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***NORTHROP GRUMMAN***



# **The Role of NSD Technologies in Achieving Advantage in Asymmetrical Conflicts**

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**Dr. Alex Fax**

Title: Manager of the Navigation and Applied Sensors Technology Center

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His area of expertise includes research and development of navigation architectures for collaborative Unmanned Aerial Vehicle (UAV) operations, advanced micro-electro-mechanical systems (MEMS) inertial sensing, and alternate formulations development of optimal control problems for mechanical systems such as spacecraft.

Dr. Fax's LEGAND Program-relevant technical and management qualifications include: Principle investigator for Advanced Pos/Nav and Tracking the Future Force (APNTFF) program; management of internal and contract research and development programs; and directing a cross-functional team to execute advanced development work.

He won the 2004 venture to develop navigation software for man-wearable prototype navigation systems for Army/CERDEC, and has served as technical lead for the NavNet IRAD program, as well as the technical lead for the Silicon Accelerometer (SiAc) error reduction endeavor.

Dr. Fax's research experience includes: Sensor integration for robust personal navigation; strategies for robust, optimal multi-vehicle cooperative motion, emphasizing satellite and UAV formation flight; and he pioneered research in interactions of graph theory and control theory for analysis of vehicle formation behavior.

Dr. Fax earned a Doctorate degree in Control and Dynamical Systems, and a Master of Science degree in Control and Dynamical Systems from the California Institute of Technology. He received a Bachelor of Science degree in Mechanical and Aerospace Engineering from Princeton University.

Dr. Fax has several professional and academic awards. He has co-authored and presented technical publications and has created several patent pending products for Northrop Grumman.



**Dr. Charles Volk**

Vice President and Chief Technologist  
Northrop Grumman, Electronic Systems, Navigation  
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Dr. Volk joined Litton Industries' Guidance and Control Systems Division (GCS) in 1977. His initial work involved the development of a nuclear magnetic resonance gyroscope, which was a practical extension of his doctoral thesis in atomic physics.

In 1980 Dr. Volk joined the Aerospace Corporation in El Segundo, California and worked on refinement of atomic clocks for GPS and MILSTAR programs.

In 1984 he returned to Litton GCS assuming increasing levels of responsibility, and was named Vice President of Engineering.

When Northrop Grumman acquired Litton Industries, Dr. Volk became the Vice President of Engineering and Manufacturing for the Western Region of Northrop Grumman's Electronic Systems Sector.

He was appointed Chief Technologist for Navigation Systems Division in 2003.

Dr. Volk earned a Doctorate degree in Physics from Indiana University, and his undergraduate degree in physics from Lake Forest College.

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## Abstract

Many counter-insurgent conflicts have seen the advantage go to the smaller, less technologically sophisticated group because the insurgents operate with better local intelligence; can strike effectively over short distances and have decision times much shorter than the technologically superior force. There are a large number of initiatives currently underway in the United States to better understand the dynamics of counter-insurgencies, also referred to as asymmetrical conflicts including improved surveillance, more rapid dissemination of intelligence and shortening the kill-chain timeline.

One element that is crucial to gaining the advantage in an asymmetrical conflict is being able to improve the precision and accuracy of positional information. Being able to identify friendly forces, unfriendly forces and targets of interest with precision on the order of one meter or less will allow the superior force to effectively project its power and deprive the insurgent force of local cover.

Inertial technologies and products developed by the Navigation Systems Division (NSD) of Northrop Grumman have demonstrated the ability to support positional accuracies on the order of a meter or less. Greatly improved location precision coupled with improved surveillance sensors and agile, secure communications systems will enable a shortened kill-chain timeline and aid in the United States gaining the advantage in asymmetrical conflicts.

## 1. The Challenges of Asymmetric Warfare

The U.S. National Military Strategy<sup>1</sup> outlines the desired characteristics of a transformed fighting force – that it be fully integrated, expeditionary, networked, decentralized, adaptable, and capable of decision superiority and lethality. These capabilities will enable the United States to prevail against the diversity of current and future threats, including both conventional enemies and irregular adversaries such as terrorists and insurgents. Common to these characteristics is the need to:

- Acquire massive amounts of data/intelligence from distant and diverse sources.

- Collect the data/intelligence to locations where they can be analyzed.
- Analyze the data and convert it into actionable information.
- Disseminate information to those who can exploit it.
- Display relevant information in a meaningful fashion so it can be exploited effectively.

