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THESIS

**TACTICAL SPACE – BEYOND LINE OF SIGHT
ALTERNATIVES FOR THE ARMY AND MARINE CORPS
GROUND TACTICAL WARFIGHTER**

by

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September 2007

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**TACTICAL SPACE: BEYOND LINE OF SIGHT ALTERNATIVES FOR THE
ARMY AND MARINE CORPS GROUND TACTICAL WARFIGHTER**

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ABSTRACT

United States Army and Marine Corps ground tactical warfighters find themselves conducting operations across greater distances and with more autonomy from their higher commands than ever before. As their areas of operations become larger in modern conflicts, and distributed operations become more the norm, deficits in the tactical warfighter's ability to conduct beyond line of sight (BLOS) communications, intelligence, surveillance, and reconnaissance (ISR), blue force tracking and situational awareness (BFT/SA), and position, navigation, and timing (PNT) become more noticeable, vulnerable and dangerous. The capabilities existing in the tactical space this warfighter operates within and from where he is supported cannot meet his needs now, nor will they likely meet his needs in the future.

While upgrades and expansion of current satellite and unmanned aerial system (UAS) architectures will expand these BLOS capabilities, it is not likely they will increase sufficiently to reduce the deficit in support. A new regime, the High Altitude Area of Interest (HAAI) also known as near space, provides potential capabilities specifically tailored to the tactical warfighter.

This thesis reviews the BLOS requirements of the tactical warfighter, identifies the current and future deficits in each area, and identifies emerging areas of support. It then provides recommendations on further development of integrated architectures spanning multiple regions, to provide efficient, persistent, and sufficient BLOS capabilities to the tactical warfighter.

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TABLE OF CONTENTS

I.	INTRODUCTION.....	1
A.	TACTICAL TROOP NEEDS.....	3
B.	SPACE: THE FINAL FRONTIER?	3
C.	TACTICAL SPACE AND HAAI SYSTEMS	4
II.	DEFINING TACTICAL SPACE	5
A.	REFINING THE CONCEPT OF “TACTICAL SPACE”	5
1.	Military	5
2.	Military in Civil Publications.....	6
3.	Government	6
4.	Civil	6
B.	DEFINITIONS	6
1.	Space.....	7
a.	Military.....	7
b.	Military in Civil Publications	8
c.	Government.....	8
d.	Civil.....	8
e.	Space Defined	9
2.	Near Space / High Altitude.....	9
a.	Military.....	9
b.	Military in Civil Publications	11
c.	Government.....	12
d.	Civil.....	12
e.	Near Space / High Altitude Defined.....	13
3.	Tactical.....	13
a.	Military.....	13
b.	Military in Civil Publications	15
c.	Government.....	15
d.	Civil.....	16
e.	Tactical Defined.....	16
4.	Tactical Warfighter	16
a.	Military.....	16
b.	Military in Civil Publications	17
c.	Civil.....	17
d.	Tactical Warfighter Defined.....	18
5.	Tactical Space.....	18
a.	Military.....	18
b.	Military in Civil Publications.	18
c.	Government.....	19
d.	Civil.....	19
e.	Tactical Space Defined	19
III.	TACTICAL REQUIREMENTS.....	21

A.	MILITARY ORGANIZATIONS	21
1.	Army.....	21
2.	Marine Corps	22
3.	Generalizations.....	23
4.	Unit Interactions	23
B.	TACTICAL USER REQUIREMENTS	23
1.	Communications	26
2.	Intelligence, Surveillance and Reconnaissance (ISR).....	28
3.	Blue Force Tracking and Situational Awareness (BFT/SA)	30
4.	Position, Navigation and Timing (PNT).....	31
5.	Can-Do vs. Should-Do	32
IV.	TACTICAL CAPABILITIES DEFICIT.....	35
A.	COMMUNICATION.....	36
1.	Current Communications	36
a.	<i>Current Communications Capabilities</i>	36
b.	<i>Current Communications Deficit.....</i>	40
2.	Future Communications.....	45
a.	<i>Future Communications Capabilities</i>	45
b.	<i>Future Communications Deficit</i>	50
B.	INTELLIGENCE, SURVEILLANCE AND RECONNAISSANCE (ISR)	53
1.	Current ISR.....	53
a.	<i>Current ISR Capabilities</i>	54
b.	<i>Current ISR Deficit.....</i>	56
2.	Future ISR.....	59
a.	<i>Future ISR Capabilities.....</i>	59
b.	<i>Future ISR Deficit</i>	63
C.	BLUE FORCE TRACKING AND SITUATIONAL AWARENESS (BFT/SA).....	66
1.	Current BFT/SA.....	66
a.	<i>Current BFT/SA Capabilities.....</i>	67
b.	<i>Current BFT/SA Deficit</i>	69
2.	Future BFT/SA.....	70
a.	<i>Future BFT/SA Capabilities</i>	70
b.	<i>Future BFT/SA Deficit.....</i>	71
D.	POSITION, NAVIGATION AND TIMING (PNT).....	72
1.	Current PNT.....	72
a.	<i>Current PNT Capabilities</i>	73
b.	<i>Current PNT Deficit</i>	73
2.	Future PNT	75
a.	<i>Future PNT Capabilities</i>	75
b.	<i>Future PNT Deficit.....</i>	75
E.	CONCLUSION	77
V.	TACTICAL SPACE	79
A.	COMMUNICATIONS	81

1.	Emerging Communications Solutions.....	82
a.	Emerging Space Communications.....	82
b.	Emerging HAAI Communications.....	83
c.	Emerging Terrestrial / Aerial Communications.....	85
2.	Communications Recommendations.....	86
a.	Space Communications Recommendations.....	86
b.	HAAI Communications Recommendations.....	88
c.	Terrestrial / Aerial Communications Recommendations.....	94
B.	INTELLIGENCE, SURVEILLANCE AND RECONNAISSANCE (ISR)	95
1.	Emerging ISR Solutions	95
a.	Emerging Space ISR.....	95
b.	Emerging HAAI ISR	97
c.	Emerging Terrestrial / Aerial ISR.....	98
2.	ISR Recommendations	100
a.	Space ISR Recommendations.....	100
b.	HAAI ISR Recommendations	101
c.	Terrestrial / Aerial ISR Recommendations.....	104
C.	BLUE FORCE TRACKING AND SITUATIONAL AWARENESS (BFT/SA).....	104
1.	Emerging BFT/SA Solutions.....	105
a.	Emerging Space BFT/SA	105
b.	Emerging HAAI BFT/SA	105
c.	Emerging Terrestrial / Aerial BFT/SA	106
2.	BFT/SA Recommendations	106
a.	Space BFT/SA Recommendations	106
b.	HAAI BFT/SA Recommendations	107
c.	Terrestrial / Aerial BFT/SA Recommendations	109
D.	POSITION, NAVIGATION AND TIMING (PNT).....	109
1.	Emerging PNT Solutions.....	109
a.	Emerging Space PNT	109
b.	Emerging HAAI PNT	110
c.	Emerging Terrestrial / Aerial PNT	111
2.	PNT Recommendations	112
a.	Space PNT Recommendations	112
b.	HAAI PNT Recommendations	112
c.	Terrestrial / Aerial PNT Recommendations	113
VI.	CONCLUSION AND RECOMMENDATIONS.....	115
A.	REGIME RECOMMENDATIONS	116
1.	Space Regime Recommendations	117
2.	High Altitude Area of Interest Regime Recommendations.....	120
3.	Terrestrial / Aerial Regime Recommendations.....	125
B.	RECOMMENDED SOLUTION	127
	DEFINITIONS	133

LIST OF REFERENCES	137
INITIAL DISTRIBUTION LIST	143

LIST OF FIGURES

Figure 1.	Graphical Depiction of the Gaps Filled by Near-Space.....	2
Figure 2.	Regions of the Earth’s Atmosphere and Orbital Space (not to scale).....	10
Figure 3.	Notional Growing SATCOM Needs of DoD, IC, and NASA.....	41
Figure 4.	Notional Transformation from Legacy to Transformational Communications Architecture (TCA).....	48
Figure 5.	Future Constellation Merging.	49
Figure 6.	FCS Tier Communication Structure.	49
Figure 7.	Satellite Imagery Resolution Comparison.	57
Figure 8.	Timeline of Current and Planned DoD UAS Systems.....	66
Figure 9.	Current Blue Force Tracker Configuration (Simplified).	68
Figure 10.	Example of BFT Coverage Capability 7 April 2003 OIF.....	69
Figure 11.	Current Layers of the Infosphere.	80
Figure 12.	Use of HAA systems for In-Theater Communication.	93
Figure 13.	Notional Operational Timeline from 300km Circular Orbit.....	96
Figure 14.	High Altitude Contribution to warfighter.	120
Figure 15.	High Altitude Representative Platforms.	121
Figure 16.	Near Space Alternatives and Timelines.....	123
Figure 17.	Recommended Range Extension Architecture.	125
Figure 18.	User to Satellite Communication Through HAP (USH) Architecture.....	129
Figure 19.	Layered Net-Centric Architecture.....	130

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LIST OF TABLES

Table 1.	Excerpt from MAGTF Capabilities List.....	25
Table 2.	SBCT Information System Architecture.....	27
Table 3.	Brigade-level Satellite Communication Systems.....	39
Table 4.	Comparative Capabilities of Current UAS.	55
Table 5.	FCS UAS Characteristics and Performance.	62
Table 6.	Techniques for Improving Bandwidth.....	82
Table 7.	Comparison of Terrestrial, High Altitude, LEO, and GEO Communication Systems.	87
Table 8.	Comparison of High Altitude Platform with GEO Satellite Communications.	89
Table 9.	Comparison of Mission-useful Distances for Various Platforms.	124
Table 10.	Relative Strengths of Satellites, Near-Space Platforms, and Air-Breathing Assets.	127

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LIST OF ABBREVIATIONS AND ACRONYMS

AAR.....	After Action Review
ACE.....	Air Combat Element
AFSPC	Air Force Space Command
AI.....	Area of Interest
AOA.....	Analysis of Alternatives
BCT.....	Brigade Combat Team
BFT	Blue Force Tracker
BFT/SA.....	Blue Force Tracking and Situational Awareness
BLOS	Beyond Line of Sight
BMC4I	Battle Management Command, Control, Communication, Computers, and Intelligence
CLD.....	Combat Logistics Detachment
COP.....	Common Operating Picture
COTS... ..	Commercial off the Shelf
CS.....	Combat Support
CSS	Combat Service Support
DARPA.....	Defense Advanced Research Projects Agency
DO.....	Distributed Operations
DoD.....	Department of Defense
DVB	Digital Video Broadcast
EMWCL.....	Expeditionary Maneuver Warfare Capabilities List
EO	Electro-Optical
FBCB2	Force XXI Battle Command and Control
FBCB2-BFT.....	Force XXI Battle Command and Control – Blue Force Tracker
FCS	Army Future Combat System
GEO	Geo-Stationary Orbit
GPS	Global Positioning System
HAA.....	High Altitude Airship
HAAI.....	High Altitude Area of Interest
HALE.....	High Altitude Long Endurance
HAP.....	High Altitude Platform
HBCT.....	Heavy Brigade Combat Team
HIS	Hyper Spectral Imagery
IBCT	Infantry Brigade Combat Team
ICD.....	Initial Capabilities Document
IED.....	Improvised Explosive Device
IR.....	Infrared
IRIS	Internet Routers in Space
ISR	Intelligence Surveillance and Reconnaissance
ITU.....	International Telecommunications Union
JCA	Joint Capability Area
JCTD.....	Joint Capability Technology Demonstration

LEO.....	Low Earth Orbit
LOS.....	Line of Sight
MAGTF.....	Marine Air-Ground Task Force
Mbps	Megabits Per Second
MCL	MAGTF Capabilities List
MEB.....	Marine Expeditionary Brigade
MEF	Marine Expeditionary Force
MEO.....	Medium Earth Orbit
MEU(SOC)	Marine Expeditionary Unit, Special Operations Capable
MILSATCOM.....	Military Satellite Communications
MSL	Mean Seal Level
MTOE	Modified Table of Organization and Equipment
NASA.....	National Aeronautics and Space Administration
NCA	National Command Authority
NDIA.....	National Defense Industrial Association
OIF	Operation Iraqi Freedom
ORS.....	Operationally Responsive Space
PNT	Position, Navigation and Timing
POS/NAV	Position and Navigation
PSYOP	Psychological Operations
SA	Situational Awareness
SATCOM.....	Satellite Communication
SBCT.....	Stryker Brigade Combat Team
SBR.....	Space Based Radar
SMDC	Army Space and Missile Command
SPF	Stratospheric Platform
TACSAT	Tactical Satellite
TENCAP.....	Tactical Exploitation of National Capabilities
TF.....	Task Force
TMD.....	Theater/Tactical Missile Defense
TOE.....	Tables of Organization and Equipment
TRADOC	Training and Doctrine Command
UAS.....	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
UNS.....	Universal Needs Statement
USA.....	United States Army
USAF	United States Air Force
USMC	United States Marine Corps
WIN-T	Warfare Information Network - Tactical

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I. INTRODUCTION

You can fly over a land forever; you may bomb it, atomize it, pulverize it and wipe it clean of life but if you desire to defend it, protect it, and keep it for civilization you must do this on the ground, the way the Roman Legions did, by putting your young men into the mud.¹

That quote from Fehrenbach captures the purpose of the Army and Marine Corps ground tactical warfighter. These men and women often conduct their operations in austere environments with support from systems that consider them “disadvantaged users.” They are warfighters by the fact that they are actively prosecuting warfare for their country, in the region known as the close fight. They are a tool of the government, an attempt to make change when political, economical, and diplomatic attempts have failed.

The purpose of this thesis is to explore beyond line of sight (BLOS) alternatives to support these ground tactical warfighters. The terrain that they operate within is complex and rugged. The infrastructure to support them is sparse and immature. The enemy they face is intelligent, quick, knowledgeable of the terrain and people, and often hidden among civilians. To prosecute the fight he is in effectively, this tactical warfighter needs the ability to leverage technologies and systems that grant him an advantage in seeing and knowing the enemy first, so he can strike the enemy first.

The basic tools of these warfighters have not changed tremendously in the last six decades. Surely, they have all improved in technology, but the equipment of the modern ground tactical warfighter is essentially the same as that of his grandfather. Especially in many of today’s conflicts, where the nature of the conflict mitigates the use of many of our more lethal systems such as artillery and air support, the tactical warfighter’s equipment is quite similar to that of his grandfather’s.

While better weapons, armor, and similar equipment enhances the tactical warfighter’s ability to fight his enemies, the tools that will make him successful are perhaps those that allow him to offset his adversary’s advantages within the indigenous

¹ T.R. Fehrenbach, This Kind of War: A study in Unpreparedness (New York: Macmillan, 1963).

population. Enhanced technological effects, delivered seamlessly to the appropriate level of unit commander, can make the tactical warfighter far more effective than he is now. Specifically, the tactical warfighter requires enhanced capabilities in BLOS communications, tactically responsive intelligence, surveillance, and reconnaissance (ISR), blue force tracking and situational awareness (BFT/SA), and position, navigation and timing (PNT). Improvement in these four areas provides tremendous advantages to the ground tactical warfighter, allowing him to operate more effectively while distributed over greater distances.

The figure below shows an overview of the trade space that can provide this support to the tactical warfighter. Space, the High Altitude Area of Interest (formerly near space), and the aerial (terrestrial) regions each provide specific advantages and disadvantages in each functional capability. This thesis seeks to identify these strengths and weaknesses, show gaps in the tactical warfighter's support, and then provide recommended architecture solutions.

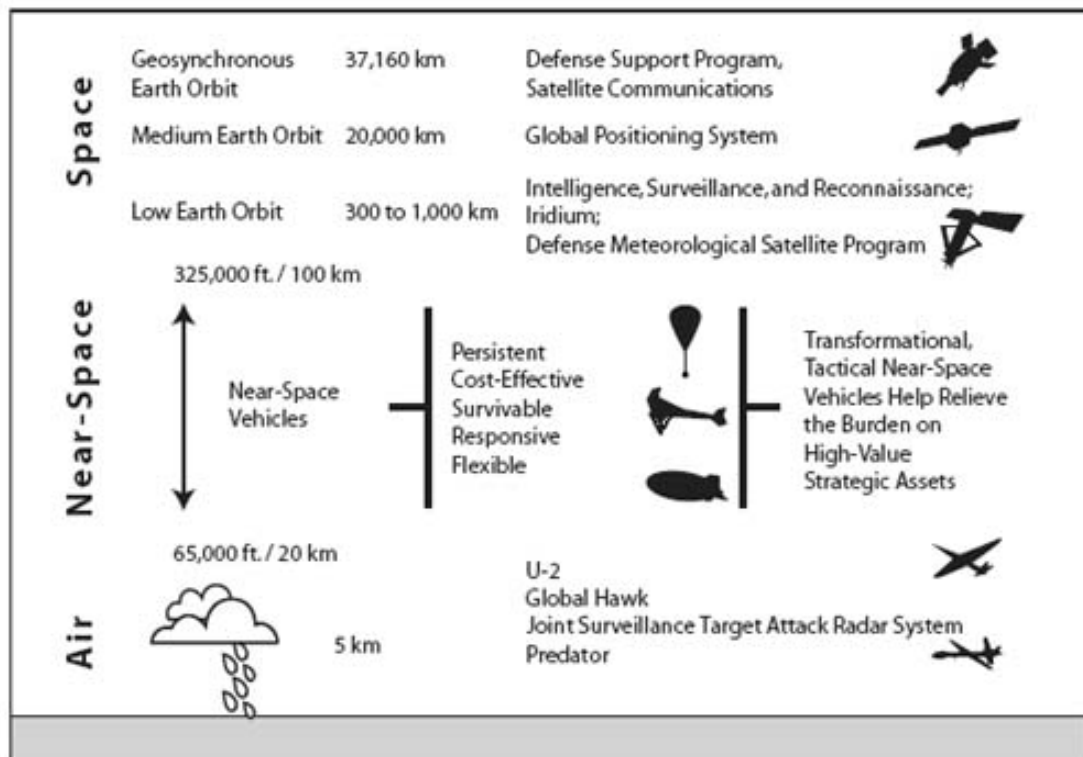


Figure 1. Graphical Depiction of the Gaps Filled by Near-Space.²

² Edward B. Tomme and Sigfred Dahl, "Balloons in Today's Military – An Introduction to the Near-Space Concept," *Air and Space Power Journal* 19 (December 2005), 5.

A. TACTICAL TROOP NEEDS

Currently, many of the BLOS capabilities provided to the tactical warfighter were afterthoughts. Often, they were the result of capabilities provided by strategic systems that were discovered could provide some tactical capability. Few of these existing systems were designed specifically to support the often-unique needs of the tactical warfighter. While the tactical warfighter will not likely complain when given an enhanced capability, he often must make do with what he is given. To stay ahead of his modern and future adversaries, the tactical warfighter needs systems designed for and dedicated to his unique fight. The tactical warfighter needs to understand what he needs, understand how to transfer those needs into requirements, and then supervise the development of systems that will fill those requirements.

Making an existing system better is not always the best way of meeting increasing requirements. Sometimes a system has specific limitations that are inherent due to physical or operational reasons. Trying to force a system to do something it is not suited for provides some capability but rarely in an efficient or cost-effective manner. Exploring new regions or technologies assumes some risk, yet the potential outcome is quite often worth that risk. The United States has a long tradition of finding innovative solutions to problems that have allowed the fielding of incredibly complex and capable systems. It is time that this innovation and development supports the “disadvantaged user” with BLOS capabilities, allowing that term to be placed into historical record.

B. SPACE: THE FINAL FRONTIER?

Space was the ultimate achievement; to leave the constraints of earth’s gravity and atmospheric effects behind was empowering. After many decades of space exploration, operations, and experience, we find that the ultimate high ground has some very real constraints and limitations.

Space can perhaps meet all the BLOS requirements for the tactical warfighter, but to do such would be cost prohibitive and extremely inefficient. Space effects are critical

to our nation, in both military and civil sectors. Our military would be unable to execute large numbers of essential missions without the effects provided by space, specifically at the strategic and operational level.

In most cases, space is perhaps not well suited for the unique situation of the tactical warfighter. The tactical warfighter operates on a different scale, his timeline is smaller, his distances are smaller, his unit size and capabilities are smaller, his support staff is smaller, his budget is smaller, and his decision cycle must be smaller. Smaller does not make things easier, however, especially when it comes to making tactical decisions with lives at stake. Due to availability, priority, and responsiveness, space is usually not the perfect match to tactical requirements.

C. TACTICAL SPACE AND HAAI SYSTEMS

What if we create a near space, what if we gave it to the space guys? So that space guys were forced to be less platform centric and more results oriented. We tell them to solve the problem of persistency. What if we did that? I bet it would work.³

General Jumper's key point here is that the tactical warfighter does not care where his support comes from. The tactical warfighter cares that he has that support when he needs it. High altitude systems promise to be uniquely suited to meet the needs of the tactical commander in a regional area. At the tactical level, it is not often necessary to communicate with the other side of the world, but rather, over the next two ridgelines. As such, a regional capability may be better suited to tactical needs. High altitude systems, as part of an overall architecture, may be the proper answer for meeting the needs of the tactical warfighter, and not a competing asset with space or other systems.

³ General John P. Jumper, USAF (2004, October 27), Speech given at the C4ISR Summit, Danbury, MA, 27 Oct 2004.

II. DEFINING TACTICAL SPACE

A. REFINING THE CONCEPT OF “TACTICAL SPACE”

There are many publications, both published and available on the Internet, which discuss the concepts of “Tactical Space.” Many of these documents use vague terms or common rhetoric to support a specific point, or to appeal to a target audience, without clearly defining the terms or their meanings. Initially, we will define many of these often-misused terms to establish a standard baseline for discussion. We have chosen to divide “Tactical Space” into four communities of information: Military, Military in Civil Publications, Government, and Civil. As the focus of our thesis involves support to the “Tactical Warfighter,” our definitions will center on this group of warfighters.

We will first establish what encompasses each of our four communities of information and then, in each community, provide applicable definitions (where available) to each term, we define. While there are other sources for definitions, we have chosen these four communities and the associated definitions based on current work in the area of “Tactical Space.” In many cases, there are competing definitions and we will compare those to define the term for this thesis.

In the end, we will provide a common definition for the terms “Space,” “Near-Space / High Altitude,” “Tactical,” “Tactical Warfighter,” and “Tactical Space” as they apply to the support of Army and Marine Corps forces operating at the tactical level of war.

1. Military

Inside the Department of Defense (DoD), there are doctrinal publications at both the individual service and joint levels. We will extract from the most commonly accepted, the definitions and requirements to define these terms as a basis of discussion. We understand that there are cultural differences between the services and we hope to capture a common, understandable definition that transcends these differences. All of these definitions are published or accepted definitions, used to demonstrate to the reader the common ground, as well as the differences among various segments of the DoD. Our

focus, again, is on the Brigade (USA) / Regiment (USMC) and below units operating at the tactical level. The sources used include various published joint and service doctrinal publications and manuals, joint memorandums, and initial capability documents (ICD).

2. Military in Civil Publications

These publications will cover articles produced or written by members of the United States military for presentation in civilian publications. Also included will be any presentations given during non-military or non-governmental conferences. While these definitions do not constitute policy or doctrine, they represent individual thought by those who are closer to the problem or have a genuine interest in the topic presented.

3. Government

Government documents referenced will encompass any publication contracted by the government (military/government, i.e. DARPA) to evaluate a need or capability. These will include reports from organizations such as the Rand Corporation and National Defense Industrial Association and Universities, as well as NASA and other government (non-DoD) agencies with interests in this area.

4. Civil

Civil documentation will be from any unsubsidized and/or independent entity that conducted its own research in support of a need or capability. These will include any corporation, private company, and personal entities that may have conducted some need or capability research independently.

B. DEFINITIONS

As discussed earlier, we will now highlight the most accepted or used definitions as presented by the popular players in military space. Although your perspective on the battlefield will affect your definition and its application to you, we will attempt to take the intent of all these perspectives and definitions and form a definition favorable to the discussion of the application of effects provided to the ground tactical user. This will provide a common language and foundation to frame discussion. Nowhere in our research have we come across much of an attempt to establish definitions for these often

haphazardly used terms. Most writers assume that the readers accept and/or understand their point of view or definition, even if exhaustive searches for an actual definition prove futile. Whether intentional or not, this lack of definition creates confusion and misleads the readers as to the capabilities or intended use of a system. We hope to avoid any confusion and make our claims by replacing the use of often clichéd words with specifically defined terms. The most ambiguous terms we will cover are, “Tactical Warfighter,” “Tactical Space” and “Near Space / High Altitude.” For completeness, we include and start with the terms “Space” and “Tactical,” as they are slightly better understood and are required in developing any definitions derived from them.

1. Space

a. Military

The joint definition of space, according to Joint Pub 3-14, “Joint Doctrine for Space Operations, is, “A medium like the land, sea, and air within which military activities shall be conducted to achieve US national security.”⁴ This definition, while useful perhaps at the joint level in showing that space is like as any other medium, does not help much in our discussion. Fortunately, most individual services share a common understanding of its definition. A representative and concise definition, as used by the US Army is:

The part of the universe that extends from the upper limits of the earth's atmosphere outward. While a precise limit cannot be ascertained, in general it begins at about the altitude above the earth that corresponds to the lowest stable satellite orbits and above which aerodynamic forces can no longer support the control of conventional aircraft. This is usually an altitude in excess of 100 kilometers.⁵

As part of the DoD, military personnel avoid setting hard altitude limits on the lower limits of space. While the US Government maintains a desire to keep the boundary of space a loosely defined region, the military will follow suit. It is hard to predict today, what orbital capabilities will exist in the future. Setting arbitrary numbers

⁴ U.S. Department of Defense, Joint Publication 3-14: Joint Doctrine for Space Operations, (Washington: Government Printing Office, 2002), GL5.

⁵ U.S. Department of Defense, Department of the Army, Training and Doctrine Command Pamphlet 525-3-14: The United States Army Concept for Space Operations in Support of the Objective Force, (Washington: Government Printing Office, 2003), 38.

based on current technology and capabilities would surely pose complications in the future where orbits might be maintainable at lower altitudes than currently envisioned.

b. Military in Civil Publications

Military personnel writing in civil publications follow either the military or government definition of space, with few drastic differences. Those differences were not sufficient to warrant any influence on our process.

c. Government

There are no specific definitions or limits accepted by the United States Government on the term “space.” Government definitions often define “space” based on the capabilities or characteristics of an object rather than where it operates. This absence of limits does not restrict our operations in support of the U. S. National Space Policy.

The United States rejects any claims to sovereignty by any nation over outer space or celestial bodies, or any portion thereof, and rejects any limitations on the fundamental right of the United States to operate in and acquire data from space....The United States considers space systems to have the rights of passage through and operations in space without interference.⁶

d. Civil

The debate as to where and how to define space and its demarcation with our own protected airspace continues, much like the following quote expresses:

There are major differences in the legal realms of outer space and air space and yet no agreed and defined legal boundary exists between the two. States are affected by the different legal regimes of air and space law in many ways, most especially in relation to state sovereignty and national jurisdiction⁷

Most other articles fall on one side or the other of this stance. Nations and entities seem to either oppose or support clearly defining space. There appears to be little middle

⁶ U. S. Office of Science and Technology Policy, Executive Office of the President, U.S National Space Policy, (Washington: Government Printing Office, 2006), 1.

⁷ Alexandra Harris and Ray Harris, “The Need for Air Space and Outer Space Demarcation” (London: University College, 2006), Available from <http://www.sciencedirect.com/science>; Internet; accessed 18 January 2006.

ground or compromise on the subject. As of now there is no accepted definition in the civil community for space except as defined by the characteristics of the object operating in either airspace or outer space.

e. Space Defined

For the purpose of our topic, support to tactical operations, and to focus on the real intent at hand, we will define space as the altitude of perigee or orbit in which a spacecraft (designed for operations in that environment), can maintain an orbit for an extended duration (months for comparative analysis to tactical operations).

2. Near Space / High Altitude

a. Military

Though there are many definitions of “Near Space” in military documentation, there is a consensus that it occupies a general area of the atmosphere. The Navy and Air Force define “Near Space” as between 65,000 and 325,000 feet. Operational characteristics of current aircraft systems define the lower boundary of this region. Two such definitions are, “Near Space systems will operate in the harsh natural environment between 65,000 and 325,000 ft.”⁸, and “The domain above typical aircraft operational altitude and below the orbital realm (65,000 and 325,000 ft domain) provides the advantages of wide area and persistent sensor coverage to bridge the gap between UAVs and satellites.”⁹

The Army position is that “the high altitude region of the stratosphere and mesosphere is defined as that region between the tropopause and the region of orbital space, 18 to 100km above MSL.”¹⁰ Converted to common measurements, that is around 59,000 feet to 328,000 feet. This difference is not significant considering the scope of the difference, and generally shows the different perspectives between the Air Force and

⁸ U.S. Department of the Air Force, HQ Air Force Space Command, “Initial Capabilities Document For Operationally Responsive Space - Near Space Draft v. 7,” (March 2006), 13.

⁹ Ibid., 5.

¹⁰ U.S. Department of the Army, Training and Doctrine Command, TRADOC Pamphlet 525-7-4 Concept Capability Plan for Space Operations 2015-2024, (Washington: Government Printing Office, 2006), 12.

Navy, who look at air distances in altitude by thousands of feet, and the Army who measures distances primarily on land, with measurements rounded to nearest kilometers.

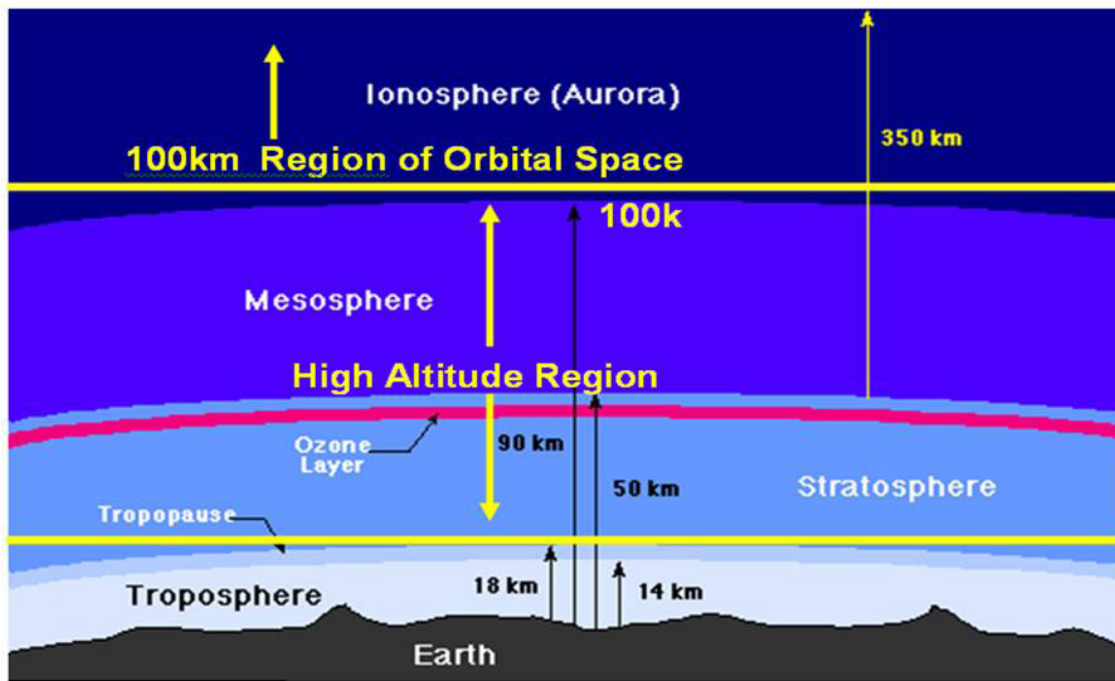


Figure 2. Regions of the Earth's Atmosphere and Orbital Space (not to scale).¹¹

At the onset of a military discussion, concerning the utility of this region for military use, it seemed necessary to define the space. By doing so, it would allow a service to claim the region as part of their area of responsibility. Due to legal ramifications and service conflicts, it has been necessary to eliminate the label and focus on the effects and platforms to operate in this area.

