Smart Sensorweb

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The Sower. Artist. Lee Hodges Ventura. CA

There is a revolution going on in the world of sensors. In the year 2000, it is now possible to proliferate sensors and mount them on any platform stationary or moving, from the individual soldier on up. We can literally buy sensors by the pound and toss them out into the environment as throwaways. It is possible to rapidly configure wireless networks of sensors that collect, relay, process, and archive the outputs of large arrays of heterogeneous sensor fields. For those of us who have spent our professional lives providing high end sensors to the military, this realization comes as quite a shock for it changes the way we think about conducting military functions such as intelligence, surveillance, and targeting. This monograph briefly explores the genesis of this capability and where it may lead for future military forces and operations.

Background. In 1997, I asked the National Academy of Sciences to conduct a study on directions in sensing for the twenty first century. The study was called Advanced Research and Experiments in Sensing (ARES). This physics panel of this first ARES used the above illustration, "The Sower," to represent their concept for a radical new direction in sensors. The physics panel said that the military does a great job of fielding high end sensors that tend to be large, heavy, work well at long standoff ranges, and are too expensive to throw away. Their advice was to move to the other end of the spectrum and work on cheap, small, low to modest performance sensors that could literally be sprinkled around the battlefield. They hypothesized that networking and clever processing of large sensor arrays could solve some of the more difficult problems facing the military. The word Sensorweb was coined at ARES to connote the idea that these low end sensors would be netted together to provide useful military information.

In 1998, the idea was endorsed by the Army Science Board in the context of providing situational awareness and organic sensing capabilities at the battalion and lower echelons. In 1999, the Smart Sensorweb program was approved and funded as one of the five major thrusts of the Deputy Under Secretary of Defense for Science and Technology.

The Military Need. Figure 1 below shows the unique capabilities that sensor webs can provide. Current intelligence, surveillance, and reconnaissance (ISR) are roughly summarized on the right. Note that the sensors and platforms depicted there are not viewed as throwaway systems. By being local and everywhere, the Smart Sensorweb can in principle see into urban canyons, buidlings, windows, sewers, rough terrain, and deep forest canopy. Such capabilities are unlikely to accrue to overhead sensors. Take foliage penetration synthetic aperture radar (FOPEN SAR) as an example. Because of it's long wavelength, the aircraft must fly a greater distance create an aperture with adequate resolution to yield meaningful imagery of objects under trees. Geometry, terrain masking, motion compensation, and the specular nature of the target signatures pose physical limitations on the ultimate performance we may ever hope to derive from FOPEN SAR. Although we may expect to obtain useful cueing from it, albeit with a fairly significant false alarm rate, we will need to rely on other sensors for confirmation and identification. This problem can be addressed readily by the deployment of an intrusive sensor field surgically dropped in areas where cueing sensors indicate that a closer look is warranted. Taking this example a bit further, assume that FOPEN SAR has given us several alarms in a heavily forested area and that moving target techniques have confirmed that there has been recent vehicle traffic in the area. Using our new web technology, we can envision dropping disposable low light level cameras and even micro thermal imaging sensors into the area, perhaps mixed with acoustic and magnetic sensors to attempt to identify and pinpoint targets. We can then send weapons to points in the web, weapons that are not even capable of sensing the targets on their own.