The sources of these data and the clients of the information are spread out both geographically and hierarchically – from unattended ground sensors to unmanned vehicles to brigade commanders to the Pentagon to the weapons themselves. It is understood that the movement of information from acquisition to display must happen rapidly, reliably, and, to a large degree, autonomously throughout the fighting force.

Nowhere is this challenge greater than in the domain of asymmetrical warfare. Asymmetrical warfare, loosely defined as combat in an urban setting against small, loosely organized groups of insurgents employing a mix of crude weapons and advanced commercially available technologies, does not arise haphazardly – it “naturally evolves from a sound ... analysis by an intelligent, freethinking, and adaptive threat.”<sup>2</sup> In other words, the tactics of asymmetrical warfare are implemented precisely to counter the strengths of the U.S. military. With regard to the movement of data and information discussed above, asymmetrical warfare counters the United State’s technological advances in the following ways:

- Combatants are not easily distinguishable from non-combatants and do not employ mechanized transport or weaponry that could be identified by the United States’ sensing capabilities.
- Combatants do not cluster in large groups that would facilitate locating and neutralizing them.
- Urban terrain confers significant advantages to the enemy, often increasing his mobility while decreasing the United States’ mobility. Enemy combatants are therefore highly mobile and tend to conduct multiple, sporadic, low-level attacks. This severely limits the time value of information collected regarding a threat. If data cannot be acted upon within minutes, it is

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<sup>1</sup> *The National Military Strategy of the United States of America: A Strategy for Today, a Vision for Tomorrow*, U.S. Joint Chiefs of Staff, 2004.

<sup>2</sup> Field Manual 3-06, *Urban Operations*, Headquarters of the Dept. of the Army, 1 June 2003.

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often useless.

- Urban environments present substantial physical occlusion and electromagnetic clutter that inhibit communication, self-location, and location, tracking, and targeting of threats.
- Advanced United States capabilities such as precision strike are of limited use due to the imprecision of available targeting data in comparison to the density of urban environments.
- The density of urban environments and the proximity of U.S. forces, enemy forces, and noncombatants means that information which is not precisely tagged with highly accurate position coordinates is of limited value. Insurgents can operate more effectively at shorter ranges that cannot be countered by the larger force without having highly accurate positional information regarding both the location of friendly forces and targets of interest.
- Urban operations are frequently conducted in a decentralized fashion by dismounted soldiers. As a result, situational awareness occurs at the soldier level (as opposed to the platoon or vehicle level). This drastically increases the amount of data collected and disseminated, stressing all levels of the communication system. The dismounted soldier must maintain precision in situational awareness at the precision of a meter or less or his superior fire power will be neutralized.

## 2. Rapid Decision-Making, Global Information, and NSD

Information superiority in any conflict, including asymmetric warfare, can be characterized in terms of the relative speed with which one side can observe, orient, decide, and act on newly arriving information. This concept, known as the OODA loop and first described by Col. John Boyd of the U.S. Air Force<sup>3</sup>, characterizes how opponents absorb and react to the ongoing stream of new information. The side that can process and act upon data more quickly enjoys an enduring tactical advantage – it not only strikes faster, it anticipates the opponent's next moves and

effectively counters them. Adversaries who are weak by conventional measures employ asymmetric warfare precisely because it confers upon them the OODA loop advantage. Asymmetric adversaries maintain the OODA loop advantage by operating in the time and space scales of their adversary.

Large forces enjoy tremendous advantage when they operate over vast spatial dimensions and over long periods of time. Operation Desert Storm and the initial days of the war in Iraq are excellent examples of the insurmountable advantage the larger, more organized force enjoys when it controls the space and time scales of the conflict. Coalition forces operated in a coordinated fashion over hundreds of kilometers and controlled the actions of multiple forces for hours and days. By contrast, the last few years of Iraq have been controlled by small groups of loosely organized insurgents whose strength is the ability to operate over very small distances and for extremely short periods of time. Because the insurgents dictate the terms of the conflict, the OODA loop advantage naturally belongs to them.

This historical pattern is seen in the major post-World War II conflicts between large armed forces and insurgents<sup>4</sup>: France in Indochina from 1945 to 1954; the British in Malaya from 1948 to 1960; the French in Algeria in the 1950's; the United States in Vietnam; the Soviet Union in Afghanistan; Israel in the occupied territories and Russia in Chechnya. Of these seven, four were outright failures for the larger force, two are ongoing with no clear prospect of victory and only one, the British effort in Malaya, is considered a clear success for the major force.

