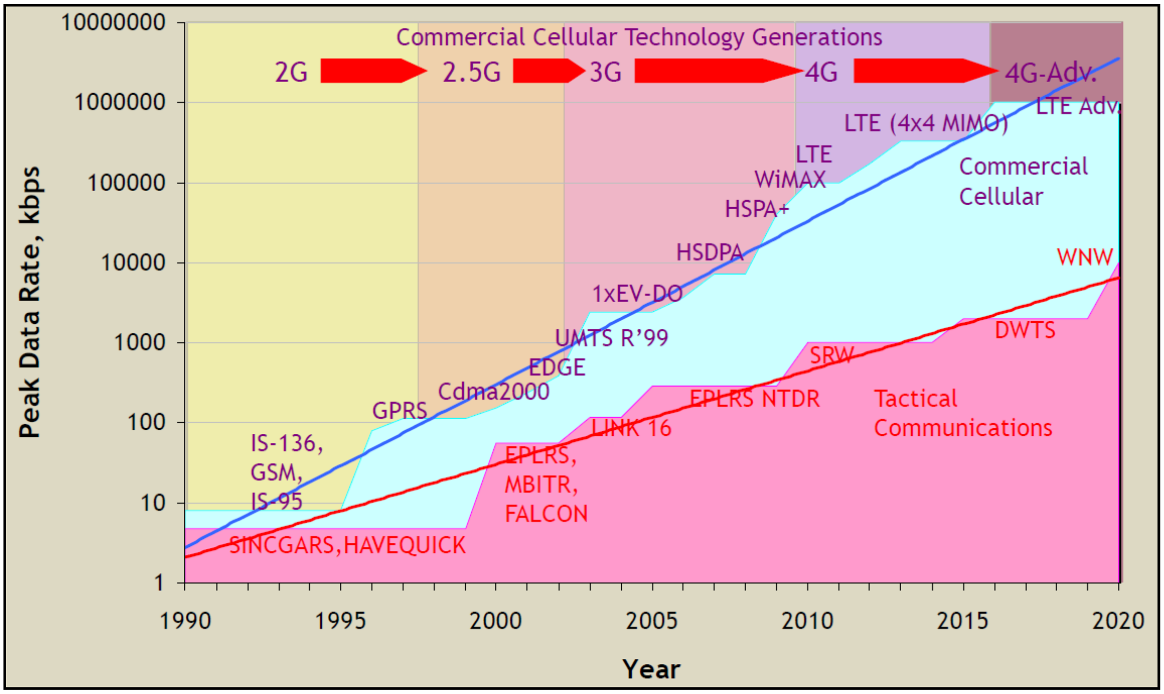

Figure 3. Gap Between Tactical and Commercial Communications Technologies (Chiarelli, 2009)

It is worth highlighting that this trend is driven by the high level of commercial research and development (R&D) spend on mobile technology development. Some sources suggest commercial firms are spending $60 billion/year on competitive R&D in this industry (Oceus Networks, 2013). As this year-on-year spend accumulates, it significantly outstrips DoD R&D spend on proprietary mobile communications, leading to the observed gap in Figure 3. Based on the DoD budget outlook, it is unlikely that this gap will close and rather more likely that the gap between proprietary and COTS may continue to grow in upcoming years.

This gap between proprietary and COTS system would not matter if DoD entities didn't want the capabilities that very high data rates coupled with powerful smartphones can offer, such as full-motion video, powerful mapping and visualization capabilities, and a raft of productivity-improving applications. However, these capabilities are highly desirable for our tactical forces. We need to have them, and we need to acquire them faster than our adversaries do. To do so requires that we find some mechanisms for leveraging fast-improving COTS technology, suitably adapted for our military's needs.

The Private-Public Productivity Gap

Accompanying this mobile technology gap, some evidence suggests that an important productivity gap has opened up between the private and public sectors over the past 25 years.

U.S. budget director Peter Orszag (2010) highlighted that there is a growing productivity gap between the public and private sectors. “Government too often is inefficient and wasteful, he argued, and Americans are rightly skeptical about its ability to perform effectively” (Eggers & Jaffe, 2013, p. 6). Orszag (2010) highlighted that historically public and private productivity were very similar. But starting in 1987, private-sector productivity improvements picked-up, while in the public sector after 2000 data suggests productivity actually fell (see Figure 4).

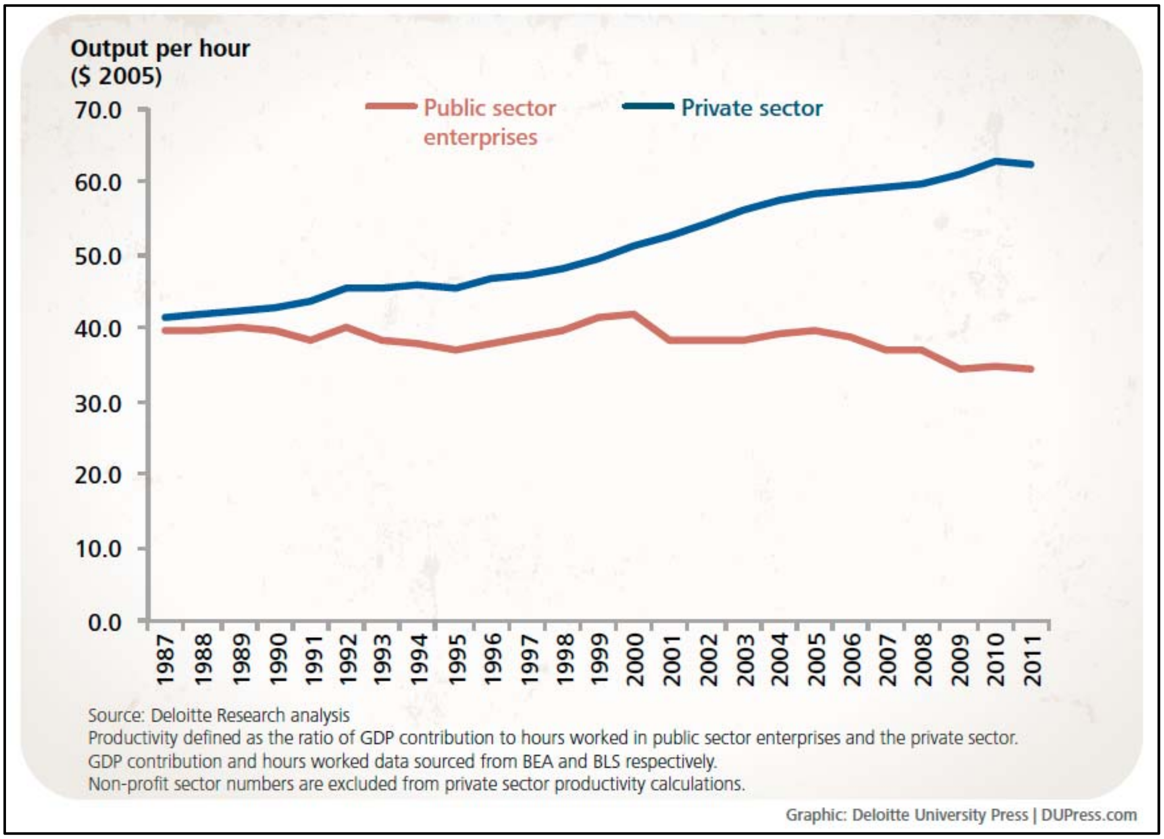

Figure 4. Private and Public Sector Productivity in the United States (Eggers & Jaffe, 2013)

Orszag (2010) argued that citizens perceptions of government inefficiency were being fueled by the gap they observed between public-sector and private-sector use of information technology and that they saw large improvements in efficiency and technology at work and home (the Internet, mobile devices) but not in their interactions with government.

The main message here is that there are *productivity* arguments for smartphone/private cellular network adoption by the USMC, as well tactical benefits.

What's Happening: Two Smartphone Investments Considered

MARCORSYSCOM H2 Smartphone Sleeve

Given the context for tactical smartphone adoption laid out in the previous section, various DoD initiatives are underway to leverage COTS smartphone and cellular networks for military use. One of these is a MARCORSYSCOM initiative to develop a sleeved smartphone as a Trusted H2 device under an initiative dubbed the Mobility JCTD (Dixon, 2013).

An example of a smartphone sleeve is shown in Figure 5, this one from Lockheed Martin's Monax system, which is called the Lynx.

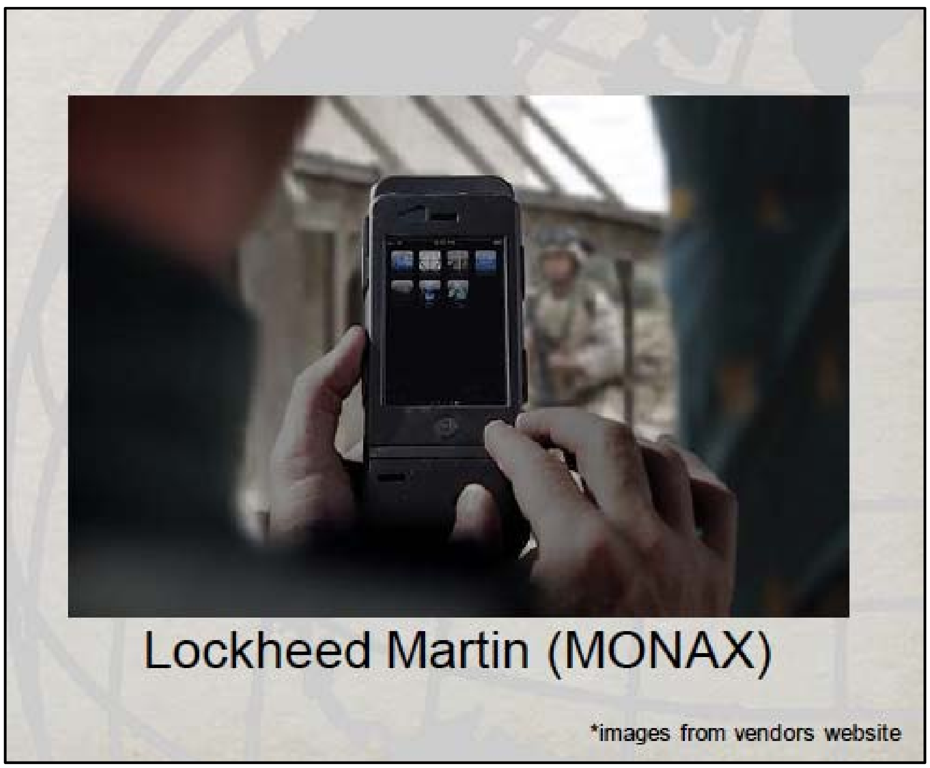

Figure 5. Example of Sleeved Smartphone (Dixon, 2013)

Currently, the USMC has no plan for acquiring an alternative technology that will enable data at the squad or platoon level before fiscal year (FY) 2017. The capability gap that this represents is recognized in the USMC and could be filled by the Mobility JCTD.

The basic user requirement for a Trusted H2 device is as follows:

- multiple small-form factor devices (i.e., smartphone and tablet sizes);
- lightweight, sufficiently rugged device;
- low battery use;
- enough data storage capacity for mission requirement;
- access to multiple data domains via cellular network, WiFi, and Bluetooth;
- COTS multitasking operating system;
- a display readable in direct sunlight and no light;
- GPS;
- meets security requirements;
- voice recognition, audio alerts, push-to-talk;
- camera;
- and affordability (replacing instead of repairing).

Though the Mobility JCTD is framed in terms of meeting the USMC's tactical requirements, this initiative may be equally important from a productivity-enhancing perspective, and hence the financial parameters of the project are crucial to consider. This forms the basis of the BCA we assess in this study.

JOLTED TACTICS JCTD

One major initiative that is ongoing to develop COTS cellular technology for the U.S. Army is the JOLTED TACTICS JCTD. This JCTD utilizes technology from Oceus Networks, among other vendors, to enable secure battlefield communications. An illustration of how the system is envisaged is shown in Figure 6.