While it is currently popular to use the term “Near Space” in scientific, academic, and industry circles, the Department of Defense is officially moving away from the term, as is clearly outlined by the Chief of Staff of the Air Force:

There are only two categories of space: air space and outer space. The term "near space" has no meaning in domestic and international law, and any activities conducted at near space altitudes must be analyzed using the

¹¹ U.S. Department of the Army, Training and Doctrine Command, TRADOC Pamphlet 525-7-4 Concept Capability Plan for Space Operations 2015-2024, (Washington: Government Printing Office, 2006), 11.

applicable legal regime for air space or outer space. The United States does not recognize a specific altitude at which air space ends and outer space begins...¹²

As stated in a memorandum policy letter from the Director of the Joint Staff, the term “near space” is no longer to be used by the DoD, in joint usage, and should be discouraged at all levels. ¹³

b. *Military in Civil Publications*

The Air Force stays well grounded with the definition in an article by Lt Col Ed “Mel” Tomme, USAF and Col Sigfred “Ziggy” Dahl, USAF,

Near-space is well below orbital altitudes. Being roughly defined as the region between about 65,000 and 325,000 feet, it is too low for sustained orbital flight and above the region where air-breathing engines and wings work very well.¹⁴

This definition builds on an earlier article concerning Air Force Space Command:

As Air Force Space Command (AFSPC) furthers its utilization of the high frontier, it’s looking for persistence that doesn’t have to reside quite so far out of this world. The command is focusing on developing programs that will operate in the near-space region, which is located between 65,000 feet and 325,000 feet.¹⁵

At the UCCS Near Space Symposium for 2006 and 2007, the term “Near Space” appeared frequently in use, though there was no formal definition outlined except by individual members.

¹² Mary Walker, “Memorandum for the Secretary and The Chief of Staff of The Air Force, Subject: Legal Regime Applicable to ‘Near Space’,” 27 September 2004.

¹³ Ryan Henry, “Memorandum for Director, Joint Staff, Subject: Use of the Term ‘Near-Space’,” 29 January 2007.

¹⁴ Tomme, “Balloons in Today’s Military,” 5.

¹⁵ Jennifer Thibault, “Developing the Near Frontier, Military Aerospace Technology. Online Edition 6:1, Available from <http://www.military-aerospace-technology.com/article.cfm?DocID=1210>; Internet; accessed 12 September 2007.

Army Space and Missile Defense Command (SMDC) stated in 2006, that “Near Space” was the region between 60,000 feet and 100,000 feet.¹⁶ In 2007, a similar briefing used the term “High Altitude” as being located between 20km (65,000 feet) and 100 km.¹⁷

c. Government

Much like the United States government’s desire not to numerically define space, the government also has no numeric or scientific definition of “Near Space.” To define “Near Space” would force its upper boundary to be the lower boundary of space, which would violate United States National Space Policy. This hard altitude limit has serious legal ramifications and as such would likely be opposed for the same reasons as the formal definition of space altitudes.

d. Civil

There is considerable difference among civil definitions of what “Near Space” actually is. One definition is that near space assets are “High Altitude Platforms (HAPs) or Stratospheric Platforms (SPFs), and located 17–22 km above the Earth’s surface.”¹⁸ The International Telecommunications Union (ITU) defines the term High Altitude Platform Station (HAPS) to describe a “station located on an object at an altitude of 20 to 50 km and at a specified, nominal, fixed point relative to the Earth.”¹⁹

In the 2006 Near Space Symposium, the Space Data Corporation stated its understanding of this region to be between 65,000 and 100,000 feet.²⁰ During the 2007 Near Space Symposium, the Near Space Corporation identified anything greater than

¹⁶ Jeff Faunce and Stew Stout, “Army Activities in Near Space” Briefing to the Near Space Symposium, Colorado Springs, CO, 2 February 2006, Jeff Faunce and Stew Stout, United States Army Space and Missile Defense Command, slide 4.

¹⁷ Jeff Faunce, “Army Activities in High Altitude” Briefing to the Near Space and High Altitude Operations Symposium, Colorado Springs, CO, 22 February 2006, slide 7.

¹⁸ Stylianos Karapantazis and Fotini-Niovi Pavlidou, “Broadband Communications Via High-Altitude Platforms: A Survey,” IEEE Communications Surveys, 7, (First Quarter 2005): 1.

¹⁹ Ibid.

²⁰ Phil De Carlo and Shawn Bratton, “Deployment of a Military Near Space Communications System” Briefing to the Near Space Symposium, Colorado Springs, CO, 3 February 2006.

65,000 feet up to, but not including 100,000 feet as near space.²¹ QinetiQ's Zephyr Hale UAS defined mission altitude for near space as anything greater than 30km (60,000 feet).²² University of Colorado at Colorado Spring's (UCCS) SANSRG (Space and Near-Space Research Group), who sponsored the 2006 and 2007 Near Space Conferences, uses the region 12-62 miles (~63,000-~327,000 feet/100km), in an article.²³

e. Near Space / High Altitude Defined

For our discussion, we will attempt to limit ourselves to the label of "High Altitude Area of Interest" (HAAI) throughout this thesis. This thesis defines HAAI as, airspace above 65,000 feet, up to but not including the orbital regime. Loosely, this range excludes all but very specialized air-breathing manned aircraft as well as current and projected orbital systems. Our objective is not to recommend what service or agency should have operational control of this area, but rather to highlight how the region can support the "Tactical Warfighter."

3. Tactical

a. Military

Without surprise, we find that traditional military publications provide well-developed and established definitions of the term tactical. Both joint and service publications had no shortage of complementary definitions for the terms tactics and tactical, as well as providing context and framework for both terms.

JP 3-0 Joint Operations defines the tactical level, from a Joint Perspective, as:

The tactical level focuses on planning and executing battles, engagements, and activities to achieve military objectives assigned to tactical units or task forces (TFs). An engagement normally is a short-duration action between opposing forces. Engagements include a wide variety of actions between opposing forces. A battle consists of a set of related

²¹ Near Space Corporation and Technology Service Corporation, 2007 Near Space Symposium. Slide 6.

²² QinetiQ Corporation, "Zephyr HALE UAS," Briefing to the Near Space Symposium, Colorado Springs, CO, 22 February 2007.

²³ University of Colorado at Colorado Spring's (UCCS) SANSRG (Space and Near-Space Research Group), The Gazette, (Colorado Springs), July 23, 2005.

engagements. Battles typically last longer; involve larger forces such as fleets, armies, and air forces; and normally affect the course of a campaign.²⁴

The publication continues speaking of the tactical level as:

The level of war at which battles and engagements are planned and executed to achieve military objectives assigned to tactical units or task forces. Activities at this level focus on the ordered arrangement and maneuver of combat elements in relation to each other and to the enemy to achieve combat objectives.²⁵

FM 1-02/ MCRP 5-12A defines the Tactical Level of War as,

The level of war at which battles and engagements are planned and executed to accomplish military objectives assigned to tactical units or task forces. Activities at this level focus on the ordered arrangement and maneuver of combat elements in relation to each other and to the enemy to achieve combat objectives.²⁶

FM 3-0 defines the Tactical Level as:

Tactics is the employment of units in combat. It includes the ordered arrangement and maneuver of units in relation to each other, the terrain, and the enemy to translate potential combat power into victorious battles and engagements. A battle consists of a set of related engagements that last longer and involve larger forces than an engagement. Battles can affect the course of a campaign or major operation. An engagement is a small tactical conflict between opposing maneuver forces, usually conducted at brigade level and below. Engagements are usually short - minutes, hours, or a day.²⁷

The manual continues with that definition with:

Tactics is also the realm of close combat, where friendly forces are in immediate contact and use direct and indirect fires to defeat or destroy enemy forces and to seize or retain ground. Exposure to close combat separates Army forces from most of their counterparts. Army forces fight

²⁴ U.S. Department of Defense, Joint Publication 3-0: Joint Operations, (Washington: Government Printing Office, 2006), II-2.

²⁵ U.S. Department of Defense, Joint Publication 3-0: Joint Operations, (Washington: Government Printing Office, 2006), GL-31.

²⁶ U.S. Department of Defense, Department of the Army and Department of the Navy, United States Marine Corps, Field Manual 1-02 / Marine Corps Reference Publication 5-12A: Operational Terms and Symbols, (Washington: Government Printing Office, 2004), 1-182.

²⁷ U.S. Department of Defense, Department of the Army, Field Manual 3-0: Operations, (Washington: Government Printing Office: 2001), 2-5.

until the purpose of the operation is accomplished. Because of this, they are organized to endure losses, provided with combat service support (CSS) to generate and sustain combat power, and trained to deal with uncertainty.²⁸

Finally, we discuss how higher-level headquarters determine and support the tactical fight:

The operational-level headquarters sets the terms of battle and provides resources for tactical operations. Tactical success is measured by the contribution of an action to the achievement of operationally significant results. Battles and engagements that do not contribute to the campaign objectives, directly or indirectly, are avoided.²⁹

b. Military in Civil Publications

Here we find that the military member usually understands what “Tactical” means. Where the confusion sets in is that in the civil publications or forums the audience does not always understand and often thinks “small in size” is equivalent to tactical. LtCol Tomme gives a concise and accurate definition of tactical when talking about space assets and effects as:

In a computer programming language, “tactical” would be a reserved word. When one uses it to sell a program to a warrior, the warrior has a very specific understanding of what that technical term means: applying to small-scale, short-lived events, usually involving troops in contact.³⁰

While Tomme speaks about the size in his definition, he refers to such in respect to engagement sizes, not the size of actual equipment.

c. Government

Government definitions of “Tactical” do not exist outside of the DoD. Other than using the reference of “Strategic” as the goal, mission or direction of the government, then operational and tactical as lower echelons of action used in order to achieve that strategic goal, there is no need at this level to define tactical.

²⁸ Department of the Army, Field Manual 3-0: Operations, 2-5.

²⁹ U.S. Department of Defense, Department of the Army, Field Manual 3-0: Operations, (Washington: Government Printing Office: 2001), 2-5.

³⁰ Edward B. Tomme, The Strategic Nature of the Tactical Satellite, (Maxwell, AFB: Air University, 2006), ii.

d. Civil

For the purpose of our work, the term tactical has no relevance outside the military or civil paramilitary organizations. However, when discussing tactical satellites we have come to the discovery that most professionals in this area do not fully understand the true definition of “Tactical,” as it applies to combat operations, or any other tactical segment of warfighting operations. Something being small or short duration does not make it tactical, in a military sense. The fact that a tactical-sized unit can use an asset does not mean that it either should be or will be available to them due to prioritization of need and cost and utility analysis of the asset.

e. Tactical Defined

For the duration of this thesis, the use of the term “Tactical” is used with the understanding and intent as defined here. Tactical in reference to units are those of the size to operate independently for a short period of time and/or toward limited mission goals, in our case, units at or below Army Brigades and Marine Regiments. Tactical in reference to missions are those executed in a period that the unit tasked can operate autonomously without continuous re-supply or control from higher headquarters.

4. Tactical Warfighter

a. Military

While defining tactical was straightforward, we were not able to find a coherent and accepted definition, for the ambiguous term “Warfighter,” in any military document. Many documents and persons frequently use the term “Warfighter,” but in extensive research, we were unable to find an actual definition of the term. We will define the term “Warfighter” to be any person in the military from the Commander in Chief to the newest E-1 graduated from basic training that is actively involved in the execution of warfare. They are all, by oath, directed to support and defend the constitution in the capacity of the military. In current cases, “Warfighter” can and likely does apply to members of other national agencies that are conducting direct action in support of ongoing-armed conflicts. It is further necessary to clarify that this thesis focuses on the disadvantaged user status of ground tactical warfighters, those serving

within the Army and Marine Corps and excludes the Air Force and Navy who do not generally face the same austere tactical environments.

b. Military in Civil Publications

During the recent American Institute of Aeronautics and Astronautics' 5th Operationally Responsive Space Conference in April 2007, there was significant discussion on supporting the "Warfighter." A member of the audience eventually asked the pointed question of "who is the Warfighter?" Air Force LtCol Carol Welch answered that the "Warfighter" is dependent on the acceptance of risk. The conversation went on to say that the "Warfighter" and his assets are determined by the risk imposed by those assets. This says that the "Warfighter" is defined by risks or assets not his capability to conduct actions as a unit.

Numerous publications and articles mention the "Tactical Warfighter" but leave it to the reader to determine who this person actually is. Again, the writer assumes both the author and the reader know what the other is referring to and agree. When doing so, it is advantageous to the writer to remain ambiguous, to increase acceptance by a wider audience. Using our definition of "Warfighter," from above, one can see how any person in the military reading the information could think, "They are talking about me."

c. Civil

Civil companies will use the term that will most likely get the attention of the person or organization that can afford what they are selling. As they are trying to sell some product or service to the largest possible audience, it is not in their best interest to define this "Tactical Warfighter" customer in a clear manner. This fact is painfully obvious when reading most TACSAT articles or information from almost any other entity trying to sell space to the "Tactical Warfighter." It would be ludicrous to say that there is no utility for the "Tactical Warfighter" from space-based assets. However, to sell a space-based asset on the premise that it can and most importantly will support the "Tactical Warfighter" can be both dangerous and disastrous.

d. Tactical Warfighter Defined

The “Tactical Warfighters” referenced in this thesis are the personnel attached to the Brigade or Regiment size units, or below, who are operating in a hostile area, possibly under austere conditions. Essentially, we understand that company, platoon and squad sized units execute most patrols or other tactical operations. These smaller units are most likely the “disadvantaged user.” Units on patrol and executing distributed operations (DO) require certain capabilities to execute their mission.

5. Tactical Space

a. Military

The phrase “Tactical Space” as a standalone term is one that we have not found used elsewhere. The military often uses it in the context of tactical space effects or tactical space system, but not as a term of its own meaning.

b. Military in Civil Publications.

The closest use of the phrase by anyone directly related to the military is as follows:

While global coverage may be a valid requirement for applications such as navigation and communication, other missions may only require continual coverage of a particular geographic region. This is particularly true for tactical national security space systems supporting combat forces during a particular military crisis.³¹

In this quote, we see that national security systems are useful to support tactical operations, but still no definition of “Tactical Space.” Again when reading the phrase, one must take into account that this is first about “Space,” then “national security” and lastly “Tactical.” Using those words together one can quickly see that these systems are not for the tactical units directly but for national security and the word “Tactical” refers to using those assets in support of a tactical operation.

³¹ Scott C. Larmore, “Partially Continuous Earth Coverage from a Responsive Space Constellation,” Briefing to 5th Responsive Space Conference, Los Angeles, CA, 23 April 2007.

c. Government

Here we again see no formal definition or use for the phrase that we have decided to use as a cornerstone for this thesis.

d. Civil

Here we find the first separation of the level of unit combatants and space as an area to facilitate a requirement:

A program to leverage that is underway is Internet Routers in Space (IRIS) that recently announced a Joint Capability Technology Demonstration (JCTD) where a space hardened router will be placed on Intelsat's geostationary satellite IS-14, expected to launch in 2009. The system will provide access to the Internet from remote regions of Europe, Africa and the Americas. This commercial GEO-based system along with other IRIS initiatives and/or potentially more accessible high altitude platforms (at a lower cost) may be excellent proving grounds for developing and testing net-centric communications and standards at the tactical level in space.³²

This was the only reference found that specifically addresses the different areas of capability to support a requirement(s) and how they can support any specific level of warfighting unit, specifically tactical. This capability, without the requirement of liaison with higher or marked increase in the tactical unit's autonomous support requirement, is the desire of any tactical unit.

e. Tactical Space Defined

Our definition for "Tactical Space" must cover a specific list of foundations, some of which we have already defined for this specific purpose. For this reason, the reader must understand the preceding sections.

"Tactical Space" is the operational environment that the tactical warfighter operates within and is from where he gets his support. "Tactical Space" is dedicated specifically to providing capabilities to the tactical warfighter, to facilitate his mission(s) and address his status as a disadvantaged user.

³² Jeffrey L. Janicik, "Net-centric Operations and Responsive Spacecraft – A guide to Implementation," Paper presented at the 5th Responsive Space Conference, Los Angeles, CA, 23 April 2007, 8.

This “Tactical Space” can refer to both orbital and/or sub-orbital systems that provide capabilities traditionally only available from space assets. These capabilities have to be specifically dedicated to the “Tactical Warfighter” as he executes his tactical mission(s). These definitions and references establish a common frame of reference for discussion on providing much needed capabilities to the “Tactical Warfighter.”

III. TACTICAL REQUIREMENTS

A. MILITARY ORGANIZATIONS

1. Army

The highest level United States Army organization on which we will focus is that of the Brigade Combat Team (BCT). The BCT is a modular unit that exists in several types. These types are the Infantry Brigade Combat Team, the Heavy Brigade Combat Team, and the Stryker Brigade Combat Team.³³ These new BCTs are the basic building block for Army future operations, replacing the previously organized Divisional Brigades that were less mobile, less deployable, and less able to operate as self-sustaining units across large areas.

The areas covered by BCTs are well beyond historical areas of coverage for tactical ground units. Doctrinally, BCTs should operate in an area with a radius of 60km³⁴, with a Future Combat Systems equipped BCT extending that radius to 75km. BCT units in Operation Iraqi Freedom are reporting areas of operations extending to 200 by 200 km.³⁵ Units operating in areas much greater than their doctrinal organization capabilities must establish terrestrial based communication relays, shuffle around extremely limited SATCOM assets, or operate outside of communications range with higher headquarters. All three options tremendously increase risk to the units forced to execute them.

Under the Army's recent transformation initiatives, these BCTs have greater capacity to operate independently, for longer periods. This transformation results in a similar-sized unit, in regards to combat forces, but with more ability to conduct independent command and control, as well as the ability to better sustain itself without

³³ U.S. Department of Defense, Department of the Army, Field Manual 3-90.6: The Brigade Combat Team (Washington: Government Printing Office, 2006), xvi.

³⁴ U.S. Department of Defense, Department of the Army, Army Comprehensive Guide to Modularity, (Washington: Government Printing Office, 2004) 2-12.

³⁵ U.S. Department of Defense, Department of the Army, Training and Doctrine Command Technical Report 06-014: Aerial Sensor and Relay Capabilities Based Assessment Final Report Volume II, (Washington: Government Printing Office: 2006), C-8.

higher headquarters support. The BCT transformation gives brigade-sized elements greater flexibility to function over larger areas in a more autonomous manner.

Generally, the BCT transformation removes the specialization of certain previous elements and allows for more units able to conduct similar missions.

Current deployed brigades within the Army are between 2500 and 4200 soldiers, depending on task organization and manning. There are also variations in size due to type of brigade, with armored and Stryker units having slightly more soldiers than infantry units of the same size.

2. Marine Corps

The Marine Corps forms and tasks its units to perform at specific levels of operations and in warfare. Traditionally the Marine Corps has functioned primarily at the tactical level to provide a forward presence and crisis-response with the level of impact including all levels of war. Although the Marine Corps has a formal structure for command and support, it traditionally organizes for operations into Marine Air-Ground Task Forces (MAGTFs). Commanders tailor these task forces to specific operations and requirements. MAGTFs come in three doctrinal sizes: Marine Expeditionary Force (MEF), Marine Expeditionary Brigade (MEB) and Marine Expeditionary Unit (Special Operations Capable) (MEU (SOC)).

For simplification, the MEF is roughly a division or greater sized ground component, a wing or greater sized air component and one or more logistics groups. A MEF is between 20,000 and 90,000 Marines and deploys as a major component in full-scale warfighting. This force size also applies for strategic levels of planning and warfighting.

The MEB is roughly a reinforced infantry regiment, a Marine Air Group (MAG) and a Combat Logistics Regiment. This force is highly configurable and can contain anywhere from 3,000 to 20,000 Marines and is used for Crisis Response and Small-Scale Contingencies. Due to the range of utility of the MEB, it can function as both an operational and tactical unit for planning and warfighting.

The most used and normally operated size unit is the MEU (SOC). This unit is comprised of a reinforced infantry battalion, a Marine Air Combat Element (ACE) or composite squadron and Combat Logistics Detachment. This size unit ranges from 1,500 to 3,000 Marines and acts as a forward presence for theatre commanders. Being special operations capable (SOC), they are trained for enhanced capabilities, to address specific crisis possibilities. This unit operates at the tactical level of war but very possibly influencing all levels of warfighting up to the strategic level.³⁶

3. Generalizations

From the preceding information, definitions, traditional uses and initial direction we have decided to restrict the scope to tactical units. As defined from above, this will include the Army's BCTs and the Marine Corps Brigade (MEB) and below.

4. Unit Interactions

We will now accept the fact that both services at this level execute very similar if not the same level and types of missions. The organizational differences on how the services execute the same mission are not significant at this level and the thesis will only address significant differences.

This thesis assumes that units in question are at Modified Table of Organization and Equipment (TOE) levels of personnel and equipment; meaning that all authorized equipment is on-hand, serviceable, and operates as demonstrated in actual use when applicable. While fully manned and equipped units are often not realistic in actual practice, we offer the best-case scenario in this discussion.

B. TACTICAL USER REQUIREMENTS

Many sources define requirements of the Warfighter that are achievable with space or space-like effects. Here again we are only concerned about the "Tactical Warfighter" and what is required for those size units to operate in the full scope of

³⁶ U.S. Department of Defense, Department of the Navy, United States Marine Corps, Marine Corps Concepts and Programs 2006, Available from, <http://hqinet001.hqmc.usmc.mil/p&r/concepts/2006/APPA.htm>; Internet; accessed on 12 September 2007.

tactical warfare. The Army's future doctrine in regards to space effects shows an increasing need for increased capabilities for information at the tactical level.

At the tactical level, Objective Force units see first, understand first, act first, and finish *decisively as the means to tactical success* [emphasis in original]. Operations will be characterized by developing situations out of contact; maneuvering to positions of advantage; engaging enemy forces beyond the range of their weapons; destroying them with precision fires; and, as required, by tactical assault at times and places of our choosing. Commanders will accomplish this by maneuvering dispersed tactical formations of Future Combat Systems units linked by net-centric C4ISR capabilities for common situational dominance. With these capabilities, the Objective Force will master the transitions at all levels of operations. Space systems provide critical support to the Objective Force "Quality of Firsts."³⁷

A study by the National Defense Industrial Association (NDIA) of Joint Warfighter shortfalls, identified from the AFSPC Strategic Master Plan and Combatant Command/Service Requirements, progressively defined the top requirement shortfalls for the joint forces. The prioritized shortfalls, at all levels were:

1. Tactical BLOS Comms on the move
2. Wideband Reachback & Dedicated Strategic Comm
3. Persistent ISR & Red Force Tracking
4. Change Detection, Detect Mines & IEDs
5. Blue Force Tracking
6. Battlespace Awareness
7. Foliage-Penetrating ISR
8. Signals Detection & Characterization
9. All Weather Imaging
10. Detonation/IR Detection & Characterization
11. PSYOPs
12. Fleeting Target Strike³⁸

Another document from the Rand Corporation breaks these basic warfighter requirements down to the lower level of tactical warfighter requirements. This study reiterates the points made above.

The most basic communication requirements for dismounted soldiers are to know (1) their own location, (2) the location of friends, and (3) the location of enemies. Transmission power and antenna size will be limited

³⁷ U.S. Department of Defense, TRADOC PAM 525-3-14, 10.

³⁸ Major General Don Hard (USAF Ret.), "National Defense Industrial Association (NDIA) Near-Space Summer Study Final Briefing," 9 November 2005, Slide 14.

to what can be practically worn and battery-powered. In buildings, tunnels, and similar locations, geo-location via GPS is extremely limited.³⁹

The Marine Corps trail of requirements, from After Action Reviews, Expeditionary Maneuver Warfare Capabilities List (EMWCL), and Universal Need Statements (UNS) feed into the MAGTF Capabilities List (MCL). This list ties to the Joint Capability Area (JCA) and Marine Corps Tasking List (MCTL). The list of capability gaps from the MCL are prioritized by areas such as Logistics, Fires and Maneuver, etc.

In the list the capability gaps that are relative to our topic are:

Gap # / Division	JCA	MCTL	Description of Capability Gap by Task
Fires and Maneuver Integration Division	Provide and Employ Joint Fires / 14 JCA's Supported	Unmanned Aircraft systems / Supports 23 of 49 FMID FAA tasks	Very limited capability in poor weather conditions. Interoperability limited by capabilities of CAC2S. Tier I and II need POM 10 continuance or capability will be lost. POM 10 new start required for Tier III capabilities due to current Tier III capability sundown.
Intelligence Integration Division	4.5.2.0 Intelligence Architecture Development 7.0.0.0 Joint Protection 9.3.0.0 Conduct Decisive Maneuver 14.0.0.0 Joint Special Operations and Irregular Warfare 14.2.0.0 Direct Action 14.4.0.0 Unconventional Warfare	2.1 Plan and direct Intelligence Operations 2.1.1.5 Support targeting	Limited ability to rapidly disseminate actionable intelligence and relevant products, to include sensor to shooter Near Real Time (NRT) data to the lower tactical levels (BN and below).
Intelligence Integration Division	4.2.0.0 Observation and Collection (All Domains)	2.2 Collect data and intelligence	Limited ability to establish and maintain a persistent, multi-sensor collection architecture to enable a covert, "unblinking eye" view within a defined battlespace.
Intelligence Integration Division	14.4.0.0 Conventional Warfare	2.2 Collect data and intelligence	Limited ability to collect on rapidly changing threat signals of interest.
Command and Control Integration Division	Provide Robust, reliable communications to all nodes, based on the varying requirements of those nodes (FORCenet 1)	5.1.1 Provide and Maintain Communications	Gap in the ability to operate voice and data C2 systems to the squad level. Gap in the ability to define and display operational picture with minimum latency, incorporate air and ground tracks, do so on-the move and over-the-horizon from any platform Gap in the ability to operate C4I systems on-the-move and over-the-horizon Technological solution needed to build hybrid terrestrial/celestial networks which combine the low data latency aspects of terrestrial networks with the BLOS capability of celestial networks, in order to maintain complete, accurate blue force picture

Table 1. Excerpt from MAGTF Capabilities List.⁴⁰

³⁹ Leland Joe and Isaac Porche III, Future Army Bandwidth Needs and Capabilities, (Rand Corporation, 2004), 20.

⁴⁰ U.S. Department of Defense, Department of the Navy, United States Marine Corps, Marine Corps Combat Development Command, Capabilities Development Directorate MAGTF Capabilities List (MCL), Approval Brief, 5 February 2007.

From these lists, we can start to pick those critical “tactical warfighter” requirements and identify which are most important to the successful execution of his mission. We see these requirements distilled down to: communications; persistent ISR; Blue Force Tracking and Battlespace Awareness; and Position, Navigation and Timing.

1. Communications

Within the term “communications,” we are including those requirements that include voice and data. These systems may be secure or open channel. The most needed level of this requirement is not at the inter-tactical layer or in higher headquarters; it is the link between higher headquarters and the tactical level unit. The need to transfer and communicate between the tactical and higher levels of command becomes increasingly difficult as our operations move into the environments of mountainous terrain, built up areas, and over extended distances for distributed operations. High-Level Operational Concept Graphics (OV1) from service representatives and contractors repeat this requirement often. Showing diagrams and using PowerPoint does not get the “tactical warfighter” connectivity. The traditional way of setting up and securing terrestrial relays does not support the current tactical environment or the future concepts for the Army or Marine Corps.

In a study by the Rand Corporation addressing US Army communication requirements:

Achieving high mobility on a rapidly changing battlefield will require considerable bandwidth, the Army is not the only claimant— joint, coalition, and civilian organizations may be simultaneously operating in a region. Available bandwidth is affected by the required information flows that need to be supported by communications.⁴¹

This thesis does not address requirements for management of bandwidth. We will assume, for now, that proper allocation of frequencies will occur for the equipment available to execute current and future missions.

⁴¹ Joe, Future Army Bandwidth, 9.

Below is an example of the Stryker Brigade Combat Team (SBCT) communications set-up for Brigade-level communications net in a study of systems that are organic to the Brigade. The eight (8) networks used are those systems currently fielded to the SBCT.

Purpose of Net	Type of Communications	Number of Users
Command	HF, voice	17
Situation/command and control	SINCGARS, data	10
Army Battle Command System (ABCS) Data	NTDR, data	34
Operations and intelligence	SINCGARS, voice	31
Situation/command and control	EPLRS, data	71
Command	SINCGARS, voice	33
Administration/logistics	SINCGARS, voice	20
Fire support	SINCGARS, voice	10
Total		226

Table 2. SBCT Information System Architecture.⁴²

These eight networks with 226 users were at the BCT-level only. These do not include the subordinate level elements at battalion or company level that have many of the same nets. Those eight networks also rely on terrestrial relays through ground retransmission of predominantly frequency modulation (FM) nets. Each of these retransmission sites requires manning and security, which detracts from tactical operations.

This quote sums up the conclusion for communications that captures the typical cyclic thought process of users and providers.

These measurements are taken in an exercise environment and hence represent demands for only a narrow slice of a real operation. However, it

⁴² Joe, Future Army Bandwidth, 20.

is apparent that current and near-term systems will not meet capacity or mobility needs of the current force. Far-term (2007+) systems will meet the needs of the current force, but demands can also be expected to grow in the interim.⁴³

In this case, we can readily see that what was then far-term (2007) is now present, and while our capabilities have increased, so have our requirements. We currently see the deficit in capabilities predicted in that report.

2. Intelligence, Surveillance and Reconnaissance (ISR)

Intelligence, surveillance, and reconnaissance is the combination and integration of capabilities and tasks that include planning and directing, collection, processing, and production phases of the intelligence process, as well as the common functions of analyze, disseminate, and assess.⁴⁴

Intelligence, Surveillance and Reconnaissance (ISR) capabilities for the tactical unit are probably the most addressed requirement lately. It may be because tactical warfighters have grown accustomed to these capabilities in recent years. Since many of the ISR products produced are from space-based assets and the higher echelons in the military and government rely heavily upon them, it is only natural for the lower echelons, tactical units, to desire the same products or capability. To compound the problem for the tactical unit, however, these national system products tend to be very large and not easily acquired by tactical units due to the communication bandwidth constraints previously discussed.

The prioritization and processing of ISR requests occur at the national level. As a result, until the President of the United States, the Intelligence Community, the CFLCC Commander, the Corps Commander, and the Division Commander have all imagery products that they feel they need, the “Tactical Warfighter” is not going to get what he asks for, unless his mission is the main effort for one of the aforementioned commanders. This is one problem while the other problem is the timeliness of the information. The operational and strategic decision makers and units are and should be looking further down the time line. Tactical forces are often looking at an immediate timeline. The lives

⁴³ Joe, Future Army Bandwidth, 23.

⁴⁴ U.S. Department of Defense, TRADOC PAM 525-3-14, 23.

of troops in close contact frequently depend upon the receipt of timely ISR information. However, the request cycle for ISR resources is typically too long to be responsive to those needs. The recurring theme here will be the fact that “you get what you pay for,” or in other words, “ownership has tremendous benefits.”

Strategic or national systems undeniably cost hundreds of millions or billions of dollars to design and operate. The operating budget of the DoD and government is of the size to support this cost. Some services such as the Navy and Air Force also, due their operational nature, have greater justification for the use of both space-based assets and strategic level air-breathing assets such as U2 and Global Hawk. These services generally deploy and use these strategic assets at the operational level, since those services typically fight at that level within theaters of operation and will utilize internal and external ISR assets when needed.

The tactical units, however, do not have the capability, resources, or money to own, operate, and maintain a space-based ISR platform. Even if a tactical unit could own a space-based ISR asset, ownership within the DoD is sometimes tenuous. Higher-level headquarters can and often do decide that an asset “owned” by your tactical unit better serves their needs and will direct tasking or transfer of that asset for their own purposes. It is at this point that, even if the tactical unit owned and/or operated its own “tactical satellite,” the tactical unit must hope/demand/suggest to higher that they need that asset to the point that it is absolutely required to execute the mission. Either they must be successful in that campaign or they must have an alternative asset at hand. Currently these alternatives are either older imagery that is in archives, or the use of unmanned aerial systems (UASs). UASs have proven to be an incredible asset at all levels of combat operations. They have become an essential and required component of the tactical units’ arsenal. However, UASs have their own limitations that need to be addressed, specifically that of persistency.