Studies of this conflict have shown that among the best practices of the British were measures taken to control the spatial and temporal dimensions of the conflict.<sup>5</sup> For example, use of population control measures such as personnel checkpoints and national identity cards, combined with the cultivation of sympathetic local authorities, prevented the insurgents from infiltrating the cities and allowed the British to fight them in the jungle, away from population centers. With the British fighting on favorable terms, and with the insurgents unable to operate inside the decision space of the British, a successful insurgency could not be mounted. These lessons are valuable for fighting

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<sup>3</sup> *The OODA Loop by Col. John Boyd* – see for example: Boyd, *The Fighter Pilot Who Changed the Art of War*, Robert Coram; Little, Brown: 2003. *The Strategy of the Fighter Pilot*; Keith H. Hammonds; Fast Company 52, pp. 98-105; June 2002.

<sup>4</sup> *A Victory, But Little Gained*, Daryl G. Press and Benjamin Valentine; The New York Times, November 17, 2004.

<sup>5</sup> *Best Practices in Counterinsurgency*, Kalev I. Sepp, Ph.D., Military Review, May – June 2005; pp. 8-12.

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today's insurgencies, yet not every lesson can be directly applied. For example, the existence today of large urban centers makes certain population control measures infeasible, and points more strongly in the direction of employing technological tools to retain the OODA loop advantage.

The Global Information Grid, or GIG is one of the elements by which the United States is attempting to operate within the decision space of insurgents. The GIG has emerged as the organizing concept for DOD's goal of deploying a global infrastructure that facilitates the movement of information as described earlier. The central idea of the GIG is that data can be collected from numerous, world-wide nodes; processed and filtered at base stations and intelligence facilities and then information can be provided back to the most appropriate nodes in a timely fashion. The GIG implements a global Internet-like network supported by a constellation of satellites that implement medium-area networks. Lower-altitude aircraft and surface assets – ground vehicles, mobile C2 stations, surface ships, dismounted soldiers, and even weapons – act as nodes on the network.

The intent of the GIG is to harness the United State's prodigious technological capability to regain the advantage at the local level and operate in timeframes competitive to that of the insurgents. Sometimes referred to as "shortening the kill chain," the GIG goes further – it enables the United States to assess enemy activity and act upon it within time and space scales smaller than the insurgents can. The goal is to collect massive amounts of data, distill it into information, reason on it, and return it to the field in short enough time so U.S. troops can implement localized actions to neutralize impending threats. As an example, the goal is not to be able to detect improvised explosive devices (IEDs) before they detonate, but to determine ahead of time where and when insurgents are likely to place them and to intercept the insurgents before they can do so.

The ability to achieve this goal depends not only on fielding the GIG to move data. It also depends on the quality of the data being supplied, and the ability of the soldiers to act on information once they receive it. The positioning and geolocation solutions supplied by Northrop Grumman's Navigation Systems Division are key technologies in enabling the GIG to be an effective tool in keeping the OODA loop advantage. Put simply, controlling the spatial dimensions over which conflicts are executed requires highly accurate positioning and remote geolocation technologies.

These technologies enable the United State's prodigious remote sensing capability to attach ultra-precise position tags to received images, and enables soldiers to act on that data by giving them their own and other blue force's positions accurately and on time. In the following sections, we describe NSD's diverse array of technologies and how they are applied to giving U.S. forces the upper hand in asymmetric warfare.

### 3. Navigation System Division and Asymmetric Warfare

Northrop Grumman's NSD inertial navigation products and technologies play a significant role in addressing many aspects of these challenges of asymmetric warfare. Determining accurate position and orientation is a classical problem that continues to be highly relevant for modern warfare challenges, and NSD is at the forefront of developing new technologies that address the U.S. military's current and future needs. In the sections below, we describe some of NSD's contributions to giving the United States the upper hand in asymmetrical warfare:

1. ***Maintaining the GIG.*** The Global Information Grid (GIG) has emerged as the organizing concept for the DOD's goal of deploying a global infrastructure that facilitates the movement of information as described earlier. NSD's inertial products service platforms at all levels of the GIG – from satellites to dismounted soldiers – enabling them to reliably communicate and constantly share time-critical information.
2. ***Breakthrough sensor accuracy for networked precision strike.*** The increasing role of aircraft, ground vehicles and dismounted soldiers as mobile sensors gives their navigation systems added roles as target geolocation systems. Increasingly, navigation systems are tightly coupled with sensors to provide the accuracy required for precision strike in the dense environments typical of asymmetrical warfare. NSD has invested substantially in technologies that augment its inertial navigation systems to give them added value as target geolocation systems.
3. ***Situational awareness for urban warfighters.*** As discussed earlier, a major challenge in asymmetrical warfare is supplying dismounted soldiers with meaningful, timely situational

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awareness, as well as extracting soldier-derived information and making it available to the GIG. Knowledge of a soldier's position is essential to supplying him with relevant information or attaching significance to information he supplies. This is an especially demanding challenge because the soldier's position must be known to very high accuracy (~1 meter) in an environment that is frequently GPS-denied or GPS-corrupted. NSD is developing and integrating key technologies to supply the dismounted soldier with this crucial situational awareness tool.