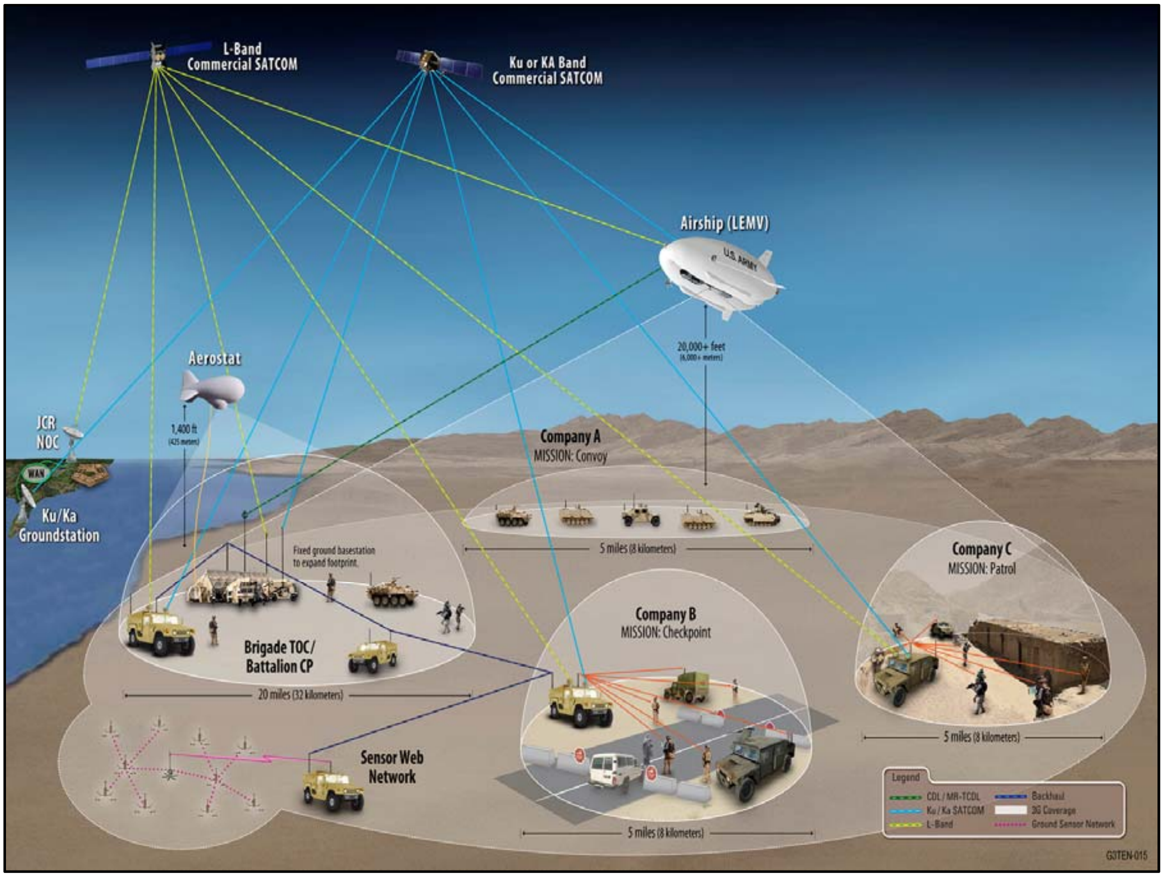

Figure 6. Illustration of Oceus Networks System (Oceus Networks, 2013)

The JOLTED TACTICS JCTD has been the major DoD venue for developing and evaluating Oceus Networks 4G LTE cellular technology for tactical use, including NSA (National Security Agency) security acceptance and the development of a “Deployable Spectrum Plan” for the acquisition of suitable government-owned or commercially owned cellular spectrum globally.

As of the time of writing, the Army has bought 36 XIPHOS 4G LTE systems from Oceus Networks for $17 million (M. Liguori, personal communication, August 2013). These systems are a small, deployable, private Cellular system that can be fixed or mobile (land, sea, air) and that creates a cellular network “bubble” that delivers tactical broadband capability (exceeding 1.5 mbps, potentially ranging up to several hundred mbps) over a range of up to 20 miles. If those systems work well, the Army may extend that purchase to between 2,000 and 5,000 Oceus Networks systems over time to meet aspects of its tactical communications requirements.

At this point, JOLTED TACTICS is more of a U.S. Army initiative than a USMC initiative, but the capabilities offered by such a system may also be attractive for USMC.

In what follows, we consider opportunities to deploy an Oceus Networks cellular network to increase the capabilities of the USMC company COC. The alternative we consider is a highly mobile, Oceus Networks-based COC as a substitute (under some circumstances) to the current convention of a semi-mobile COC with tents, tables, communications gear, generators, and so forth. Radical though this might appear at this time, what we propose is a thought experiment that envisages a somewhat old-fashioned/traditional company COC that is composed of a few Humvees occupied by the company's command staff, with all of their work accomplished on mobile devices (such as iPads and smartphones). Supporting this would be a complete virtualization of all of the software COC personnel require to accomplish their warfighting tasks (i.e., an entirely cloud-based IT architecture). This thought experiment forms the basis of the second BCA we assess in this study.

Smartphone Benefits: Where Do They Come From?

The Achilles heal of prior studies of smartphone technology adoption (Ball, 2013; Dixon & O'Neal, 2011) has been identifying *why* smartphones generate benefits (causes of benefits) and *how much* benefit they generate (size of benefits). Both need to be framed clearly in order for decision-makers to have a clear idea of the value proposition of deploying smartphones in whatever capacity. This is true for evaluating the tactical benefits of having smartphones available, as well as the productivity benefits.

It is worth noting that the productivity benefits of smartphones come from combining their capabilities with changes to organizational (or household and individual) processes and practices. It is important to understand that smartphones on their own do not improve productivity; instead, they are better viewed as an enabler or facilitator of productivity improvements (i.e., they help make people more productive by changing the ways they can accomplish tasks). However, the pervasiveness of mobile telecoms technology impacts on economic activity calls to mind the notion "general purpose technologies" described by David (1990). Such technologies make their impact felt by the sweeping changes they allow to productive arrangements, as highlighted by David's (1990) famous study of the impacts of the dynamo on a wide range of manufacturing and household activities. Of note, it takes time—historically, several decades—for general-purpose technologies to bleed through the economy completely because of the cycle of capital investment: For example, the reorganization of U.S. manufacturing plants took several decades of the early 20th century (David, 1990).

To study the benefits case for smartphones, we looked at a wide expanse of research, ranging from macro economic studies of cross-country comparisons of mobile phone use, to micro-level studies of the use of mobile devices in healthcare settings (scientific studies using control groups), to case study evidence (i.e., anecdotal data).

Data Collected

Macro Economic Studies

The impact of mobile devices is detectable at the macro level by studying cross-country variations in mobile phone penetration and correlating it with measures of economic growth and productivity improvements. The relationship between productivity growth and mobile phone penetration growth across a panel of countries is summarized in Figure 7.

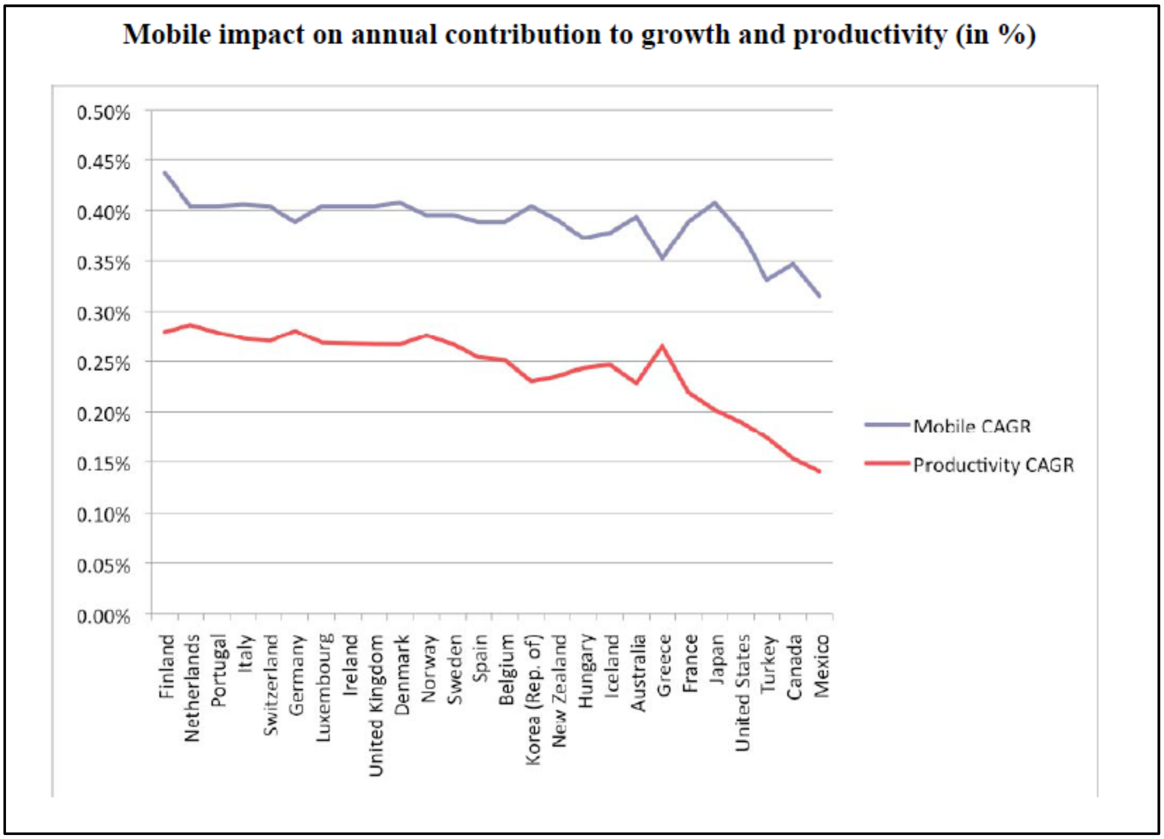

Figure 7. Mobile Impact on Annual Contribution to Growth and Productivity (Gruber & Pantelis, 2010, p. 36)

One important study on this topic is by Gruber and Pantelis (2010), who study these relationships across a large panel of countries. They conclude the following:

> The main findings show that mobile telecommunications diffusion significantly affects both GDP growth and productivity growth. … While in high income countries the mobile telecommunications contribution to annual GDP growth is 0.39%, for low income countries this falls to 0.19%.

> The growth contributions were also calculated for individual countries and this shows a very large range of contributions. Finland enjoys the highest growth contribution equal to 0.44% annually, while the last in the list Nepal has growth returns from mobiles of around 0.12% annually. …
>
> Qualitatively similar results and rankings are also obtained by looking at impact of mobile telecommunications infrastructure on productivity growth. … The contribution of mobile telecommunications infrastructure to productivity growth for high penetration countries is close to double that of countries with low mobile penetration. (Gruber & Pantelis, 2010, p. 41)

Although it is possible that the causal relationship between mobile phones and growth and productivity might be reversed (i.e., represent a wealth effect, with more mobile devices being purchased because countries are richer), it seems unlikely that mobile devices are not contributors to productivity improvements. To see why this is, one has to look at more detailed data on mobile device use, which we do next. In the meantime, we should hold the thought in mind that the overarching relationship between mobile phone penetration and productivity or GDP growth could flow causally in both directions (i.e., be a case of reciprocal causation).

Scientific Studies of Productivity Impacts of Mobile Devices in the Healthcare Industry

One research literature that has conducted many studies on the use of technology in improving productivity is healthcare (West, 2012). A systematic review of 13 studies of mobile handheld technology was conducted by Prgomet et al. (2007). These studies in general are well done, benefitting from the general practice in the healthcare and medical literature of using control groups to compare with the results of a treatment group (in the case of these studies, the “treatment” group was the group using the new technology). The review found that personal digital assistants (PDAs) positively impacted response times and error prevention, and provided superior data management and accessibility. The greatest benefits occurred when time was a critical factor (i.e., when rapid response was crucial). *These results seem very relevant for tactical use of smartphones by the USMC.*

For example, in a study by Adams et al. (2006), emergency department nurses wirelessly forward electrocardiograph (ECG) images to a cardiologist’s PDA, finding that there was significantly shorter door-to-reperfusion time (50 minutes) compared with control groups (101 minutes and 96 minutes). Two other studies we reviewed provided qualitatively similar results.

A different set of studies explored the issue of information accuracy (one measure of quality) by examining medication errors with and without PDAs. Grasso et al. (2002) found that a large reduction in medication errors occurred when doctors made prescriptions using a PDA rather than hand-written notes that had to be transcribed by nurses.

In another study, Sintchenko et al. (2005) analyzed the impact of mobile on-the-go information access via PDAs. The setting was patient management by intensive care unit (ICU) physicians who were given electronic access to laboratory data. Results showed that a significant decrease in antibiotic prescriptions occurred, and the average patient length of stay in the ICU shortened significantly (13% decrease).

A final interesting study is by VanDenKerkhof et al. (2003), who compared PDA use to paper records for patient pain management. The key factor examined was the comprehensiveness of information and the time it took to collect it—*again, these are two factors that pertain strongly to the tactical military environment, where speedy and comprehensive information collection can be highly valuable.* Results showed that doctors with PDAs were 25% faster collecting information and that they collected more comprehensive information more consistently (documented side effects were 5–100% for paper charting, but 98–100% for PDAs).