A tactical unit does not have the time or manpower to fight the current process of acquiring relevant and timely ISR intelligence from national and strategic systems. While higher-echelon units are responsible for handling these requests, those organizations have their own priorities and concerns. The commander at the tactical level

must be able to see the where and when on the battlefield, with some level of persistency, to support his maneuver plan. Even with the use of UASs that provide the where and when, there are still serious limitations in persistence and coverage.

3. Blue Force Tracking and Situational Awareness (BFT/SA)

Blue Force Tracking and Situational Awareness (BFT/SA) is the accurate ability to identify friendly positions within the time required for the tactical commander to make decisions pertinent to his mission. It also incorporates known enemy information into a similar interface, allowing the Warfighter to understand the disposition of his own forces and their geographical relationship to his enemy.

Distribution of BFT/SA to necessary users is essential. Distribution to users that do not need the particular unit's information wastes bandwidth, increases latency, and poses a greater security risk. The attempt to increase BFT/SA too far up the chain increases bandwidth requirements and reduces the access to information down the chain. BFT/SA availability and need to know are not the same. Resolving the debate for distribution of this information is not within the scope of this paper. However, it is paramount that those who need to know this information have it. The elements who need to know would be those in direct command and those that are providing direct support. It would be ideal for close air support to have a local common operating picture (COP) with a BFT picture overlay in order to acknowledge appropriate clearances and provide accurate targeting. This capability would be invaluable in close quarters such as mountains and urban areas. Often those controlling the supporting fires (air, mortars and artillery) cannot see the whole picture and could unknowingly put friendly forces at risk of fratricide.⁴⁵

BFT/SA, in particular, has greatly aided in the execution of war at the tactical level. Using systems such as Force XXI Battle Command and Control Brigade and Below (FBCB2) and Blue Force Tracker systems, units down to the section level can know where they are and where other units or elements are in relation to them. Injection of enemy force locations by other primarily intelligence systems, such as the All Source

⁴⁵ "Blue on Blue ground incidents during Operation Iraqi Freedom," Defense Update, International Online Defense Magazine, 2004, Available from <http://www.defense-update.com/features/du-2-04/fratricide-2.htm>; Internet; Accessed on 12 September 2007.

Analysis System (ASAS), allows for a rather robust red SA, which allows the digital warfighter to decide and act faster than his enemy.

The current capacity of BFT in theatre is a shared 2.6 kbps. This limits the situational awareness (SA) update to 5 minutes minimum, considered near-real-time. While five minutes may be suitable update time for a dismounted unit operating at walking speeds, aircraft and mechanized forces can move a tremendous distance in between five minute refresh times. The bandwidth restrictions provide for a limited number of supportable platforms. To provide more capacity to larger or more dispersed units or those in rugged and or heavy foliage areas requires significant more capacity and cost.

The hurdle to getting a clear picture starts with the different systems fielded by the Army and the Marine Corps (i.e., Grenadier Brat, FBCB2 etc.) and trying to integrate the individual data in to the COP. Although currently working through the arduous JCIDS process, that integration is a difficult task since the services and not DoD fund these programs. The point is to understand that not everyone needs to know where everyone else is on the battlefield. Those that do need to know where particular sets of units are need to know that information faster and with better certainty. Those above may only need to know the units' general positions and not the specific locations of all their personnel. Those below may only need a COP for their unit and the next higher unit's position.

4. Position, Navigation and Timing (PNT)

Position, Navigation and Timing (PNT) covers far more than just the use of Global Positioning System (GPS) to identify a unit's location on the ground. Timing, though not likely something that many tactical units would address as a requirement, is almost essential for today's modern secure communications. Most modern communication systems, specifically those that operate in secure modes, require highly accurate timing to properly encrypt and decrypt signals.

The GPS constellation is generally sufficient for most tactical operations, with a large number of satellites operating in specific orbits in order to provide near-global

coverage with PNT. This system provides the same information to “warfighters” at all levels of conflict. While the GPS system works well in most cases, augmentation by non-orbital systems could be extremely useful in situations such as urban or mountainous operations. In such situations, terrain, both natural and manmade, can interfere with the GPS signal or cause multi-path problems that can degrade accuracy.

In the near term, global positioning, velocity, navigation, and timing capabilities, provided by the GPS constellation, are our sole method of providing force-wide common location and timing essential for simultaneous, distributed operations (knowing where you are, where your buddy is, and where the adversary is). GPS provides the “common grid” for precision engagement and maneuver, and a mechanism for effective BLOS blue force tracking to land forces.⁴⁶

While “Tactical Warfighters” pride themselves on the ability to operate using alternatives to GPS such as maps, compasses, and pace count / odometer, resorting to such drastically reduces the pace at which units can know and understand the position of themselves and their surrounding elements on the ground. A GPS receiver allows for almost instantaneous knowledge of very accurate position location, versus a more difficult and time-consuming process of map/compass navigation.

5. Can-Do vs. Should-Do

While both the Army and the Marine Corps can operate in a technologically disadvantaged state, using previous generation capabilities to execute their missions, operating in this manner would greatly slow down our time lines and would degrade the enhanced chances of success our rapid decision-making processes have enabled. The tactical warfighter can operate using line of sight radio networks with multiple relays, scouts observing enemy positions from high ground, paper maps with graphic overlays of enemy and friendly positions, and map, compass and pace counts for navigation. While possible, the level of collateral damage that would occur during our operations would also likely increase, which is not likely acceptable in our heavily media-monitored operations. The tactical ground warfighter using a compass and map with FM radios and using conventional means to execute fires is very much a proven capability. However, to move at the speed and with the precision required on the battlefield of today and

⁴⁶ U.S. Department of Defense, TRADOC PAM 525-3-14, 16.

tomorrow, the requirements above are needed in sufficient quantity and availability to allow the tactical warfighter to execute his mission.

Current capabilities in each of these areas are not sufficient for maintaining the technological advantage that our forces rely on to completely dominate our adversaries. As we become more dependent on information in order to conduct our operations, we must have even greater increases in these capabilities at the tactical level, where success or failure occurs rapidly and with clear consequences measured in the loss of lives and individual systems. Existing systems are not fully able to meet the needs of strategic and operational forces, leaving the tactical user as a perpetually disadvantaged user.

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IV. TACTICAL CAPABILITIES DEFICIT

Having established communications, ISR, BFT/SA, and PNT as our four focus areas for BLOS capabilities required by the ground tactical warfighter, it is now necessary to show where there are deficiencies in meeting those requirements. There is a clear current deficit in capabilities in these four areas that affects the tactical-level warfighter's ability to carry out current mission sets efficiently and effectively. Without devolving into an exercise in counting bits per second, it is possible to show current deficiencies in required capabilities and project future deficiencies based on projected or expected system fielding.

Many organizations and programs exist to develop existing areas of technology to meet the current and future deficiencies in communications, ISR, BFT/SA, and PNT better. While often plausible and very efficient, none of these improvements or any combination of those will likely decrease or remove the deficit between what tactical users need and what they receive. While some of these technologies are promising, the future systems will likely only allow us to meet our current needs better, without any real expectation of meeting anticipated future needs. Essentially, in ten years we will likely be able to meet our current needs, putting us no further ahead in satisfying tactical communications, ISR, BFT/SA, and PNT requirements of the future.

As our doctrine shifts toward offsetting reduced force size with increased abilities to observe, orient, decide, and act more rapidly, improvements in the four core requirement sets chosen for this paper are essential. We cannot fight the war of tomorrow with tomorrow's force structure and today's technology and capabilities. As the BLOS deficit grows between requirements and capabilities, this is what we ask of our warfighters at the tactical level.

A. COMMUNICATION

1. Current Communications

a. Current Communications Capabilities

Currently, communication capabilities are generally limited to either traditional LOS systems or satellite communications. Some capability exists for non-satellite BLOS communications, such as the short-term use of helicopter-based retransmission of FM communications nets, but such are very specialized and generally commit a valuable combat asset that likely better used for their intended purposes. HF radio capabilities are also very limited in use at the tactical level, requiring large antennas and being much more complicated to operate than FM voice systems. Each of these options has tremendous limitations at the tactical level.

Satellite communications, while available, are not sufficient for any real DO or regular use in tactical engagements. Limitations in the fielding of actual systems are only part of the problem, the larger issue being availability of channels on existing satellite systems. Even if a tactical unit can gain access to an appropriate radio set and cryptographic keys--the physical requirements for use--there are not enough channels or available bandwidth to allow easy adding of lower-echelon units to satellite communications. In such cases, when required, the tactical unit must operate on frequencies and channels normally reserved for units several echelons above their own, tying up higher-level communication nets with their tactical traffic.

LOS radio primarily using voice is the most common form of tactical communication. While this works well in the close fight, it is limited in range and with increasing distances between units requires multiple relay sites, each requiring a security element that removes valuable manpower from the unit's primary mission. Additionally, engagements in urban and mountainous terrain pose real problems for communication both internally and to the next higher level, specifically for needs such as supporting fires, re-supply, and medical evacuation (MEDEVAC). Often, this requires additional retransmission sites established upon clearly visible high ground for higher-level nets, which require additional security and further decrease available manpower to contribute to the unit's primary mission.

The “MILSATCOM Satellite Communications for the Warfighter” publication gives a good understanding of the current architecture and what benefits they provide to users. It not only gives us a view of what the world is like for the end users and individual services, but also a view of how things need to operate in the future.

Even though there was no integrated vision or overall scheme in their development, until recently the collection of "legacy" systems adequately supplied the needs of DoD users. However, as the need to fight as a joint team has increased, and as the tempo and breadth of the battlefield have expanded, warfighters no longer have the luxury of "stove piped" systems. The separate classes of users have merged.

These users have traditionally turned to a variety of services to meet their combined communications needs. Most of these needs are met by terrestrial means. Communications needs that are satisfied through space fall into two categories of systems: militarily owned and operated systems and commercial leased systems. The choice of system and the relative mix of services provided through these two sources reflects the varying needs of the user and the conditions under which they operate.⁴⁷

The above states that the need determines the choice of systems. While very limited alternatives make that likely true, the real issue is that the choices are limited to two options. Either they can afford to own and operate their own systems or they must rent or lease it from outside sources. In either case, at the tactical level, the warfighter has no real choice in the process. His budget does not support either option and he is at the mercy of his higher command to gain any satellite capabilities whatsoever. Essentially, the systems he has access to use are not developed based on his requirements, but rather are given to him to use when it is convenient, or when someone can figure out a tactical use for a system designed for some other purpose.

Within commercial and military owned satellite communication systems, fielded man-portable satellite-enabled systems fall into two general categories: civilian systems such as Iridium and Thuraya satellite phone systems, as well as more traditional military man pack systems. The satellite phone options provide good coverage in most latitudes and the convenience of access when needed, in a relatively small package, but

⁴⁷ U.S. Department of Defense, Department of the Air Force, *MILSATCOM Handbook Volume 1*, (Air Force Space Command, 2000), Available from <http://www.globalsecurity.org/space/library/report/2000/lsn4app1.htm>; Internet; Accessed on 12 September 2007.

do not give the traditional and familiar method of multiple user communication nets. The military systems tend to require setup of a directional folding antenna and require yet another full-size radio system.

For the higher-level units, such as brigade, more traditional satellite communications use large-aperture antennae with radio systems mounted on trailers or vehicles. These require stationary setup and a rather large footprint for these reasons:

High-gain antennae like these are required due to the extremely weak nature of the signal coming from geostationary satellites 30k km above the earth. High bandwidth requirements for data transmission and the large distance mean huge antennae are needed. Antenna size could be considerably reduced by increasing the signal strength. That increase could come by making bigger transmitters in GEO (expensive) or by locating the comm repeater closer (i.e., on airborne or near-space platforms—much less expensive).⁴⁸

Current tactical Army and Marine Corps elements field both UHF and SHF communication systems at the brigade level. Common UHF systems include AN/PSC-3(limited), AN/PSC-5 Spitfire (most common) and AN/VSC-7 (mounted in vehicles). These systems use satellite systems such as UHF – Tactical Satellite Communications (TACSATCOM) and Ultra High Frequency Follow-On (UFO). Tactical units using SHF (includes HF) use the AN/TSC SMAR-T radios mounted in vehicles or trailers and working off satellite systems such as the Defense Satellite Communications System (DSCS), and the Wideband Global Satellites (WGS).

Current Army BCT Modified Table of Organization and Equipment (MTOE) list very limited assets for BLOS communications at the brigade-level. These assets exist only at Brigade which loans them to lower-echelon units as needed, within availability. This usually requires one staff element temporarily losing their internal capability to support the lower-level unit. A review of the most current MTOEs for Infantry, Stryker, and Heavy BCTs shows the limited number of these assets. Table 4 summarizes these limited assets. It is important to note that some of these systems, such as the multiple SMART-T are actually redundant systems, with only one active at any single moment. SATCOM on the Move (SOTM) terminals such as the PSC-5s, are

⁴⁸ Edward B. Tomme, Personal e-mail (4 September 07).

limited not only in number but also by available channel access. Further, it is more appropriate to call these systems “SATCOM on the Pause,” as with few exceptions; the user must setup a foldable antenna in a particular direction to get suitable gain from the satellite. When loaned to lower echelon units, subordinate units must often operate on frequencies shared by both BCT and Division level units. A battalion or company operating outside of their unit Area of Operation (AO), piggybacking on the Division Tactical Satellite Net is not a very efficient or preferred communication plan.

Unit Equipment	IBCT 2007 MTOE	SBCT 2006 MTOE	HBCT 2006 MTOE
C-5 SOTM Terminal	7	6	6
SC-190 Trojan Spirit	1	1	0
SC-154 SMART-T	2	1	3

Table 3. Brigade-level Satellite Communication Systems.⁴⁹

Terrestrial communications, the greatest volume of tactical communication, occur primarily by voice over very high frequency (VHF) radio systems such as the PRC-119 SINCGARS (Single Channel Ground and Airborne Radio System) or the PRC-148 MBITR (Multi-band Inter/Intra Team Radio) system. These systems weigh between two and 20 pounds, are usable while moving, and can transmit at ranges between 5 and 35 km depending on terrain and dismounted or mounted configuration (using power amplifiers and vehicle or mast antennae). The tactical warfighter, at this level, uses these types of radios to coordinate maneuver, call for artillery, request

⁴⁹ Review of MTOE documents for 1st BCT 101st Infantry Division, 1 BCT 3rd Infantry Division (Heavy), and 1st BCT 25th Infantry Division (Stryker), U.S. Army Force Management Support Agency, Available from <https://www.usafmsardd.army.mil>; Internet; Accessed on 4 September 2007.

MEDEVAC, and generally communicate with both peers and higher/subordinate organizations. These radios are time-tested and useful but have disadvantages such as power requirements, distance and terrain limitations (buildings or earth), weight (radio and battery requirement) and secure communications requirements (SINGARS).

b. Current Communications Deficit

The variables involved in actual bandwidth requirements for tactical units are so numerous that it is difficult to determine a fixed number of bits per second for a unit of a certain size. Within the Army structure alone, there are three general types of BCTs, with typically six different battalion types in each BCT, with over a dozen different types of companies represented, with various compositions of personnel, missions, and equipment, it is easy to see that no single answer of requirements is easy to determine. There are as many answers to the question as there are iterations of the question asked. One answer to the question of a generic BCT-level unit gives, “At the tactical, ground level, the data rate need could be hundreds of megabits per second. Raw sensor data (from UAVs) are major contributors to these requirements.”⁵⁰ This estimate from 2003 also did not fully take into consideration the multiple versions and numbers of UAS in a future BCT or the enhanced digital systems for communication now seen.

⁵⁰ Joe, Future Army Bandwidth, 42.

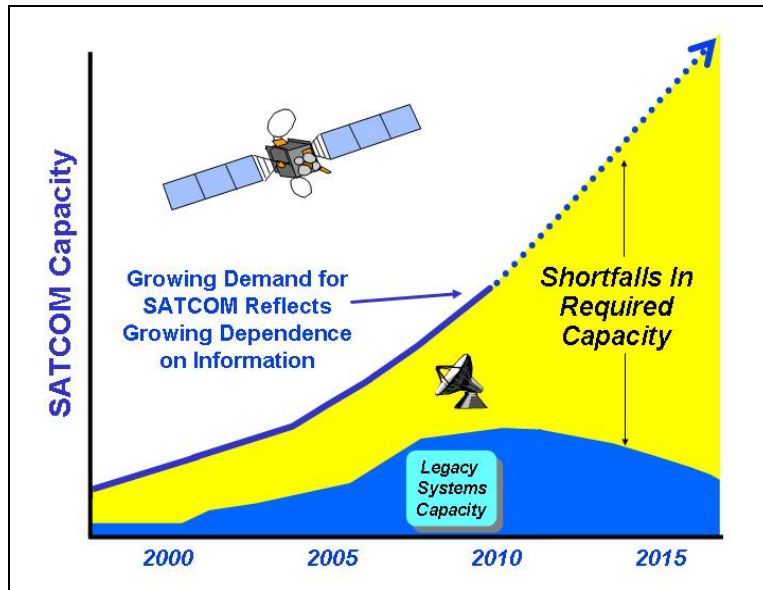


Figure 3. Notional Growing SATCOM Needs of DoD, IC, and NASA.⁵¹

The deficit in communications is increasing at the tactical level due to the type and duration of current missions. Tactical units are more likely to execute missions in remote areas or over much larger geographic areas than ever before. Current conventional radios, using LOS or satellite systems, do not currently support extended operations or multiple units executing these missions concurrently. The distance alone, puts a strain on traditional terrestrial systems, with the requirements for power and logistics support even further away. The periodic requirement to establish retransmission sites for LOS communications reduces combat manpower availability, as these sites require security, tying the maneuvering element (or some support element) with the same continuous line of communication issues that have limited military operations since Clausewitz coined the term in 1832.⁵² To operate farther from their support the tactical unit must establish and secure communication nodes every 20 to 40 km in order to retransmit their radio nets. To complicate such situations further, often it is necessary to operate on multiple frequencies between each different set of retransmission sites,

⁵¹ U.S. Department of Defense, U.S. Strategic Command, Initial Capabilities Document for Satellite Communications (SATCOM) Systems, (Washington: Government Printing Office: 2003), 8.

⁵² Carl Von Clausewitz, On War: The Complete Translation by Colonel J.J. Graham, Book 5, Chapter XVI, Available from <http://www.clausewitz.com/CWZHOME/VomKriege2/BK5ch16.html>; Internet; Accessed on 12 September 2007.

requiring switching between frequency sets as the unit moves. This section on terrestrial communications further clarifies these limitations:

Current terrestrial communications systems are dependent on LOS transmission. The effectiveness of LOS transmission is increasingly limited because units operate at greater distances and in complex terrain. Terrestrial relays can be used to extend LOS transmission, however they require detailed network planning, are limited in range, lack flexibility, and require combat power to secure, defend and support. The vast, asymmetric battlespace prevents the force from holding and defending the terrain necessary to provide a robust terrestrial network.⁵³

The old way of doing business and operating by sayings such as: “Comms by exception,” puts lives at stake. This meant that actually having communication was an exception, not the rule. Communications and information flow is becoming essential to survival on the battlefields of the current and future forces. As our forces become smaller, while remaining responsible for the conduct of more complex operations at greater ranges, communication capabilities must increase at the same or greater levels.

BLOS communications seem to offer tremendous advantages to the tactical warfighter. Currently, satellites provide the predominant BLOS communications. As shown in figure 3 above, there currently are not enough satellites, channels, or systems to meet the needs of these tactical users. Additionally, with the exception of UHF SATCOM systems, most satellite systems do not allow for easy communication on the move due to the relatively weak signals coming from geosynchronous orbit.

If the deficit in communications capability that exists, as stated in numerous studies and shown in the previous figure, is that large at the strategic and operational level then the bandwidth available at the tactical level will be even less. Currently, at the brigade-level, there is one primary asset for wideband satellite access and at best seven individual UHF terminals, primarily for voice communications. Higher-echelon units loan these systems, not fielded to battalion level, when required by the tactical situation.

⁵³ U.S. Department of Defense, Department of the Army, “Initial Capabilities Document for Aerial Layer Network Transport,” (USASC&FG: 2007), 4.

The Army and Marine Corps, having both conducted extensive operations in urban and mountainous environments at the tactical unit level, have noted through After-Action Reports (AAR) and Urgent Needs Statements (UNS) the deficit in communications in the environments in which they expect to operate within in the near future.

The U.S. Army's combat operations in Afghanistan and Iraq in 2001 and 2003, respectively, showed that the forces lacked adequate intra-unit communications, particularly at lower echelons, and that the use of satellite communications resources offered a future solution. The promise of satellites was borne out by the success of Blue Force Tracker, a communications system used to track the locations of units and vehicles connected to low-orbit communications satellites.⁵⁴

The same ICD shows the usefulness of satellites for widespread BLOS communications using the Blue Force Tracker (BFT) system. It is important to realize that BFT, while a very useful tool for providing near real time BFT/SA, has little tactical communication capability. Bandwidth, message size, and latency of delivery severely limit BFT communications. Currently few existing satellite communication systems provide truly tactical SOTM capabilities at the tactical level. Those that do are either limited to Special Operations or the use of commercial telephones such as Iridium, which are not conducive to tactical operations.

Another vulnerability to our tactical warfighters conducting DO is the assurance of immediate access to communications. Waiting for access to a visible satellite or worse, waiting for a satellite to enter view is not a viable option for communications where delays potentially cost lives. The possibility of that network not being available due to some level of network warfare could also prove detrimental to our small units operating remotely. Although SATCOM has great advantages, it is not without its vulnerabilities.

Currently, satellite communications (SATCOM) is being relied on to connect distant units, hopefully in an assured manner. However, the

⁵⁴ Lewis Jameson, Geoffrey Sommer, and Issac Porche III, High-Altitude Airships for the Future Force Army, (Rand Corporation: 2005), 2.

exclusive use of military or commercial SATCOM may not be available to meet all of the Army's connectivity needs.⁵⁵

There are great challenges to operating in a BLOS communication environment. By continuing to execute distributed operations (DO) or conduct conventional operations across large distances, in multiple theatres, it becomes increasingly apparent that the current SATCOM structure cannot and does not support the tactical warfighter.

The two greatest barriers to satellites providing required BLOS communications at the tactical level are cost and control. Cost and control are related, as typically the level of command that owns the system and pays for it, ultimately decides how to operate it.

Satellite-based communications are very expensive to field and generally have limited bandwidth and availability. Those assets with continuous availability are extremely expensive to build, and the costs of boosting them to their distant geosynchronous Earth orbits (GEO) put them well beyond the price range of operational and tactical commanders. The existing alternatives—terrestrial communications systems such as cell phone networks—are difficult and time consuming to set up and are not responsive on a moving battlefield.⁵⁶

The existing solution to the lack of BLOS communication support to the tactical warfighter is the support of future space systems to provide more bandwidth. These systems are both expensive and slow to design, build and launch. To compound the problem of availability, terrestrial systems develop at faster rates, and inevitably add bandwidth requirements with their improved capabilities. The requirements for BLOS communications is increasing faster than we can field satellite systems to close the current gap. To combat this tendency, satellite systems designers modify them during development in an attempt to meet changing needs. This perpetual redefinition adds to requirements creep and cost overruns, keeping us one-step behind in our timely system fielding, and ensuring the tactical warfighter maintains his disadvantaged user status.

⁵⁵ Jameson, Sommer and Porche III, High-Altitude Airships for the Future Force Army, xi.

⁵⁶ Tomme, "Balloons in Today's Military," 4.

2. Future Communications

Future communications systems, both ground and space-based, promise capabilities and availability that tactical warfighters currently require. Most of these systems, designed and developed to meet future projected needs, fall victim to budgetary constraints, often because of the acquisition process failing to estimate future needs in the early development process, which causes a compromise of actual fielded capability. Generally, it seems that future systems give us the capability to meet today's needs, when fielded, but leave a continued gap in the capabilities needed at the time of their fielding.

a. Future Communications Capabilities

It is essential that projected requirements tie directly to specific systems and programs scheduled for fielding. Trying to predict future requirements for systems that are not yet in development becomes more daunting if not nearly impossible. Future systems need a previously unknown capability for flexibility and configurability, to provide for unexpected requirements and or increases in related technologies.

The complexity of such forward design planning is evident in an excerpt from a TRADOC report concerning use of the aerial layer.

By 2017, the solutions identified provide the necessary conceptual, organizational, and platform/payload structure to address the gap, with the exception of the capabilities provided by the one identified payload that has no matching platform. Based on the efforts to maximize Joint and Army assets, an alternative to the backbone network relay payload has to be found, or a platform identified to support the payload under current development. This may require a new start material solution, modification of existing aircraft, or the exploration of high altitude, persistent platforms under exploration by the services for similar requirements.⁵⁷

This quote refers to overall recommendations concerning sensor and relay capabilities within the aerial layer, predominantly using UAS. In the report, a clearly defined requirement is identified, a payload to fulfill the expected requirement is identified, but no current or projected system is able to place that payload into operational use. Such problems require rather drastic changes in the way a system develops, in this

⁵⁷ U.S. Department of Defense, Department of the Army, Training and Doctrine Command, Technical Report 06-014: Aerial Sensor and Relay Capabilities Based Assessment Final Report Volume I, (Washington: Government Printing Office, 2006), 44.

case, possibly requiring new material solutions or entirely new platforms. This also reinforces the problems of technological capabilities developing at different rates. This document shows a capability expected to meet a need, without any sure way of deploying it. Clearly, the existing way forward in this region of tactical space is not sufficient to meet the needs of the warfighter and something more is required, one possible solution offered being high altitude systems.

Terrestrial communications systems for the future tactical warrior should allow him to meet his needs within LOS of other elements. Using new radios, waveforms, and mesh network systems should allow the tactical warfighter never before seen capabilities to share and access data and information within his local area. Improvements in his local area, within LOS, do little to reduce his requirements to be able to talk longer distances between both peer and senior-subordinate units. Future systems require some way for both developing and legacy systems to extend beyond the LOS restrictions of tactical operations.

Satellite communications (SATCOM) systems have the greatest focus for development for the future communications of the tactical warfighter. The persistence and wide area coverage provided by space-based communication systems are key features that the tactical warfighter needs as he conducts more operations, farther from adjacent units and higher headquarters. Currently, tactical warfighters are “disadvantaged users” in regards to SATCOM. The requirements of size and weight force these users to resort to small aperture antennas and low-powered transmitters, reducing their bandwidth tremendously. Space platforms are distant, by any measure, and sufficient signal gain with mobile, tactical platforms is often difficult to attain. The Operationally Responsive Space initiative has attempted to address this fact with its TACSAT program. Here we see one extreme of bringing the benefits of SATCOM to the tactical level.

We believe we will give the soldier on the ground the ability to control a spacecraft payload. That’s going to be a ground-breaking sort of development for the way we use spacecraft,” said Peter Wegner, the Responsive Space Lead for AFRL, at Kirtland Air Force Base, N.M. ... Warfighters would be able to control or communicate with the satellites with existing communications and imagery dissemination systems, like a

Common Data Link radio. There may also be the ability to communicate with the satellite directly with hand-held UHF radios.⁵⁸

There are many other initiatives intended to bring space capabilities to the tactical warfighter, however, there is no overall architecture in development that will truly tie these various systems into a working architecture, designed to meet the needs of tactical warfighters.

Reviewing the current fleet of communication/data satellite systems, most of which have met or exceeded their projected life expectancy, it is clear that most are generations behind current technology levels. The dependency on commercial communication infrastructure is noted by Lieutenant General Kevin T. Campbell, current commander of Army Space and Missile Defense Command.

He [Campbell] also reiterated that the Pentagon is looking to reduce its reliance on commercial satellites for communications by expanding military satellite communications (MILSATCOM) infrastructure. MILSATCOM "is deficient in terms of bandwidth. We don't have what the warfighters need," Campbell acknowledged. He said that some 80 percent of satellite intelligence and imagery now comes from commercial satellites. "We would like to get that figure down to around 50 to 60 percent commercial, with the balance being around 40 to 50 percent" military satellites, he said.⁵⁹

Systems now in development for the future have faced tremendous setbacks in technology maturity, cost overruns, and other developmental issues. Even with such problems, the future systems show promise in supporting the warfighter with better more agile and secure systems in which to operate. These improvements will allow tactical warfighters the capabilities, in the future, that they need today.

We see from the SATCOM Initial Capabilities Document the planned transition for legacy to future systems or Transformational Communication Architecture (TCA). Figure 4 shows various areas of risk and related capability improvements, including systems designed specifically with tactical communications in mind. Actually

⁵⁸ Patrick Chisolm, "Micro-Eyes in Space," Military Geospatial Technology, Online Edition 4, 3, Available at <http://www.military-geospatial-technology.com/article.cfm?DocID=1547>; Internet; Accessed on 12 September 2007.

⁵⁹ Marina Malenic, "Army to Expand Number of Space Operations Officers," *Inside the Army*, 20 August 07.

focusing on tactical users is a tremendous departure from the strategic nature of previous generation's satellite systems that found some tactical usefulness, with few exceptions. Future systems are designed, from the beginning, with tactical support in mind.

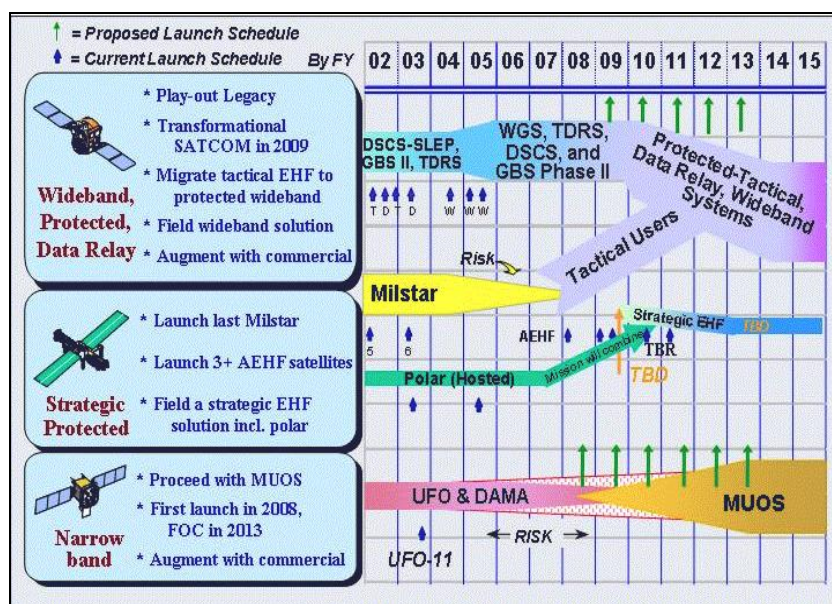


Figure 4. Notional Transformation from Legacy to Transformational Communications Architecture (TCA).⁶⁰

Satellite systems require a tremendous expenditure of time and money to develop and field. While it is economically more feasible to develop and field our own systems, we are often not budgeted for the future funding to see such systems to completion. A popular alternative is the use of leased commercial systems to augment our SATCOM capacity. This can be both an expanded capability and a tremendous vulnerability. Commercial systems do not have the same requirements for protection and assured access as our military systems. While providing tremendous capability, their employment accepts some greater risk, as they are easier to acquire and fund in the short-term. Figure 5 from the MILSATCOM Handbook shows a simpler version of our transition to new constellations with the leased commercial lines allocated a greater share of the load.

⁶⁰ U.S. Department of Defense, *ICD for SATCOM*, 12.