#### 4. Maintaining the GIG

The central idea of the GIG is that data can be collected from numerous, world-wide nodes; processed and filtered at base stations and intelligence facilities and then information can be provided back to the most appropriate nodes in a timely fashion. To accommodate the explosion in node count due to dismounted soldiers and unattended ground sensors, mobile mesh networks are currently being investigated as a means of extending the GIG to local situations. In a mobile mesh network, a local area network (LAN) connected to the GIG is created rapidly in response to a local activity. The LAN would consist of a small number of nodes in which each deployed individual, the troop transport vehicles and possibly locally deployed UAVs would serve as a node in the mesh network. Figure 1 shows a common depiction of a local deployment of a mesh network connected back through local platforms to the GIG.

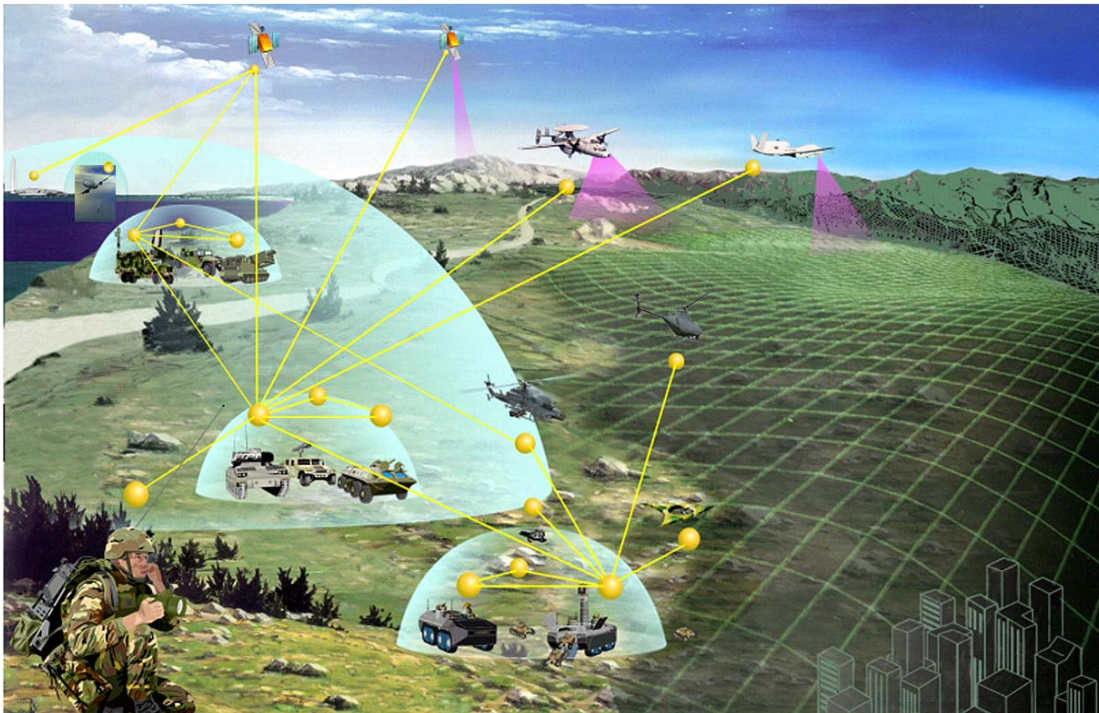
The future reliance of the GIG on laser communications for its space and airborne communications backbone represents a significant technological step forward and demonstrates the criticality of reliable, precise navigation to the maintenance of the GIG. Mobile laser communication terminals require precise position knowledge to establish the communication link and frequently

require precise motion compensation to maintain the communication link. As this link is not dedicated, but hops between many air and ground nodes at a rapid rate, the need for precise position and orientation knowledge is especially critical.