Individual Case Studies

There are a great many individual case studies described in multiple reports on mobile devices (for examples, see Entner, 2012; Eggers & Jaffe, 2013). Here we cherry-pick three key examples that are highly relevant for the USMC because they powerfully illustrate the impact mobile devices can have in organizational work.

Probably the singlemost famous case study of the impact of mobile devices is Jensen's (2007) study of the use of mobile phones by fishermen in the southern Indian state of Kerela. This case was published in *Quarterly Journal of Economics* (*QJE*), the top economics journal in the world, and is highly cited by other economists. Jensen (2007) specifically examined the "law of one price," an economic prediction that claims ought to be true if information can be exchanged relatively without cost, because individuals will arbitrage goods from one location to another until any price dispersions are eliminated (i.e., they will buy low in one location and transfer to a higher priced location). Prior to the introduction of mobile phone service in Kerela, it was common for there to be many inefficiencies in the fishing industry, as fisherman did not know which locations had excess demand or supply on any given day. The result was discounted fish on some beaches, high priced fish in locations that were short, and significant wastage.

Jensen (2007) examined the introduction of mobile phone services in Kerela between 1997 and 2001 used to communicate between fisherman (offshore, deciding which market to sail their catch to) and wholesalers (on the beaches, observing local demand on the day, and competitor presence). He found that price dispersion and waste were nearly eliminated by the adoption of mobile phones, which increased both consumer and producer welfare.

The case is considered powerful because it illustrates very clearly the value of information in making markets work efficiently, a concept that goes all the way back to Hayek's (1945) observations about the use of knowledge in society and why socialism was bound to lead to inefficiencies compared to capitalist economies. Of course, the same basic principles hold true for tactical operations: Local information is highly valuable; to the extent that smartphones might enable superior information gathering and dissemination, it will give the USMC a combat edge.

A second, very pertinent, case study comes from the United States Air Force (USAF) air mobility command's adoption of iPads to meet the mapping requirements of aircrew (USAF, 2013). Prior to iPad adoption, aircrew carried flight bags with several pounds of paper maps onto the aircraft. The USAF purchased 2,725 iPads for $1.6 million to use as electronic "flight bags." Probably the biggest benefit air crew experienced was one of the least tangible: Because of the iPad's GPS facility, aircrew could search the iPad faster than they could search paper maps, so the iPads improved situational awareness—and therefore safety—because aircrew spent less time in heads-down mode, and more time heads-up. Another way of capturing these benefits is to say that the iPads improved aircrew productivity.

The financial benefits were tangible in several regards and are an interesting model for thinking through how the USMC could improve the productivity of its COCs, for example. The iPads allowed the USAF to eliminate $3.2 million/year for printing maps and charts and $1.7 million/year in printing paper manuals (i.e., $4.9 million/year, which is roughly a four-month payback on the iPads). In addition, the lower weight of the iPads (compared to paper maps) saves $0.8 million/year in aircraft fuel and has allowed a 90% reduction in staff hours maintaining maps and charts, saving a further $0.9 million/year on 22,000 staff-hours. In sum, a simple payback for the iPad adoption was $6.6 million on a $1.6 million investment, i.e. a payback of approximately three months.

Of course, USMC helicopter pilots have their own stories of their struggles for iPad adoption in the cockpits of their aircraft, where iPad adoption has a similar (but arguably more critical) value for situational awareness in their missions. We merely use the USAF case here because the financial impacts of this case have been rigorously analyzed (USAF, 2013).

A final example of a highly relevant mobile device adoption comes from a Eggers & Jaffe (2013) report on the federal adoption of smartphones. The report cites the example of 2,300 foster-care caseworkers in Miami-Dade County, Florida. Before smartphone adoption, caseworkers spent 50–80% of their total time on administration. The availability of smartphones changed their work in many ways. They now spend less time in transit to face-to-face meetings because they can video-conference into them from any location. Smartphones have a silent panic button, which increases caseworkers safety. Caseworkers now instantly upload time- and location-stamped images to an online database; they also directly enter their case notes from the field, reducing redundant recording and entering tasks. Overall, the adoption of smartphones has led to a 30% increase in home visits, more timely reporting, and better compliance with state law (a measurable and significant productivity boost).

The caseworkers example illustrates some of the ways smartphones might be used to improve the productivity of Marines. Instant upload of time- and location-stamped images could be used to improve situational awareness in tactical operations but equally as well can be applied to home-base preparations, where the ability to create a maintenance order can be facilitated with an image of the gear that needs maintenance attention or a squad leader could send his riflemen an image of the exact set of gear they need to prep for the next mission. And who wouldn't save time if they could video-conference into any meeting from any location in their home base or barracks?

The Structure of Smartphone Benefits

In this section, we summarize what we have learned about the basic benefits yielded by smartphone use. We organized them into six overarching categories: scavenging time, faster response times, increased information availability, speedier data entry, elimination of paper/printing/publishing costs, and cheap, already adopted technology.

Scavenging Time From the Margins (i.e. "Multitasking")

Time and time again, studies indicate that the reduction of unproductive or semi-productive time is a major benefit of smartphones. Because these devices allow individuals to work from any location, they waste less time goofing off and are instead more likely to use marginal minutes to send or respond to a few emails (see data in Figure 8). This use of time results in more work getting done in marginal time slots, such as during the few minutes between meetings or while waiting for colleagues or the bus. Eggers and Jaffe (2013) quoted a study that estimated this additional productive time amounts to 30 minutes/day for police officers. Using smartphones for activities such as video conferencing reduces efficiency losses, such as time spent in transit between meeting locations (as noted in the Florida caseworker study). Surveys also indicate that people simply are available more hours if they are smartphone equipped: In one survey of U.S. federal employees, Meritalk (2013) estimated that federal employees are connected to their work for an additional nine hours/week if they have a smartphone.

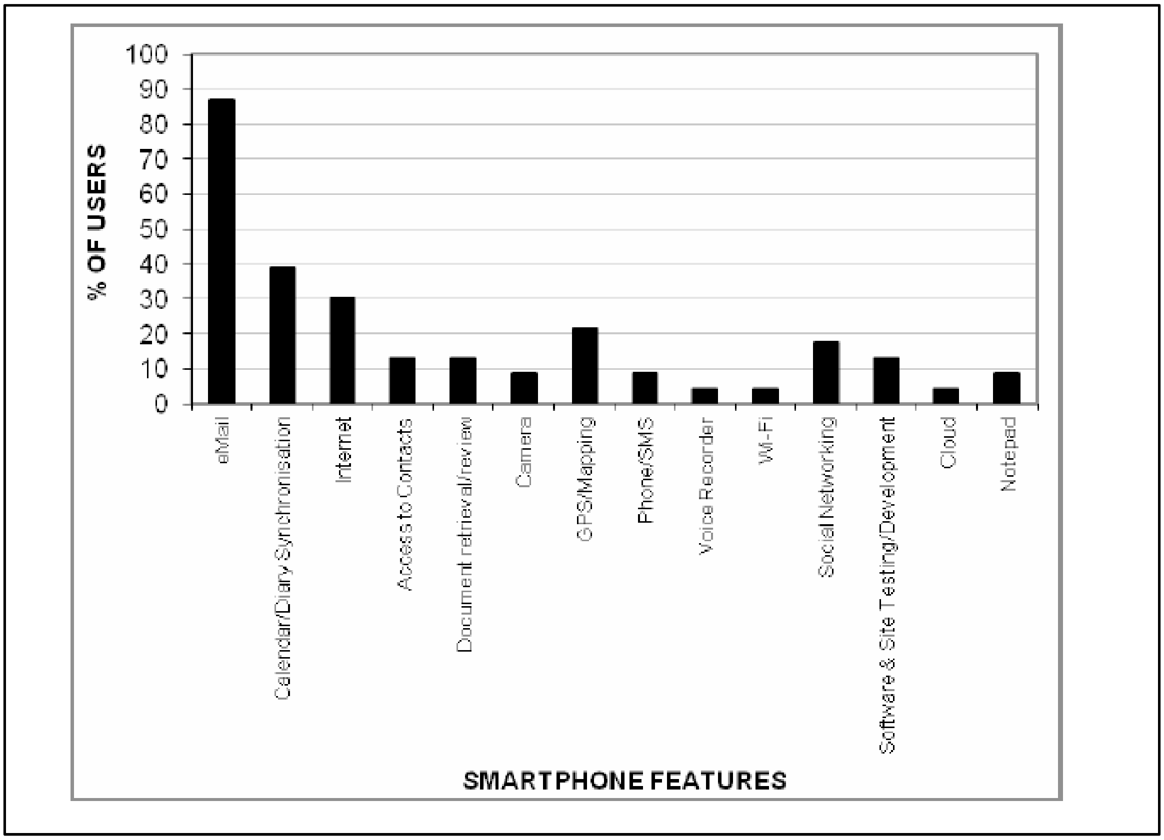

Figure 8. Perceived Smartphone Features With the Most Benefits According to User Surveys (Hopkins, 2012)

Faster Response Times

Increased responsiveness resulting in reduced wait times for co-workers is the second major benefit of smartphones. This allows faster and better coordinated work flow. Research shows that more than 80% of people keep their mobile device within 10 feet at all times, and more than 90% respond to a message within 15 minutes. A Forrester Research Inc. survey (2012) of 305 IT decision-makers found that 76% saw increased employee responsiveness and decision-making speed from the deployment of mobile devices. Reporting on a survey of Australian smartphone users, Hopkins (2012) stated, “When asked how working behavior has been affected by the added mobility a smartphone brings the most popular response was greater responsiveness (27%)” (p. 71).

Increased Information Availability

Greater information availability is another significant benefit of smartphones. This is a product with the ability to conduct lightning-fast searches of enormous information stocks. Obvious benefits include decision support (e.g., a reduction in drug medication errors owing to doctors checking for drug interactions or patient medical history before prescribing new medicines). Research on shopping habits shows that shoppers are increasingly using online search while in stores in order to assist their shopping choices, a form of improved situational awareness. The USAF's use of iPads makes a related point: an improvement in situational awareness stemming from automatic location tracking and rapid search available on an iPad compared to paper maps and charts. Improvements in the formatting and presentation of data can also aid situational awareness. Further benefits of increased information come from the multimedia capability of smartphones, in particular the ability to share images (a picture can be worth a thousand words) and to automatically time- and location-stamp images. Finally, the ability to prompt for information responses can be advantageous. For example, using a custom app, diabetes patients can receive personalized daily coaching and prompting to monitor blood sugar levels, nutrition, activity, and medications. This works well for diseases that have been shown to respond well to active management.

Speedier Data Entry

Reduced data entry times result in decreased costs of information gathering. We have already seen this in examples such as Florida caseworkers uploading multimedia files in seconds instead of writing up a report. The same phenomenon can also be seen in reduced error in data transcription when doctor's use a PDA to directly input discharge instructions and prescriptions, instead of writing them by hand. Physician studies also show that more data gets entered when done directly at the patient's bedside. Amtrak train conductors use mobile devices to enter maintenance work orders and update maintenance schedules, which is, again, faster than the old paper-based methods. Furthermore, we have already seen ways in which the ability to use automatic data elements—such as GPS location or time/date stamping—automates some elements of data entry, and therefore improves productivity. Automatically knowing the location of coworkers is an example. Such location data can be used for mapping and improving the situational awareness of Marines in tactical environments, or for enhancing the capability to call an ad hoc muster while back at home base.

Elimination of Paper/Printing/Publishing Costs

We saw in the USAF iPad case a detailed example of how mobile devices can reduce or eliminate paper and printing costs. Amazon Kindle books are a further example of the same phenomenon. Moving bits is usually cheaper than making/printing/moving paper.

Cheap, Lightweight, Low Power, Easy to Use, Already Adopted

Lastly, there are certain characteristics of smartphones that flow from their very ubiquity: the fact that they are already adopted (therefore, the USMC does not have to undertake an expensive implementation or training program); that they are cheap, owing to the vast volumes manufactured (cheap enough to throw away instead of repair, and cheap enough to upgrade regularly); that they have lower power consumption than alternative devices; they are low weight (which matters for applications in military aircraft and when people are hauling them); and, finally, that they are easy to use (intuitive for today's riflemen, many of whom have grown up using them as their main electronic communication device).

Measuring the Benefits: Consumer Surplus

The mix of data on the economic benefits of mobile phones suggests that while it is true (based on case-study and health data) that every particular situation has a different set of costs and benefits (which makes measurement an idiosyncratic, case-by-case affair), it is also true that these benefits aggregate to a common picture of significantly positive productivity impacts of mobile technology, which is visible at the country level.