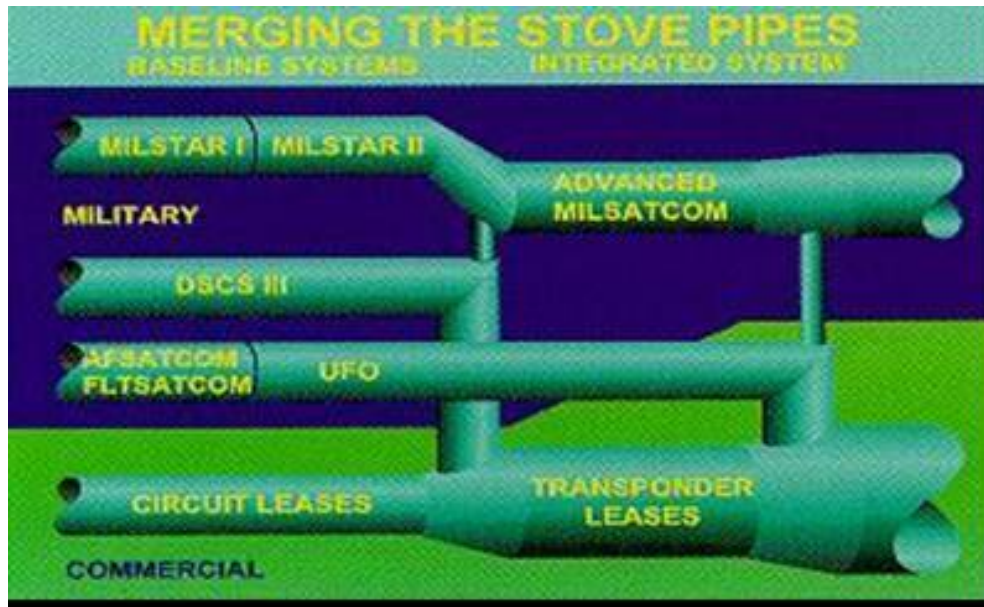


Figure 5. Future Constellation Merging.⁶¹

The Army's Future Combat System Structure shows a terrestrial system with multiple domains and gateways. Using the JTRS backbone for the larger areas and connectivity to the units beyond the range of their LOS systems, the FCS has more link options, allowing better connection to the communication grid without the need to switch radios or frequencies. What is essential is that we do not drive our operations by our communication capabilities, but rather we develop our communication capabilities to facilitate our maneuver.

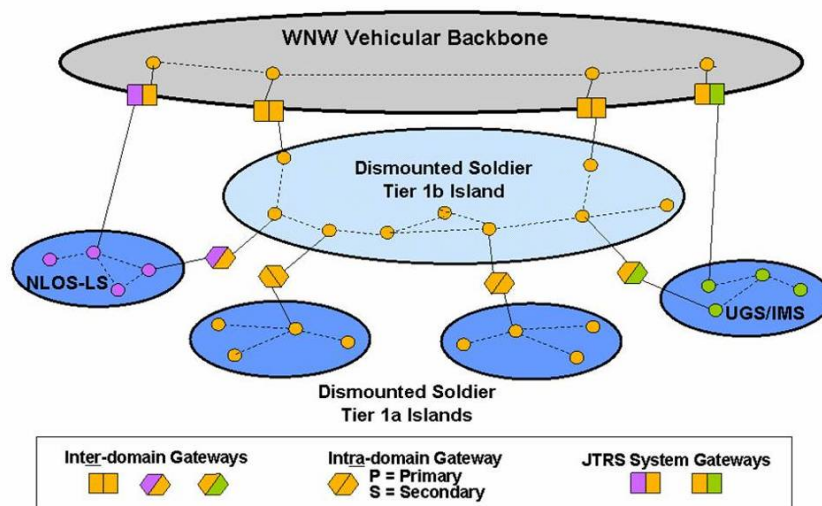


Figure 6. FCS Tier Communication Structure.⁶²

⁶¹ U.S. Department of Defense, *MILSATCOM Handbook Volume 1*.

The JNTC (Joint Network Transport Capability) program already extends SATCOM network capability down to the Battalion level. Lower echelons have historically been limited to use of terrestrial radios for their voice and data solution. As the force transforms making the Brigade Combat Team (BCT) the central fighting unit, its area of responsibility increases significantly. Once in theater, troops may be widely dispersed and constantly mobile on an extended, and rapidly changing battlefield, supported by a long and disparate logistics trail. When terrain and foliage are considered, terrestrial radios alone will be inadequate to maintain a connected network. Although tactical relays mitigate this problem, they require forces to secure them, constrain positioning when considering non-contiguous, multi-front battlefields, and cannot adequately serve Special Operations Forces (SOF) operating behind enemy lines. Beyond line of sight (BLOS) solutions are required to keep the network connected. Unmanned Aerial Vehicles (UAVs) can close this gap, but offer limited coverage area, persistence on station, and resource availability. SATCOM is another solution. Today, commercial SATCOM is used to fill some of these BLOS gaps in the architecture. As MUOS becomes available, it will inherit many of the missions currently met by commercial SATCOM. This extent of this migration as well as its ability to service other missions described herein is limited by overall system capacity and resource allocation, particularly in theater.⁶³

b. Future Communications Deficit

The deficit in communications is not necessarily a bandwidth or number of systems issue. It lies in the type and capabilities of these systems and their usefulness in meeting tactical requirements. Legacy and developing systems will provide a tremendous LOS communication capability at the tactical level. Units will be better able to conduct traditional operations at all levels with improved interoperability with joint elements. However, providing secure, long-haul communication capabilities, required for DO and large area operations, will require a new architecture that is not tied to multiple ground repeater sites. A statement from the commander of Army SMDC further acknowledges this future deficit.

Earlier this month, the command's deputy chief of staff for operations and plans told Inside the Army that the military's ability to generate information and its need to exchange it will continue to outpace the

⁶² Russell Langan, "Interim Integrated Network Study," Briefing for Army Research, Development & Engineering Command, Communications-Electronics Research, Development, and Engineering Center, 9 September 2005, Slide 12.

⁶³U.S. Department Of Defense, Mobile User Objective System (MUOS) Concept of Operations Version 2.0, (U.S. Strategic Command, 2006), 21.

MILSATCOM infrastructure and, potentially, even the commercial infrastructure available for the next decade.”⁶⁴

Bandwidth and frequency management are not included in the scope of this thesis, but are discussed as a foundation for understanding the problems that influence future systems and their architectures for support of tactical warfighters. A 2006 TRADOC report provides an estimate on required future bandwidth.

A recent study, which considered the Modular Force in the 2017 timeframe, estimated that bandwidth requirements by a brigade would range broadly from 4 Mbps - 60 Mbps depending on the type of brigade. A complete FCS-equipped BCT might demand up to 140 Mbps.⁶⁵

While it is arguable that a BCT will not constantly require that much bandwidth, the study is only an estimate and does not likely consider real world scenarios in which multiple tactical units within the BCT are executing missions. This architecture must be capable of meeting the maximum requirements, through permanent capability or a surge capacity controlled by the unit in question.

The Unmanned Aerial System Roadmap reports predicted gaps in needs for current and developing systems. “By 2010, existing and planned capacities are forecast to meet only 44 percent of the need projected by Joint Vision 2010 to ensure information superiority.”⁶⁶ This shortfall will extend down the levels of command; the largest impacts being felt at brigade and regiment levels. With the estimated 44 percent of the needed capacity, this shortfall in bandwidth will severely affect operational tempo and the scope of missions that are executable.

Army Future Combat Systems (FCS) networks expect to require full-time unmanned air vehicles to provide relays.⁶⁷ This need is likely due to increasing requirements for communications and other demands placed on limited space-based

⁶⁴ Malenic, “Army to Expand.”

⁶⁵ Department of the Army, Technical Report 06-014 Volume 1, C-12.

⁶⁶ U.S. Department of Defense, Office of the Secretary of Defense, Unmanned Aerial System Roadmap 2005-2030, (Washington: Government Printing Office, 2005), 61.

⁶⁷ U.S. General Accounting Office, “GAO-03-1010 Report: Issues Facing the Army’s Future Combat Systems Program,” August 2003, Available at <http://www.gao.gov/new.items/d031010r.pdf>; Internet; Accessed on 12 September 2007.

communication systems. FCS networks require a more robust and adaptable system than can be provided by the planned architecture.

In the recent ICD for Aerial Layer Network Transport, inclusive of other outside studies, we find the same conclusion. The limited physical constraints and resources are by far the limiting factors of the current and future planned architectures for communications.

Satellites have finite bandwidth, which limits the amount of data transmitted and the number of users that can access the satellite resources. Throughput requirements as recognized in the Satellite Database will outpace the deployment of future military satellite communications constellations. Intelligence requirements alone will saturate current and planned satellite constellations. Future satellite bandwidth will only meet 44% of warfighter requirements.⁶⁸

The true scope of the deficit in future communication capability has not been widely accepted. As more research occurs, future tactical warfighter dependency on systems that cannot be supported by currently proposed architectures will be increasingly evident. Current focused studies are already publicizing this shortfall, but nothing significant seems to be in place to address the clear problem. The Aerial Sensor and Relay Capabilities Based Assessment used a very benign environment to determine just minor difficulties. With greater and more realistic terrain and weather challenges, the scope of the problem becomes even greater. If our currently projected systems cannot function in the best-case scenario, they are sure to fail given the more difficult real-world nature of combat.

A FCS trade study report found that in one scenario with relatively little terrain or weather challenges, the unit was able to maintain connectivity without an aerial layer. However, significant congestion resulted in the terrestrial layer without the aid of aerial relays. Overall the report noted that network latency increases without aerial nodes, and that aerial relays dramatically improve network performance. This work suggested use of aerial relays for range extension and reduction of network congestion.⁶⁹

From the previous information and studies, we see that the deficit in communications for the tactical warfighter is real and immediate. There are many reports

⁶⁸ Department of the Army, "ICD for Aerial Layer," 5.

⁶⁹ Department of the Army, Technical Report 06-014 Volume I, C-18.

to support the future shortfalls that we will encounter in the future with little or no remediation below the Corps or Division level. The tactical headquarters obviously does not need the same bandwidth as their higher headquarters, but as you consider the number of elements operating at the tactical level and the desire to provide more and more information to the individual warfighter, these BLOS communications requirements quickly multiply. When dispersed tactical elements require BLOS communications, projected architectures fall woefully short in capability.

B. INTELLIGENCE, SURVEILLANCE AND RECONNAISSANCE (ISR)

In the past decade, the nature of intelligence, surveillance and reconnaissance (ISR) has shifted from a mission conducted by tactical warfighters to a requirement that they levy on systems. This shift in thinking created tremendous changes in the management and consideration of ISR. Due to the nature of the current and future operations and the size of the units executing these distributed missions, the need for organizationally controlled or tasked ISR capabilities is greatly increased. Traditionally, ISR assets, beyond that of binoculars exist well above the tactical level. Requesting ISR products, most often imagery, from strategic or national level assets is a time consuming task that involves multiple iterations of request cycles, during which a tactical request may not ever actually be satisfied.

The former commander of US Strategic Command (USSTRATCOM), Gen. Cartwright testified that the architecture to support this need for persistence from STRATCOM was “Our objective is a global, persistent, 24/7 collaborative environment-comprising people, systems, and tools.”⁷⁰ The tactical user needs the same level of support, albeit of a more localized region.

1. Current ISR

Current ISR requirements and capabilities remain disjointed among the services and the various subordinate agencies within them. Those units requiring these ISR products rarely own the assets. Passing requirements to platforms, having those missions executed, the data analyzed and returned to the unit requiring the intelligence products is

⁷⁰ General James Cartwright, Commander of United States Strategic Command, Testimony before the Senate Armed Services Committee on 16 March 2005.

currently time-consuming and challenging in many ways, often failing to function within compressed time scales required of tactical operations.

a. Current ISR Capabilities

The ISR capabilities that the tactical warfighter has access to are either national means, requested for mission planning or Unmanned Aerial Systems (UAS), either tasked by or organic to that unit. National assets, due to heavy competition for their products, are not task able within the time constraints or priority levels of tactical warfighters, causing UAS to become the tactical ISR asset of choice.

Space-based assets, by their nature, are very expensive and complicated. They exist to provide a specific user or customer with a specific capability. These systems typically operate in space to meet a requirement that can only be met by a space-based system. The strategic and operational access to space based assets is a very specific and controlled environment. The products provided are protected with multiple layers of security. With these security protocols in place, the current system often makes the responsiveness to requests for the capabilities or products too slow for the tactical unit. Although all the capability exists to support the needs of the tactical warfighter, they can only meet those needs if given sufficient priority, typically assigned to the national or strategic element for which the system was designed or deployed.

The other ISR means most commonly used now by the tactical warfighter is the UAS. The introduction of the UAS into the battlefield provides a huge capability to fill the responsive level of ISR needs. UASs are divided into tiers for the capability and unit level for which they support. These tiers, however, are not universal across the services. They again are dependent of the services requirements and their individual missions. For the Army and the Marine Corps, these tiers (I, II, III) are rather closely aligned. These tiers as defined by the Marine Corps Warfighting Lab are:

Tier I UAS - man-packable, hand-launched, autonomous systems designed to provide the small unit commander with a reconnaissance and surveillance capability to see over the next hill on the battlefield or around the next building in the urban environment.

Tier II UAS - designed to support our Divisions, Regiments, Battalions and MEUs.

Tier III UAS - designed primarily to support a MEF or Joint Task Force-level command.⁷¹

The table below shows the current inventory of terrestrial based assets used to gather ISR data at the tactical level. The scope and size of these assets are indicated with their corresponding capabilities. Omitted from this table is the cost and controlling authority of each asset. Operational and maintenance costs often dictate the control level of these assets. Each of these assets provides invaluable sources of information, previously unavailable below the national level space based ISR systems.

System	Raven RQ-11	Pioneer RQ-2B	Shadow 200 RQ-7B	Hunter MQ-5B	Fire Scout RQ-8B	Predator MQ-1B	Global Hawk RQ-4B
Weight (lb)	4	130	375	1800	3,150	10,500	32,250
Wingspan (ft)	3.4	11.4t	14	34	27.5	66	131
Payload (lb)	2	25	60	200	600	750	3,000
Ceiling (ft)	1,000	10,000	15,000	18,000	20,000	50,000	60,000
Combat Radius (nm)	6	40	68	144	150	2,000	5,400
Endurance (hr)	1.5	2	7	18	6	20-30	28

Table 4. Comparative Capabilities of Current UAS.⁷²

Current operational terrestrial platforms used by the tactical unit and below include the Pioneer for the Marine Corps and for the Army the Raven and Shadow. The famed Predator and Global Hawk systems are strategic assets currently used in strategic and operational roles.

At the Marine Corps Battalion and below the current platform is the Dragon Eye, scheduled for transition to the Joint Raven B UAS. Tier II UAS supports the Marine division, regimental, battalion and Marine Expeditionary Unit (MEU) commanders. Currently, the Marine Corps uses a fee-for-service agreement for two Scan

⁷¹ Brigadier General Randolph Alles, Commanding General, Marine Corps Warfighting Lab, Testimony before the House Armed Services Committee Subcommittee on Air and Land Forces On Intelligence, Surveillance and Reconnaissance (ISR) Programs on April 19, 2007.

⁷² Data compiled from U.S. Department of Defense, Office of the Secretary of Defense, Unmanned Aerial System Roadmap 2005-2030, (Washington: Government Printing Office, 2005).

Eagle UAS systems to fill the Tier II level. This Tier will be capability gapped until a fully funded, JROC approved program can support the mission. The current Tier III platform is the aged and proven Pioneer. With service life problems of its own, the US Army's RQ-7B Shadow will replace the Pioneer in the future. The Shadow will be an interim platform until attainment of a suitable replacement that fulfills all capability requirements set by the Marine Corps for a Tier III UAS.⁷³

The Army currently employs the RQ-5 Hunter and the RQ-7 Shadow to support its warfighters. The Army, while currently organized rather closely to the Marine Corps in its Tiers, will change its structure and categorization to the FCS model.

b. Current ISR Deficit

In the past, tactical level units operated as subordinate elements in direct support of large-scale operations by their higher headquarters. Those tactical units received information gained by higher-level ISR assets that were available and applicable to that unit's portion of the overall fight. Modern doctrine has shown a clear shift in operations of our ground forces from large-scale, contiguous operations to those of distributed units operating autonomously over areas many times larger than ever. This change to independent planning and operations at the BCT level requires that ISR capabilities become readily available to these units for their independent planning.

ISR assets currently utilized by theater and regional commanders were, not more than two decades ago, strictly national assets supporting strategic operations and goals. Changes in technology and proliferation of space-based assets to other nations quickly threaten to outpace our ability to provide ISR products in significant time and detail to maintain the level of technical advantage needed to dominate the future battlefield. Army Space and Missile Defense Command (SMDC) mirrors this view about the overall lack of available ISR and communication support.

⁷³ U.S. Department of Defense, Department of the Navy, United States Marine Corps, Marine Corps Concepts and Programs 2007: Unmanned Aerial Vehicles, Available from, <http://hqinet001.hqmc.usmc.mil/p&r/concepts/2007/PDF/Chapter%202/Part%202/C&P2007Chap2pt2Emerging%20Capabilities%20; Internet; Accessed on 12 September 2007, 62-63.>

Current Army Lack of Persistent ISR: Large area-coverage problem, Low probability of detecting a transient ISR event, Inability to determine long term processes or operations, Insufficient Communications Resources, Oversubscribed, expensive satellite communications, Lack of bandwidth, Poor localized control and assuredness.

Current Operational Inefficiencies: High sortie rates drive to excessive operational costs, Excessive logistic footprint to sustain persistence.⁷⁴

Of all the ISR products that the tactical warfighter needs, the most obviously useful and valuable one is electro-optical imagery. Human beings make decisions and we understand and are comfortable with processing the information provided by pictures. ISR imagery products are effective and tactically useful. The right picture can decrease planning time and increase the effectiveness of a tactical unit, if it is a picture of what they need to see, when they need to see it. Tactical units need accurate imagery of their Area of Interest (AI) and Area of Operations (AO) at a resolution that is practical for decision making at his level of warfare. This resolution typically requires at least one meter (1m) or better imagery, which provides tactically relevant intelligence, such as identifying vehicles by type and number.

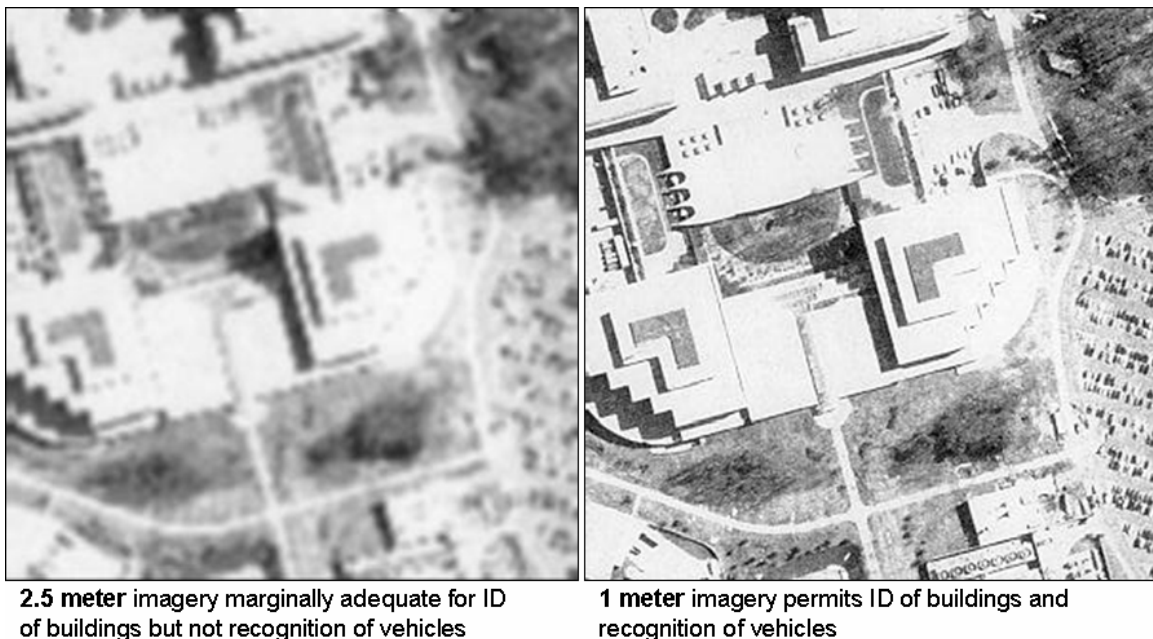


Figure 7. Satellite Imagery Resolution Comparison.⁷⁵

⁷⁴ Faunce, “Army Activities in High Altitude,” slide 6.

⁷⁵ John Brock and Michael Yarymovych, “Operational Utility of Small Satellites,” paper delivered to the Air Force Science Advisory Board Summer Session, 28 June 2007.

Systems satisfying this resolution requirement from space are very expensive to build and operate. Also, purchasing commercial imagery at that resolution, while less costly, is not responsive enough due to low revisit rates of usually individual satellite imagery systems. A good explanation of the relationship between attainable resolution to sensor and platform distance is:

Finally, the resolution of an image, the ability to distinguish small, closely spaced objects from each other, is directly related to how far away the object is. The shallower the angle, the further away the objects being imaged and the poorer the resolution. At shallower than certain angles, the images become useless as the information desired (discriminating between tank and truck, for example) can no longer be obtained. For these and other reasons, imagery satellites seldom look more than about 30 degrees off-nadir, where nadir is the direction of an imaginary line extending from the satellite straight down toward the center of the earth⁷⁶

In addition to the ISR sensing requirements for the tactical and theatre commanders there is the limiting factor of how many assets we have available to support all levels of warfare. Satisfaction of the need for newer technology and more capable systems on orbit is plagued with the same acquisition problems characteristics of many high priced programs. It is not common knowledge that, “There are surprisingly few national ISR assets actually orbiting the earth. These assets are frequently needed for higher-priority missions and are so heavily tasked with strategic missions that they may not be readily available to operational or tactical commanders.”⁷⁷

The proposed method of fulfilling requirements for timely ISR for the tactical commander is to allow local command and control of UAS. UAS platforms discussed earlier provide the limited ability to sense within a tactical AO and to persistently observe any particular object of interest, within the limits of the system employed. While proving to be valuable assets, UAS have many limitations in support of the tactical commander, such as loiter time, range, resolution and field of view. Other related issues are the logistics of supporting these platforms, requiring critical support

⁷⁶ Tomme, Strategic Nature, 9.

⁷⁷ Tomme, “Balloons in Today’s Military,” 3.

structure as well as increased manpower and airspace de-confliction problems. Attaining persistent ISR requires greater levels of complication in all areas of support and operations of UAS.

The current ISR capability mix with their associated deficits is frustrating and restricting to tactical commanders. These deficits require a hard look to the future to provide better systems with greater responsiveness, at a price that allows the tactical warfighter to control and task ISR resources on a tactically beneficial timeline.

2. Future ISR

Development of future ISR capabilities and satisfying emergent operational sensing requirements in support of the warfighter are a significant focus in the ISR community. Achieving these objectives in a relevant and practical matter will prove to be the truth teller for many programs and concepts.

a. Future ISR Capabilities

What types of capabilities are tied inherently to the requirements of the user? When we fail to define either the user or requirements then we are doomed to failure and a waste of precious resources, time, and money. This failure in definition and execution places the warfighter at greater risk with inadequate products or assets they do not need.

An often-repeated ISR requirement is that of persistent surveillance. With the definition of persistence being relative to the mission or AO, for continuous operations, smaller areas and type of surveillance required in the tactical arena, persistence is not practical from space-based assets. This is not to say that space-based ISR assets cannot support the tactical commander, but that these national assets are not likely dedicated to the tactical level. In fact, the Army, Navy, and Air Force each have TENCAP organizations designed specifically for Tactical Exploitation of National Capabilities. The support from future space-based ISR systems is better suited for the strategic and operational levels for reasons of cost and security. The occasional support to the tactical level is always greatly appreciated and requests may be supported given the allocation schedule of these future systems. Greater diversity of ISR assets is required to

better support warfighters at all levels, especially at the tactical level where some concerns such as strategic over flight are not requirements. Integration of these various assets must more efficiently use their products and capabilities as outlined here:

Space and terrestrial architectures cannot be stand-alone or stove-piped architectures. They must be fully integrated with other surveillance architectures, to provide the Objective Force commander with complete battlespace awareness, and enable the Army to provide dominant land power support to the JFC. Given the short timelines of a tactical battlespace, the cycle time required, from tasking to dissemination and receipt of all-source, integrated products, must be in near real time. Additionally, development of a mid- to far-term capability to cross cue intelligence and non-intelligence platforms will lead to more responsive and comprehensive targeting information.⁷⁸

The use of micro satellites and programs such as TACSAT from Operationally Responsive Space (ORS), will give us some practical experience in providing future capabilities from space specifically to the tactical warfighter. Initially, tactical satellite assets still prove inadequate in both cost and capabilities as required by the tactical commander. Scenario-based training and use for the ground operations will truly determine whether these “tactical” space based assets can achieve their advertised capabilities.

Future non-orbital capabilities seem to be more realistic in their performance and supportability at the tactical level. At sub-orbital altitudes, it is possible to convert ISR requirements to sensor capabilities and develop a curve of capabilities versus altitude. Such would be a very simplistic model, subject to scrutiny about environmental factors such as wind, radiation and atmospheric effects. One however can build the model to derive insight such as stated here.

Accuracy specifications for the SBR (Space Based Radar) are classified, but if similar equipment were used aboard the HAA, the resolution of the HAA sensor products at surveillance distances of 22 km to over 500 km should be significantly better than the resolution of the space-based radar at 1,000 km from earth. Further, while the radar range from 22 km altitude will be much less, the radar null area at the center of coverage—the “nadir hole”—will be considerably smaller. Atmospheric attenuation of signals to and from an HAA, however, will be greater across the mean

⁷⁸ U.S. Department of the Army, TRADOC PAM 525-3-14, 17.

distance of coverage because of the relative increase in grazing angle and greater exposure to lower-altitude atmosphere.⁷⁹

While taking into account the above quote, tactical warfighters do not need the large areas of coverage gained by space-based radar systems. The tactical area of interest is much smaller, easily fitting within the footprint of a high altitude radar platform. While such systems are tactically useful, the tactical warfighter would benefit more from a tailored application over his area.

As the Army moves forward in its force transformation and organization it further defines its ISR requirements for support. The current terrestrial based system will transition to provide a more robust and responsive structure to support the tactical commander without total reliance on space based assets.

The Army's FCS consists of 18 systems, 4 of them unmanned aircraft that are expected to appear in an experimental brigade in 2008 and reach IOC in 2014. TRADOC designated Raven as the interim Class I UAV, an improved Shadow as the interim Class III UAV and Fire Scout as the Class IV UAV in April 2004. A fifth UAV category, Class IV B, has been created, requiring 24-hour endurance by a single aircraft, perhaps the eventual ER/MP UA.⁸⁰

Here a reliance on organizationally owned assets is predicted vice requesting support from higher echelons and nationally controlled assets, most of which are already over tasked. This Army and Marine Corps move to more indigenous assets is further evidence of the current deficit in ISR capabilities needed to support the tactical warfighter. Acquiring and deploying newer and more capable UAS controlled at the tactical level is another step in constructing a more robust and responsive ISR architecture.

⁷⁹ Jameson, High-Altitude Airships, 47.

⁸⁰ U.S. Department of Defense, Unmanned Aerial System Roadmap 2005-2030, 12.

Characteristics:

	Class I UAV	Class II UAV	Class III UAV	Class IV UAV
Type	Platoon UA	Company UA	Battalion UA	Brigade UA
Weight	5-10 lb	100-150 lb	300-500 lb	> 3,000 lb

Performance:

	Class I UAV	Class II UAV	Class III UAV	Class IV UAV
Endurance	50 min	2 hr	6 hr	24 hr continuous ops
Radius	8 km	16 km	40 km	75 km
Transport	Manpackable (35 lb system)	2 Soldier Remount	2 Man Lift	100m x 50m Recovery Area
Aircraft	Raven (interim)	TBD	Shadow (interim)	Fire Scout

Table 5. FCS UAS Characteristics and Performance.⁸¹

Above is the Army's FCS UAV layout. The characteristics are indicative of the added weight and logistics required for that size unit. Specification of UAS requirements down to a platoon level underscores the need for integrated and internal ISR capability required for execution of future missions.

The Marine Corps Warfighting Lab (MCWL) is currently performing test and evaluation exercises on a hand-launched, back-packable, micro air vehicle. These assets and future similar platforms will further extend ISR capabilities in the Marine Corps to lower levels with more capable means in which to obtain their products.

Known as the Wasp, it is being developed and employed in conjunction with the Defense Advanced Research Projects Agency. The fourteen deployed Block II Wasp systems have flown more than 1,000 sorties in-theater with tremendous success. This Micro UAS extended user evaluation has provided small-unit leaders with unprecedented situational awareness during combat operations and has developed and validated joint tactics, techniques and procedures. We see the Wasp as a complement to the Tier I Raven B UAS.

Another MCWL effort, the USMC Tier II UAS Concept Demonstrator, SpyHawk, will be employed as a test platform for evaluation of emerging technologies. It will also be used to develop and refine Tier II UAS concepts of employment and tactics, techniques, and procedures; and to collect data to inform Joint Tier II program of record development.⁸²

⁸¹ U.S. Department of Defense, Unmanned Aerial System Roadmap 2005-2030, 12.

⁸² Alles, Testimony on Air and Land Forces On Intelligence.

The products having an immediate and relevant effect on their missions or combat effectiveness show the move to more information independence from traditional sources. The next step in the future ISR architecture is HAAs operating in the HAAI. These HAA platforms address the gap between tactical and strategic capabilities and the ability to support the warfighter as missions are completed and AO's change.

Persistent surveillance from a fixed position is an important need that HAAs can meet. Over time, they can facilitate continuous collection and comparison analysis of terrain covered by different sensors, such as IR, EO, and HSI. Comparisons can highlight changes like freshly turned dirt along a roadway where bombs have been emplaced, and fusion of data from multiple sensors may furnish tracking data on targets under foliage.⁸³

The capabilities of future HAAs will bring a new view of ISR capabilities to the operational and tactical levels. These HAA based ISR systems will allow a shorter decision chain for some sensing. The positive effects of these regional systems will be the reduced load on national assets and multiple source information to support all echelons of the warfighters.

Future systems and integrated ISR architectures, proposed and currently in demonstration phases, look to possess the needed capabilities to support the tactical warfighter. The optimal system mix and ISR architecture will take time and experience to determine. The fact that the mix is tailor able without placing new items in orbit on long timelines and high costs is a step toward effectively responding to address the widening gap in ISR resources. Many of these Systems of Systems (SOS) and Families of Systems (FOS) appear effective in design and development but they must progress through the JCIDS process and secure funding.

b. Future ISR Deficit

ISR requirements in support of tactical warfighters will continue to widen. While the needs and requirements for ISR products grow at an ever-increasing rate, the resources available to service requirements remain relatively constant. Without a

⁸³ Jameson, High-Altitude, 47.

corresponding increase in capabilities or an information flow reduction the commander will continue to be restricted by the availability of information used to make a timely and educated decision.

Future space assets required to support the strategic level of warfare will be replacing a robust yet aged architecture, with many current platforms in use beyond their expected service lives.

In the area of space-based collection, unanticipated technical problems with some satellite programs in development will likely cause scheduling delays and cost increases. Moreover, an insufficient priority on developing cutting-edge technologies ensures that the core mission of space intelligence--to collect secrets--will continue to languish and become increasingly limited.⁸⁴

The lack of quantity of space assets places a greater strain on those systems that are available and operational. Further reliance and competition of commercial systems is becoming another factor that affects the tactical warfighters technological advantage. With the availability for all customers, imagery in particular, from commercial vendors or other state owned assets threatens our information dominance. The obvious drawback to this is responsiveness and revisit required for many ISR needs. The expense of these products is seen by some to be cost prohibitive to design, build and launch a similar state-owned asset, when one could buy it from commercial sources. A singularly important requirement for an ISR asset is assurance and security. The developing Operationally Responsive Space's TacSat initiative to bring the space-based ISR to the control of the tactical users becomes inadequate after thorough examination. The claims that TacSat will solve the tactical warfighters' ISR requirements are misleading and impractical.