Geopositioning on both a global and local level is crucial not only to the effective deployment of the network, but to its use by different assets to execute network-centric warfare. As an example, a Global Hawk aircraft may detect a target of interest. Using its surveillance sensors, the geographical coordinates of this target are determined in terms of latitude, longitude and altitude. These coordinates are relayed through the GIG to a local commander who can deploy a small force to rapidly identify and engage the target. Crucial to the local commander is knowing the precise position of each of his deployed personnel so that the relative position of the target to the deployed personnel can be precisely ascertained. These challenges will be explored further in subsequent sections.

NSD's inertial technologies and products play a significant role in the deployment and use of the GIG. NSD supplies navigation systems, such as the fiber-optic based LN-251, to accurately determine the position, velocity and heading of the high value platforms in the GIG such as the Global Hawk and E2. Augmented with differential GPS corrections, the LN-251 can dynamically determine the platform's instantaneous geoposition to accuracies of less than one meter. With the low noise characteristics of the NSD's accelerometer technology, these high value platforms can determine their velocities to accuracies of a few millimeters per second. These accuracies are important when the inertial system supports laser communications as well as capabilities such as precision sensing and strike to be discussed below.

Figure 2 provides a representative listing of the NSD inertial equipment that is found at each node of the GIG and local mesh network.



**Figure 1. Common Depiction of the GIG with an Extended LAN**

<b>GIG/LAN Node</b>	<b>NSD Inertial System Examples</b>	<b>Function</b>
Surveillance Satellites	Scalable Space Inertial Reference Unit (SSIRU) – HRG based inertial reference system	Satellite stabilization and pointing. Pointing of surveillance sensors for geolocation. Pointing of laser communication terminals.
Surveillance Aircraft: Global Hawk U-2 JSTARS E2 MMA	LN-251 – INS/GPS-StarFire™ Enabled LN-200 – IMU	Aircraft Navigation/transfer alignment to sensor IMU's. Stabilization of surveillance sensors. Motion compensation for laser communication terminals.
Fighter/Attack Aircraft: F-16 F/A-18 F-22	LN-100 LN-260 LN-200	Aircraft navigation/transfer alignment to sensor IMU's. Stabilization of surveillance sensors.
Various Helicopters	LN-100F – INS/GPS LISA-200 LN-200	Navigation. Attitude Heading Reference. Sensor/Pod stabilization and pointing.
Small UAV (Hunter)	LN-251	Navigation and target geolocation.
Self-propelled Artillery	LN-270	Land navigation, gun pointing.
Troop Carrier	LN-270 – INS/GPS Mobile MAGU	Land navigation. Geolocation of target from moving platform.
Laser Range Designator: Troop Deployed	MAGU – Miniature Azimuth Gyro	Non-magnetic determination of azimuth for geolocation of targets.
Individual Soldier	MEMS IMU	Personal navigation.

**Figure 2. NSD Inertial Systems Found at all Levels of the GIG**

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## 5. Networked Precision Strike

The U.S. military's ability to deliver weaponry from aircraft with standoff distances of tens of kilometers to precise locations is one of its most fearsome capabilities. As discussed above, however, the tactics of asymmetrical warfare are carefully designed to thwart this capability. It is well understood that our military is limited not by its ability to deliver a weapon to a given point, but to precisely determine the location of the threat. In the case of asymmetrical warfare, misidentification of threat location can potentially lead to fratricidal casualties or civilian casualties that the enemy can exploit via the media to their strategic advantage.

The need to upgrade our precision strike capabilities to meet the asymmetrical threat has led to the development of new technologies and CONOPs. Examples include:

- **Improved sensor imagery.** The need for high-resolution sensor imagery has never been greater. Ultimately, the ability of the GIG's resources to turn data into actionable information will be limited by the quality of the data it receives. The resolution of the image plays a crucial role in differentiating threats from noncombatants and in enabling fusion of data from other sources. This is true currently, when analysis of sensor imagery is done by human operators, and will continue to be the case as these capabilities are automated and homed on the GIG. For mobile airborne platforms at large standoff distances from the threats, generating these high resolution images is a significant challenge.
- **Networked Remote Strike.** The source of reliable targeting information is often not on the airborne sensor platform, but with the soldier on the ground, with an unattended ground sensor, or with another aircraft. In a networked environment, the weapons platform has the ability to exploit this information in real time and deliver a weapon while the information is still timely. Currently, this sort of analysis can take hours, is labor-intensive, and does not meet the needs of conducting asymmetrical warfare. Ultimately, however, this capability will enable U.S. precision strike

capabilities to be leveraged against asymmetric threats. In the most aggressive concept, the weapons themselves are linked to the GIG, receiving real time updates about threat status and location as they are delivered.