For the purposes of the analysis in this study, we wanted a broader, aggregate measure of benefits that—while representing an average across many users—could ultimately provide a robust basis for analyzing USMC options for smartphone deployment without having to conduct a time-and-motion study for many different USMC smartphone deployment opportunities. For this, we followed the Office of Management and Budget (OMB) guidelines, which suggest using "consumer surplus" as a guide to benefits, where available.

OMB A-94 Financial Aanalysis Guidelines

Consumer surplus is defined as "the maximum sum of money a consumer would be willing to pay to consume a given amount of a good, less the amount actually paid" (Zients 2013, p. 18). As shown in Figure 9, economists represent consumer surplus graphically by drawing a downward-sloping demand curve (representing consumer demand for the good as a function of its price) and then drawing a price line in the same diagram representing the price at which the good is available. The shaded triangle bounded by the demand curve, price line, and *y* axis represents the surplus, or benefits, consumers capture from purchasing the good.

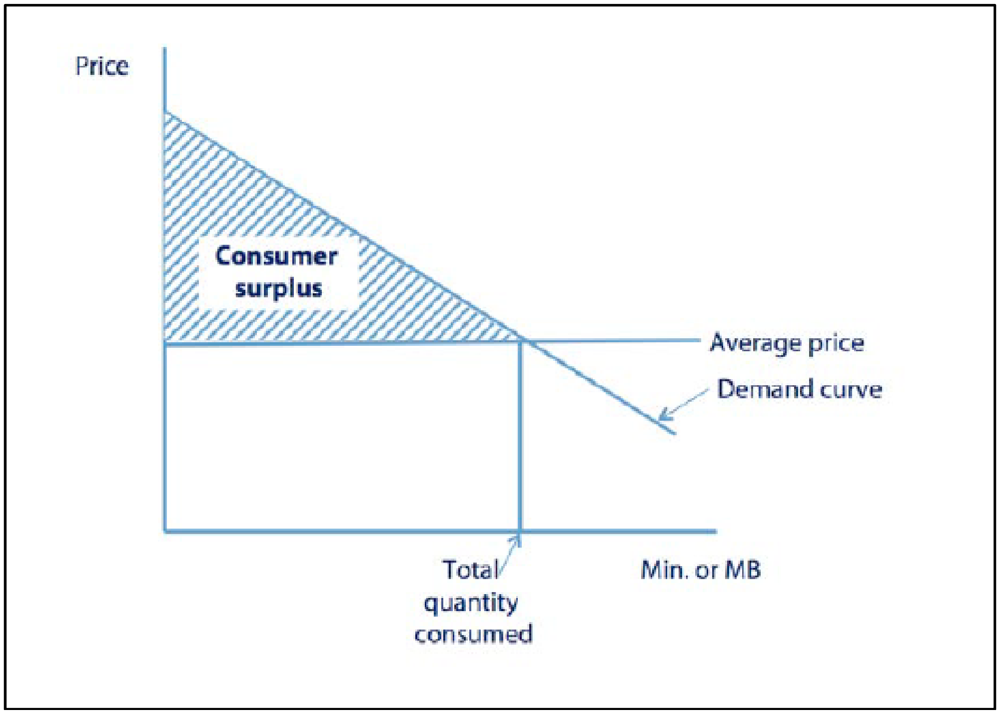

Figure 9. Consumer Surplus
(Nordicity, 2012/2013, p. 13)

It is worth noting that while consumer surplus is a well-grounded concept that is frequently used in economic theory, measuring it is much more difficult. For example, OECD (Organization of Economic Cooperatio & Development) and Massachusetts Institute of Technology (MIT) economists have engaged in a significant public debate over telecommunications policy in Mexico that in large part is driven by disagreements over the appropriate measurement of consumer surplus (OECD, 2012; Hausman & Ros, 2012). Here we follow OMB guidelines in using commercially available data wherever possible to make an estimate of consumer surplus. The following is according to OMB Circular A94 (Zients, 2012):

> ***Measuring Benefits and Costs.*** The principle of *willingness-to-pay* provides an aggregate measure of what individuals are willing to forego to obtain a given benefit. Market prices provide an invaluable starting point for measuring willingness-to-pay, but prices sometimes do not adequately reflect the true value of a good to society… When market prices are distorted or unavailable, other methods of valuing benefits may have to be employed. *Measures derived from actual market behavior are preferred when they are available.*
>
> ***Inframarginal Benefits and Costs.*** Consumers would generally be willing to pay more than the market price rather than go entirely without a good they consume. The economist's concept of *consumer surplus* measures the extra value consumers derive from their consumption compared with the value measured at market prices. *When it can be*

> *determined, consumer surplus provides the best measure of the total benefit to society from a government program or project.* (p. 7)

Therefore, we looked for data about actual market behavior available in prior studies on consumer surplus to build a picture of how it might be reasonably measured for smartphones.

UK Radio Communications Agency Report 2001

Probably the earliest econometric report on consumer surplus from mobile devices was published by the UK's Radio Communications Agency in 2001. It used a stated preference methodology to survey 500 private and business mobile phone users for their willingness to pay for mobile services and then compared this to the prevailing prices available to compute a consumer surplus for the UK mobile sector (phones and pagers).

Data indicated ("UK Radio Communications," 2001, p. 47) that business users had a consumer surplus of GBP (pounds sterling) 47.18/month, amounting to $2.52/day.

Consumers indicated a value of GBP16.27/month, which approximates $0.87/day.

The divergence in values between private and business users is important because it aligns with the intuition that mobile devices may be significantly more valuable to organizations than to private users.

Nordicity, Canadian Wireless Telecommunications Industry Report 2013

A similar set of consumer surplus calculations were conducted for the Canadian mobile market for 2012, including mobile broadband value as well as voice/text. The report (Nordicity, 2013) found the following:

- Mobile voice/text has a consumer surplus of US$9.0 billion for 27.4 million Canadian subscribers. This equates to $0.90/day/subscriber.
- Mobile broadband has a consumer surplus of US$2.5 billion for 10.9 million Canadian subscribers, which is $0.63/day/subscriber.
- Therefore, the total consumer surplus in Canada is approximately $1.53/day/subscriber, across all segments of users.

U.S. Data: Entner Report 2012

According to Entner (2012), consumer surplus for the U.S. mobile industry has been estimated several times over the past decade. Economist professor Jerry Hausman (MIT) estimated that the U.S. consumer surplus was in the range of $80–150 billion for 2002. At the time, industry revenues were $77 billion and there were

141 million wireless subscriptions. Economist professor Thomas Hazlett (George Mason University) testified before the U.S. Senate that the estimated U.S. consumer surplus was at least $80 billion per year in 2003. Based on the 141 million subscribers, this indicates a consumer surplus of at least $1.55/day/subscriber, ranging up to $2.91/day/subscriber. This data reflects mainly voice/text use.

In 2012, industry revenues were $185 billion (CTIA, 2013). Extrapolating from this, Entner (2012) estimated that consumer surplus was $504 billion in 2012, taking into account the increased user base and lower price of mobile services. Assuming 326 million wireless subscriptions (CTIA, 2013), this equates to a consumer surplus of $4.24/day/subscriber. In Entner's analysis, 90% of this surplus was for voice.

U.S. fixed/home broadband had 88 million subscribers in 2013 ("List of Countries," 2013). Empirical analysis conducted by Greenstein and McDevitt (2012) for the OECD indicates that the fixed broadband connectivity generated an annual consumer surplus of US$95 billion in 2010 in the United States, which is $2.96/day/person. Based on the methodology used by Nordacity for Canada, mobile broadband was valued at approximately 40% of the value of fixed/home broadband, indicating a consumer surplus of $1.18 for the United States. There are 234 million mobile broadband subscribers in the United States.

Europe-United States Comparisons

A final methodology for indicating consumer surplus comes from cross-country comparisons of mobile phone prices.

Data indicates that mobile phone penetration is higher in Europe than in the United States, with the six largest European countries (by population) having a 126% penetration rate, as compared to 104% for the United States.

However, Europeans often pay considerably more for their mobile service. Figure 10 indicates the costs of mobile phones across OECD countries, according to the OECD's (2011) report on telecommunications. This data uses a basket of 300 calls per month (10 per day) as provide a guideline price across different markets.

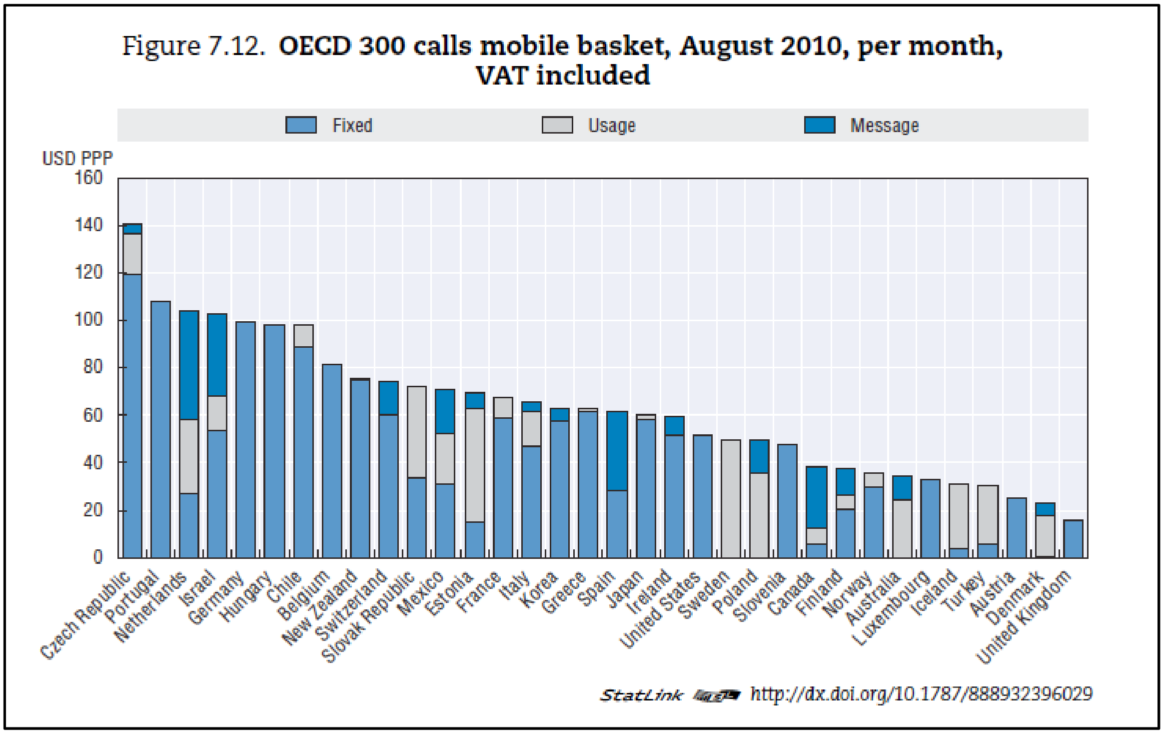

Figure 10. OECD 300 Calls Mobile Basket, August 2010, Per Month, VAT Included
(OECD, 2011, p. 261)

The upshot of the data is that the U.S. basket price, at $51.61, is less than half the price of a similar service in Germany (at $105.29, with a 130% penetration rate). In the Netherlands, Portugal, Hungary, Israel, and Chile, users also pay double the U.S. price for a typical mobile phone service (the OECD average is $62.55).

We can use the above data as a fairly strong indicator that the typical U.S. subscriber has a consumer surplus of at least $50/month, which is $1.67/day/subscriber, just based on the prices sustained in the marketplace in other rich, first-world, comparable economies, such as Germany and the Netherlands, and so forth.

Sum Up: Range of Possible Consumer Surplus

Table 1 summarizes the data gathered in the prior studies on consumer surplus.

Table 1. Table Summarizing Consumer Surplus Data

Country	Type of Service	Consumer Surplus $/day
UK, 2001	Voice: Private users	0.87
	Voice: Business users	2.52
Canada, 2012	Voice: All users	0.90
	Mobile broadband	0.63
U.S., 2002/03	Voice/text: All users	1.55–2.91
U.S., 2010	Voice/text: All users	4.24
	Mobile broadband	1.18
U.S.–Europe comparison	Voice/text: All users	1.67
Average	Voice/text (7 data points)	2.09
Average	Mobile broadband	0.90
Sum	**Mobile voice & broadband**	**2.99**

Averaging and adding these data points is admittedly a crude methodology for obtaining an indicative value for the consumer surplus generated by smartphones. However, it serves the purpose of creating an analytical *baseline* for examining the business case for adopting smartphones in various applications.