If the experiment goes as planned, a tactical user will be able to upload commands directly to the spacecraft, have it carry out the imaging and then downlink that imagery within minutes.

⁸⁴ U.S. House of Representatives, 106th Congress Report: Intelligence Authorization Act for Fiscal Year 2001, 16 May 2000; http://www.fas.org/irp/congress/2000_rpt/hr106-620.html; Internet: Accessed on 19 September 2007.

Warfighters would be able to control or communicate with the satellites with existing communications and imagery dissemination systems, like a Common Data Link radio. There may also be the ability to communicate with the satellite directly with hand-held UHF radios.⁸⁵

The tactical commander does not have the money or manpower allocated to operate his own space-based asset. He also does not have the time in his decision cycle to task an orbital asset that will only be available for a maximum of 15 minutes, spread in small intervals throughout several days of coverage of his AO. Although the TacSat program is an excellent proving ground for technologies, it is ill suited for the combat commander at the tactical level, if he ever actually has priority for tasking the asset in the first place.

The final line comes down to the realization that our future space ISR systems will do little to impact the tactical warfighter directly. Space-based ISR assets are uniquely suited and required for many missions. Support of the tactical warfighter is neither their primary nor their most efficient use. As a result, these limitations in usefulness and priority should lead into the development of less expensive and capable systems that function in the terrestrial environment. With the increasing development of HAAs and UAS to fill the gap documented in both services, we look to address the current ISR gap.

The future road map for UAS looks to be fairly well organized. The ability to distribute products and capabilities at different tiers down to the lowest tactical unit required is a great capability. Such distribution of capabilities and assets allows for increases in ISR capabilities not only to the tactical warfighter, but also to all agencies and organizations above him, as higher-level assets are free for their intended usage. To configure maneuver units and supporting assets allows a commander greater flexibility and ability to cover more terrain. This asset allocation will also support decisions of the higher commanders who may be able to make their decisions faster due to less latency in information from forward units.

⁸⁵ Chisolm, "Micro-Eyes."

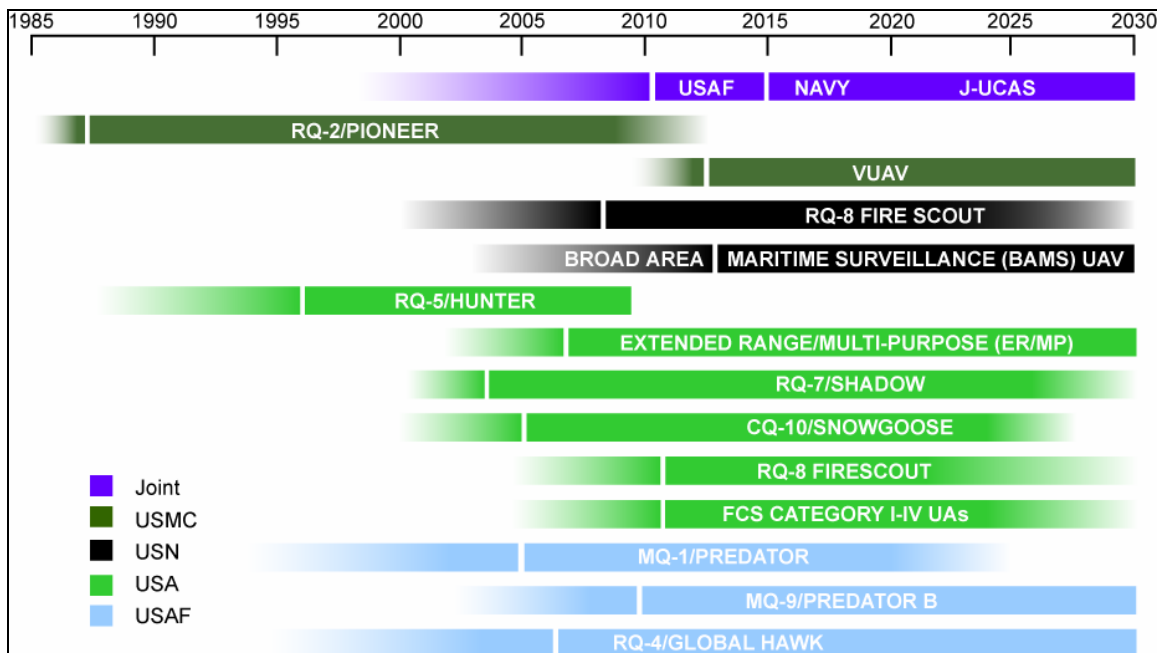


Figure 8. Timeline of Current and Planned DoD UAS Systems.⁸⁶

C. BLUE FORCE TRACKING AND SITUATIONAL AWARENESS (BFT/SA)

Blue force tracking (BFT) and situational awareness (SA) (BFT/SA) represents two different but supporting capabilities. BFT is concerned specifically with the location of blue or friendly forces within an AO and reporting that information. Situational Awareness adds information on enemy or adversary forces and other pertinent battlefield information to the same overlay or Common Operating Picture (COP). The technologies being developed to integrate all the sources of data continue to be updated. Currently, the U. S. Army uses the Force XXI Battle Command, Brigade-and-Below (FBCB2) and Blue Force Tracker (FBCB2-BFT) suites to provide a COP to its units at the BCT level and below. The U. S. Marine Corps uses the Command and Control for the PC (C2PC) suite for its tactical level picture, using inputs from the FBCB2 systems. Both services are currently working toward a joint compatible system, such as the FBCB2-BFT.

1. Current BFT/SA

The BFT system currently fielded by the Army and the Marine Corps uses the L-band satellite version of FBCB2-BFT. This is a satellite -based version of the more

⁸⁶ U.S. Department of Defense, Unmanned Aerial System Roadmap 2005-2030, 3.

robust LOS FBCB2 system. FBCB2-BFT allows users with the same L-band version of the system to have near-real time knowledge of friendly elements. At brigade and higher levels, this BFT feed can be input into other COP systems, such as EPLRS based FBCB2, Maneuver Control System (MCS), and Global Command and Control System (GCCS).

a. Current BFT/SA Capabilities

The FBCB2-BFT system allows for near-real time updates on position of friendly forces integrated with a digital map to provide commanders with a visual representation of the battlefield. As more information feeds into the COP, ranging from friendly aviation to enemy positions, the system provides the much-needed seamless look at the battlefield. The system relies on various communication architectures such as FBCB2, SMART-T, GCCS and other SATCOM links to feed various systems of friendly force information. Each individual system gains position information from an attached GPS receiver and this information travels half way around the world and back to update surrounding unit locations for the satellite-based versions of BFT. This long path causes inherent latency with updates due to distance traveled, processing at the CONUS-based site, and then the return trip.

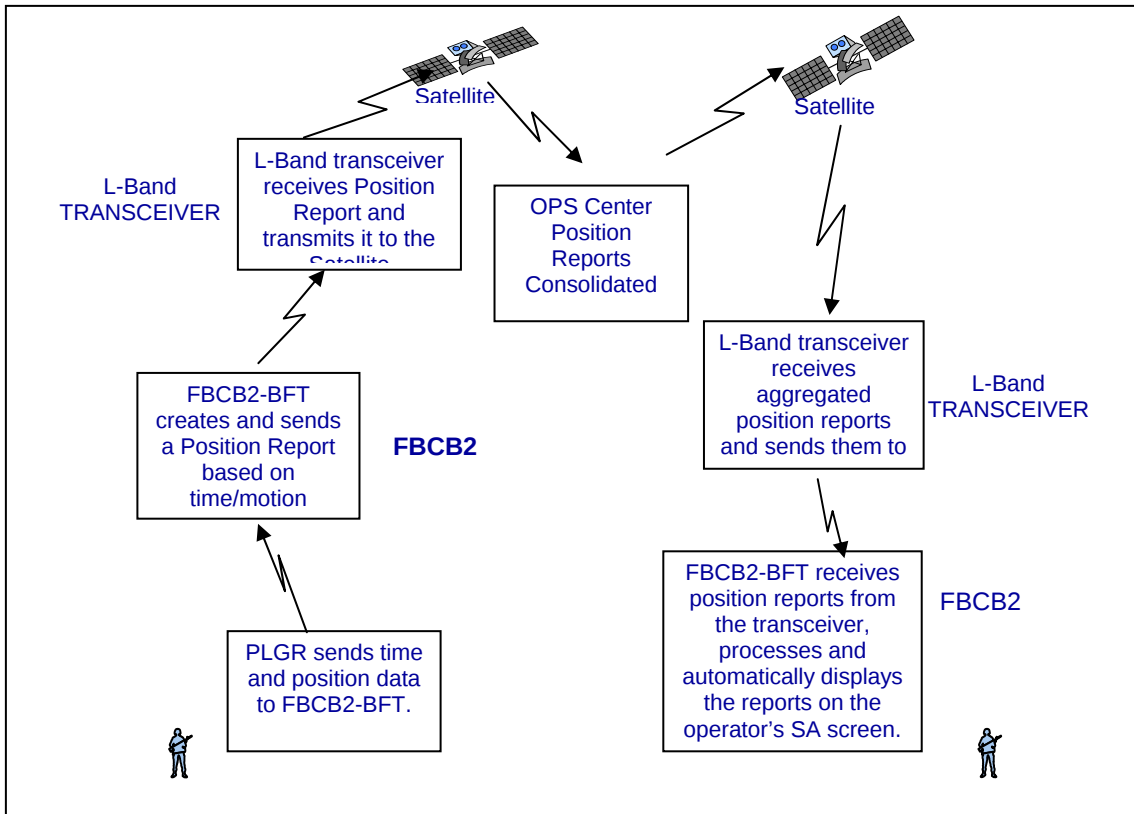


Figure 9. Current Blue Force Tracker Configuration (Simplified).

Figure 9 shows a simplified schematic of the current BFT operation and how it integrates at the tactical level. By allowing personnel, vehicles and aircraft to determine their own locations and view that of all others reporting on their display we greatly reduce the possibility of fratricide and accelerate the tactical decision cycle of commanders.

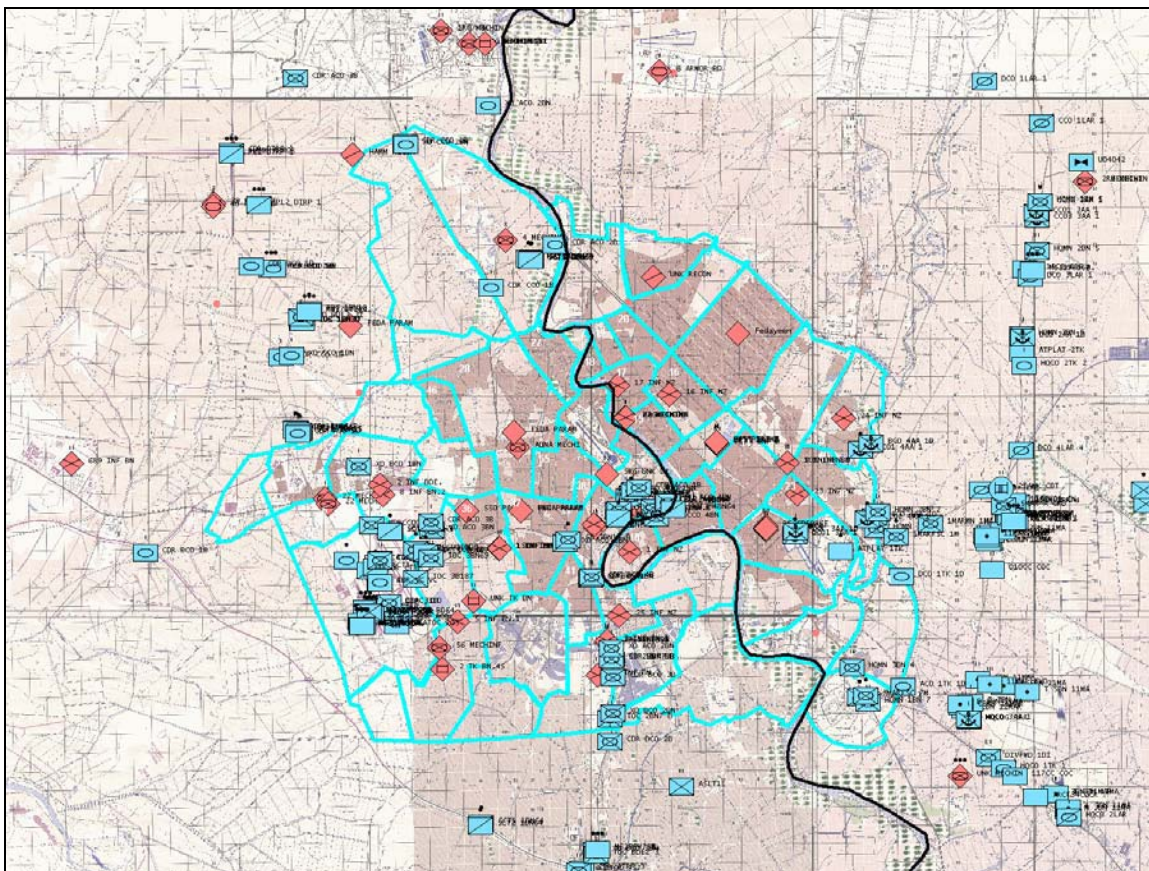


Figure 10. Example of BFT Coverage Capability 7 April 2003 OIF.⁸⁷

Figure 10 shows an example of the COP provided by BFT. The user interface allows for selection of scale for the map to enable smaller units to focus only on their AO. BFT's proven capability to show near-real time location of friendly units has saved lives and has compressed time necessary for mission planning in some cases from days to hours.

b. Current BFT/SA Deficit

The greatest deficit in the BFT system is due to the bandwidth of the L-band communication link. While the position data and text capabilities are relatively small, the required bandwidth used quickly adds up as the distribution of BFT systems increases to additional units due to their great tactical value.

⁸⁷ Department of the Army, Technical Report 06-014: Volume II, C-16.

The most beneficial area of improvement would be decreasing the update time required for BFT between adjacent units. Mobile units, especially aviation or vehicle-mounted ones can travel tactically significant distances in the time taken for a BFT update. Further, in urban terrain, even small distance differences can tremendously change the situation for the nearby force. For example, awareness of which side of a building a friendly unit is located is essential in preventing fratricide incidents.

The update times currently available for BFT are inadequate for units engaged in combat. The radio-based FBCB2 system continuously updates the local COP between units in the same network, with higher tiered FM nets updating between peer and higher-level units with slightly greater update times. The L-band version of the same system has significant latency, measured in minutes, which limits its usefulness in the close fight, particularly in urban terrain.

Another deficiency in current BFT systems is the level at which they are fielded. Current BFT systems require a vehicle or command post mounting system and are about the size of a modern personal desktop computer with flat screen monitor. As such, these are rarely issued below the company level for dismounted elements, and below the platoon level for mounted elements. Individual vehicles and soldiers, not typically outfitted with the system, leave some units with no coverage, while others are only represented by a single vehicle, often that of the unit's leader.

2. Future BFT/SA

The value of BFT and its demonstrated capabilities will continue to grow as the environment and missions continue to change toward more distributed and nodal operations. BFT systems must be capable of adaptation and interaction with users across the full mission spectrum and update as required for the mission.

a. Future BFT/SA Capabilities

Future capabilities of BFT systems appear promising with the development of systems such as the Commanders Data Assistant (CDA) and other Personal Data Assistants (PDA). As technology develops, the size and weight of these systems decreases, with current systems providing limited FBCB2-BFT capabilities to

dismounted users in roughly the same package as a 1st generation PSN-11 GPS receiver. While the tactical warfighter may not need tremendous amounts of bandwidth in hand at all times, the ability to see a real-time report of his Forward Line of Own Troops (FLOT) is crucial. The next generation of equipment and level of deployment will provide an increased capability for coordination and communication within the unit and with their higher commanders.

b. Future BFT/SA Deficit

The utility of BFT to the tactical warfighter is undeniable. The term ‘near-real time’ does not, however, provide the tactical warfighter the update times required, currently, nor does it provide adequate security for the data. The latency in information is a byproduct of the network utilized. The use of a space system allows for large area coverage by dispersed and varied units at a cost of latency in update time. The LOS based system, FBCB2, has excellent update characteristics with nearby units, but distant units will not display. Currently, the ability to introduce information from one system to another requires higher-level units with gateways to inject and convert data between system formats.

The BFT application is well suited for the space segment and for tracking forces on a large scale where a time delay of minutes and position lag of hundreds of meters are not a great concern. For the tactical warfighter, especially in close engagements, meters and seconds count. The warfighter needs the rapid update times of the FBCB2 LOS system with the range and availability of the BFT L-band system. This system does not currently exist.

The BFT system requires tailoring to the level of unit involved in the mission. If it is a small unit, then LOS systems are adequate, providing the terrain or surroundings do not prevent clear transmission and receiving of the signals. For larger sized tactical units such as the Brigade, BLOS systems may be more suitable since they tend to have more support and capability to link to those networks. The greatest deficit is for those units below the Brigade, specifically dismounted units without the benefit of

vehicles to carry FBCB2 or similar systems. For tactical maneuver elements such as the platoon or company, LOS may not be sufficient to cover the range or support bandwidth required for their operations.

D. POSITION, NAVIGATION AND TIMING (PNT)

Accurate Position, Navigation and Timing (PNT) capabilities are critical assets for the tactical warfighter. Tactical warfighters are critically reliant upon these capabilities. PNT is essential for BFT/SA, synchronizing secured communication nets, enabling employment of precision munitions, and providing quick and precise geo-location. These capabilities have become critically essential in our modern warfare and are all significant contributors to our technological superiority in ground tactical operations.

1. Current PNT

The current constellation of Global Positioning System (GPS) satellites provides worldwide coverage of the earth with not only position and navigation information but also very accurate timing. Position information allows the warfighter to know, quickly and accurately, where he is located on or above the surface of the earth. Modern GPS receivers allow access to that information as well as giving the warfighter vector and distance data to plotted points from his current location. The GPS signal is publicly available within the latitude ranges covered by the system. Military users have additional capability provided by a second secured channel that allows for greater accuracy as well as more jam resistance. The navigation capability provides valuable service to all fixed and mobile users from dismounted soldiers to high-speed fixed wing aircraft.

While positional knowledge is important, an equally important value provided by GPS is accurate timing. Without GPS timing, the quick and easy ability to synchronize and secure encrypted voice and data communication nets is impossible. Most common secure communications require accuracy in timing to operate in secure modes. GPS allows this common time reference, globally. Additionally, this same timing reference is critical to almost every banking institution for security and management of electronic

transfers of all types, including ATM withdrawals. Without the GPS timing signal, synchronization of modern communication systems would not be possible.

a. Current PNT Capabilities

The capabilities of the current GPS constellation and equipment are sufficient for most environments. The ability to provide precise positioning information requires multiple satellites in view to provide optimal geometry. Precision timing between spacecraft provides the individual user accurate position location, suitable for most civil and military use. While the GPS system works well in most terrain and situations, GPS accuracy degrades in mountainous and built-up urban areas, such as cities. Unfortunately, the tactical warfighter must often operate within built-up areas such as Iraq and mountainous areas such as Afghanistan. While it is foolish to base our future capabilities on current wars, it is highly likely that we will continue to conduct tactical operations within these types of terrain in the future.

Current tactical users employ the AN/PSN-11, AN/PSN-11(V) 1, Precision Lightweight GPS Receiver (PLGR) AN/PSN-13 as well as a variety of Commercial off the Shelf (COTS) receivers designed for civil use. These provide the tactical user a lightweight, handheld computerized receiver that provides very accurate position data in a matter of seconds as well as accurate timing and navigation assistance.

b. Current PNT Deficit

A limitation of our current architecture is the ability to get clean signals into areas surrounded by high vertical structures that mask and restrict signal propagation. The effects of multi-path signals due to path bounces and multiple signals reaching the receiver from the same satellite at slightly different times, but with the same codes causes an error of one type. Loss or reduced number of signals reduces the accuracy of our equipment and makes our reliance on those systems in that environment tenuous at best. The requirement of at least four satellites to obtain a 3 dimensional solution may be problematic and cause a loss of equipment function at an inopportune time, especially within urban or mountainous terrain where the horizon is not clear.

The GPS system transmits a signal from 10,900 nautical miles away and produces a very weak signal on the earth's surface. This is much like viewing a 25-watt light bulb from the same distance. This low signal strength is one of the largest deficiencies in the current system, contributing to weakness against jamming and spoofing attacks.

Other more directed problems are the cases of jamming and spoofing. Jamming will become highly proliferated in our future operations. In our current fights, lower tech forces have attempted to use GPS jammers to interfere with our ability to fight as we intend to. With many of our weapon systems and equipment relying on GPS guidance, adversaries target the weak signal at the surface of the earth by overpowering it with terrestrial transmitters at the same frequency. The loss of a GPS signal, in a jamming environment, may prevent the user from reacquiring navigation signals until the jamming ceases or they get far enough away from the jamming signal to acquire a good satellite signal. GPS signal jamming can be deliberate or as in many cases, inadvertent. The typical user cannot identify whether he is intentionally or inadvertently jammed, and only knows that an essential capability is no longer available to him, unexpectedly.

The ability to spoof the GPS signals is another limitation in the system. Spoofing is the replication of the GPS signal to provide bad or erroneous data to the receiver causing an error in position and timing. This method of GPS attack is more subtle than jamming, since the user may only detect that his position is in error but is still receiving a signal. If the user does not recognize his position information as incorrect, he could report his position or other data erroneously. The timing portion of GPS will also not function in a spoofing situation, since it will not match up with other times on the same frequency. The result can be that a communication net can become unsynchronized during spoofing attacks and communication might be lost due to synchronization errors.

The current PLGR system accesses the Precise Positioning Service (PPS) when operated with COMSEC. This provides it with Selective Availability, Anti-Spoofing and Anti-Jam capabilities. The PLGR is phasing out, with the Defense

Advanced Global Positioning System (GPS) Receiver (DAGR) replacing it. This newer DAGR provides a greater security and technology to help defeat our adversaries' current tactics against PNT and GPS.

2. Future PNT

The current block of GPS III satellites deployed is the next generation with more bands and more signals with power increases in signal strength to 40 watts. These satellites should be operational by the year 2013 or earlier. With a more advanced satellite system, improved user equipment should take full advantage of the improvements and security of the next generation GPS equipment.

a. Future PNT Capabilities

The added capabilities that the next generation GPS space segment offers is an improvement on the current PNT capabilities for the warfighter. The use of a spot beam for the military channel will increase its power received at the ground and make it more resistant to jamming and spoofing. The better timing and error resolution provides position information that is more accurate, especially when linked to the FBCB2 and other BFT/SA systems. The added capabilities of the space segment will provide more secure and dependable links to the warfighter.

The user segment of PNT requires receivers for the tactical warfighter that can ensure connectivity in a hostile electronic and battlefield environment. Many things can affect the GPS link. Ensuring the tactical warfighter can effectively execute his mission will require many improvements to the current receivers. Improvements in equipment such as the DAGR and hardware like the Selective Availability and Anti-Spoof Module (SAASM) will attempt to ensure the tactical warfighter has the ability to fight in that hostile environment. Other equipment upgrades for vehicles and aircraft will enable interoperability and better coordination.

b. Future PNT Deficit

The increase in power from space to the ground, although significant, is still rather small compared to the amount of power an adversary can emit from a

terrestrial jammer. Although these jammers can become a target themselves by being active emitters, remote activation allows them to be distant from their operators. Developing systems will be able to identify some of these adversary actions and notify the user of a potential problem. SAASM will help greatly for a time before our enemies determine and counter its capabilities.

A continuing future deficit is a shortage of GPS receivers for tactical warfighters at the lower levels of organization. This shortage in systems is filled with either individually or unit-purchased civil receivers. Even military issued receivers without current cryptographic keying are not much better than civilian receivers. The use of civilian transmitters to fill the gap is potentially dangerous to those who use them and others interacting with that user. These commercial systems while more susceptible to jamming and operating with lesser accuracy, offset those risks with the tremendous capability provided by civil receivers in comparison with the use of traditional navigation techniques.

Improvements in software and internal hardware for receivers will likely have the most impact on the tactical warfighter. A better receiver will allow him more capabilities in the navigation portion of the system, that part completely reliant on manipulating the position signal with processing at the receiver. Anyone that has used a first generation PSN-11 and then tried your typical COTS receiver can easily see the additional capability provided by upgraded receivers and software. First generation GPS receivers used very complicated button sequences and required extensive training to operate effectively. Modern versions use more efficient control inputs as well as more intuitive information display.

Changes in the space segment, other than incremental block changes, will not make significant changes in our overall GPS capability. How we use and manipulate the signals after they reach the user or ensure that the signal reaches him will provide our greatest future gain. By increasing signal security, we can reduce the jamming and spoofing of signals. Another method to increase GPS capability is to establish Differential GPS (DGPS) sites. These sites may be land based for long-term

engagements or could be airborne for initial hostilities, rough terrain or denied areas. The DGPS concept uses a local known point to determine localized GPS error, providing greater accuracy within that region.

E. CONCLUSION

At the tactical level of war, the “disadvantaged user” status of the tactical warfighter in regards to BLOS systems remains a real concern. While this status and his increasing requirements for support are acknowledged more than ever before, current and future systems are unable to now or in the forecasted future, provide the tactical warfighter with adequate levels of communications, ISR, BFT/SA and PNT, specifically in the types of terrain he will likely operate. Traditional methods of providing these assets to the warfighter use either additional LOS radio or BLOS satellite systems.

It is clear that the traditional methods of providing these capabilities will not be sufficient in the future to meet these increasing needs. The tactical warfighter doesn’t need a specific system to necessarily fix any one of these capability gaps, he instead needs a system of systems, encompassing a wider range of delivery platforms for information that can be accessed by a common receiver, suited to his unit type.

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V. TACTICAL SPACE

Having identified the key capabilities required in the areas of communications, ISR, BFT/SA and PNT, and the associated deficit in each, concerning the tactical warfighter, the thesis will now propose solutions to mitigate the deficits. Departing from the more traditional concepts where tactical space relates specifically to orbital assets, the proposed architecture sees tactical space not as a physical region but rather as a type of support. No single region or regime solves all of these requirements for the tactical warfighter in all scenarios.

Current BLOS systems are predominantly space-based for the tactical warfighter. Satellite systems due to their high cost and complexity previously existed for support of national-level and strategic purposes. While recent trends have placed these same assets in support of the prosecution of warfare, even at the tactical level, these systems are still strategic in design and nature. Various programs such as the services' Tactical Exploitation of National Capabilities (TENCAP) programs work to identify innovative methods of supporting tactical level forces with national strategic capabilities. These programs essentially determine how to fit a square peg in a round hole as opposed to building the round peg that the tactical warfighter requires.

Tactical commanders face shortfalls in BLOS capabilities that prevent their ability to execute expanding operations and missions. Existing BLOS systems provide inadequate performance, especially in the areas of communications and ISR. Future systems, while improved, face continual delays, resulting in over tasking of current systems and shortcomings of the newly fielded system due to some level of obsolescence. Future systems seek to provide more of the same, adding additional satellites or terminals to the same inadequate model of support.

The Army's Concept for Space Operations in Support of the Objective Force further highlights these BLOS needs.

Internetted, overhead (high altitude and space) communications, and ISR far-term capabilities, and the means to protect them, are critical to provide

the essential communications, timely and accurate surveillance, and en route mission planning and rehearsal capabilities for deploying forces.⁸⁸

Warfighters at all levels receive data from multiple sources. These three layers are terrestrial, air (including the HAAI), and space. Only through efficient use of all three layers is any real reduction in the BLOS deficit achievable. While improvements in any of the layers will likely provide greater capability, the cost vs. benefit analysis between alternatives in different regimes is essential to provide the greatest and most appropriate capabilities at the most reasonable cost. The capabilities required by strategic and operational commanders are not always the same as those required by the tactical commander. The tactical level of war is a unique area of operations with very focused and tailored requirements, not a smaller version of the higher levels. Systems to support the tactical warfighter must be fielded based on tactical requirements, not by watering down higher-level needs.

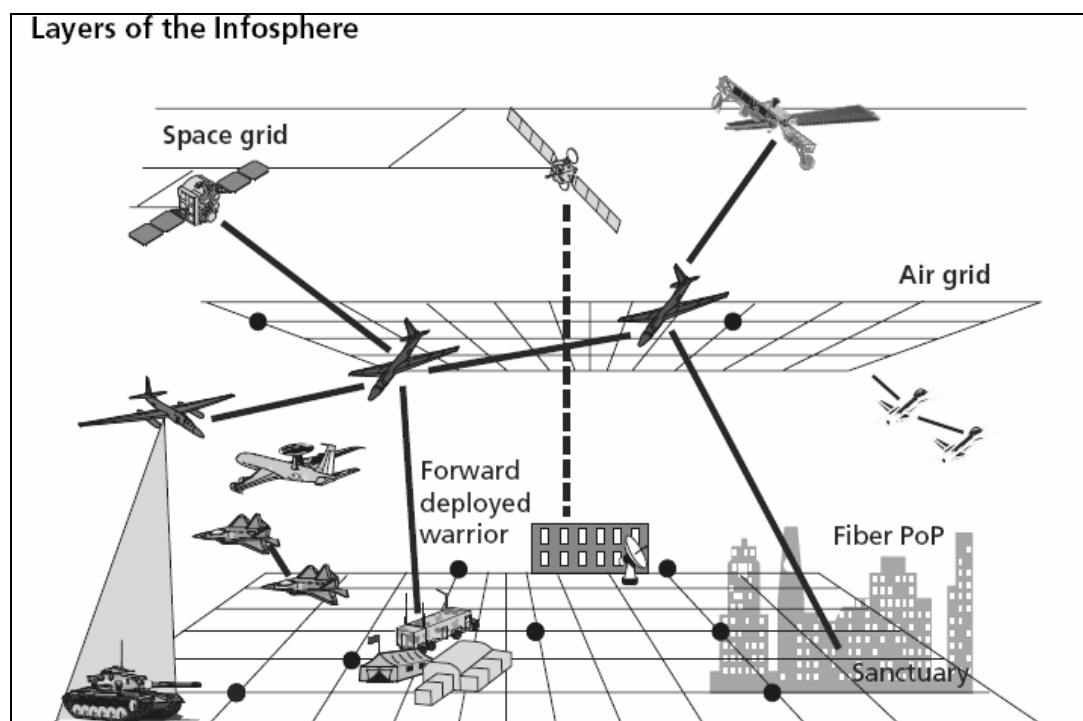


Figure 11. Current Layers of the Infosphere.⁸⁹

⁸⁸ U.S. Department of the Army, TRADOC PAM 525-3-14, 15.

⁸⁹ Joe, Future Army Bandwidth, 56.

A. COMMUNICATIONS

Persistent and assured communications is arguably the BLOS capability that most directly influences tactical success. Tactical commanders rely on many different systems that require communications to facilitate. Synchronization with senior, subordinate, and peer units and requests for fire support, medical evacuation, and logistics are critically reliant on the warfighter's ability to communicate with elements outside of his line of sight. Tactical level commanders do not have the luxury of waiting for optimal or non-peak times to communicate for these essential elements. The tactical commander must be equipped with communication systems that allow him to talk to who he needs to, when he needs to. A failure in either of these two needs easily translates into the loss of human lives, either friendly or civilian. While the amount of bandwidth the tactical commander requires may be less than his superior headquarters, his need for timely information and communication may be, in many cases, more urgent. To remove these gaps, current and emerging solutions to the BLOS communication deficit for tactical warfighters must consider tactical requirements as their own unique entity, not as a subset of higher issues.

Proposed solutions to the current communications gap range from eliminating some communications requirements to the deployment of entire constellations of communications satellites for tactical warfighter support. While greater efficiency in our use of bandwidth is surely desirable, telling the tactical warfighter to do more with less is not a rational and realistic option to reduce his bandwidth requirements. In the same way, adding more systems, links, hardware, receivers, power, widgets or gadgets does not truly help the tactical user become more effective. The table below provides five possible techniques for improving available bandwidth.