Achieving these capabilities shows the evolving role of inertial navigation systems in supporting warfighter needs. Whereas the quality of an inertial navigation system is often measured in terms of its accuracy over long periods of time while unaided, these capabilities depend on the ability of the inertial system to accurately measure short term sensor velocities and rotations. NSD has incorporated technological discriminators into its product line that give it unparalleled performance in image generation and geolocation. These discriminators include:

- Unlike conventional targeting, networked targeting requires that the sensor platform accurately know the target's geolocation, as opposed to its location relative to the sensor. With reliable, accurate geolocation information, target coordinates can be shared on the GIG and exploited by those who can best react to the threat. To know the target's geolocation, the sensor platform must know its own geolocation very accurately. NSD's integration of GPS augmentation systems such as NavCom's StarFire™ technology enable us to achieve sub-meter absolute position accuracy in dynamic environments.
- Unlike conventional ring-laser gyros, ditherless inertial instruments such as fiber-optic gyroscopes can be placed in close proximity to sensors to accurately measure sensor motion without inducing unacceptable vibrations near the sensor. NSD's navigation grade inertial instruments have demonstrated superior target location error (TLE) in comparison to its industry competitors.
- For sensors whose size, power, or cost constraints preclude the use of a navigation-grade inertial system, NSD's transfer align technology can be exploited to network multiple inertial systems on a single aircraft. In this fashion, the effective performance of a smaller, lighter inertial unit such as an LN-200 can be augmented to that of a navigation grade

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unit such as an LN-251. This capability dramatically raises the effectiveness of SAR and EO/IR sensors in a cost-effective manner.

An example of these technological discriminators at the dismounted soldier level is described in the next section.

## 6. Situational Awareness for Dismounted Soldiers

Asymmetrical warfare inevitably involves engaging the enemy on his terms – confronting his decentralized forces where they can be identified, often in urban centers or in inaccessible mountain hideaways<sup>6</sup>. This leads to an increased reliance on dismounted soldiers to locate, identify, and engage the enemy. It is essential that the tools of networked warfare be made available to the dismounted soldier, meaning that real-time situational awareness be made available to the soldier, and that soldier-derived information be uplinked to the GIG. The demands that dismounted soldiers place on this architecture are extreme, and not only because of the number of dismounted soldiers. Just like the aircraft and weapons discussed earlier, the soldier must be equipped with accurate geolocation information so the data he generates can be effectively used, and so the GIG can filter situational awareness data to give him what he needs. These demands are stressed in various ways for dismounted soldiers, such as:

- Dismounted soldiers frequently operate in GPS-denied or GPS-corrupted environments.
- Dismounted soldiers require a very accurate position fix for situational awareness in urban environments. Typical requirements are that absolute position be known to one meter, so situational awareness software can resolve what room within a building the soldier (or a sensed threat) is in.
- Soldiers cannot carry navigation-grade inertial systems with them due to size, weight and mobility constraints.

- Soldiers cannot carry substantial additional battery weight to support conventional inertial systems for long missions.

These constraints describe the challenge of navigating in the “last quarter mile” of the soldier’s trajectory – when they leave their vehicle and enter buildings where navigation and tracking are most difficult.

NSD is at the forefront of developing navigation solutions for dismounted soldiers that meet the accuracy and availability constraints of dismounted soldier missions as well as size, weight and power requirements. It is increasingly apparent that no single technology will emerge in the near term to produce a sensor that meets these needs. Rather, NSD is working toward novel integration of existing sensors to satisfy these requirements.

Under a development contract with the U.S. Army’s Communications and Electronics Research, Development and Engineering Center (CERDEC), and in conjunction with Northrop Grumman’s Mission Systems Sector, NSD is integrating a suite of four sensors into a prototype wearable navigation system that interfaces with the U.S. Army’s FBCB2 situational awareness system. The intent of the program is to demonstrate that accuracy and robustness can be achieved through intelligent application of a diverse suite of navigation sensors. While each sensor has its limitations, NSD is demonstrating that as an ensemble, they can compensate for each other’s weaknesses and produce a robust result. The sensors include:

- An embedded GPS receiver that supplies GPS information when it is available.
- A MEMS IMU that produces inertial measurements, though at much lower accuracy than an LN-251 or LN-200.
- A dead reckoning system that senses soldier footsteps and that can be used to estimate a soldier’s movements due to walking.
- A ranging capability built into the soldier’s communication link that supplies range information to other soldiers as well as fixed or vehicle mounted base stations.