In economic theory, “households” (individual private consumers) ought to value available technologies based on their utility and purchase a basket of goods that creates the greatest amount of utility for them. Mobile penetration rates of well over 100% in most developed economies—if economic theory is to be believed—demonstrates that households believe mobile phones create surplus value (utility) for them.

Moreover, in line with OMB Circular No. A-94 (Zients, 2012), cross-country comparisons of mobile phone prices allow us to triangulate the various consumer surplus analyses discussed here with actual consumer purchasing behavior in similar countries—a natural experiment in mobile phone valuing. Cross-country comparisons give us a strong basis for arguing that, whatever value consumer surplus really is, it is highly likely to be more than $1.67/day/subscriber, because we know that subscribers in other wealthy countries are willing to pay this much for their mobile services over and above what U.S. consumers and businesses pay. These measures pass the test, therefore, of being derived from actual market behavior.

At this point, early (2001) UK estimates of consumer surplus probably under-represent the consumer surplus available in the UK today, because mobile service prices have reduced dramatically in the UK 1999–2013. Similarly, one reason why Entner's (2012) U.S. estimates are higher than the estimates made in 2002/2003 is that prices on average are lower. Hence, the consumer surplus has been enlarged.

One basic issue in our analysis remains: To what extent is the identifiable consumer surplus similar or different for organizations, rather than private users? The data calculated here represents an average for all users, both private and organizational. The UK Radio Communications Agency Report (2001) study is the only study we know of that specifically broke out business users from private users, and data there indicated that business users had a significantly higher willingness to pay for mobile services (and hence a significantly larger consumer surplus). This difference is presumably based on the productivity benefits captured by organizations/businesses from having their employees use mobile devices. These perceptions are also born out in the data we showed earlier from prior studies (see Figure 9) of smartphone benefits (i.e., business users do perceive significant benefits from having employees always connected via email, knowing their location via GPS, and being able to multitask from anywhere).

Therefore, for the purposes of the foregoing analysis we will assume that smartphone benefits spillover to organizations, and that the heavy use of smartphones in organizational work is indicative that the value of smartphones to organizations is more likely to be above the $2.99 average indicated in Table 1 than below it. Alternatives to using this assumption are also discussed.

Financial Analysis

Methodology and Assumptions

For this economic analysis, we are applying standard economic principles that account for the total operational cost of the items under consideration. This analysis will not only consider the direct costs of the acquisition of the smartphones and sleeves, but will also consider the time value of those purchases, as well as the operational considerations. By following standard evaluation principles, this analysis can be logically compared to other potential choices on an even footing.

Operational considerations for this analysis include the fully burdened cost for fuel, fuel consumption, and maintenance, as well as the consumer surplus extracted from the deployment of the gear. Factors and assumptions are as follows.

Net Present Value

The standard financial evaluation methodology we use for our analysis is net present value (NPV). We use the OMB's (A-94) definition of NPV: "The difference between the discounted present value of benefits and the discounted present value of costs" (Zients, 2013, p. 19).

In some places, we also compute internal rate of return (IRR). IRR is defined as the percent return for a project's cash flows when the NPV is set to zero.

Finally, we compute simple paybacks in some places. *Simple payback* is defined as the initial investment in year 1 divided by the subsequent cash flows and is stated in years.

Inflation and Discount Rates

A five-year period is used for this study because this is the approximate life of handheld smartphones. OMB Circular A-94 Appendix C (Zients, 2013) indicates that real interest rates on treasury notes and bonds is -0.8% for five-year maturities, and therefore we use this number as the discount rate in our analysis. (The nominal five-year rate is 1.1%, and the projected inflation rate for the period is 1.9%). For 10-year analysis, the real discount rate of 0.1% is used, again per OMB A-94 (Zients, 2013).

Economic Life of Equipment

The economic life for smartphones and sleeves is assumed to be five years, owing to battery erosion and general wear and tear.

20% of smartphones are assumed to be replaced every year owing to breakage or loss.

All current equipment is assumed sunk cost, and therefore all analysis is based on marginal costs/benefits analyzed.

Fully Burdened Cost of Fuel

In line with DoD policy, we use the fully burdened cost of fuel (FBCF) as our benchmark for tactical energy cost because most electricity supplied in the tactical environment is obtained via portable generators. We researched an appropriate FBCF for this study based on Schwartz, Blakeley, and O'Rourke's (2012) report, which highlights the wide variance in fuel costs experienced in tactical environments. The FBCF is an effort to capture the hidden costs of supplying fuel to tactical environments and, therefore, to aid the DoD in making appropriate analysis of technology alternatives by capturing the true cost of getting fuel to the location where a DoD entity consumes it. The CRS report (Schwartz et al., 2012) states that

> in 2010, the Marine Corps estimated the fully burdened cost of fuel in Afghanistan at between $9 to $16 per gallon if delivered by land, and between $29 to $31 per gallon if delivered by air. An Army study estimated the fully burdened cost of fuel in Iraq at $9 to $45 per gallon, depending on the type of force protection used to and the delivery distance, while an Air Force study estimated the fully burdened cost of

> fuel delivered by land at $3 to $5 per gallon and $35 to $40 per gallon for aerial refueling. A 2008 report by the Army Environmental Policy Institute estimated that the fully burdened cost of fuel for a Stryker brigade in Iraq ranged from $14.13 to $17.44 per gallon. (p.6-7).

Based on these estimates, we use $15/gallon as our baseline assumption, with a high assumption of $30/gallon and a low of $10/gallon used for our sensitivity analysis.

Fuel Usage

Fuel use for a company COC was estimated at 20 gallons/day to generate 157 kWh on average. Of this energy requirement, 29% was estimated for equipment, 64% for environmental control, and the balance of 7% for other uses.

Unit of Analysis/Force Size

For the smartphone sleeve investment, a USMC squad is the unit of analysis, consisting 13 riflemen. We assumed 1,620 squads in the USMC in total.

Companies are our unit of analysis for the Oceus Networks cellular infrastructure investment. A company consists of 182 Marines total, 117 of which are riflemen, 65 in a support role. Of these 65, 10-12 are located in the company COC, with the rest dispersed around the company. We assumed 225 companies in the USMC in total. It should be noted that these numbers are not fixed, and the headcount of a Marine company varies both historically and according to mission requirements.

Current USMC force strength is 195,000 (as of February 2013).

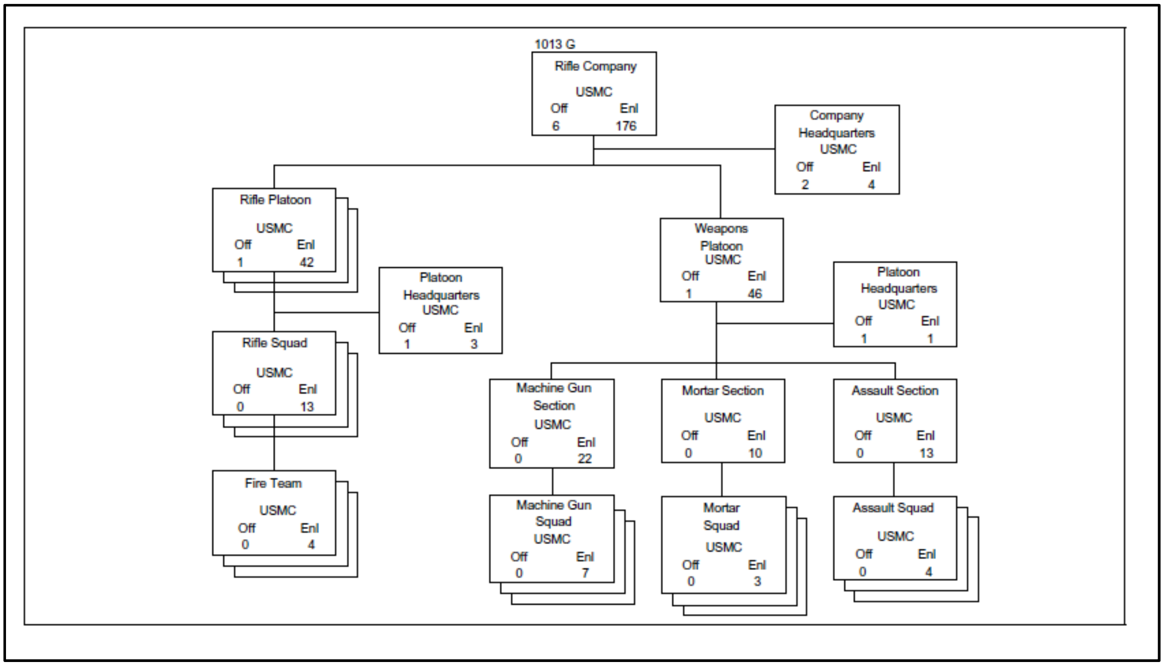

Figure 11. USMC Rifle Company Organization
(USMC, 1998)

Labor Days Assumed

We assumed Marines work 365 days/year when deployed (our base case). The USMC policy is two days dwelling at home station for every one day deployed in the field.

For COC personnel, we assumed 365 days working. One way of looking at this is that smartphones are assigned to jobs rather than to individuals. Therefore, whoever is on duty is the smartphone owner for that job during the duty period. All smartphones, therefore, are assumed to work 24/7/365.

Sensitivity Analysis

According to OMB Circular A-94 (Zients, 2013),

> Sensitivity Analysis. Major assumptions should be varied and net present value and other outcomes recomputed to determine how sensitive outcomes are to changes in the assumptions. The assumptions that deserve the most attention will depend on the dominant benefit and cost elements and the areas of greatest uncertainty of the program being analyzed. (p. 11)

For our analysis, we used the following four variables for sensitivities:

- FBCF—average $15; low $10; high $30 / per gallon;
- COC fuel savings—average 30%; low 10%; high 50%;

- Sleeve cost—average $1,100; high $2,200; and
- Consumer surplus—average $2.99/day; low $1.50; high $6.00.

Trusted H2 Sleeve Cost

MARCORSYSCOM will make an initial (unrecoverable) investment in developing and testing a sleeve that meets its requirements.

The Mobility JCTD states a target price for sleeves is $980 (Dixon, 2013). According to materials we have assessed, Lockheed Martin has quoted Lynx sleeves for its Monax system at $1,100. We use the $1,100 assumption for our analysis.

Oceus Networks System Acquisition Cost

We assume a single Oceus Networks system costs $450,000. For our baseline analysis, we assumed a salvage value of an Oceus Networks system as $1 after five years.

IT Virtualization

We assume that an entirely cloud-based IT architecture is provided to warfighters to accomplish their combat-related tasks (when deployed) and their various management tasks (when at home station, training, at barracks, etc.). We do not cost the development of this capability into our analyses, because our assumption is that this capability will be provided through other USMC projects and programs and is therefore fixed/sunk for the purposes of this study (which is focused on equipment rather than software). For example, the USMC may borrow software features such as various apps and a virtualized Blue Force Tracker from the U.S. Army and adapt them at small/marginal/incremental cost. Other apps may be COTS that USMC adapts, or straight COTS configured by the user to meet user needs. We recognize that there may be some software development costs in order to gain incremental capability, but we assume that they are outside the scope of this study.

Consumer Surplus

For our base case, we assumed a consumer surplus per smartphone of $2.99/day based on the data we gathered from prior research (see Table 1).

Another way of gauging this consumer surplus is to compare it to productivity improvements that would reflect the same dollar amount. Let us considered two ranks of personnel. Based on USMC labor costs for 2013, E1 rank personnel cost the USMC $48,041 (including benefits). Assuming a 2:1 dwell at home base (the USMC policy guideline), USMC personnel would spend 243 days/year at home base while deployed. $2.99 represents a 1.51% productivity improvement from utilizing a smartphone. For O1 personnel, cost to the USMC is $82,926. Based on the same assumptions, $2.99 is equivalent to a 0.88% productivity increase.

Home Base/Barracks/Combat Operations Center WIFI Infrastructure

We assume barracks/home base and COC has WIFI or a similar service available at a fixed cost to the installation; therefore, smartphones are considered to ride on this network without generating incremental costs. However, we note that there is no current requirement for WIFI in deployed Marine units at the current time, nor at major barracks, which currently rely on commercial systems. Using the same logic, we explicitly exclude cellular service from our analysis in all locations on the basis that it is not essential to the utility of the devices that we analyze.

This assumption is helpful for keeping our analysis simple and focused, but future research should investigate the typical incremental costs that might be generated by providing WIFI service, including in austere locations where backhaul costs and data usage rates are significant enough that these costs need to be incorporated into the analysis of smartphone economics in order to generate a more complete and accurate picture.

Equipment Maintenance Costs

For the purposes of the analysis, we assume maintenance costs are the same for sleeved smartphones as for alternative devices, such as PRC-152s and 153s. We therefore ignore these costs as a “wash” on a per-item basis.