Technique	Specifics and Potential Improvements
Increase capacities of links	Higher frequencies and optical frequencies ($\times 10$), frequency reuse and spectral-efficient radios ($\times 2-20$), directional antennas ($\times 2-300$)
Improve routing efficiency	Use new protocols for ad hoc networks, i.e., smarter routing and/or node aggregation and clustering ($\times 2-10$)
Add a vertical element	Airborne or satellite increases connectivity/ decreases network load ($\times 2-4$)
Adjust needs of applications	Incorporate communications into database architecture (JCDB); data compression and fusion (multiple orders-of-magnitude improvement)
Manage bandwidth operationally	Treat bandwidth as a limited operational resource ($\times 3-5$)

Table 6. Techniques for Improving Bandwidth.⁹⁰

Increasing the capacity of links, improving routing efficiency, and adjusting the needs of applications are all techniques that are also very applicable to civilian and commercial communications systems. These will continue to develop at a rapid rate, due to the greater population affected by the changes. Communications experts have sought these changes for some time already, as civilian bandwidth requirements increase rapidly. Managing bandwidth operationally is something that units currently do out of necessity, due to limited available capability. The final option, the addition of a vertical element, shows great promise to providing a new capability rather than improving or reducing the requirement on existing systems.

1. Emerging Communications Solutions

a. *Emerging Space Communications*

Space is the current first choice for global communications in a sparse environment. While severely limited in many capabilities, compared to robust terrestrial wire networks, space provides a level of access required by the military that other systems cannot provide. The tremendous line of sight benefits to the warfighter are

⁹⁰ Joe, Future Army Bandwidth, 44.

widely advertised and undisputed when access is available. However, for the tactical warfighter, space assets are not accessible in sufficient types or number. An obvious solution would be to procure more, better and bigger satellites, however, for the tactical user, this has its own inherent problems. Specifically, the tactical warfighter cannot afford or accept requirements for large antennas, sophisticated architectures, or issues with his communications disappearing over the horizon at inopportune moments.

Geostationary (GEO) satellites can cover enormous areas with millions of users; for this reason significant investments have been employed for commercial exploitation of satellites. However, GEOs suffer from very critical free-space path loss and propagation delay, which require large antennas and sophisticated architectures and protocols at the customer receivers. Not only that, technological constraints for on-board antennas prevent the possibility of optimizing the cell dimension on the ground, thus potentially lowering frequency reuse efficiency and, consequently, overall capacity. These problems can be partially solved with the use of low orbit (LEO) satellites; however, these suffer from the widely investigated issues related to the rapid appearance and disappearance in the sky portion visible to the receiver. This means that LEO-based systems must include an efficient handover protocol among cells and satellites.⁹¹

Current experiments such as the TacSat from Operationally Responsive Space (ORS) program show some promise for control of satellite by tactical units. While the possibility of deploying long duration communication platforms in Medium Earth Orbit (MEO) or Highly Elliptical Orbits (HEO) is investigated, the problems with communications in these two orbital environments are still not fully understood. Those environmental challenges and power requirements due to increased range may quickly raise costs far beyond the budgets of tactical level commanders.

b. Emerging HAAI Communications

The HAAI is part of the aerial layer. Currently few, if any, air-breathing platforms conduct routine long-term communications capabilities at high altitude. The few systems that even operate within the region such as Global Hawk and the U-2 are highly specialized ISR systems that provide no communications mission, other than

⁹¹ Emanuela Falletti, Massimiliano Laddomada, Marina Mondin, and Fabrizio Sellone, "Integrated Services from High-Altitude Platforms: A flexible Communication System," IEEE Communications Magazine, (February 2006), 124.

perhaps the transmission of data collected by sensors on the platform. Essentially, the HAAI is currently void of any assets to support the communications capabilities of the tactical warfighter.

The Army is interested in the development of High Altitude Long Endurance (HALE) systems. Although these various systems are still in an early phase of development, the Army sees potential capabilities in these types of systems and has provided some funding for research and development.⁹² These platforms show tremendous potential for support, specifically to the tactical warfighter.

The Marine Corps is not currently evaluating any specific HAPs for future communication support. Some experimental systems have been evaluated for capabilities to support the Marine Corps, but none were found sufficient to support the C4ISR capabilities required in the short-term. The Marine Corps further relies on other services for portions of its support, making it redundant and wasteful to spend many resources for parallel program development.

The Navy and the Air Force both have interest and programs concerning the HAAI. The Navy has been the executive agent for lighter than air vehicles since their inception but does not operate at the higher altitudes. The Air Force systems currently involve systems out of its TENCAP program, specifically Talon Topper and Combat SkySat. These systems both consist of variations on high-altitude free-floating balloons to extend hand-held LOS communications systems over hundreds of miles.

There are currently no fully funded DoD high altitude programs that are expected to provide communications to the tactical warfighter other than the free-floating systems. Several commercial entities see value in the region for communications and have developed prototype HAPs with tactical support in mind. One such system is the Zephyr HALE UAS under a three-year demonstration to provide communications relay.⁹³

⁹² "High Altitude Airship," GlobalSecurity.org, Available at <http://www.globalsecurity.org/intell/systems/haa.htm>; Internet; accessed on 12 September 2007.

⁹³ Graham Warwick, "U.S. Military Plans for New UAV to Stay Airborne for Five Years," Available at <http://www.flightglobal.com/articles/2007/05/23/214154/us-military-plans-for-new-uav-to-stay-airborne-for-five-years.html>; Internet; accessed on 12 September 2007.

A Zephyr HALE UAS with a communications relay payload, orbiting for weeks at a time at 60,000ft+ provides a comms link at typical hand held frequencies in real time for ground communications over an area of thousands of square miles. Communication links are permanent due to the persistent nature of Zephyr allowing the mission to progress.⁹⁴

c. Emerging Terrestrial / Aerial Communications

For purposes of this thesis, the terrestrial layer is restricted to and defined as land-based communications existing on land with transmitter, receiver, and any intermediate relay stations being at the ground or at low altitudes. Essentially, these cover traditional LOS communications and low altitude (below HAAI) airborne relay systems.

Current terrestrial communications systems have provided greater security and power, in better and more capable radios, with smaller batteries and more bandwidth. Due to their LOS nature, however, they have done little to extend the range of the tactical warfighters communications without creating physical lines of communication that require persistent security. UASs may provide some increases in the ranges of LOS communications, but still suffer from persistency issues as well as frequent mismatches in the size of the unit's AO and the footprint of the UAS system.

The short-term view of the use of the aerial layer for communication improvements describes the use of UASs for communication support of the tactical warfighter. This study addresses the value of HAPs in support of tactical commanders, but cautions on the requirement to ensure that these assets are available to that level of command.

The airborne communications layer contains manned and unmanned aerial vehicles carrying communications payloads. Aerial communications relays will be present at relatively low altitudes on vehicles controlled by the tactical commander, such as Hunter and Shadow and future UAVs. At higher altitudes, Army forces will rely on larger joint, national and commercial aerial platforms such as mid-altitude airships, aerostats, or Global Hawk to provide coverage to a wider area. High-altitude aerial vehicles also route traffic to the space layer. Since these platforms are not

⁹⁴ QinetiQ Corporation, "Zephyr HALE UAS."

under direct control of the tactical commander, policies must be established to ensure these assets can be readily used as needed.⁹⁵

The use of an aerial network layer of some kind greatly improves conventional terrestrial network capabilities, reducing latency and improving bandwidth. “The WIN-T AOA found that most key performance parameters could be met when an aerial layer was employed, but could not without the aerial layer.”⁹⁶ This statement sends a strong message in support of an integrated architecture for current and future terrestrial systems. The use of low altitude platforms, either free flying or tethered, would be an easy step in the evolution of extended LOS communications for the tactical warfighter.

2. Communications Recommendations

There are many ways to provide greater communications capabilities to the tactical warfighter. Not all of these options are effective due to the tactical warfighter’s unique properties and limitations. The tactical warfighter often conducts operations in an austere environment, with little or no infrastructure, with limited ability to transport systems, limited personnel to operate systems, and most often in harm’s way. Systems that provide him capabilities must be simple, durable, compact, lightweight, and easily transportable. The tactical warfighter, at the most basic level, is a man walking, with everything he needs carried on his person. He must be able to walk where he needs to go and talk to others, beyond his line of sight, when he needs to.

a. Space Communications Recommendations

Currently, space provides our most effective BLOS communication asset for the tactical warfighter. At the same time, this is the most expensive method of communication that the tactical warfighter has access to, especially as a disadvantaged user. Developing systems for and operating systems in space is inherently expensive.

⁹⁵ U.S. Department of Defense, Department of the Army, Training and Doctrine Command Pamphlet 525-1-0.1: The United States Army Objective Force Battle Command (C4ISR) Concept, (Washington: Government Printing Office) 95-96.

⁹⁶ Department of the Army, Technical Report 06-014: Volume II, C-18.

While space can answer the communications needs of the tactical warfighter, the limited number of very expensive systems makes those assets more likely assigned to elements above the tactical level.

More overhead communications systems are needed, but satellites are costly and require either expensive geosynchronous satellites or many low- or mid-earth-orbit satellites. Potential alternative platforms are solar-powered high-altitude airships and airplanes flying at or above 65,000 feet.⁹⁷

The quote above brings out the point of cost being prohibitive to the lower levels of warfighters. The tactical warfighter does enjoy some of the benefits of space but space is not sufficiently accessible by the tactical warfighter to meet his requirements.

	Terrestrial (e.g., B-FWA)	HAP	LEO Satellite (e.g., Teledesic)	Geosynchronous Satellite
Station coverage (typical diameter)	< 1 km (spot service)	Up to 200 km (regional service)	> 500 km (global service)	Up to global (quasi-global service)
Cell ^a size (diameter)	0.1–1 km	1–10 km	~ 50 km	400 km min.
System deployment ^b	Several base stations before use	Flexible	Many satellites before use	Flexible, but long lead time
Estimated cost of infrastructure	Varies	\$50 million upward?	~ \$9 billion	> \$200 million

Table 7. Comparison of Terrestrial, High Altitude, LEO, and GEO Communication Systems.⁹⁸

Table 7 shows the benefits space platforms provide are specific to their region. The ability to provide near global coverage supports our ability to fight and operate anywhere in the world. The footprint of these systems helps to ensure the commander on the ground has access to networks needed to execute his mission. These high-cost satellite systems were developed for strategic level forces, due to their near global coverage. It follows that those space systems best support those strategic assets for which they were designed.

⁹⁷ Jameson, High-Altitude, iii.

⁹⁸ Tim Tozer and David Grace, “High-Altitude Platforms for Wireless Communication,” Electronics and Communication Engineering Journal, June 2001, 134.

Also visible are the drawbacks to space systems. The cost of space systems is high and for the essential capabilities they bring to the warfighter, especially at the higher levels of command, they are cost-effective. The benefit to the tactical warfighter is limited tremendously by this cost and the limited availability of space-based assets. You cannot easily create additional capability or bandwidth on orbit. To provide support to the tactical warfighter requires that some capability be transferred from another element or level of organization. Further, spacecraft are rather inflexible, requiring a trade of lifespan if a decision to move an asset to support an uncovered region is made. The true cost of moving a satellite to support an unforeseen operation in a remote area of the world could cost millions or billions of dollars in future capabilities lost. The availability, cost and complexity of operations for space-based assets do not support the tactical warfighter well, and in most cases, are better tailored to strategic and operational support.

For the tactical warfighter, space does not appear to be the best solution to support his communication requirements. While more orbital assets, directly suited and developed to support the tactical warfighter would be welcome, it is doubtful that any future budget will support the needed number and types of systems to fulfill the needs of the tactical warfighter for communications alone. The support from space to the tactical warfighter is incredible, when available. The tactical warfighter needs a capability developed and fielded to meet his requirements and tailored to his mission. The tactical warfighter uses space, currently, rarely to communicate around the globe, but more often, within the same geographical region.

b. HAAI Communications Recommendations

The HAAI region may prove to be an area that is specifically suited to the budget, requirements and needed capabilities of the tactical warfighter. With properly developed and fielded systems, the tactical warfighter could likely remove the label of “disadvantaged user” from his vocabulary. Additionally, the regional BLOS capabilities provided by HAPs would reduce the tactical warfighter’s need for space assets, freeing them for use by higher-level organizations and elements, operating in even larger geographical areas.

Table 8 shows a quick comparison between a GEO communication satellite and a similar functioned HAP. Specifically for the tactical warfighter, who rarely needs to communicate regularly beyond a 200km coverage radius, the additional coverage area of GEO satellites is unneeded. The reduction in free space path loss helps to lighten and shrink required communication receivers and antennas. Reduced propagation delay is also much better suited for voice communications, which are essential in tactical communications.

	HAP	GEO
Maximum one-way propagation delay (ms)	1	240
Radius of the coverage area (km)	200 ¹	7300
Deployment cost	around 50 M\$	200-300 M\$
Free space loss (dB)	152.1	207.4
¹ Considering a HAP placed at 21 km altitude and 5° minimum elevation angle useful for communication		

Table 8. Comparison of High Altitude Platform with GEO Satellite Communications.⁹⁹

The following list details the “Advantages and Features of HAP Communications” as determined by the article “Broadband Service Delivery from High Altitude Platforms.”

Rapid deployment, Relatively low cost upgrading of the platform, Broadband capability, Large area coverage and fewer problems with obstructions (compared with terrestrial), Very large system capacity, Flexibility to respond to traffic demands, Ideally suited to multimedia services, broadcast, and multicast, Low propagation delay, Less ground-based infrastructure, Low cost and, Incremental deployment.¹⁰⁰

This list is a very broad look at HAPs for commercial employment, but it takes little imagination to see clear military utility based on the study.

⁹⁹ Ernestina Ciana, Ramjee Prasad, Maruo De Sanctis, Aldo De Luise, Mirko Antonini, Daniele Teotino, and Marina Ruggieri, “Integrated Satellite – HAP Systems,” *IEEE Radio Communications*, December 2005, S34.

¹⁰⁰ Tim Tozer and David Grace, “Broadband Service Delivery from High Altitude Platforms,” paper delivered to Communicate 2000 Online Conference, 2-13 October 2000, London, UK, 3.

The use of secure cellular-like networks is another possible employment of communication systems from HAPs. Another study proposes that HAPs and satellite systems are not competitive with each other, but rather that each has tremendous advantages if employed in a consolidated architecture that takes advantage of each system's capabilities at the proper location within the architecture.

Due to lower latency and the more favorable link budget of ground-HAP links, HAPs are a more cost-effective solution than satellites for the provision of services to mobile users. A cellular like pattern with frequency reuse can be achieved by spot beam antennas on the HAP, thus achieving high spectral efficiency. As a base transceiver station (BTS) of a 2G or 3G cellular system, HAP can fill in the gaps in network coverage and cover areas prior to the establishment of full terrestrial coverage.¹⁰¹

No commander would likely refuse the ability to increase the range of his existing communications systems to 50 times greater than he can currently talk. This would allow the tactical commander the ability to deploy his forces throughout his increased AO, without the need for complicated and resource intensive communication relay sites. The increased range could ensure the ability to coordinate with supporting arms and support units.

An in-theater example cited by combatant commanders is that blue forces on the ground using line-of-sight radio communications are limited to a footprint of approximately five to seven nautical miles. One of the near space projects currently in the demonstration phase uses communication relay to extend the range of those radios out to nearly 300 nautical miles.¹⁰²

The citation above provides an example of what a system could provide. Army and Marine Corps are the prime users of such systems and systems of that type should be developed and deployed to meet those specific needs. To fight ashore and establish a self-sustaining command in areas of the world without a communications infrastructure or to operate in sparse environments without having to use scattered communication nodes would greatly increase the operational capabilities of tactical warfighters.

¹⁰¹ Cianca, "Integrated Satellite – HAP Systems," S33.

¹⁰² Thibault, "Developing the Near Frontier."

Army FCS, Marine Corps DO, and the increasing trend for tactical units to operate in increasing sizes of AOs, require more information access and communication networks capabilities at these lower levels.

The Army has a critical need for an airborne layer for future force networks. The successful production of airships could satisfy this requirement: their communications and surveillance capabilities should considerably improve force performance in the theater battlespace. Airships can function as surrogate satellites. In comparison to space-based assets, they offer the advantages of shorter transmission distances for relaying ground-based communications and shorter ranges for sensor surveillance of the battlefield and acquisition of ground targets. In fact, a host of innovative uses for such a platform have been proposed, including but not limited to (a) the use of HAAs as optical relay platforms from a ground station, (b) the use of HAAs as hub nodes that relay communications to and from satellites, or (c) perhaps the use of HAAs as mobile computing platforms.¹⁰³

The Army's need for more capability starts from the future organizational structure. The Army's current operations and Marine Corps' doctrinal operations have placed an immediate need for greater communication capability that will only increase with time and operational tempo.

HALE systems enable the links to the GIG and logistics C2 structure enabling the exchange of critical maneuver support and logistical information for units operating BLOS and platforms operating over the horizon.¹⁰⁴

This quote from the Army's Space Operations document provides an insight as to some of the benefits HALE systems can potentially provide. The ability for a commander to know the progress of his subordinate units could provide for faster logistical support and information sharing with adjacent units.

The benefits of HAAI available are not only in what capabilities that they could support for the tactical warfighter but also the benefits of taking advantage of better physics. Greater BLOS capability is useless to the tactical warfighter if he cannot carry it. Reduced power requirements mean fewer and lighter batteries. Further, HAPs can potentially extend existing radio systems to formerly BLOS ranges using software and or

¹⁰³ Joe, Future Army Bandwidth, 40.

¹⁰⁴ Department of the Army, TRADOC PAM 525-7-4, 35.

operational concept changes. These changes are transparent to the user, who will gain the additional benefits without having to change existing equipment, training, or CONOPS.

A passive antenna on a satellite that received 1 watt of power from a transmitter in its footprint would receive between 100 and 400 watts on a near-space platform, implying that it could detect much weaker signals (10 to 13 dB weaker).¹⁰⁵

Similarly for communications, the power received by a passive antenna drops off roughly as the square of the distance to the transmitter. A passive antenna on a satellite that received one watt of power from a transmitter would receive several hundred watts on a near-space platform, implying that it could detect much weaker signals. The signal strength improvement for active systems such as radar would be about a factor of 100,000.¹⁰⁶

Some of the examples of potential gains from HAPs are evident, just from the aspect of communications capability enhancements. Currently, communication is the commander's most valuable asset. Other information that can be passed over these nets would provide an invaluable picture of the battlefield in real time.

¹⁰⁵ Tomme, Paradigm Shift, 12.

¹⁰⁶ Tomme, "Balloons in Today's Military," 7.



Figure 12. Use of HAA systems for In-Theater Communication.¹⁰⁷

The above figure demonstrates the possibilities of a future HAA operating within a theater of operations. The capabilities proposed, in support of the tactical warfighter, would provide tremendous increase in operational effectiveness.

Recommendations for further research into communication capabilities in HAAI should be consistent with the needs of the tactical warfighter. These systems promise to provide a capability that is, at present, either inadequate or non-existent. The use of the HAAI is essential to the tactical warfighter in his current and future missions of supporting the joint commanders in their operational and strategic goals. Many private and commercial corporations, ready to close the gap in communications at the tactical level, have already begun developing the trade space for HAPs. We must ensure that the requirements of the tactical warfighter are met by realistically developing and procuring appropriate systems.

¹⁰⁷ Hard, "Final Briefing," Slide 30.

c. Terrestrial / Aerial Communications Recommendations

While terrestrial communications technology is well developed and proven, such systems are rather ineffective when pushed BLOS. Future terrestrial communication systems and architectures focus on JTRS and SATCOM OTM. These areas are important and deserve due process. The push toward net-centric and flexible communications requires even more flexible communication platforms.

The Marine Corps future communication systems include the Command and Control On-the-move Network Digital Over-the-horizon Relay (CONDOR). CONDOR will use EPLRS and tactical data networks to link smaller units to higher either by extending traditional LOS communications via a mesh architecture or SATCOM.

Very Small Aperture Terminal (VSAT)/Support Wide Area Network (SWAN) is proposed to provide SATCOM capability further down the tactical chain to lower levels of the MAGTF. Although this system will increase the connectivity of commanders to higher via satellite it still does not give the tactical warfighter any better way to talk to his battalion or company commanders. It may provide better capabilities to lower levels than normal but they are still running over the same over-tasked space-based networks.

These systems should be net-centric and operate over any available network. These systems will provide a seamless architecture that would allow disparate units operating on different systems to establish communication and provide a degree of support to the tactical warfighter.

A promising addition to the terrestrial region for communication support is the use of tethered aerostats by the Army and Marine Corps. These systems provide many of the same capabilities expected from HAPs, with more developed and fielded technologies, albeit on a smaller scale and footprint. These platforms provide some tremendous capabilities for the lower levels of tactical command. The Rapid Aerostat Initial Deployment (RAID) from TCOM is such a platform that can be fitted with any number of payloads. Usually it is a down looking radar or sensor package for monitoring activities within a moderately sized footprint.

B. INTELLIGENCE, SURVEILLANCE AND RECONNAISSANCE (ISR)

The ability to visually observe and identify certain information about enemy or friendly forces, and terrain provides a tremendous tool that allows the commander to shorten his decision cycle and thereby act faster than his enemy.¹⁰⁸ This gives the tactical warfighter greater abilities to act first and bring combat power to bear upon his objectives more effectively and efficiently. This capability is more essential at the tactical level than ever before due to the more dispersed and independent operations conducted by tactical units.

1. Emerging ISR Solutions

a. Emerging Space ISR

Space has long been the region of choice for ISR capabilities. Nations first developed space based ISR systems during the cold war, in the form of national technical means, in order to verify treaty limitations concerning strategic and nuclear forces of their adversaries. These capabilities remain essential, perhaps more so today, to allow a nation to remain vigilant for strategic threats from deep within foreign locations. In the last couple of decades, the availability of space-based ISR has proven extremely useful in the prosecution of warfare at the tactical level. This support has not been specifically dedicated to the execution of conventional warfare, but rather provided when convenient and the priority of such support was allowable by the intelligence community for which the ISR systems were designed.

ORS and the TacSat program are currently experimenting with greater use of commercial off the shelf (COTS), and responsive space systems, advertised as support for the warfighter. These capabilities, while perhaps tailored to tactical level needs, are not able to fulfill those needs in any significant way. TacSat program satellites operate in low orbits, due to cost of production and launch. These low orbits translate to short availability periods over an area of interest, even shorter and more infrequent if not the

¹⁰⁸ John R. Boyd, *A Discourse on Winning and Losing*. Air University Library document number MU43947, August 1987.

specific region that the system was launched to cover. Further, to provide any useable level of persistence the number of satellites required in a LEO orbit would make the cost unfeasible in support of tactical operations.

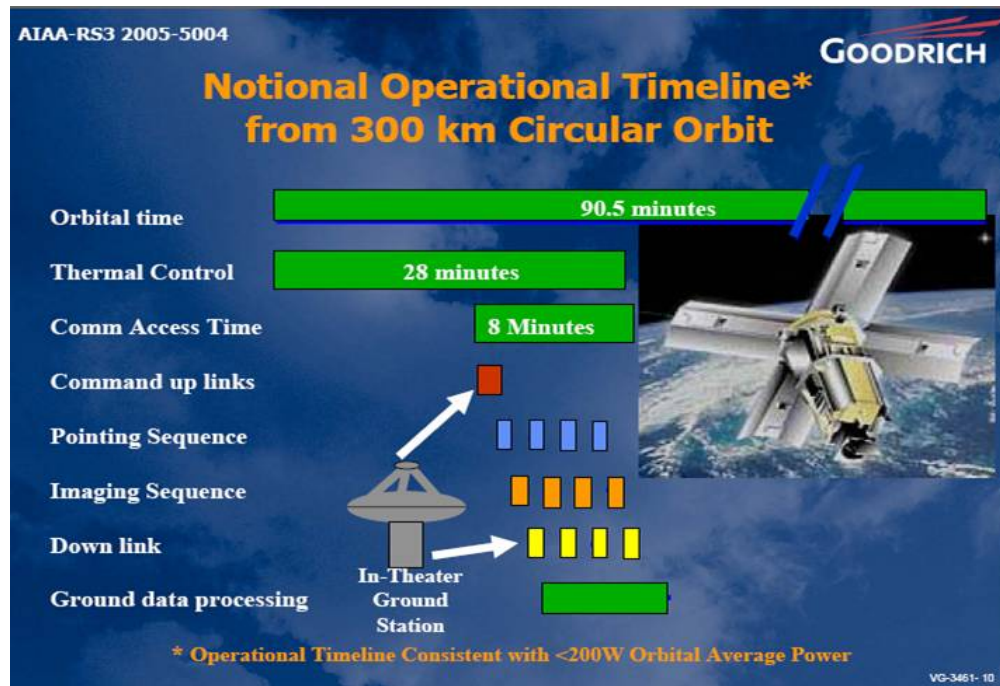


Figure 13. Notional Operational Timeline from 300km Circular Orbit.¹⁰⁹

Figure 13 shows a notional EO/IR TACSAT platform utilizing a modified version of the proven DB-110 sensor camera, currently used in aerial applications. Of note is the timeline included that shows the breakdown of system use during a typical 90-minute orbit. If the target and ground site are in favorable locations, this satellite can provide NIIRS 4.5 quality EO imagery from nadir to 30 degrees off-nadir and transmit that data to the ground station.¹¹⁰

Though the above chart gives very general timeline measurements, it clearly shows the limited communication access time of 8 minutes. A requirement for command uplink to be pre-determined and designated, and a very small window for pointing, imaging, and then down-linking the imagery to the ground station, that will likely give no more than 3 to 5 images over the target area, provided no drastic slewing is

¹⁰⁹ Charles Cox and Frederick Gilligan, "Reconnaissance Payloads for Responsive Space," Briefing to the 3rd Responsive Space Conference, 26 April 2005, Los Angeles, CA, Slide 10.

¹¹⁰ Gilligan, "Reconnaissance Payloads," Slide 9.

required and the target is close to nadir. This data then requires additional time, on the ground, for processing before it ever becomes available to imagery analysts to interpret what the image means and thus provide good intelligence value. Further, due to the orbits they operate in, these small satellites will only likely provide a handful of useful images over any geographical area in a day, and often not pass over that region for several days at a time. Such images, while obviously of some use, do not provide a reliable level of support for the tactical warfighter, who may conduct entire operations within the non-available time of the satellite system.

Emerging solutions to support the tactical warfighter directly from space with ISR capabilities seem to be beyond the cost benefits and current technology available. The utility of space-based systems are great but their specific ability to support tactical operations, whether due to priority, availability, or capability, is not yet convincing.

b. Emerging HAAI ISR

Emerging HAAI platforms, capable of filling the needs of the tactical warfighter, require the implementation of existing system capabilities, adapted to the HAAI and modified to meet the longer activity periods and expected reduced power capacity of HAPs.

The need for assets to fill gaps in tactical ISR, specifically using HAPs has already been explored for operations such as those ongoing in Afghanistan and Iraq. Developing systems, such as the High Altitude Reconnaissance Vehicle (HARVe), a product of John Hopkins University Applied Physics Laboratory, could provide a responsive ISR capability to a theatre commander or initial joint commander in theatre, in the distant future. This prototype could be rocket launched to its predetermined location and then deployed. After deployment, it would self-inflate and move to its assigned position. Currently the expected payload would be an imagery package.

The previously mentioned Zephyr HALE UAS also intends to provide ISR assets to the tactical warfighter. While developed to support Special Operations Forces in austere communication and ISR environments, the Zephyr could provide excellent capabilities to a tactical commander.

Another Zephyr orbiting at similar altitude provides persistent surveillance imagery down linked to local commanders thus improving the battlespace awareness of the team on the ground. Zephyr is stealthy and goes unnoticed. Zephyr's low cost means many platforms may be deployed in support of multiple missions.¹¹¹

Many of the currently developing and experimental systems are at the very beginning of the spiral technological development process. The technology needed to field a fully capable HAP for ISR does not exist yet. Commercial satellite ISR systems and existing UAS systems have set the groundwork for the optical sensor systems of these future HAPs. Actual fielded solutions may not see a single HAP performing all aspects of ISR for the tactical warfighter, but rather a HAP platform, outfitted modularly with different ISR payloads, will be the preferred system, based on changing requirements for information. It is understandable that the high altitude problem is a difficult one, but it shows the greatest promise in support of persistent ISR at the tactical level and as such, failure to pursue it with vigor is unacceptable.

c. Emerging Terrestrial / Aerial ISR

Terrestrial ISR capabilities, specifically those of low to mid altitude UASs and tethered aerostats have increased tremendously in recent history. Lower unit procurement and development cost, as well as immediate operational test fielding, has provided benefits that the tactical warfighter can see immediately. Operations in both Afghanistan and Iraq have provided not only the motivating need but also extremely challenging environments to test these systems in, under actual combat operations.

In Afghanistan, the US Army has employed radars mounted on high towers and in aerostats, with Raytheon acting as prime contractor for this Rapid Aerostat Initial Deployment (Raid) program. The Tcom-produced aerostat, which is far less expensive to operate than a fixed-wing drone, is flown for five days at heights of 350 to 900 ft, compared to the 110 ft of

¹¹¹ QinetiQ Corporation, "Zephyr HALE UAS."

the tower. It carries a 90 kg payload, normally consisting of a FLIR Systems Safire III EO/IR sensor. Three systems have been delivered and three more are planned. In Iraq, the US Army also employs the much smaller Lockheed Martin Rapidly Elevated Aerostat Platform (Reap), which is deployed from the back of a Hummer. It carries a 16-kg payload with Raytheon day/night cameras and operates at 300 ft, giving a horizon at 33 km. Two have been deployed to Iraq and two more are planned.¹¹²

The above example brings useful and developing technologies to the warfighter with a capability that will help him execute his mission while a system is in development. Using a developing system in operational use is beneficial to both developer and user, as it allows for actual use testing in authentic environments. It also provides the end user more input into the development of specific systems, better ensuring that the tactical warfighter needs are met in final production and fielding. These terrestrial based systems provide the tactical warfighter with five-day persistent capabilities formerly only available from national systems and aircraft, both of which are more expensive and are not under direct tactical control.

Other emerging terrestrial platforms are the UASs. Although already fielded in many areas and at many levels, the ability to provide more systems, at lower unit levels, provides capabilities where they are often needed most. With “Marine-proof” platforms that are simple to operate and rugged enough to withstand operation in rough conditions, these small, tactical UASs place few burdens on the tactical commander, while providing tremendous capabilities. Systems such as the SpyHawk UAS provide a technology test-bed in which to allow the Marine Corps Warfighting Lab (MCWL) to test emerging capabilities and subsystems for ISR possibilities. Systems such as this also provide a valuable service in developing concept of operations (CONOPS) and tactics, techniques and procedures (TTPs).

¹¹² Eric Biass and Roy Baybrook, “Shift in Service Attitudes,” *Armada International*, March 2006, Available at http://www.armadainternational.com/06-3/complete_06-3.pdf; Internet; Accessed on 12 September 2007, 2.

2. **ISR Recommendations**

a. Space ISR Recommendations

The recommendation for space systems supporting the ISR mission at the tactical warfighter level does not involve the development and launch of more space-based ISR systems, particularly those of electro-optical and infrared systems. Space based radar promises to provide a useful capability to the tactical warfighter, from space, specifically if fielded with aspects of coherent change detection (CCD) and moving target identification (MTI).

Likely, the greatest impact to the tactical warfighter from space will continue to manifest itself in the various services' TENCAP operations. These operations should be expanded, as they are well known for leveraging existing national and strategic systems with innovative methods of providing support to the tactical and operational warfighter. These capabilities from existing space systems do not require extensive development, manufacturing, launch or operations, making them much more cost-effective than the space systems they exploit.

The ORS TacSat program should continue development of lower-cost space systems and its exploration of support for the tactical warfighter. As the program develops and expands, in the future, the tactical warfighter may see real capabilities fielded that support tactical operations. The true tactical utility of these initial systems will likely be limited, but the research into solving the deficits of the tactical warfighter are important and the developments of this program may well enhance more conventional satellite development and fielding. Currently, persistent capabilities to the warfighter will only be possible with large constellations of satellites from this program, however.

While not the optimal solution for ISR capability in support of the tactical warfighter, the importance of space-based ISR assets should not be underemphasized.