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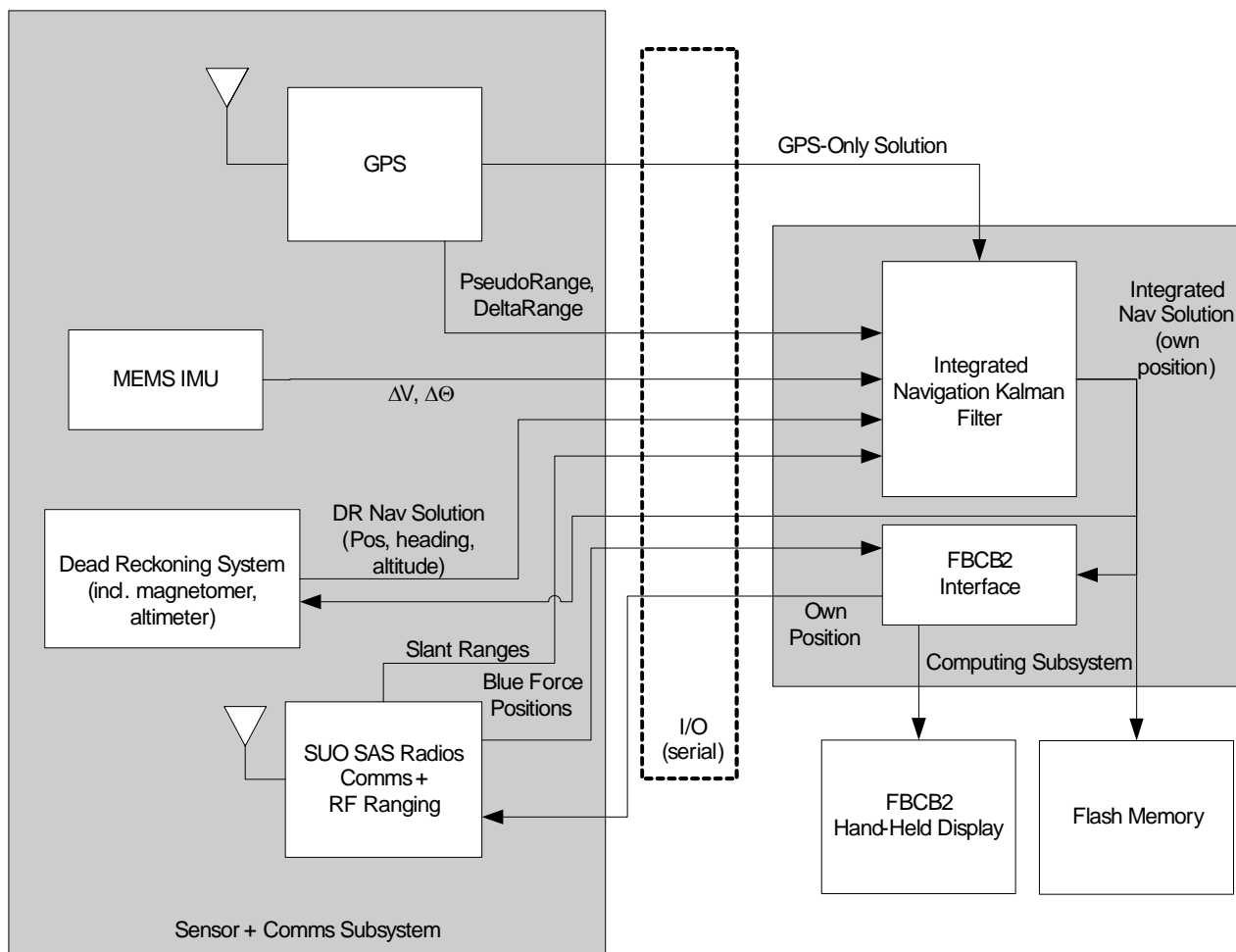
<sup>6</sup> *An Army of David*, Glenn Reynolds; Nelson Current; 2006.

Together, these sensors have the potential to deliver accurate position information to the soldier. The dead reckoning system does not drift in the fashion that inertial systems do, and helps to keep the inertial solution bounded. The ranging signals act like GPS fixes, with the advantage that they work more robustly inside buildings. The potential of this system is being realized through NSD's work in robustly fusing the data streams from these sensors into a single Kalman Filter that enables the navigation system to reject outliers and correct for signal corruption such as multipath errors. This architecture, together with the interface to FBCB2 is shown in Figure 3.