(Note: Currently, at the squad level, fire team leaders and squad leaders have communications devices; total maintenance costs might increase if every rifleman was equipped with a communications device because the total number of devices would increase substantially).

For the COC, maintenance cost is $5,600 per month for the CAPTSET only, which is a conservative number that does not include the maintenance costs of the C2 communication systems (M. Liguori, personnel communication, September 2013). In our analysis we reduce this cost by a target percentage to reflect the non-use of equipment that—in our thought experiment—would be replaced by Oceus Networks private cellular network capability. To do this, we did a count of items of equipment and assumed an average cost of maintenance for each item. An Oceus Networks XIPHOS 4G LTE box is assumed to have the maintenance cost of one item. Therefore, if 50% of the current equipment in the COC is no longer needed in our thought experiment, we assume 50% reduced maintenance costs.

Smartphone Costs

We assume USMC buys commercially available smartphones that meet its requirements from various suppliers, such as Motorola, Samsung, Apple, and Nokia.

The target price for smartphones is $640 each, per the Mobility JCTD (Dixon, 2013). We expect smartphone prices will decline over time, in line with the historical pattern of declining prices for such devices. For the purposes of our analysis, we assume a 5%/year price decline (real $).

For COC use, some personnel may prefer a device with a larger screen, in which case we assume iPads or similar devices are acquired instead of a smaller form-factor smartphone. Costs/prices for these devices are assumed to be the same.

Table 2 is a summary of all assumptions that will be incorporated into the economic analyses.

Table 2. Assumptions for Economic Analyses

Assumptions	
Riflemen in a squad	13
Additional personnel at a COC	65
Duty days per year	365
Smartphone price	$640
H2 sleeve price	$1,100
L-3 Guardian phone price	$3,250
PRC-152	$4,800
PRC-152A	$10,000
Oceus Networks RU module (200 connections)	$450,000
Tethering equipment (smartphone to PRC-152)	$1,434
COC equipment maintenance costs/month	$5,600
Maintenance cost saving	50%
COC fuel use/gallons per day	20
FBC fuel	$15
Fuel savings projected	30%
Dwell time (% at home base)	67%
Barracks efficiency benefits/productivity gain/cost saving/per day	$2.99
Inflation	1.1%
Discount rate	-0.8%
# Squads in USMC (approx. 21,000 riflemen)	1620

Baseline Analysis: Squad Level (13 riflemen)

Alternative 1: Sleeved Smartphones vs. PRC-152/152A

The first case is the baseline of a single smartphone with the trusted H2 sleeve. The items are purchased in year 1, with an expected life of five years (see Table 3). We assume that 20% of smartphones need replacing every year;

therefore, we built the cost of a replacement phone into the smartphone analysis. Sleeves are assumed to be rugged enough not to need replacing, but they will need maintenance.

Table 3. Net Present Value of One Sleeved Smartphone

Alternative 1: 1 sleeved smartphone		Year 1	Year 2	Year 3	Year 4	Year 5
Smartphone & H2 Sleeve Cost		$(1,740)		$(578)		
In Barracks Efficiency (Consumer Surplus)		$731	$731	$731	$731	$731
Annual cash flows		$(1,009)	$731	$154	$731	$731
Discounted Cash Flow		$(1,009)	$737	$156	$749	$755
Net Present Value	**$1,389**					
Internal Rate of Return	**44%**					

In this scenario, the smartphone with sleeve has a positive net present value of $1,389 over a period of five years. Additionally, it demonstrates an internal rate of return of 44%. These benefits are gained through the application of consumer surplus, which is greater than the purchase price.

Because the sleeved smartphone has a positive NPV, it makes sense to adopt it to obtain these benefits; however, a second part of this analysis must also consider the costs and benefits of the sleeved smartphone versus the current PRC-152 radios. We assume that the Marine Corps already owns PRC-152s; therefore, these PRC-152s are a sunk cost and not applicable to this analysis.

The economics of the sleeved smartphone is stronger if we assume that the USMC's other option is to buy new PRC-152As ($10,000 each, with a price range of $10,000-30,000 depending on the particular model specified) that have a capability set that overlaps with the capability set a sleeved smartphone would have. Based on the efficiency benefits, USMC would be over $11,000 better off buying a sleeved smartphone than new PRC-152As (see Table 4). Using the assumption that the USMC would need a minimum of 2,000 devices to meet its needs at the squad leader level, this amounts to a $22.8 million difference in acquisition costs.

Table 4. Comparison of Sleeved Smartphone to PRC-152/152A

NPV of sleeved smartphone	**$1,389**
PRC-152A	$(10,000)
Price differential	**$11,389**
For 2,000 units (PRC-152A)	$22.8 million

For the purposes of the analysis, we assume maintenance costs are the same for sleeved smartphones as for PRC-152s and therefore can be ignored. We also assume the tactical utility of both items is similar and therefore can be ignored. In reality, the radios have some advantages over smartphones, and vice versa, depending on mission needs and user preferences. This smartphone option provides no tactical broadband (defined as a wireless network with data rates greater than 1.5 mbps). In effect, sleeved smartphones replace PRC-152s, but nothing else changes. (Of note, the more expensive PRC-152A option can provide a level of tactical broadband capability, having the capability to establish a 4 mbps tactical data-network that can be shared by other users).

In order to demonstrate the implications of this analysis on a USMC unit, we chose the smallest combat organization of a squad. Typically, a squad has 13 members, of which four currently utilize communications devices. By extending the prior analysis from a single smartphone with sleeve to 13 devices (one each for every squad member) the NPV increased to $19,700 and achieved an internal rate of return of 50% (see Table 5 below).

Table 5. Net Present Value of Sleeved Smartphones for a Squad

Alternative 1A: Squad Level Analysis: Smartphones with tactical sleeves		Year 1	Year 2	Year 3	Year 4	Year 5
Smartphone & H2 sleeve cost (13 units)		(22,620)	(1,581)	(1,502)	(1,427)	(1,355)
In barracks efficiency (consumer surplus)		9,506	9,506	9,506	9,506	9,506
Annual cash flows		(13,114)	7,925	8,004	8,079	8,150
Discounted cash flow		(13,114)	7,989	8,134	8,276	8,416
NPV of sleeved smartphone Internal rate of return	**19,700** **50%**					

Alternative 2: Smartphones for Barrack's Use Only

The second alternative to consider is to look at the use of the smartphone as a communications and management tool in the home base/barracks environment. This is the area where some Marines are currently using personal smartphones for their daily lives. For this analysis, we consider a 13-person squad that will employ sleeveless phones for official management and communications tasks. There will be no changes to tactical equipment, and we assume that there is no tactical broadband available.

Table 6. Smartphones for Barracks Use Only

Alternative 2: Smartphones only for barracks use		Year 1	Year 2	Year 3	Year 4	Year 5
Smartphone cost		$(8,320)	$(1,581)	$(1,502)	$(1,427)	$(1,355)
In barracks efficiency (consumer surplus)		$9,506	$9,506	$9,506	$9,506	$9,506
Annual cash flows		$1,186	$7,925	$8,004	$8,079	$8,150
Discounted cash flow		$1,186	$7,989	$8,134	$8,276	$8,416
NPV of sleeved smartphone	**$34,000**					

In this scenario, the smartphone with sleeve has a positive NPV of $34,000 over a period of five years (see Table 6). These benefits are gained through the application of consumer surplus, which is greater than the purchase price.

Alternative 3: Smartphones Sharing 1/14 Oceus Networks System (No Sleeves)

The next alternative for the squad level involves a shared Oceus Networks system paired with smartphones for each member of the squad. The Oceus Networks system is the Army's JOLTED TACTICS capability and will require upfront investment cost for the USMC. For this analysis, which is at the squad level, we are assuming that each squad requires only 1/14 of the total system; thus, only those costs will be considered. We recognize that an entire Oceus Networks system will need to be purchased, thus providing capabilities for multiple squads.

Operationally, this alternative provides for tactical broadband capability, which will enhance the ability for the user to gain functionality from the smartphones. Additionally, this analysis does not consider local spectrum or transmission costs, such as satellite communications. This option is only viable in permissive environments and may require host country approval (see Table 7).

Table 7. Oceus Networks System With Smartphones

Alternative 3: 1/14th Oceus system with smartphones	**Real $**	Year 1	Year 2	Year 3	Year 4	Year 5
Smartphones plus 1/14 Oceus system		(40,463)	(1,581)	(1,502)	(1,427)	(1,355)
In barracks efficiency (consumer surplus)		9,506	9,506	9,506	9,506	9,506
Annual cash flows		(30,957)	7,925	8,004	8,079	8,150
Discounted cash flow		(30,957)	7,989	8,134	8,276	8,416
NPV of Oceus with smartphones	**$1,858**					
Internal rate of return	**2%**					

The NPV of this alternative is less than the sleeved phones option due to the need for greater investment in the first year. However, this option does have a positive NPV and internal rate of return, thus making it economically viable. With the additional capabilities the Oceus Networks system provides regarding tactical broadband, this alternative may be attractive to the commander.

Alternative 4: L-3 Guardian Option Sharing 1/14 Oceus Networks System

Concerns may exist about the use of commercial technology in the tactical environment when secure systems are required. The L-3 Guardian was developed with oversight by the National Security Agency (NSA) to enable classified communications using both voice and data. The L-3 Guardian is configured to allow both classified and unclassified communications over commercial as well a government networks. This alternative also allows for tactical broadband capability.

Although the L-3 Guardian does not require a sleeve for secure communications, it is more expensive and its ability to be upgraded depends on government contracts. The price for a single L-3 Guardian is $3,250. This alternative looks at the incorporation of the L-3 Guardian into the Oceus system at the squad level. This alternative will consider 1/14 use of the Oceus capacity.

Table 8. Alternative 4: L-3 Guardian Plus 1/14 Oceus Networks System

Alternative 4: L-3 Guardian plus 1/14th Oceus		Year 1	Year 2	Year 3	Year 4	Year 5
L-3 Guradian phones plus 1/14 OOceus system		$(74,393)	$(8,450)	$(8,450)	$(8,450)	$(8,450)
In barracks efficiency (consumer surplus)		9,506	9,506	9,506	9,506	9,506
Annual cash flows		(64,887)	1,056	1,056	1,056	1,056
Discounted cash flow		(64,887)	1,064	1,073	1,081	1,090
NPV of L-3 Guardian phones plus 1/14 Oceus system	**(60,579)**					

This alternative has a negative NPV due to the high cost of investment in both the Oceus systems as well as the L-3 Guardian phones (see Table 8). With productivity being the sole benefit, this approach would not achieve a positive NPV due to the need to update the technologies. However, this might still be a viable option when security is of primary consideration.

Alternative 5: Tethered Smartphone Concept (Tethered to PRC-152)

The U.S. Army developed a concept where a smartphone could be physically tethered to a PRC-152A radio to allow for some additional capabilities. This solution adds minimal costs to an existing squad if we assume that the current inventory of one PRC-152A per squad would remain unchanged. However, in order to provide a comparison point to a sleeved smartphone capability, in the current analysis we analyze the cost of providing all 13 members of a squad with a smartphone tethered to a PRC-152A. This option would not provide tactical broadband capabilities.

Table 9. Smartphones With Tethered PRC-152As (Squad Level)

Alternative 5: Smartphones plus Tethered 152s		Year 1	Year 2	Year 3	Year 4	Year 5
Smartphone plus PRC-152A plus tethering equipment		(89,362)	(1,581)	(1,502)	(1,427)	(1,355)
In barracks efficiency (consumer surplus)		9,506	9,506	9,506	9,506	9,506
Annual cash flows		(79,856)	7,925	8,004	8,079	8,150
Discounted cash flow		(79,856)	7,989	8,134	8,276	8,416
NPV smartphones with tethered PRC-152As	**(47,042)**					

This alternative (see Table 9) has a negative NPV due to the high cost of providing each Marine with a PRC-152A in addition to a smartphone and the tethering equipment. This might be a viable alternative for initial testing, where no additional PRC-152As need to purchased. However, this option becomes very expensive because of the need to purchase new $10,000 PRC-152As (instead of a $1,100 sleeve) plus $1,434 of tethering equipment, in addition to the cost of smartphones.

Table 10 provides a summary of results for a 13-person squad.

Table 10. Table Summarizing Net Present Values for a 13-Person Squad

Alternative	Option	5-year NPV
1	Single-sleeved smartphone	$1,389
1b	13 smartphones w/secure sleeves	$19,700
2	13 barracks-only smartphones	$34,000
4	Smartphones sharing Oceus Networks system	$1,858
4	Guardian L-3 sharing Oceus Networks system	$-60,579
5	Smartphones tethered to PRC-152As	$-47,042

Baseline Analysis: Company Level Analysis

The next alternatives look at the application of smartphones at the company level. In these scenarios, there are two different manners in which the company level is considered. First is the COC and support staff of 65 riflemen total, and second is the whole company that comprises 182 people.