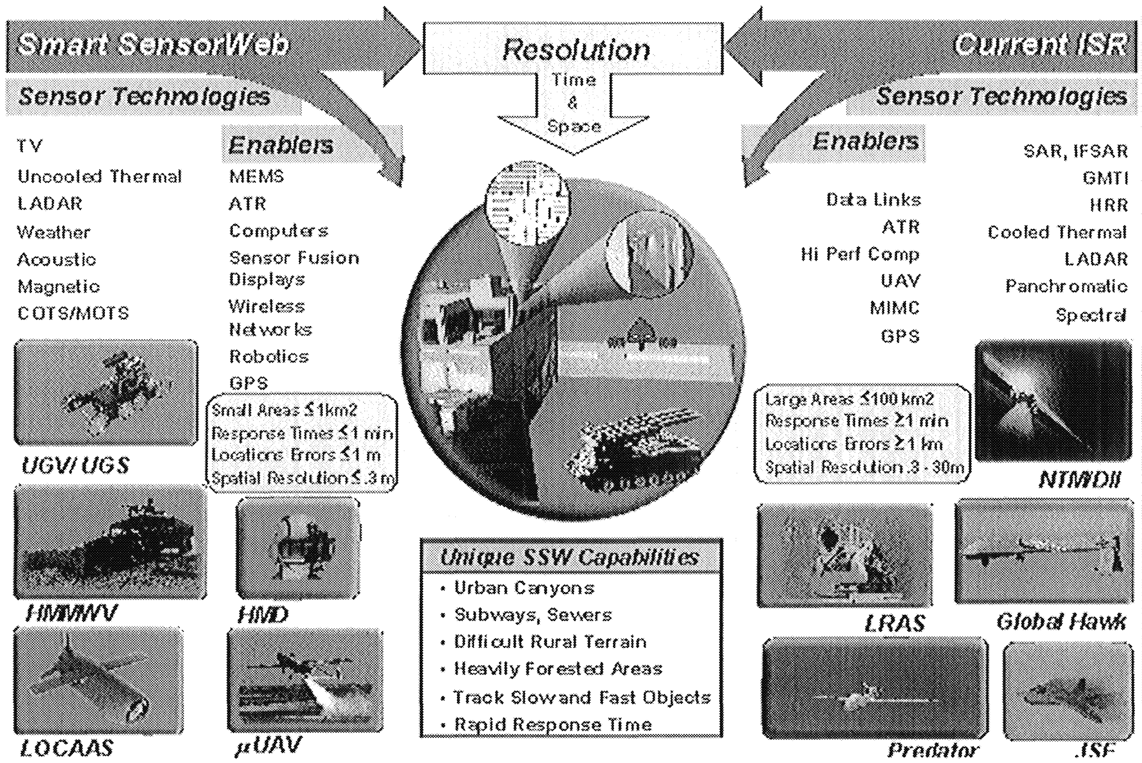

Figure1. Smart Sensorweb augments standard ISR in difficult scenarios where geometry and physical barriers limit the power of conventional standoff sensors. " Being there" is the essential ingredient to rapid response and full awareness.

To sum it up, the sensor web provides resolution with more favorable geometries on the short time scales needed for weapons use.

The Technology. What makes this possible? Extraordinary advances have occurred over the last decade in sensors, microelectronics, and communications – in both the military and commercial sectors. Imaging sensors include : TV cameras, low light level CCDs, cooled and uncooled thermal cameras, laser radar, multi-spectral imagers, and imaging radar. Non-imaging sensors include : laser rangefinders, designators, weather sensors, chemical and biological agent sensors, physiological status sensors, seismic, acoustic and magnetic sensors. In communications, we have the rpaid growth of wireless and cellular networks, In navigation we have the global postioning system (GPS) and micro electro mechanical systems (MEMS).

A notable example is the development of the "MicroFLIR," sponsored by the US Army Night Vision and Electronics Directorate (NVESD), Ft. Belvoir, Virginia. This device (Fig. 2) utilizes advances in uncooled thermal sensor technology and unique microelectronics to provide a system weighing only 70 grams, with a volume of approximately 12 cubic inches, and requiring only 540 milliwatts of power.

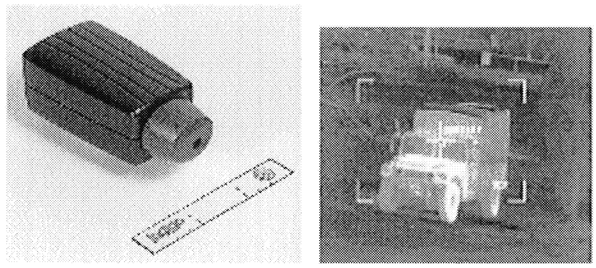

Figure 2. The MicroFLIR weighs only 70 grams and provides realtime thermal imaging in video format for either direct viewing by the soldier or wireless transmission to a sensor web.

Numerous technology advances in the non-DoD commercial sector (Fig. 3) and the rapid advances of the uses of the internet are being leveraged in the pursuit of the SSW initiative. The following chart shows the trends in miniaturization for communications and sensors. Thanks to major investments and advances in MEMS, it is now possible to mount imaging devices on handheld micro air vehicles. DARPA is working on a weather station in a 1 millmeter cube with communications ; the nickname is Smart Dust.