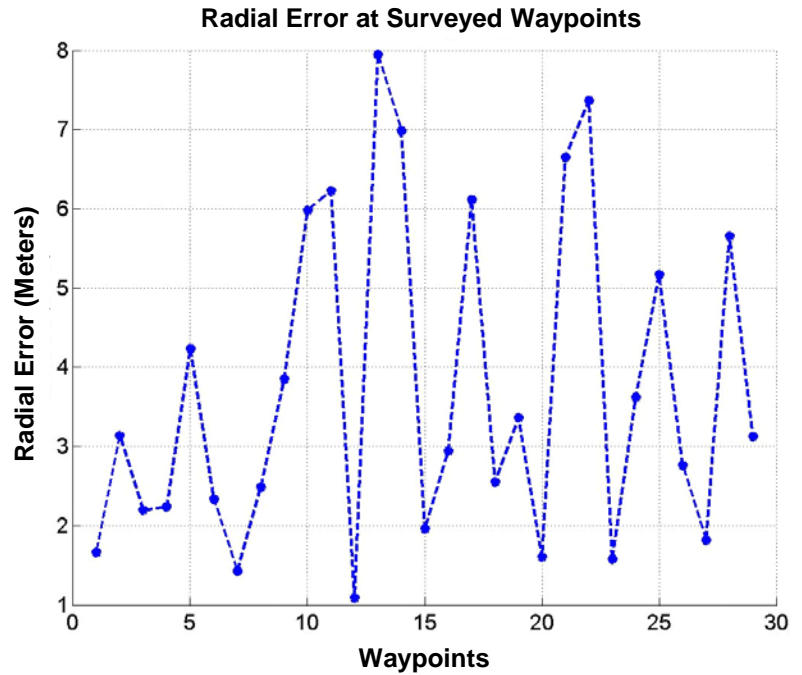
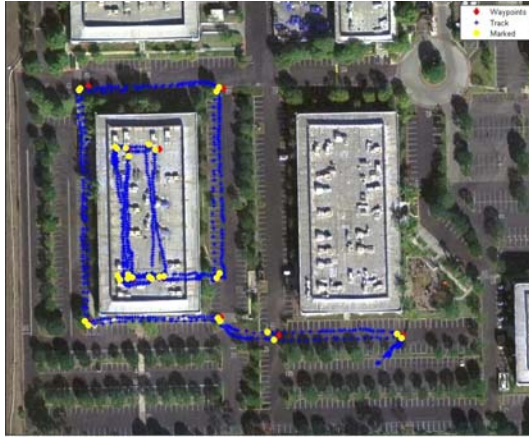
Significantly improved performance using only the IMU and the dead reckoning system has been demonstrated in preliminary testing. In this test case,

shown in Figure 4, the soldier's position is initialized outside in the presence of GPS, and he then traverses corridors in a building, where GPS is denied. The superior performance of the integrated system yields a navigation track much closer to truth than the raw dead reckoning data. Further integration of GPS and RF ranging will improve long-term performance of the personal navigation system.

This system will be used by the Army to test its effectiveness for dismounted soldier navigation. Follow-on development work will focus on miniaturization, power management, and further system robustness to mature the system to a TRL where it can be fielded.



**Figure 3. Integration of Diverse, Low-Cost Sensors Can Provide the Accuracy Needed by the Dismounted Soldier**



**Figure 4. Integrated Navigation Performance in GPS-Denied Environments**

## 7. Summary

Success in an asymmetrical conflict will require that the U.S. forces harness their strengths of large deployed versatile forces with exceptional ability to collect data and apply these abilities at the local level. An approach to achieving this capability is by extending mesh networks from the GIG. Crucial to the effective implementation of this approach is the ability to accurately position friendly forces not only in geospatial coordinates but also with respect to each other and then to be able to identify targets and accurately ascertain their coordinates so that effective, coordinated action can be taken in a timely manner. The family of NSD inertial products located throughout the expanse of the GIG and deployed in the local mesh network extensions have an unparalleled ability to provide the navigation and geolocation data to make this system effective.

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## **Strategic Programs & Business Development (SP&BD), Navigation Systems Division**

One of the main functions of the SP&BD organization is to sustain NSD's competitive advantage in all of its product lines by providing cutting edge technologies that supply entirely new capabilities to the marketplace and also enhance its current products.

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