The importance of freedom of overflight cannot be overemphasized as a positive aspect of orbital operations. Satellites are the only legal means by which overhead ISR can be performed deep inside the territory of sovereign nations during peacetime.¹¹³

¹¹³ Tomme, Paradigm Shift, 26.

If space continues to provide the capabilities that it is best suited for and not attempt to execute missions that are more effectively and efficiently executed by other systems, warfighters at all levels will find themselves with greater capabilities, better suited for their unique needs.

b. HAAI ISR Recommendations

The persistent surveillance from a fixed position by airships, in contrast to periodic snapshots from the moving platforms that satellites provide, furnishes two long-needed changes to military surveillance. These changes will allow continuous collection and comparison analysis over time of terrain covered by different sensors, such as infrared (IR), electro-optical (EO), and hyper-spectral imagery (HSI). Comparisons can highlight changes like freshly turned dirt along a roadway where bombs have been emplaced.¹¹⁴

This quote captures the essence of HAPs potential value to ISR at the tactical level. When air superiority has been achieved and ground forces are operating in close contact with enemy forces, the benefits of space-based systems, to support troops in close combat, become less important. Space based systems have proven their value consistently since their first uses, even with their many shortcomings. With the United State's ability to gain and maintain air superiority in many of our expected conflicts, it is confusing why these systems have not been in development for many years. From the days of the American Civil War and World War I, balloons and dirigibles have been able to monitor the lines and make detailed observations of the battlefield. It seems unthinkable that we have not continued to take advantage of similar "high-ground" technologies especially when advanced power sources and miniaturized electronics are making them so much more capable. With the value of airships to ISR established, we should now look to exploit this region for the true benefits that it holds.

Potential Missions for High Altitude Systems include Tactical Operations: Battle Damage Assessment, Targeting, Reconnaissance, Surveillance, Blue Force Tracking, Missile Warning, Strike Support, Strike Delivery. Tactical Support: Mapping, Tactical Communications, Theater Communications, PNT Augmentation, Meteorological Augmentation.¹¹⁵

¹¹⁴ Jameson, High-Altitude Airships, 31.

¹¹⁵ Hard, "Final Briefing," Slide 11.

The above list of tactical capabilities provided by HAPs is not all-inclusive. Such a platform, when mature and fielded, could support other collection capabilities such as MTI, CCD, and SIGINT collection. These possibilities need further research and evaluation to determine their validity for the HAAI and support of the tactical warfighter.

Only stationary or slow-moving platforms can provide the fine-grained temporal resolution demanded by new intelligence concepts, and such platforms provide the greatest cost/benefit ratio when operated from near space. From there they have extensive fields of view, are defendable, and do not conflict with conventional air operations.¹¹⁶

Link budgets and spacecraft sizing requirements are rather complex issues when designing satellites. Similar effects in HAPs, while tailored to the smaller tactical operations level, make it clear that HAPs are likely a better fit for the tactical warfighter than a satellite.

Considering a point at nadir, near-space platforms are 10-20 times closer to their targets than a typical 400-km LEO satellite. This distance differential implies that optics on near-space platforms can be 10-20 times smaller for similar performance, or the same size optics can get 10-20 times better resolution.¹¹⁷

The signal strength improvement for active systems such as radar or ladar would be factors of 10,000 to 160,000 (40 to 52 dB) for near-space platforms. These examples at nadir are *best cases* for the satellites, too.¹¹⁸

These are two examples of physical advantages of HAPs compared to similar orbital systems. Not only would the HAP perform better due to reduced distances between sensor and target (from a resolution standpoint), it is likely that these sensors would be less expensive, certainly for matters of persistence, due to the prohibitive cost required to conduct ISR from GEO or persistently from LEO orbits. The long-standing staple of the Air Force's UAS capability has limitations that HAPs can reduce or eliminate.

¹¹⁶ Edward H. Allen, "The Case for Near Space," Aerospace America, February 2006, 32.

¹¹⁷ Tomme, Paradigm Shift, 12.

¹¹⁸ Ibid.

Even when compared with air-breathing assets, near-space platforms are a bargain. A low-cost UAV that provides reasonably long persistence, the Predator, can carry 450 pounds to 15,000-25,000 ft, can travel 400 nautical miles and then loiter for 14 hours before returning to base—all for a price of about \$4.5 million each, not including infrastructure costs and the training costs required for the highly skilled rated officers the Air Force assigns to fly them. More expensive but more capable, the Global Hawk can take a 900 pound sensor package to over 65,000 ft, flying for more than 35 hours at up to 350 knots. The cost for this capability is projected to be about \$48 million each for the production versions of the aircraft.¹¹⁹

With the amazing capability that Global Hawk offers, a persistent HAP could deploy from within theater and operate for 7 to 30 times longer, providing support to the tactical warfighter within a coverage region of significance to his operational area.

The greatest persistence that a commander can currently expect from an air-breathing asset is about a day or so for a Global Hawk.^{55, 56} Air-breathing assets provide responsive, close-up, staring persistence for the duration of their limited loiter times. In contrast, one near-space platform currently receiving technology demonstration funding will be able to stay on station for *six months*, and planned follow-ons are projected to stay aloft for *years*.¹²⁰

With all evaluations and comparisons complete, we see that HAPs require some technological maturity. The spiral development and technological advances will quickly develop the HAAI systems as a mainstay of tactical and operational commanders. This allows better focus and utilization of our limited and very capable national assets in space. No one system can operate across the full spectrum of warfare, and should provide enough overlap with the next level to ensure a seamless transition. HAPs will not replace space-based assets, especially at the higher levels of war, but they can provide a tremendous increase in focused capabilities at the tactical level.

A combination of space and high altitude long-loiter radars provide an integrated air picture to the ABCS and emerging sustainment and BCS enhancing maneuver support and sustainment operations airspace management.¹²¹

¹¹⁹ Tomme, Paradigm Shift, 12.

¹²⁰ Ibid. , 14.

¹²¹ U.S. Department of the Army, TRADOC PAM 525-7-4, 35.

c. Terrestrial / Aerial ISR Recommendations

The future of terrestrial ISR specifically that of UAS systems, is a very mature field both conceptually and technologically. The ability of the warfighter at various levels to operate his own ISR systems when and where he needs them is a tremendous added capability. The Army's FCS UAS platforms should prove to be an ideal link in the overall architecture, by providing short-term persistence over small, tactically relevant areas.

Tethered sensors, already in limited use, will provide limited local area, persistent ISR. Future systems will fly higher, with longer endurance and greater capabilities. The payloads would be small and interchangeable with available power supply options. Mobile systems will allow this tethered capability, at limited speeds, or upon short halts.

The ability to have indigenous ISR assets without a reduction of combat power projection makes him more flexible and uncertain to the enemy. The ability to network the sensors into a complete picture on the battlefield or AO can increase situational awareness both up and down the chain of command.

C. BLUE FORCE TRACKING AND SITUATIONAL AWARENESS (BFT/SA)

BFT/SA provides the commander with improved visualization to understand force dispositions within his operational area. When properly working, he can see the distribution of his forces across the terrain as well as know where known or suspected enemy elements are in relationship to them. The systems are still new, compared to the other BLOS capabilities discussed, but few dispute their utility. In the best case, the commander knows the disposition of his forces, where his enemy is situated, and can see both of those bits of information with graphical overlays of his plan on digital terrain. This enhanced awareness allows him to make better and faster tactical decisions. In the current operational environment, knowing the location of widely dispersed and individually operating elements across a huge AO can prove extremely challenging. The commander needs to be able to trust his COP and the information provided to it by BFT/SA.

1. Emerging BFT/SA Solutions

a. Emerging Space BFT/SA

Space-based BFT/SA is still a developing concept, with the current use of FBCB2-BFT systems actually tested in combat and developed with feedback from operational testing. As lower-level units enter the system, the increase in subscribers often increases considerably. Without increases in bandwidth and available space systems to support BFT, the addition of subscribers results in increased latency and longer refresh rates. As FBCB2-BFT expands further, beyond users limited to those of the Army and Marine Corps, current systems will experience more latency. The increased time between updates of the local and regional COP offsets the advantage of adding more subscribers to the system. Future FBCB2-BFT systems will require additional satellite systems or more efficient bandwidth management techniques to have them remain useful with higher loads and subscriber numbers.

b. Emerging HAAI BFT/SA

There are currently no emerging interests or technologies for BFT/SA in the HAAI. The lack of this is by the design of the system to be space based for both security and utility around the globe.

The HAAI has a huge capability to fill in temporarily or permanently the needs of future BFT/SA systems. The ability to maintain position and be closer to the user will better support more tactical systems. While no proposed military uses of the system are known at this time, some investigation of similar civilian systems has been conducted.

On the other hand, HAPs can play an important role in enhancing communication capabilities in some GNSS services such as fleet management, traffic control, and infomobility. However, thus far, this aspect has not received much attention. In the case of fleet management and traffic control, mobile users (i.e., trucks or private cars) could transmit their position (computed by GPS), speed, and identification code to the HAP by using a low-cost only-transmit terminal; data are then forwarded by the HAP to the control center for traffic control or fleet management. The advantages of such a system with respect to the use of a satellite constellation (e.g., ORBCOMM) are threefold: The cost of the service (for each HAP) could be shared with other communication services. A single

HAP could be a complete and functional system locally, for instance, by exploiting fleet management in a metropolis. The improved link budget could reduce the transmit power as well as the cost and size of user terminals.¹²²

A system that provides better tracking for commercial vehicles, in a smaller package with less power requirements can surely have tremendous impact on tactical systems that conduct the same basic mission. HAPs can be tremendously useful in the tracking of friendly forces in an AO.

The absence of current military research into this area may be due to the disparity in evolving terrestrial systems currently used. As existing systems make more efficient use of both radio and satellite-based BFT/SA systems, the utility of the HAAI platforms as enablers of these capabilities will likely increase.

c. Emerging Terrestrial / Aerial BFT/SA

BFT/SA is one area of tactical capability where the move towards jointly developed systems can produce extremely positive effects. Joint FBCB2 is a great example of this capability, with a future integrated and truly joint COP a real possibility. Consequently, these systems should allow supporting arms branches within and external to the Army and Marine Corps to better support the tactical warfighter. The ability for air and indirect fires to know the disposition of troops should greatly reduce the possibility of fratricide incidents.

2. BFT/SA Recommendations

a. Space BFT/SA Recommendations

The space segment of BFT/SA is currently the only way to execute the mission BLOS without extensive radio retransmission systems. Because the space-based and terrestrial radio-based systems cannot interact at the user level, it is sometimes necessary for elements within a unit to have both systems in order to understand their own unit and those around them. Expanding L-Band access on future space architectures will ensure that as the BFT systems mature and grow that we will not face the access problem we currently have in communications.

¹²² Cianca, "Integrated Satellite – HAP Systems," S37.

Whenever units are operating in widely dispersed terrain, out of easy LOS with each other, BFT becomes the tracking system of choice. In the close fight, units of the same organization enjoy much more functionality and decreased latency by use of LOS systems of a similar nature that operate over EPLARS radios. The shortcoming between the two is that FBCB2 and FBCB2-BFT do not share information between themselves. Efforts to fix this shortcoming and conduct information sharing require COP information from both versions of the system be sent by satellite to a processing system where they are then converted and transmitted back to both systems as a COP update. This adds even greater latency than already experienced by the heavily subscribed L-band FBCB2-BFT systems.

Efforts must be made to both increase bandwidth for the L-band BFT systems while simultaneously increasing the efficiency of the user hardware and software that uses the system. Satellite-based BFT systems are useful and likely essential to our future combat operations at the tactical level and should be greatly expanded to provide BFT/SA to those forces operating beyond LOS, especially in immature theaters of operation.

b. HAAI BFT/SA Recommendations

“Potential Missions for High Altitude Systems include Tactical Operations: Battle Damage Assessment, Targeting, Reconnaissance, Surveillance, Blue Force Tracking, Missile Warning, Strike Support, Strike Delivery.”¹²³ The above quote included BFT as a potential mission two years ago. The subsequent progression of technology and capability should enable attainment of developmental capabilities today.

The expansion of FBCB2 and EPLRS LOS systems to make use of the HAAI would immediately benefit the tactical warfighter. Giving traditional LOS systems the BLOS/OTH advantage will greatly increase battlefield SA for those users while reducing required retransmission stations. Additionally, L-band BFT systems could perhaps benefit from a local transponded signal from a HAP that replicates the L-band system from satellites using the system.

¹²³ Hard, “Final Briefing,” Slide 11.

The space segment of BFT/SA cannot be discarded, but it can be relieved of the burdens of most tactical users, allowing it to track and service other users more efficiently. Existing FBCB2-BFT systems could be software converted to utilize antennae placed in the HAAI to process and propagate BFT information within the footprint of the system. The HAP could then use L-band to transmit the consolidated footprint COP for L-band BFT to the central processing centers for update of the global COP. Further, the use of L-band to satellite would provide an excellent redundant capability should the HAP system malfunction or be destroyed.

A HAP designed to support BFT/SA could provide increased capabilities in four major areas: retransmission of EPLARS FBCB2, retransmission of FBCB2-BFT in local region, integration and transmission of disparate FBCB2 systems to one another, and integration of both FBCB2 and FBCB2-BFT COPs into the global COP.

A HAP BFT/SA system could act as a single-point retransmission system for all EPLARS FBCB2 information within the footprint of the HAP. On-board computers, controlled from the ground, could consolidate this COP and propagate it, using existing EPLARS radio nets, to all units within the AO, subject to filters and other access rights. This would allow for a much shorter latency between distant units at all levels of command. It would also reduce loss of units from the COP if the vehicle or system that relays information to the next higher level of command malfunctions or is destroyed.

The same HAP could receive L-band BFT signals in the HAAI and perform local area consolidation, processing, and retransmission of BFT signals within its own coverage area. Reducing the requirement for the information to travel to CONUS and back over the L-band link would reduce latency for all users within the footprint of the HAP. The HAP could then consolidate the regional BFT COP and forward that over satellite link to the global operation center for update of the global COP.

Finally, on-board processing would allow the HAP to consolidate the COPs from FBCB2 and FBCB2-BFT systems into a single consolidated COP and transmit over both EPLARS and L-band to both user groups within the footprint. Using automation aboard the HAP, the requirement for higher headquarters elements to

consolidate and then push the other COP information down into their own system would cease to exist. A HAP system operating in support of BFT/SA could drastically improve all aspects of the capability, mitigating many of the current and future limitations of the system.

c. *Terrestrial / Aerial BFT/SA Recommendations*

The most important improvement to BFT/SA systems within the terrestrial region is that the system is fielded to lower-echelon units using hardware and software that is feasible for those units. In the future, all soldiers operating in an AO should populate, when desired, the COP at various levels. Each soldier does not necessarily need access to the COP or SA personally, but he should propagate his position into the system so his leaders know his location. The employment of the FBCB2-CDA looks to fill that niche. The Commanders Data Assistant (CDA) would provide the unit commander with a COP on a hand portable unit smaller than a clipboard.

D. POSITION, NAVIGATION AND TIMING (PNT)

Position, Navigation and Timing (PNT) refer to the key capabilities provided by the Global Positioning System (GPS) and associated receivers. Over the past twenty years, these capabilities transformed from nice to have to critical assets at all levels of operations. It is rare to see any fielded system fail to integrate some capability provided by PNT.

1. Emerging PNT Solutions

a. *Emerging Space PNT*

There are no emerging U.S. solutions to any of the foreseeable deficits in PNT from the space segment. Other nations are developing their own versions PNT constellations, which might augment our own system capabilities. GPS Block III is scheduled for fielding and is anticipated to address many of the deficiencies in current and future PNT, while remaining compatible with legacy constellation parts. Other countries have seen the incredible value and edge that the GPS system has given the United States and are currently fielding their own navigation systems.

b. Emerging HAAI PNT

To assist the user, both ground and airborne, HAAI platforms have the potential to increase availability and security from jamming or spoofing to the tactical warfighter. Differential GPS (DGPS) is not a new concept and the Coast Guard has employed it successfully for years to provide additional signals for maritime shipping lanes. Both commercial and military organizations realize the added benefit that HAPs can provide.

The Air Force Space Battlelab is currently working a preliminary investigation of GPS accuracy augmentation and GPS reconstitution using near-space platforms, and the Air Force Unmanned Aerial Vehicle Battlelab recently conducted a similar investigation that successfully demonstrated the usefulness of a UAV as an aid to GPS navigation in a jamming environment. There appear to be no technical hurdles to either augmentation or reconstitution via near-space platforms, although the number of required platforms would be significantly higher than the existing constellation to provide global coverage. It would appear to be more realistic to envision near-space reconstituting theater-sized regions.¹²⁴

The military utility of HAAI platforms provides an area to exploit the known advantages of PNT. The argument that we need global coverage would seem poorly formed since it is seemingly very unlikely that someone or thing could jam our entire constellation simultaneously. The current satellites can operate autonomously for some time without ground updates.

HAPs can provide support services to Global Navigation Satellite Systems (GNSSs) such as the Global Positioning System (GPS) and Galileo. It is recognized that as a local component of a GNSS, the HAP can enhance the required navigation performance (RNP), that is, accuracy, availability, integrity, and continuity, with respect to terrestrial components. A system that enhances the RNP for a local area (ranging from hundreds of meters to hundreds of kilometers) is often referred as a local-area augmentation system (LAAS). An augmentation system that operates on continental areas is referred as a wide-area augmentation system (WAAS). Due to its visibility, a single HAP can be a LAAS while a constellation of HAPs can provide a WAAS.¹²⁵

¹²⁴ Tomme, *Paradigm Shift*, 29.

¹²⁵ Cianca, "Integrated Satellite – HAP Systems," S37.

The military could deploy such systems when needed. For long conflicts, addition of DGPS to HAPs could provide more accuracy, especially within urban or mountainous areas, as well as easier detection of jamming and spoofing due to the higher strength signal available on the HAP.

Further studies support the feasibility of HAAI platforms to support the PNT structure, thus providing greater support to the tactical warfighter and those directly supporting him and his mission.¹²⁶ This would be a valuable tool in the fight against adversary jamming and spoofing attempts.

c. Emerging Terrestrial / Aerial PNT

Terrestrial PNT systems are currently the only way to cope with the deficit that is both existing and expected in the future. Emerging technologies in the system hardware and software show promise in supporting the tactical warfighter.

Improved military receivers, compatible with both Block II and III GPS satellites, provide the user with information about his PNT environment. The ability to lock and maintain signal reception in the face of jamming lets him continue the fight and know that someone is attempting to disrupt this capability.

Selective Availability / Anti-Spoofing Module (SAASM) provides the user with greater assurance of good authenticated signal. It has a further benefit of reducing the workload on users and support with new keying techniques to ensure secure codes.

These emerging capabilities will provide the user greater support into the near future. Continued development must follow to ensure the tactical warfighter stays ahead of the adversary, especially as other nations field alternatives to GPS and the proliferation of spoofing and jamming systems increases.

¹²⁶ Hard, "Final Briefing," Slide 11.

2. PNT Recommendations

a. Space PNT Recommendations

Space has long been the domain of PNT systems and is ideally suited for that purpose. The continued fielding of the Block III GPS constellation will provide greater support to everyone. Adversary countermeasures to our Block III systems are expected and future systems will need to overcome these countermeasures with enhanced technology or operational employment. This would be an evolving utility for the follow on to GPS Block III.

b. HAAI PNT Recommendations

In the area of HAAI, there are great possibilities and recommendations ideally suited for direct support to the tactical warfighter. Together these will assure continued success in his missions. As mentioned before, DGPS could be easily adapted to HAP. With the much closer position relative to the user, signal strength would be significantly stronger and therefore more resistant to jamming or spoofing. This would provide additional, stronger signals to augment the future constellation. The ability to attach a DGPS payload and deploy it into HAAI would give the theatre commander and his troops a more reliable PNT architecture.

With this added signal and additional safeguards, this platform would have the capability to broadcast any detected jamming or spoofing attempts within its capabilities. This would allow for precise positioning and targeting for any device and or its user. It may even be possible for the higher-strength HAP mounted DGPS system to broadcast an unhealthy status message that would take the jamming or spoofing system out of use until it could be terminated.

Further, a constellation of multiple HAPs could augment or even replace the GPS constellation, if required, by providing a dispersed aerial constellation of transmitters. This would provide regional GPS-like capabilities with potentially greater signal strength to combat widespread jamming or other disruption of GPS signals to the tactical warfighter.

c. Terrestrial / Aerial PNT Recommendations

The greatest limitation of terrestrial PNT capabilities is the fielding level of PNT receivers. Fielding of military issued units to all elements of tactical units that can make good use of them has not yet occurred. The current fielding of PNT receivers does not extend far enough down the tactical chain. Other smaller units and individuals do not have access to a military receiver, causing many individuals and units to procure COTS systems to fill this gap. Reliance on civilian systems, without the increased security and accuracy of military signals and capabilities, can increase risks to the tactical warfighter.

The development and fielding of smaller and more capable receivers, further down the tactical warfighter organizations, will provide the smallest unit or individual to be an integral part of the mission and allow him to maintain his own PNT knowledge.

When conflicts lead to a prolonged engagement, the military could deploy a ground based DGPS position. This would provide the commander and his troops with a very strong, ground powered, GPS signal to ensure authentication and security.

These recommendations for support to the tactical warfighter would assist in reducing the deficit in PNT for the tactical warfighter at the terrestrial level. Incorporating major portions or significant pieces in all layers would ensure PNT to that tactical warfighter level for the near future.

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VI. CONCLUSION AND RECOMMENDATIONS

The tactical warfighter needs expanded BLOS capabilities to support his current and emerging operations in a more autonomous manner over larger distances. This thesis has identified the tactical warfighter, what his BLOS requirements are, where these requirements are in deficit, and recommends architectural improvements to meet these deficiencies.

The ground tactical warfighter, the focus of this thesis, fights in an operational environment that is most often sparse in terms of infrastructure. The terrain is complicated, in the worst cases, consisting of urban and mountainous terrain, both of which increase the difficulties of operating in distributed formations. As LOS decreases, due to terrain, operational complexity increases, often due to the need to augment LOS capabilities with BLOS alternatives. Currently, the only fielded options for this augmentation requires the use of satellite systems hundreds of miles from the earth's surface and utilizing specific equipment to interact with them.

This thesis identified the four most important BLOS requirements of the tactical warfighter as communications, ISR, BFT/SA, and PNT. Each of these requirements provides the tactical commander and his subordinates increased ability to conduct operations across greater distances than ever, in complicated and difficult terrain, that does not favor reliance on LOS systems. Currently the tactical warfighter faces some deficits or limitations in each requirement, most of which will likely increase in the future. While improved systems are in development for future fielding, these systems will not likely overcome future deficits; at best, they will meet currently noted deficiencies in most of these requirements.

Chapter IV investigated current and future system capabilities and deficits within each requirement area, discussing the clear and current deficits that limit the tactical warfighter in today's operations. Identification of future deficits demonstrated a widening gap between the capabilities of systems in development and the expected requirements in each area needed by the tactical warfighter as operational areas expand and autonomous operations increase.

Chapter V identified emerging solutions, those systems or capabilities that show some promise but are not funded or in current development. An evaluation of these emerging systems or technologies led to recommendations in each requirement area, in the regions of space, the HAAI, and the terrestrial and aerial layers. Recommendations covered all three regions, including support of continuing or enhancing future planned systems as well as development and research into new areas, most specifically the greater exploitation of the HAAI. The largest portion of the discussion surrounded the HAAI due to that region's status as a new frontier for deployment of tactically supportive systems. Decades of experience in space and the air, along with centuries of experience on the ground, make technologies in those areas extremely mature. The HAAI, only recently seriously considered as an operational region, shows the greatest area for revolutionary alternatives to existing deficits.

A. REGIME RECOMMENDATIONS

Ultimately, no single platform or architecture will meet the BLOS requirements of the tactical warfighter. Often the solution to the tactical warfighter's requirements changes with his operational environment. In some cases, LOS communications are not a limiting factor, while other times, he must rely solely on satellite systems for his various needs. Within this tactical spectrum, lie the range of operational challenges requiring communications, ISR, PNT and BFT support. In these situations, only a consolidated and integrated architecture, made up of systems in multiple regions can meet the tactical warfighter's needs. The tactical warfighter must be equipped to conduct his mission successfully and he must be able to shed the limitations of his "disadvantaged user" status concerning BLOS systems.

The tactical space that supports the tactical warfighter composes the areas around and above him that provides him these LOS and BLOS capabilities discussed in this thesis. The following recommendations show a path, one that is more likely to meet future needs in the four areas identified, and more able to reduce future deficits in these critical requirements. A single region cannot meet all the tactical warfighter's needs.

The challenge is to identify and develop the proper systems within the appropriate regions to support the tactical warfighter with robust capabilities that enable him to accomplish present and future missions.

1. Space Regime Recommendations

We do not launch satellites just to launch them—space launch is a very expensive proposition. We launch satellites only when we determine them to be the best way to get the desired effects related to their missions in spite of their costs.¹²⁷

This statement is essential to the operation of an efficient and capable military space program. Space systems are extremely expensive and while often capable of supporting a wide range of requirements, they are very often not the most efficient or effective system for a task. Space systems are only the right choice if they are the best way or the only way to accomplish a mission. In most situations, using space to solve a terrestrial-based mission is likely to be many times more expensive than other alternatives.

Space provides our nation with many advantages, which are historical, political and technological in nature. The status of the United States, known as a space-faring nation brings tremendous international prestige and technological advantages. Space systems are less limited by matters of politics than non-orbital systems, and provide true global reach and coverage to our military forces. Space provides us many capabilities within the four critical requirement areas discussed in this thesis that would not be possible without orbital assets. The tactical warfighter uses many space assets to support his tactical operations. In some cases, space is the tactical commander's only link to outside forces and higher headquarters, and therefore critically necessary for his mission success.

Future land force operations will be regional in nature, possibly in strange areas, on short notice, with joint, combined or coalition forces, and in concert with other agencies of government... At the strategic level of war (global projection), space capabilities are used primarily to reduce the National Command Authorities' (NCA) uncertainties and support the combatant commander's requirements to execute our national security

¹²⁷ Tomme, "Balloons in Today's Military," 4.

policy... At the tactical level (ground projection), space systems provide real-time and near-realtime support to the combat, combat support, and combat service support forces that execute battles and engagements on a non-linear battlefield (i.e., close, deep, and rear operations). During combat, space systems provide: realtime position and navigation (POS/NAV) data (with accuracy unavailable from terrestrial sources); near-realtime surveillance and warning of enemy locations, activities and strength; current and projected weather information; terrain and hydrographic information, as well as other conditions of the battle space; and both internal and external communications to enhance the synchronization of close, deep, and rear operations. Seeing deep is crucial to our ability to disrupt the enemy's tempo and effectiveness of his follow-on operations. Space systems provide targeting information needed to support deep operations. Space systems can provide a more robust battle management command, control, communication, computers, and intelligence (BMC4I) architecture in conduct of theater/tactical missile defense (TMD) at the tactical level, as well as at the operational and strategic levels. Additionally, they provide an opportunity to reduce the need for man-in-the loop by streamlining the sensor-to-shooter linkage process.¹²⁸

The extract above highlights the Army's view on space and its benefits to the warfighter at all levels. Space is capable of providing the tactical warfighter with all four BLOS requirements discussed in this thesis; the issue becomes the availability and capacity of those space systems to meet all of these requirements sufficiently. Future systems seek to increase the number and capabilities of space systems, in some cases with support specifically designed for the tactical warfighter. Unfortunately, these systems cannot meet the tactical warfighter's current needs nor will they meet his future ones.

Space can provide for the communication needs of the tactical warfighter, if those limited systems prioritized tactical support. Existing space systems do not consider the tactical warfighter as their primary customer, nor are they designed for supporting him. Space provides nearly global communication support to those warfighters given access and priority.

At the strategic level of warfare, space-based ISR is the standard of choice and for good reason. ISR from space allows for legal over flight of foreign territory, providing

¹²⁸ U.S. Department of Defense, Department of the Army, Training and Doctrine Command Pamphlet 525-60: Concept for Space Support to Land Force Operations, (Washington: Government Printing Office, 1994), 1-1.

for greater national security, and allowing for accurate intelligence development, given sufficient time and priority. The tactical warfighter rarely has the availability of time or the allocated priority that makes space systems his best choice for ISR. These systems, while quite capable and useful, are generally not responsive enough to meet his needs effectively and in a timely manner. Further, the use of space-based ISR systems for tactical operations requires that some higher-level requirement for information is not met at the same time.

The use of space systems in support of BFT/SA provided the premier opportunity for some level of global situational awareness in military operations. Due to limitations in LOS systems and interoperability between different units using those LOS systems, space became a clearly suitable option for global SA. Space will continue to provide this essential capability to know the disposition of friendly forces, which aids greatly in the reduction of fratricide incidents. At the tactical level, the latency of a space architecture is unfortunately a tremendous limitation in the systems usefulness at the tactical level. The metrics of measurement in the close fight, the realm of the tactical warfighter, are measured in seconds, not minutes.

Global PNT is impossible without the use of satellites. The GPS constellation provides a tremendous capability, not only to warfighters at all levels, but also to the entire world. Limitations of these systems, specifically concerning the distance they operate from earth, make them vulnerable to enemy interference, as well as terrain effects.

Generally, space is not well suited for supporting the tactical warfighter due to physical and operational reasons as outlined in this quote.

Developing *tactically* useful payloads that can take advantage of responsive launch, however, is a different matter. A combination of *physical constraints* placed on satellites by orbital mechanics and *operational requirements* placed on their payloads by the missions that can be performed from space prevent all but the most rudimentary tactical missions from being attainable for the foreseeable future. Foreseeable tactical satellite capabilities mean that tactical requirements of persistence and coverage can only be filled by constellations of relatively large numbers of satellites. If these missions are carried out, they will cost

hundreds of thousands to millions of dollars per hour in overhead, costs that would seem to be beyond the reach of tactical or even theater commanders.¹²⁹

Space is an essential region that provides the seamless continuity from strategic to operational, and often tactical. Support to the tactical warfighter from space, when other regions are better suited to his needs, reduces those systems' capabilities to support operational and strategic needs. The tactical warfighter needs responsive systems, developed with his requirements in mind, and dedicated to supporting him. Space is not often the best way to meet the tactical commander's needs.

2. High Altitude Area of Interest Regime Recommendations

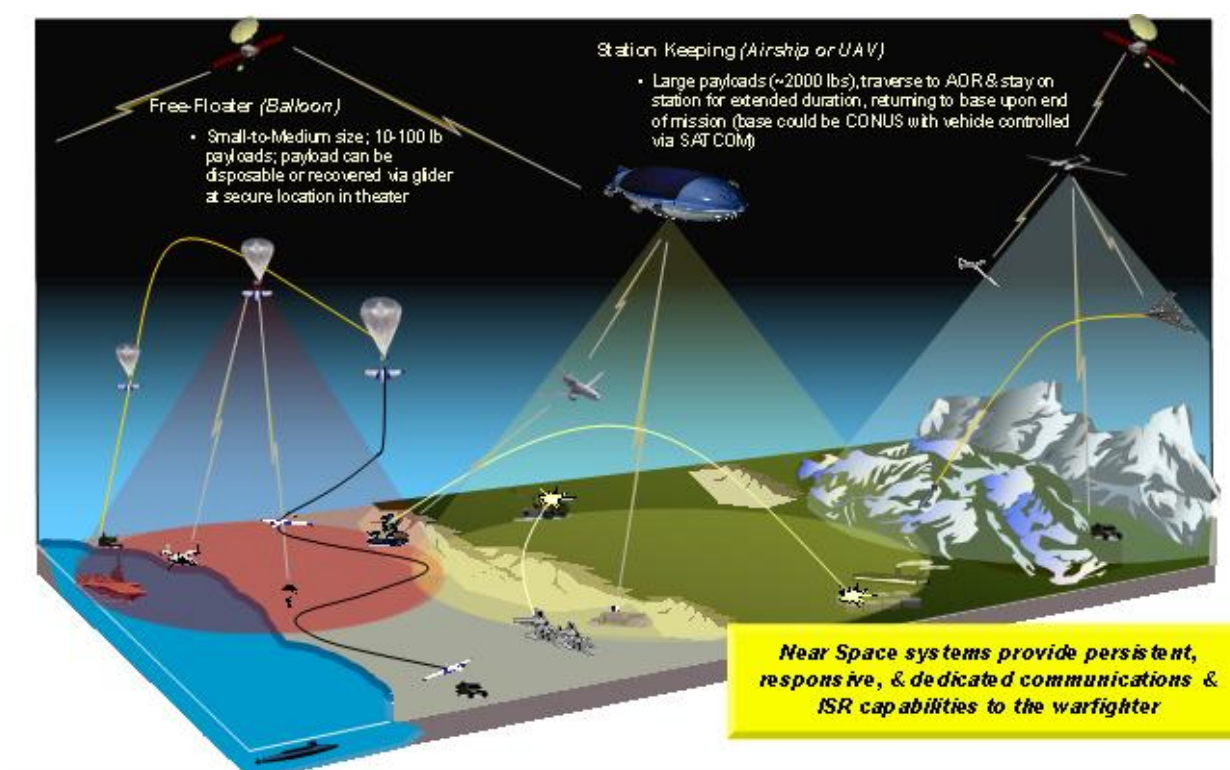


Figure 14. High Altitude Contribution to warfighter.¹³⁰

There are many systems in early development within the HAAI and some currently fielded on the lower end of complexity. This thesis does not intend to recommend which of the many types or models of HAP to develop or field, but rather to

¹²⁹ Tomme, *Strategic Nature*, ii.