Alternative 6: 65 Smartphones for support/COC personnel + 1 Oceus Networks XIPHOS 4G LTE System

This alternative provides smartphones to the 65 support riflemen of a company (without H2 sleeves) and a standalone Oceus Networks system. The benefit of this configuration is that it provides tactical broadband capabilities that allow for greater functionality on the smartphones. This is similar in structure to the Army's JOLTED TACTICS system, but it does not require tethering.

Providing the smartphones to only the tactical side reduces the power and maintenance footprint and inherently makes the COC more mobile. This also assumes that the company retain 50% of existing equipment, such as the PRC-152 and PRC-117 (see Table 11 for results).

Table 11. Alternative 6: COC Standalone Oceus Networks system plus Smartphones (No Sleeves)

Alternative 6: COC standalone Oceus Network (no sleeves)		Year 1	Year 2	Year 3	Year 4	Year 5
Equipment cost: Oceus + 65 smartphones		(491,600)	(7,904)	(7,509)	(7,133)	(6,777)
Oceus salvage value						$1
100% efficiency benefits		70,938	70,938	70,938	70,938	70,938
Avoided maintenance cost		33,600	33,600	33,600	33,600	33,600
Avoided fuel costs		32,850	32,850	32,850	32,850	32,850
Annual cash flows		(354,212)	129,484	129,879	130,254	130,612
Discounted cash flow		(354,212)	130,528	131,982	133,431	134,877
NPV	**176,606**					

Alternative 7: 65 Sleeved Smartphones for support/COC personnel + 1 Oceus Networks XIPHOS 4G LTE System

This alternative provides smartphones for 65 members of the company but also adds the trusted H2 sleeves. This is potentially the best-case scenario operationally because it provides both the flexibility of the Oceus Networks capability plus the security of the trusted H2 sleeve. However, because of the sleeve, this option does not proved for tactical broadband capability. The NPV for alternative 7 is lower than alternative 6 dues to the inclusion of the H2 sleeves (see Table 12).

Table 12. COC Oceus Networks system with Smartphones and Sleeves (for 65 personnel)

Alternative 7: COC Oceus Networks + smartphones + sleeves		Year 1	Year 2	Year 3	Year 4	Year 5
equipment cost: Oceus Networks/smartphones/ sleeves (65)		(563,100)	(7,904)	(7,509)	(7,133)	(6,777)
Oceus salvage value						$1
100% efficiency benefits		70,938	70,938	70,938	70,938	70,938
Avoided maintenance cost		33,600	33,600	33,600	33,600	33,600
Avoided fuel costs		32,850	32,850	32,850	32,850	32,850
Annual cash flows		(425,712)	129,484	129,879	130,254	130,612
Discounted cash flow		(425,712)	130,528	131,982	133,431	134,877
NPV	**105,106**					

Alternative 8: Smartphones + Sleeves + Oceus Networks System for Entire Company (182 personnel)

This final alternative takes the last example and extends it to all 182 members of a company (Table 13). This option is similar in functionality to the Army JOLTED TACTICS except we use trusted H2 sleeves for communications rather than tethering. This alternative does not provide for tactical broadband. The NPV is largest for this option, as well as the investment cost due to the expectation of consumer surplus across a larger baseline. The consumer surplus accounts for about 65% of the generated value and is thus the driving factor in this analysis.

Table 13. COC Oceus Networks With Smartphones and Sleeves (for 182 personnel)

Alternative 8: COC Oceus Networks + smartphones + sleeves		Year 1	Year 2	Year 3	Year 4	Year 5
Equipment cost: Oceus/smartphones/sleeves (182)		(766,680)	(22,131)	(21,025)	(19,973)	(18,975)
Oceus salvage value						$1
100% efficiency benefits		156,489	156,489	156,489	156,489	156,489
Avoided maintenance cost		33,600	70,938	70,938	70,938	70,938
Avoided fuel costs		32,850	32,850	32,850	32,850	32,850
Annual cash flows		(543,741)	238,145	239,252	240,303	241,303
Discounted cash flow		(543,741)	240,066	243,126	246,164	249,181
NPV	**434,796**					

Table 14 provides a summary of results at the company for either 65 support staff or the entire company of 182 people.

Table 14. Net Present Value Comparison at the Company Level

Option	**5-year NPV $**
65 smartphones + Oceus system	176,606
65 sleeved smartphones + Oceus system	105,106
182 sleeved smartphones + Oceus system	434,796

Sensitivity Analysis

The purpose of a sensitivity analysis is to determine whether there might be large changes to the NPV depending on the assumptions applied to the analysis. In the analysis of alternatives, we applied consistent and conservative estimates of costs and savings that might be realized. However, there is room for potential cost overruns and benefits that do not materialize at the expected rate.

Based on the original assumptions listed in Table 2 we applied several changes to those assumptions to determine whether there would be significant impacts that might change the way we considered the results. Table 15 compares changes to the H2 sleeve price, increasing it to $2,200 per unit. Additionally, we provide a comparison changing the consumer surplus to a low of $1.50/day to a high of $6.00/day. In each case, the alternative NPV is reflected. The columns in Table

15 with blue type indicate the original assumption that went into the analysis. In this analysis, we changed only one variable at a time, leaving all others at the level of the original assumptions.

The major outcome of this analysis is that the NPV for most alternatives shifts from positive to negative under the $1.50/day consumer surplus assumption, indicating that the precise assumption about consumer surplus is a key consideration in the business case. By comparison, the NPV results are robust to a doubling of the price of sleeves. Of note, higher consumer surplus assumptions would drive big upsides in the NPV for many of the alternative considered.

Table 15. Sensitivity Analysis: NPV Adjusted for Sleeve Price or Consumer Surplus

	Sleeve Price			Consumer Surplus	
Alternative	Average ($1100)	High ($2200)	Low ($1.50)	Average ($2.99)	High ($6.00)
1	$1,389	$289	$(463)	$1,389	$5,129
2	$34,000	$34,000	$9,931	$34,000	$82,625
3	$1,858	$1,858	$(22,212)	$1,858	$50,482
4	$(60,579)	$(60,579)	$(84,649)	$(60,579)	$(11,955)
5	$(47,042)	$(47,042)	$(71,111)	$(47,042)	$1,583
6	$176,606	$176,606	$(3,019)	$176,606	$539,473
7	$105,106	$33,606	$(74,519)	$105,106	$467,973
8	$434,796	$237,657	$(102,671)	$434,796	$1,529,796

The next part of the sensitivity analysis impacted only alternatives 6, 7, and 8. When we analyzed the alternatives at the company level, we considered the fully burdened cost of fuel (FBCF), as well as the projected fuel savings. These were not considerations at the squad level. In this analysis, we showed the FBCF at a low of $10, an average of $15, and a high of $30. The fuel savings were a low of 10%, an average of 30%, and a high of 50%. The NPV for each alternative is shown in Table 16.

Table 16. Sensitivity Analysis: FBCF and Fuel Savings

	Fully Burdened Cost of Fuel (FBCF)			COC Fuel Savings (%)		
Alternative	Low ($10)	Average ($15)	High ($30)	Low (10%)	Average (30%)	High (50%)
6	$120,966	$176,606	$343,526	$65,325	$176,606	$287,886
7	$49,466	$105,106	$272,026	$(6,175)	$105,106	$216,386
8	$426,907	$434,796	$470,707	$323,515	$434,796	$546,076

This analysis suggests that the NPV results are robust to downside assumptions about the FBCF and fuel savings. Indeed, there is considerable upside potential if FBCF and fuel savings are higher than assumed in the base case.

The final part of this analysis is to show a best- and worst-case scenario for each alternative, thus highlighting the entire range of possible results. This helps the decision-maker determine what might be the case if all assumptions are either over- or underestimated. Although this situation may not present itself in most cases, understanding both the upside and downside risks adds credibility to the analysis.

When defining the best- and worst-case scenarios, we made the following assumptions:

- Best case: Sleeve cost ($1100), consumer surplus ($6.00), FBCF ($10), and fuel savings (50%).
- Worst case: Sleeve cost ($2200), consumer surplus ($1.50), FBCF ($30), and fuel savings (10%).

The average case was the original analysis. The total variance was the differential between the best- and worst-case scenarios.

Table 17. Sensitivity Analysis Best- and Worst-Case Scenarios

Alternative	Worst Case	Average Case	Best Case	Total Variance
1	$(1,863)	$1,389	$5,129	$6,992
2	$9,931	$34,000	$82,625	$72,694
3	$(22,212)	$1,858	$50,482	$72,694
4	$(84,649)	$(60,579)	$(11,955)	$72,694
5	$(71,111)	$(47,042)	$1,583	$72,694
6	$(58,660)	$176,606	$558,019	$616,679
7	$(221,160)	$105,106	$486,519	$707,679
8	$(416,172)	$434,796	$1,545,282	$1,961,454

The results of the sensitivity analysis (shown in Table 17) are revealing, particularly for decisions made at the squad level. The total variance for alternatives 2, 3, 4 and 5 are all exactly the same, which is to be expected considering that the change in variables was limited to the sleeve cost and the consumer surplus. Although this is revealing, it does not tell the entire story. Alternative 2 (smartphones for barracks use only) is the least risky, having the only positive worst-case scenario, and the highest average and best-case scenarios. Conversely, alternative 4 (L-3 Guardian phone with Oceus Networks system) is the riskiest, with negative NPV for all scenarios.

At the company level, all three alternatives are negative in the worst-case scenario and have moderate returns on average, but the best-case scenario for alternative 8 grows very large. This is primarily driven by the consumer surplus, which applies to a larger group of people.

Across the board, consumer surplus (productivity gains) had the single greatest influence on the NPV values, will likely be a primary driver in the decision-making, and therefore is the variable most in need of further research.

Staged Investment (Real Options) Analysis

One method that organizations use to mitigate risk and increase flexibility is the application of real options. Through this approach, decision-makers have the right, but not the obligation, to buy or sell an asset at some pre-determined time in the future. This right provides an opportunity to break investments into stages. An early stage is used to determine whether a risky investment produced the expected returns, and later stages proceed contingent on this information being better understood.

Real options are analogous to financial options that are commonplace in the markets. Two basic types of options exist that allow for the purchase of an asset (call option) or the sale of an asset (put option) at some predetermined time in the future at a set price (exercise or strike price). Depending on the movement of the market, the holder of the option may or may not exercise that option at the point where the opportunity is to expire. This is where the risk lies with options. In financial options, a buyer purchases the right to buy or sell an asset at a predetermined time and at a set price in the future. If market conditions are favorable (i.e., if the market price has risen or declined sufficiently), then the holder of the option may exercise the option and extract a profit. However, if the market price has not changed enough to place the option holder "in the money," then the options expire and the holder loses the initial investment but nothing else.

The structure of real options demonstrates that while options are intended to mitigate risk, they are not completely risk-free. In order for real options to mimic financial options, the option buyer must be willing to not exercise the option if the market conditions are not favorable. Thus, if the holder of the option is obligated to exercise, the transaction cannot be considered an option. The benefit comes from the simple philosophy that options provide time for the buyer to assess market conditions. If market conditions are favorable, then the buyer exercises the options and creates value for the organization. However, if the market conditions are not favorable, the buyer will not exercise and will lose the investment in the options. The purchase to time to assess market conditions creates the value of financial options and, by association, real options.

In the scenario we are discussing here, the USMC may apply an options approach toward the integration of smartphones into tactical operations. Fundamentally, for the smartphone investment considered here, our sensitivity analysis suggests the size of the consumer surplus is an important variable about which some uncertainty exists. Because of this uncertainty, it may make sense to invest in stages, using information gained about the consumer surplus early stages to inform later stage investments. There are unknowns concerning the robustness, security, and adaptability of smartphones in the tactical environment. Therefore, a less risky place to test the concept with an early stage investment might be in a continental United States (CONUS) garrison environment and use the information gathered as an input into later stage investments.

Smartphones Only Stages (In Order to Test Productivity Benefits First)

As we highlighted in our Introduction, the best way to actually find out what the productivity benefits of smartphones is for the USMC would be to buy a batch of 1,000 phones, deploy them on an experimental basis for use as a productivity tool while dwelling at home base or in barracks, and then rigorously measure the impacts on various tasks Marines do in their everyday routines.

We broke the analysis into a three-part staged analysis where investment in future years would be made only if success was realized from prior investments. For the first option, we chose to analyze outfitting 1,000 Marines with smartphones and nothing else. As with prior analyses, we assume that there is a need for a 20% replacement each year and the real price of smartphone technology goes down by 5% per year. The assumption is that the Marines are in their home base/garrison and are not deployed. For the purpose of comparison of this option to follow-on, we chose to extend the analysis through 10 years.