¹³⁰ Rick Folks, "Near Space," Briefing to Joint Chiefs of Staff, Slide 8.

note that operational platforms within the HAAI will provide tremendous and much-needed capabilities to the tactical warfighter that cannot be otherwise fulfilled. Figure 15 shows a representative sample of HAPs in research or development. These systems generally fall within three broad categories; free floating balloons, steered floater platforms, and high altitude maneuvering systems. Within the latter category, there are further divisions into lighter than air, UAS, and hybrid systems.

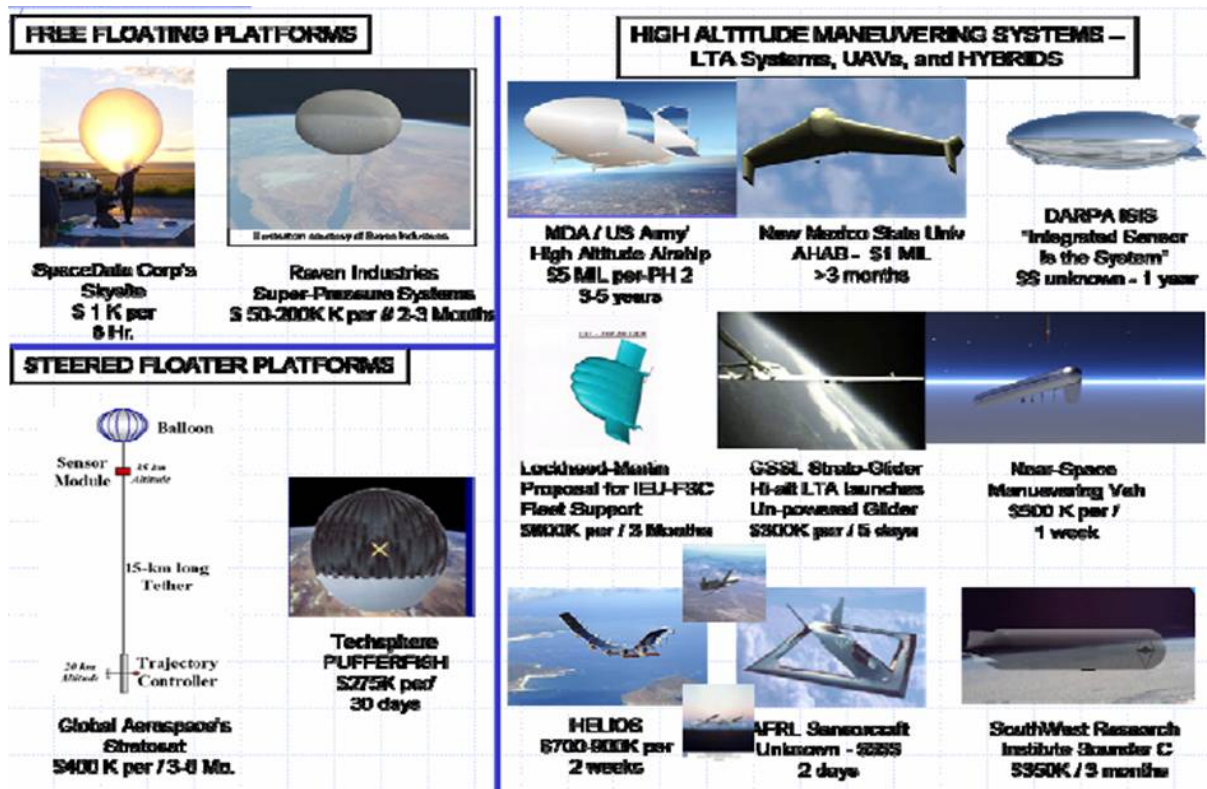


Figure 15. High Altitude Representative Platforms.¹³¹

Army doctrine already acknowledges the utility and necessity for systems operating in the HAAI in the four requirement areas of communications, ISR, BFT/SA, and PNT.

Systems operating in the high altitude region have the potential to provide rapid, on demand, dedicated capabilities augmenting strategic space assets. Further, high altitude long-loiter systems may be developed as part of the aerial layer, thus providing persistent, organic capabilities to the operational and tactical commander. These systems may provide effects such as robust

¹³¹ Hard, "Final Briefing," Slide 7.

communications, theater-centric intelligence, surveillance and reconnaissance (ISR), operational environment situational awareness, battle damage assessment, enhanced positioning, velocity, timing and navigation augmentation capabilities, and the capability to cross-cue intelligence and non-intelligence platforms leading to more responsive and comprehensive targeting information.¹³²

Further, the same document places these HALE platforms in support of tactical commanders, providing them with BLOS communication and ISR capabilities in restrictive terrain.

HALE platforms in the high altitude region are dedicated to tactical commanders. These assets link and provide positive C2 of operations such as: over-the-horizon and BLOS reconnaissance and surveillance, and attack operations; long range maneuver in difficult and restricted terrain; non-contiguous operations over extended distances. It is these assets that bring the connectivity of the network to the “last tactical mile.”¹³³

There are many versions of these systems in development and there are several significant technological challenges that must be overcome, specifically in regards to power and station keeping, especially in the lighter than air systems. Perhaps more detrimental to their development is the lack of sufficient funding devoted to this promising regime that is highly conducive to supporting the tactical warfighter. HAPs promise to provide much-needed capabilities in support of the tactical warfighter that planned development of the space and terrestrial regions do not meet. HAPs promise to be persistent, multi-functional, networked, expeditionary, flexible, repairable, and relatively inexpensive compared to current and proposed space systems.¹³⁴

¹³² Department of the Army, TRADOC PAM 525-7-4, 12.

¹³³ *Ibid.*, 37.

¹³⁴ Charlie Lambert and Mike Grace, “The High Altitude Airship in Cruise Missile Defense,” Briefing to the 2006 UCCS Near Space Symposium, Colorado Springs, CO, 16 November 2004, Slide 5.

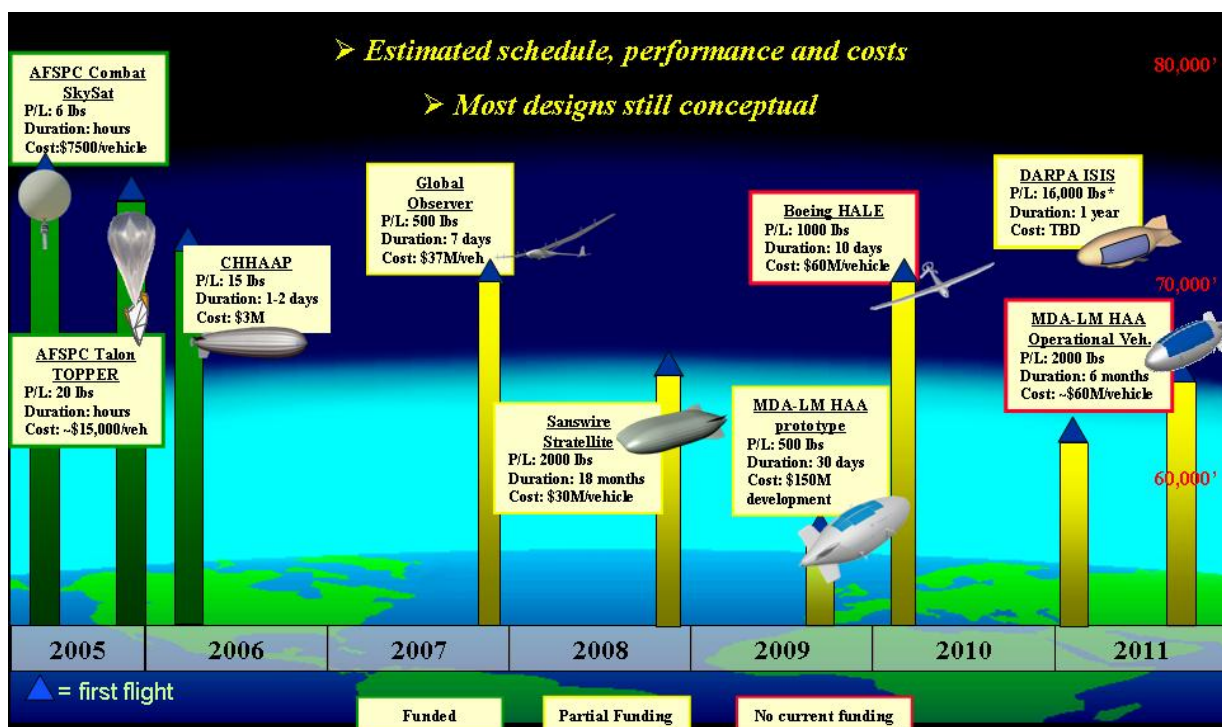


Figure 16. Near Space Alternatives and Timelines.¹³⁵

Unlike space systems and UASs, HAPs have a potential advantage in persistence. With systems designed to occupy an extremely low geostationary position, HAPs provide the tactical warfighter with BLOS support over extended periods and in direct support of his mission.

Although the near-space advantages in footprint size, resolution, received and radiated power, cost, and survivability are significant, perhaps the most useful and unique aspect of near-space platforms is their ability to provide responsive persistence, the ability to deliver their space effects to battlefield-commander-specified locations around the clock with no gaps in coverage.¹³⁶

HAPs maintain several advantages in both communications and ISR capabilities due to their distance from the supported user. Table 9 shows a brief comparison of distances applicable to both communication links and ISR collections for space, near-space, and UAS systems. Tactical, man-portable LOS radio systems have secure communication ranges that are able to transmit to a receiver in the HAAI. These radio systems can transmit with omni-directional antennas, on the same nets and frequencies

¹³⁵ Folks, "Near Space," Slide 5.

¹³⁶ Tomme, "Balloons in Today's Military," 7.

that they conduct LOS communications. This advantage in range, combined with large, tactically relevant footprint sizes for HAPs, provides a tremendous potential for the tactical warfighter to achieve reliable and continuous BLOS communications with existing and future radios designed primarily for LOS, while freeing satellite communications for use by those who truly need them and do not have a HAP alternative available.

Asset Type	Distance to:				
	Asset Altitude	Horizon	5 deg lookup	10 deg lookup	45 deg lookdown
Predator	15,000 ft.	150 miles	30 miles	15 miles	3 miles
Near-Space	120,000 ft.	425 miles	200 miles	120 miles	25 miles
LEO	200 km.	980 miles	700 miles	500 miles	120 miles

Table 9. Comparison of Mission-useful Distances for Various Platforms.¹³⁷

The same distance advantage that gives HAPs an enhanced communication capability provides advantages in ISR. Distance to the target and size of the optic are the primary attributes that determine ISR system resolution. HAPs bring the system much closer to the target, enabling either greater resolution with the same size optic, or the same resolution in a smaller optical system. Further, their potential for persistence provides further advantage over competing ISR systems where over flight and maneuverability are not concerns.

HAPs can provide enhanced support to both EPLARS and L-band BFT/SA systems. BFT systems emplaced on HAPs could receive, consolidate and retransmit BFT signals from both LOS and satellite systems within the same geographical region. This would provide faster refresh rates for both types of systems as well as more seamless translation between the different systems.

While HAPs could theoretically provide global PNT, the size of the constellation would be immense and entirely cost ineffective. What HAPs can provide in the area of PNT, specifically in support of the tactical warfighter, is the ability to provide a higher strength DGPS signal as well as enhanced capabilities to detect jamming and spoofing, as

¹³⁷ Tomme, Paradigm Shift, 25.

well as notify units within their footprint that such actions are occurring. An alternative use for HAPs in this requirement could use multiple HAPs to create a regional PNT system replacement, where the space-based GPS system was for some reason unavailable.

3. Terrestrial / Aerial Regime Recommendations

While many ground based terrestrial systems aim to provide enhanced capabilities to the tactical warfighter, the systems that provide greatest BLOS usefulness are the UAS and the tethered aerostat. The Army and Marine Corps currently field these systems, in limited numbers, to tactical units in wartime operations. These systems can perform missions in support of communications and ISR.

There is no question about the utility and capability of UASs in support of the tactical warfighter. The fielding of UASs at lower levels of command provides tactical commanders excellent capabilities to conduct their own airborne ISR on timelines that they choose. This allows tactical commander the ability to see where they need to, when they need to and thereby lets them make better-informed tactical decisions.

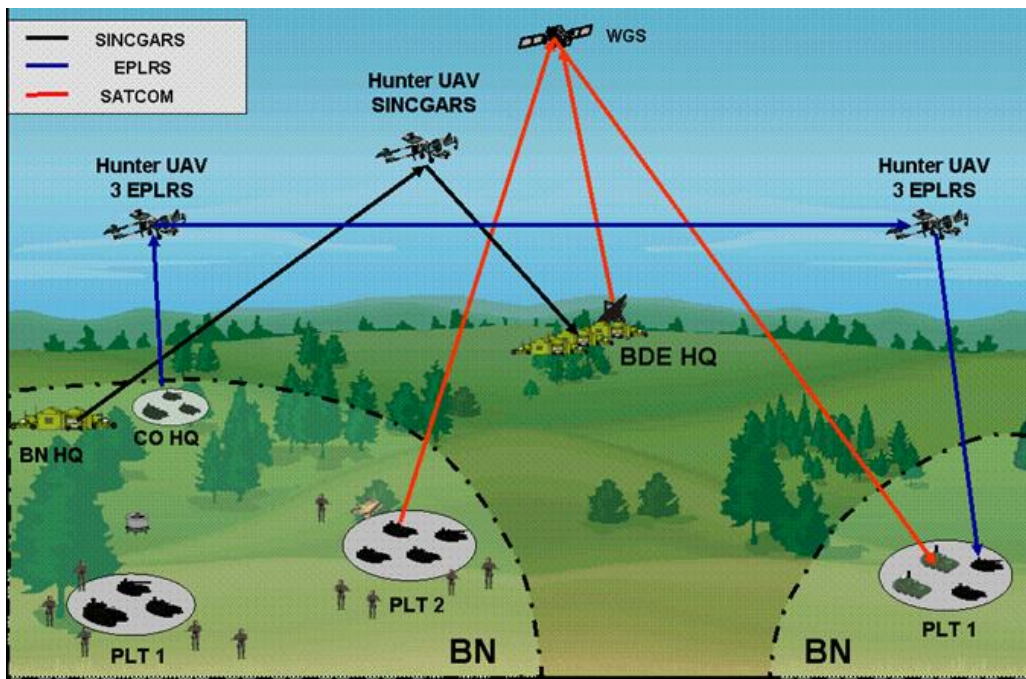


Figure 17. Recommended Range Extension Architecture.¹³⁸

¹³⁸ Langan, "Interim Integrated Network Study," Slide 39.

In the future, UASs will provide temporary and localized enhancement of communications and BFT/SA systems for tactical warfighters, on their chosen timelines. Figure 17 shows how UASs can augment both requirements, at the tactical level, without the requirement for satellites or multiple ground-based retransmissions. The unit will own and operate these systems, allowing them to use the UAS to extend their LOS communications without the requirement for security of multiple land-based retransmission sites. Recent studies found that without some sort of aerial layer, future networks are not sustainable due to bandwidth or latency reasons. The future roadmap for UAS considers UASs as a key asset in support of communications at the tactical level.

[Aerial Communication Nodes] (ACNs) can enhance intra-theater and tactical communications capacity and connectivity by providing 1) more efficient use of bandwidth, 2) extending the range of existing terrestrial LOS communications systems, 3) extending communication to areas denied or masked to satellite service, and 4) providing significant improvement in received power density compared to that of satellites, improving reception and decreasing vulnerability to jamming.¹³⁹

Currently, UASs provide the tactical warfighter with excellent and responsive ISR capabilities within the limit of their range and endurance. The future sees more capability with increases in range and duration, as well as fielding to the lowest level of tactical operations. While not persistent, they allow tactical commanders to maneuver them to observe locations within their AO at specific times and from specific points of view.

Figure 17 shows the use of UASs for augmentation of existing LOS EPLARS BFT systems, which is essentially the same as employment of UASs for LOS communication extension, only with the retransmitted nets being EPLARS based FBCB2 signals. This technique increases the range of these FBCB2 coverage areas without the requirements for security of ground or unit-based retransmission paths.

¹³⁹ Office of the Secretary of Defense, Unmanned Aerial System Roadmap 2005-2030, 61.

B. RECOMMENDED SOLUTION

As stated previously, no single regime or system can meet the many needs of the tactical warfighter for BLOS capabilities. Each regime has advantages and disadvantages in each of the four requirements explored.

	Satellites	Near-Space	Air-Breathing
Cost		✓	
Persistence		✓	
Responsiveness		✓	✓
Footprint	✓	✓	
Resolution		✓	✓
Overflight	✓		

Table 10. Relative Strengths of Satellites, Near-Space Platforms, and Air-Breathing Assets.¹⁴⁰

Table 10 lists the relative strengths of the three regimes in comparison to capabilities of the various systems. Another report discusses the strengths and weaknesses of satellites and UASs, showing that they both have advantages when used properly and in support of the right user and mission set.

Tactical communication needs can be met much more responsively and effectively with ACNs than with satellites. ACNs can effectively augment theater satellite capabilities by addressing deficiencies in capacity and connectivity. Satellites are better suited than UAS for meeting high capacity, worldwide communications needs. ACNs can enhance intra-theater and tactical communications capacity and connectivity by providing 1) more efficient use of bandwidth, 2) extending the range of existing terrestrial LOS communications systems, 3) extending communication to areas denied or masked to satellite service, and 4) providing significant improvement in received power density compared to that of satellites, improving reception and decreasing vulnerability to jamming.¹⁴¹

The most effective method of meeting the tactical warfighter's requirements is by developing systems in all three regimes that can meet his various needs most efficiently. The tactical warfighter does not much care if his communications, ISR, BFT/SA, or PNT

¹⁴⁰ Tomme, Paradigm Shift, 26.

¹⁴¹ Office of the Secretary of Defense, Unmanned Aerial System Roadmap 2005-2030, 61.

comes from a satellite, a HAP, an UAS, or a large antenna on a mast. He cares that he gets the capabilities he needs, in the quantity he needs them, at the proper time.

When one understands that it is *effects* that matter on the battlefield instead of the platform or medium from which the effects are delivered, near-space makes much more sense for many applications. There are also missions that satellites do extremely well, and for which near-space is not competitive. The point is that a layered approach whose goal is to enable space effects in the most economical, effective way will direct the acquisition of the appropriate platform using the appropriate medium, turning the current acquisitions methodology of medium-then-platform-then-effect on its head.¹⁴²

Army doctrine already seems to see the value of combining systems in multiple regimes, in this case, orbital and high altitude systems.

The combination of orbital space and high altitude long-loiter capabilities is a critical enabler for implementation of the fundamental principles of the future Modular Force concepts, particularly with respect to achieving information superiority, creating situational understanding, and operating within the high tempo, non-contiguous, simultaneous framework of distributed operations.¹⁴³

Civilian studies concerning HAPs also conclude that HAPs are not a replacement for satellite communications and systems, but rather when used in conjunction with satellite systems, HAPs can provide increased capability to more users.

¹⁴² Tomme, Paradigm Shift, 31.

¹⁴³ Department of the Army, TRADOC PAM 525-7-4, 37.

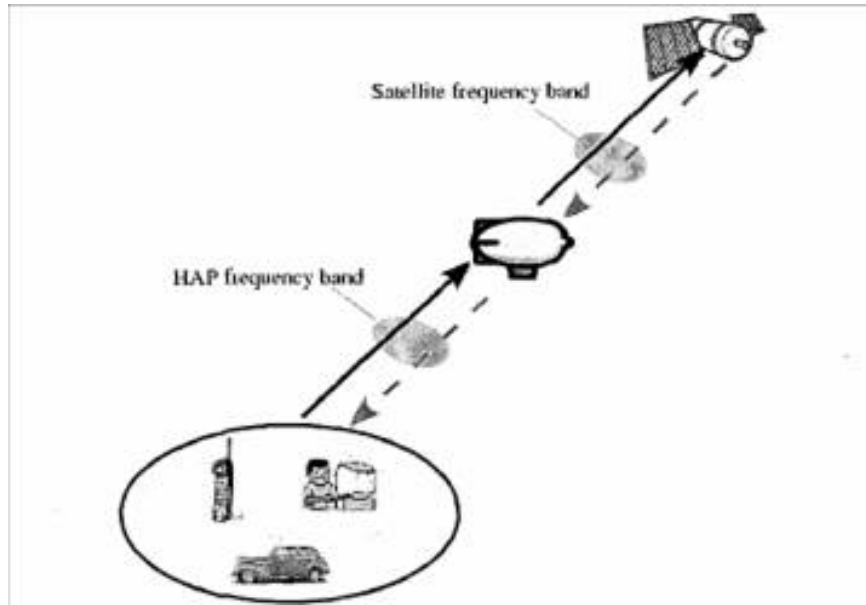


Figure 18. User to Satellite Communication Through HAP (USH) Architecture.¹⁴⁴

In this scenario, shown in figure 18, the data sending towards satellite by means of HAPs could be provided when final users are supplied with limited transmitting capability devices or even hand-held terminals. In fact, user terminals with reduced transmitting capability are envisaged to allow a direct communications with HAPs. Therefore, the user data could be sent to a HAP, which subsequently will supply the data forwarding to the satellite. In this sense, the HAP could provide the “translation” between the user terminal and the satellite (with its own specifications), acting as a terrestrial gateway satellite station placed in the stratosphere.¹⁴⁵

A similar study advocates the use of HAPs to augment both of the other regimes, providing greater synergy between all the platforms and their capabilities.

While satellites are more suited for coverage of very large areas and broadcast applications, HAPs are able to cover remote or sparsely populated areas at reduced cost and offer broadband services to mobile users when fixed directive antennas cannot be used, and finally terrestrial infrastructures are advantageous for interactive services in densely populated areas. For this reason the final design goal must be a flexible and synergic integration between satellite, stratospheric, and terrestrial segments, which can lead to a truly evolutionary scenario.¹⁴⁶

¹⁴⁴ Cianca, “Stratospheric Relay,” 2.

¹⁴⁵ Ibid., 1.

¹⁴⁶ Falletti, “Integrated Services,” 125.

Satellites, HAPs, and UASs should not compete with each other. Each provides specific capabilities with inherent limitations and all are required to meet the tactical warfighter's BLOS needs. Figure 19 shows the relationship between satellites, HAPs, and UASs. Each system provides similar capabilities at different altitudes and supports different levels of command or mission types. The figure shows both strengths and limitations of the systems, further suggesting that integration among the regimes is the most efficient method of providing these capabilities at all warfighter levels.



Figure 19. Layered Net-Centric Architecture.¹⁴⁷

While both space and aerial systems are in development as extensions and improvements of existing capabilities, HAPs are still in the early development stages, making them appear less promising due to the challenges involved with new unproven systems. Unless proven unfeasible, due to insurmountable technical issues, the development of HAPs should be pursued with increased vigor.

¹⁴⁷ Faunce, "Army Activities," Slide 7.

We need to push the envelope to determine what effects we can produce from near-space. More importantly, we need to find the right synergistic mix of air, space, and near-space capabilities to produce the battlefield effects our combatant commanders need.¹⁴⁸

The HAAI is an unexploited regime uniquely suited to support the tactical warfighter. HAPs provide coverage of tactical AOs, persistent support, modularity, upgradeability, and can extend LOS systems without drastic changes in ground equipment. Improvements in the other two regimes alone will not remove the tactical warfighter's deficit in BLOS capabilities. In order to ensure the tactical commander has the proper capabilities, new areas, specifically the HAAI, need to be developed.

¹⁴⁸ General John P. Jumper, USAF, Foreword to *The Paradigm Shift to Effects-Based Space: Near Space as a Combat Space Effects Enabler*, by Edward B. Tomme (Maxwell AFB: Air University, 2005), iii.

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DEFINITIONS

After Action Review (AAR): Formal military method of capturing lessons learned from operations after they are complete.

Area of Interest (AI): Physical area comprising a unit's area of operation and that area outside of it which can influence the unit's operations.

Area of Operations (AO): The physical area that a unit is assigned responsibility for during military operations.

Brigade Combat Team (BCT): Brigade-sized Army unit able to operate autonomously for tactical operation time frames. BCTs support divisions in accomplishing operational and strategic objectives. BCTs are of similar size and make-up to regiments.

Beyond Line of Sight: Not limited by direct line of sight between system and target. In communications, this means that the transmitter and receiver can form a link without a direct, clear path to each other.

Blue Force Tracker (BFT): Short term used to refer to FBCB2-BFT which is a L-band satellite version of the FBCB2 command and control system that reports location of friendly forces on a digital map system.

Blue Force Tracking: Systems designed to automatically track and report the location of friendly forces.

BFTSA: Blue Force Tracking and Situational Awareness. The combination of friendly force location information and enemy force location. BFT/SA systems allow the commander to understand himself and his enemy, allowing him to make decisions faster.

Common Operational Picture (COP): A shared digital view of the battlefield. A COP combines digital maps or imagery of an area with accurate geo-spatial information, location of friendly and enemy forces, operational graphics overlays, and other information. The COP is propagated at various levels, allowing for ease of understanding of the operational picture among different and separated levels of command.

Commercial off the Shelf (COTS): A product commercially available that can be modified or used by military forces without requiring a lengthy development and procurement cycle.

DARPA: The Defense Advanced Research Projects Agency (DARPA) is the central research and development organization for the Department of Defense (DoD). It manages and directs selected basic and applied research and development projects for

DoD, and pursues research and technology where risk and payoff are both very high and where success may provide dramatic advances for traditional military roles and missions.

Disadvantaged User: Communications term referring to users of a system or type of systems that are unable to utilize the full capabilities of a system. For instance, mobile users with small aperture antennas are often considered disadvantaged users of satellite communication systems.

Distributed Operations (DO): Marine Corps term for units operating beyond the limits of mutual support. These operations are deliberately executed using deliberate dispersion and decentralized decision-making to achieve advantages over an enemy in time and space.

Electro-optical/ Infra-red (EO/IR): Refers to a platform or system that provides digital visible spectrum or infrared imagery of a target.

Force XXI Battle Command and Control Brigade and Below (FBCB2): Digital command and control system used the U.S. Army. The system uses EPLARs based FM radios to propagate friendly unit locations to both peer, subordinate, and higher-echelon units. Friendly force location is overlaid with operational graphics on digital maps, allowing for greater levels of command and control. An L-band satellite version, known as FBCB2-BFT, provides less capabilities but without requirements for LOS connectivity. The two versions of the system are not compatible without some translation and injection of information from one system to the other at a higher echelon.

Future Combat Systems (FCS): Army family of systems designed to equip the soldier of the future.

Global Positioning System (GPS): Constellation of satellites in medium earth orbit that provide global position, navigation and timing through measurement of the time it takes signals to travel known distances to a single ground receiver.

Initial Capabilities Document (ICD): Acquisition document that specifies a non material or material approach (or combination of both) to meeting specific military capability gaps.

Infantry Brigade Combat Team (IBCT): As the light force, all IBCTs are uniform in design, replacing the specialized brigades of the airborne, air assault, and light infantry divisions. Though their training suits them for particular infantry missions, their standard organization facilitates their training, employment, leader development, and logistics.

Intelligence, Surveillance, and Reconnaissance (ISR): The collection of intelligence information using surveillance and reconnaissance. In this paper, it focuses on the technology and systems that implement that technology to provide intelligence to the warfighter.

Heavy Brigade Combat Team (HBCT): A single type of heavy brigade replaces the armored, mechanized, and balanced brigades of the heavy divisions, and the separate tank and mechanized brigades and armored cavalry regiments of the corps. These HBCTs field tanks and mechanized infantry within standardized combined arms maneuver battalions.

High Altitude: Airspace above 65,000 feet, up to but not including the orbital regime. Loosely, this excludes all but very specialized air breathing manned aircraft as well as current and projected orbital systems.

High Altitude Area of Interest (HAAI): The Area of Interest characterized as High Altitude.

High Altitude Platforms (HAPs): A platform for sensors or other payloads that operates in the region known as High Altitude. Generally, HAPs operate above traditional aircraft and below orbital systems.

International Telecommunications Union (ITU):

Line of Sight (LOS): Requiring a relatively unobstructed path from transmitter to receiver or from sensor to target.

Marine Air-Ground Task Force (MAGTF): Marine element organized for combat operations. Can operate in multiple sized configurations based on mission requirements.

Marine Expeditionary Force (MEF): Marine combat organized element of roughly division size.

Marine Expeditionary Brigade (MEB): Marine combat organized element of roughly brigade size.

Marine Expeditionary Unit, Special Operations Capable (MEU/ SOC): Marine combat organized element of roughly brigade size that is capable of accomplishing specific special operations missions.

Modified Table of Organization and Equipment (MTOE): Department of Defense document that prescribes organizational (personnel) and equipment requirements for a specific unit.

Near Space: See High Altitude.

Operationally Responsive Space (ORS): A space program focused on timely satisfaction of Joint Force Commander's needs, while also maintaining the ability to support others. The program focuses on rapid development and fielding of lower-cost and more specifically focused satellite systems.

Position, Navigation, and Timing (PNT): The product produced by the Global Positioning System constellation and associated equipment and receivers. PNT provides accurate geo-location, navigation assistance, and timing synchronization on a global scale.

SATCOM: Satellite communications.

Space: The altitude of perigee or orbit in which a space craft (designed for operations in that environment), can maintain an orbit for an extended duration (months for comparative analysis to tactical operations).

Stratospheric Platforms (SPFs):

Tactical Exploitation of National Capabilities (TENCAP): Programs run by all services that attempt to use national level assets to support tactical operations.

Tactical (mission): Missions executed in a time period such that the unit tasked can operate autonomously without continuous re-supply or control from higher.

Tactical Space: “Tactical Space” is the operational environment that the tactical warfighter operates within and is from where he gets his support. “Tactical Space” is dedicated specifically to providing capabilities to the tactical warfighter, to facilitate his mission(s) and address his status as a disadvantaged user.

Tactical (unit): Units of the size to operate independently for a short period of time and/or toward limited mission goals, in our case, units at or below Army Brigades and Marine Regiments.

Tactical Warfighter: Those personnel attached to the Brigade or Regiment size units, or below, who are operating in a hostile area, possibly under austere conditions.

TRADOC: US Army Training and Doctrine Command. Army command responsible for recruiting, training and educating the Army’s Soldiers. Responsible for developing doctrine and establishing standards for the Army.

Unmanned Aerial System (USA): Unmanned systems operated by ground stations that operate within airspace. These systems most often provide ISR capabilities.

Warfighter: *Ambiguous term used to describe a person involved in the prosecution of warfare.*

Warfare Information Network- Tactical: Military tactical information network.

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