The second option would take place in year 3 of the 10 year run, *if* the analysis proved that the first option provided the projected benefits. This option would extend the smartphones to three divisions of Marines, or 20,000 people. Again, the Marines would receive a smartphone and nothing else.

The same assumptions of price, discount rate, and consumer surplus that were used for prior analyses apply here as well. As with prior analyses, we assume that there is a need for a 20% replacement each year and that the real price of smartphone technology goes down by 5% per year.

The final option (option 3) would take place in year 5 and run through year 10. In this option, the plan is greatly expanded to bring the smartphone to the tactical environment. In this case, we analyze adding the Oceus Networks system to three divisions, assuming an average of 50% capacity utilization across 20,000 users. Additionally, the trusted H2 sleeve was added to the existing smartphones to provide a secure radio option that mimics the systems the USMC already has available. Again, this third stage investment is *contingent* on satisfactory results from the second stage investment and would be made only if those results suggest stage 3 is worthwhile.

Discussion of Results

The results of this analysis indicate that there is much benefit to be realized from taking a staged approach to investment. With the assumption that this program would run for 10 years and return an average level of productivity increase, with incremental investment in years 3 and 5 only if the prior investments were successful, this analysis produced a potential for $169 million in NPV at a risk of only $640,000 for the stage 1 kick-off investment and $12.8 million for stage 2.

The idea of real options assumes that a small investment will be made upfront, with the intention for a large return. However, if the anticipated upsides do not emerge, then the investor can exit the investment at a relatively small loss. In this case, the investment in 1,000 smartphones in year 1 costs $640,000, with an estimated average annual efficiency value of $731,000 for 10 years. The command has two years to ascertain whether this benefit is being realized. If so, then the command invests an additional $12.8 million in 20,000 more phones. Again, the command is given two years to determine whether the projected $14 million in annual productivity increases is being realized before making a much larger investment. If the benefits are realized, then the final investment is made in year 5. This time, the plan is to move tactical by adding the Oceus Networks system and the trusted H2 sleeves to the existing smartphones. An Oceus Networks system can handle 200 simultaneous calls; thus, we determined that a 50% usage rate, or 50 Oceus Networks systems, would be needed to support 20,000 users.

Just as with the prior analyses, it is important to consider the sensitivity of the analysis based on the low, average, and high productivity values. Table 18 demonstrates that even with low realized productivity gains, this program has a potential for $54 million in NPV over the full 10-year time span. With a high productivity gain, that value could be as high as $425 million. The realized benefit will likely fall somewhere between the low and high values.

The key to this analysis will be in properly capturing and measuring the actual productivity gains that accrue, something we do not do in this study but is clearly indicated as a key task for future research.

Table 18. Real Options Analysis Results

Option	Years	Investment	Annual Efficiency	NPV
Low Productivity				
1,000 smartphones	10	$(640,000)	$366,825	$2,116,744.00
20,000 smartphones	8	$(12,800,000)	$7,336,500	$31,007,797.00
Oceus + sleeves	6	$(44,500,000)	$10,950,000	$20,962,197.00
Total				**$54,086,738.00**
Average Productivity				
Option	Years	Investment	Annual Efficiency	NPV
1,000 smartphones	10	$(640,000)	$731,205	$5,744,202.64
20,000 smartphones	8	$(12,800,000)	$14,624,090	$88,989,055.14
Oceus + sleeves	6	$(44,500,000)	$21,827,000	$74,863,966.30
Total				**$169,597,224.09**
High Productivity				
Option	Years	Investment	Annual Efficiency	NPV
1,000 smartphones	10	$(640,000)	$1,467,300	$13,072,154.00
20,000 smartphones	8	$(12,800,000)	$29,346,000	$206,118,978.00
Oceus + sleeves	6	$(44,500,000)	$43,800,000	$205,848,414.00
Total				**$425,039,546.00**

Conclusions and Recommendations

The purpose of this analysis was to explore the application and implications of commercial smartphone technology in a tactical environment. As the USMC reduces its force structure over the coming years, the expectation for capabilities of a smaller force has not diminished. Additionally, as young Marines, people who have grown up with smartphone technology, enter the force, their personal expectations will shape the new force.

In this analysis, we looked at the application of commercial smartphone technology from several different angles. These included commercial smartphones used strictly in a home-base environment, as well as smartphones supplemented by a secure tactical sleeve that can integrate with existing USMC equipment. This analysis also took the approach of a phased deployment of the technologies into squad-, company-, and division-level organizations.

The main conclusion we draw is that the business case for deploying sleeved smartphones in the tactical environment may complement the military rationale for adopting this technology. It is the dual-use potential of this technology that makes the economics more attractive than the existing radios USMC has available. Sleeved smartphones may also be outright cheaper than existing equipment, and we have assumed that to be the case in our analyses. But the bigger benefit of smartphones will be in how they enable Marines to fight better when deployed, and work smarter when at home base (i.e., if they create options for innovation).

A secondary conclusion concerns the implementation plan and, in particular, uncertainty about what the productivity benefits of smartphones might—or might not—be. Based on extant research we have examined the economic benefits of smartphone adoption, but there is no substitute for trialing the technology to find out where the benefits lie for Marines. Therefore, we conclude that at this point, a staged investment approach would be a good choice for the USMC: for example, adopting 1,000 smartphones across a wide variety of users. This limited adoption would allow for a closer examination of the productivity benefits of smartphones in a variety of actual working environments. The USMC would retain the option to quit if the results are poor, or to invest in a large-scale roll-out if the results of the initial tests prove smartphone economics are worthwhile.

Although the focus of this report is on economic analysis, and therefore the productivity potential of smartphones, this is not to say that there aren't also significant tactical benefits of smartphones, such as faster and more accurate communication, improved information availability resulting in better situational awareness lower in the ranks, and benefits from automatic GPS functioning and possible monitoring/telemetry devices. These are further investment options for military commanders to consider if the base capabilities of smartphones prove attractive.

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References

Ball, R. (2013, June). Wireless cloud computing on guided missile destroyers: A *business case analysis* (Master's thesis, Naval Postgraduate School). Retrieved from http://www.acquistionresearch.net

Chiarelli, P. (2009, January 28). Gap betweet tactical and commercial communications technologies [Presentation slide]. Presentation at the Institute for Defense and Government Advance ment Conference at the Navy War College, Newport, RI.

CTIA. (2013). Wireless quick facts. Retrieved from http://www.ctia.org/advocacy/research/index.cfm/aid/10323 September 2013.

David, P. (1990). The dynamo and the computer: A historical perspective on the modern productivity paradox. *American Economic Review, 80*(2), 355–361.

Dixon, J., & O'Neal, M. (2011, March). *Business case analysis for secure mobile computing* (Master's thesis, Naval Postgraduate School). Retrieved from http://www.acquisitionresearch.net

Dixon, J. (2013, January 24). Handheld command & control (H2C2) information brief PM MC3, Marine Corps Systems Command.

Eggers, W. D., & Jaffe, J. (2013). Government on the go: Boosting public sector productivity by going mobile. Westlake, TX: Deloitte University Press.

Entner, R. (2012). The wireless industry: The essential engine of US economic growth. Retrieved from Recon Analytics website: http://reconanalytics.com/wp-content/uploads/2012/04/Wireless-The-Ubiquitous-Engine-by-Recon-Analytics-1.pdf

Forrester Research Inc. (2012). The expanding role of mobility in the workplace. Retrieved from http://www.cisco.com/web/solutions/trends/unified_workspace/docs/Expanding_Role_of_Mobility_in_the_Workplace.pdf

Grasso BC, Genest R, Yung K, Arnold C. (2002) Reducing errors in discharge medication lists by using personal digital assistants. Psychiatr Serv 53(10):1325– 6.

Greenstein, S. and R. McDevitt (2012), "Measuring the. Broadband Bonus in Thirty OECD Countries", OECD. Digital Economy Papers Number 197. OECD Publishing. Downloaded from http://www.oecd-ilibrary.org/docserver/download/5k9bcwkg3hwf.pdf

Gruber H and Pantelis Koutroumpis (2010). Mobile telecommunications and the impact on economic development. Economic Policy, 2011, vol. 26, issue 67, pages 387-426.

Hayek, F A. (1945). The use of knowledge in society. *American Economic Review, 35*(4), 519–530.

Hausman, J., & Ros, A. (2012). Correcting the OECD's erroneous assessment of telecommunications competition in Mexico. Retrieved from https://www.competitionpolicyinternational.com/correcting-the-oecd-s-erroneous-assessment-of-telecommunications-competition-in-mexico/

Hopkins, J. L. (2012). What value do smartphones offer business adopters? *International Journal of Electronic Business, 10*(1), 64–78.

Jensen, R. (2007). The digital provide: Information (technology), market performance, and welfare in the South Indian fisheries sector. *The Quarterly Journal of Economics 122*(3), 879–924.

Kim, S. H. (2008). Moderating effects of job relevance and experience on mobile wireless technology acceptance: Adoption of a smartphone by individuals. *Information and Management, 45*(6), 387–393.

Mashable. (2013). Smartphone penetration now 61%. Retrieved from http://mashable.com/2013/06/06/smartphones-61-percent/

Meritalk. (2013). Feds on the Go: Network Needs for Maximum Mobility. Powerpoint presentation, August 19, 2013. Downloaded September 2013 from http://www.meritalk.com/fedsonthego

Nordicity. (2012/2013). *The benefit of the wireless telecommunications industry to the Canadian economy*.

Naval Research Advisory Committee (NRAC). (2012, October). *Lightening the information load* (Naval Research Advisory Committee Report). Retrieved from http://www.nrac.navy.mil/docs/NRAC_2012_Final_Report-Lightening_the_load_15Feb13.pdf

Oceus Networks. (2013, July). *Oceus networks overview. Powerpoint presentation*. Reston, VA.

OECD. (2011). OECD communications outlook 2011. Retrieved from http://dx.doi.org/10.1787/comms_outlook-2011-en

OECD. (2012). Review of telecommunication policy and regulation in Mexico.

Orszag, P. (2010, June 8). *Remarks on government reform and fiscal responsibility.*. Retrieved from Center for American Progress website:

http://www.americanprogress.org/wp-content/uploads/events/2010/06/inf/Orzagtranscript.pdf

Park, Y., & Chen, J. V. (2007). Acceptance and adoption of the innovative use of smartphone. *Industrial Management & Data Systems, 107*(9), 1349–1365.

Prgomet, M., Andrew Georgiou, and Johanna I. Westbrook (2009) The Impact of Mobile Handheld Technology on Hospital Physicians' Work Practices and Patient Care: A Systematic Review. J Am Med Inform Assoc. 16(6): 792–801.

Schwartz, M., Blakeley, K., & O'Rourke, R. (2012, December 10). Department of Defense energy initiatives: Background and issues for Congress. Retrieved from http://www.CRS.gov

Sintchenko V, Iredell JR, Gilbert GL, Coiera E. (2005) Handheld computer-based decision support reduces patient length of stay and antibiotic prescribing in critical care. J Am Med Inform Assoc 12(4):398–402.

Radio Communications Agency Report. (2001). Consumer surpus to cellular mobile and pager users. By Hague consulting group and Accent marketing and research. Downloaded from http://www.ofcom.org.uk/static/archive/ra/topics/economic/surveys/cellular.pdf

United States Air Force (USAF). (2013). iPad adoption [Video]. Retrieved from http://9to5mac.com/2012/09/27/u-s-air-force-electronic-flight-bag-team-fought-windows-bureaucracy-and-deployed-ipads-video/

United States Marine Corps (USMC). (1998). *Organization of Marine Corps forces*. Washington, DC: Department of the Navy.

VanDenKerkhof EG, Goldstein DH, Lane J, Rimmer MJ, Van Dijk JP. (2003) Using a personal digital assistant enhances gathering of patient data on an acute pain management service: A pilot study. Can J Anesth 50(4):368 –75.

Verkasalo, H., López-Nicolás, C., Molina-Castillo, F. J., & Bouwman, H. (2009). Analysis of users and non-users of Smartphone applications. *Telematics and Informatics, 27*(3), 242–255.

West, D. M. (2012, May 22). How mobile devices are transforming healthcare. Retrieved from Brookings Center for Technology Innovation website: http://www.brookings.edu/research/papers/2012/05/22-mobile-health-west

List of countries by number of broadband Internet subscriptions. (2013). *Wikipedia.* Retrieved September 2013.

Zients, J. D. (2013). 2013 discount rates for OMB Circular No. A-94. Downloaded from http://www.whitehouse.gov/omb/circulars_a094/a94_appx-c

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