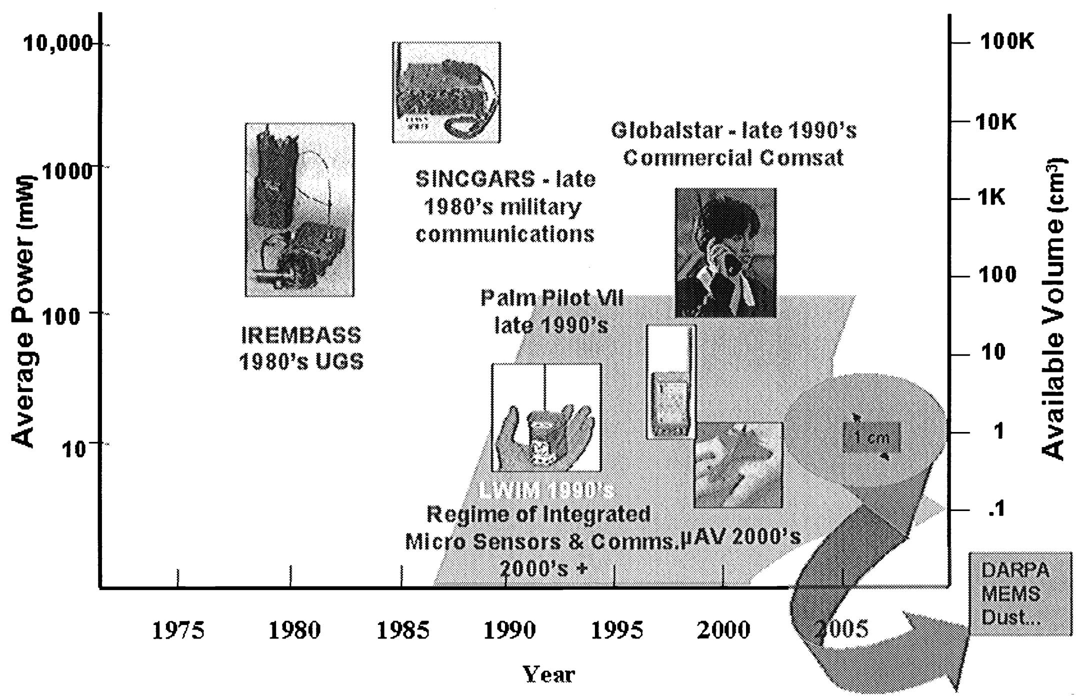

Figure 3. Powered by advances in microelectronics and MEMS, military and consumer markets will see the proliferation of low cost and expendable sensors for use in wireless networks.

The communications network of SSW will exploit advances in mobile, wireless networks supporting cell phones, interactive pagers, and laptops with PCMCIA communication cards. The miniaturization of powerful processors coupled with novel user interface technologies (e.g., voice, touch screen, gesture recognition, heads-up displays, etc.) supports the development of personal data systems that fit in the palm of a hand or on the back of a wrist, as well as hands-free computers. These devices are significant for linking the individual combatant to the power of the SSW. Bandwidth will be minimized by transmitting changes in data rather than constant streams of data. Local processors will facilitate this strategy.

Commercial wristwatches (Fig. 4) now provide Global Positioning System (GPS) information, weather information, and even remote sensing (e.g., sensors that can determine the temperature of a remote object). A remote connection through the Internet provides real-time control of cameras (pan, tilt, and zoom), an important step toward the real time, *Virtual Presence* that SSW will provide the Warfighter.

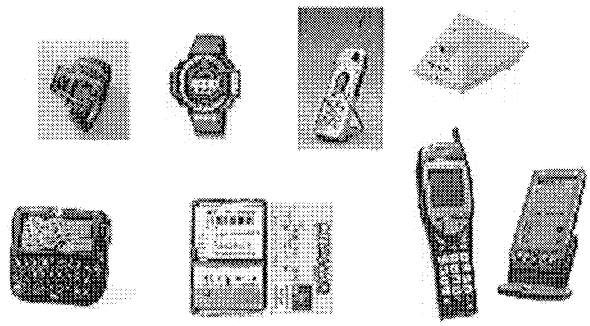

Figure 4. Consumer products derived from earlier Defense investments are stimulating the military to consider denser deployment of communications, geolocation, information, and sensors at lower echelons.

The Smart Sensorweb Program. To translate the vision of the SSW into reality, OSD is sponsoring a test bed to demonstrate state-of-the-art hardware and software technologies, from on-going DoD efforts and from the commercial sector; and to use experiments to assess technical and operational utility of these technologies. The other aspect of the test bed is to determine technical needs (power sources, bandwidth, etc.) and operational requirements (information needs, presentation capabilities, sensor employment, etc.).

For the first 2-3 years of the effort, OSD will utilize the Military Operations in Urban Terrain (MOUT) site at Fort Benning, Georgia, for test bed integration and demonstration. This site was selected particularly because local situation awareness is most difficult and most critical in built-up, urban areas. The MOUT site is fully instrumented for collecting experimental data can leverage the site personnel knowledge gained from many Joint and Service exercises and technology demonstrations over the past several years.
To identify the major SSW components and provide a framework for this multi-disciplinary effort, "Sub-Webs" were established. Initially, there were five Sub-Webs : Image, Weather, Weapons, Simulation, and Information Integration. Physio-Med Sub-Web was recently added and additional Sub-Webs are being considered, as additional capabilities (e.g., chemical and biological sensing) are included in the experiments and demonstrations.

The SSW test bed activitiy is a joint, DoD-wide, effort, involving DARPA and all the Services, including : the Air Force Research Laboratories (AFRL), the Army Research Laboratory (ARL), the Army Night Vision Electronics and Sensors Directorate (NVESD), the Office of Naval Research (ONR), and other Service Labs and Research Centers throughout the U.S.

The First Experiment. In late August of 2000, the first experiments with live troops were conducted at Ft. Benning, Ga, location of the McKenna MOUT site. Figure 5 shows the top level architecture. The results were encouraging and surprising. Troops using formative SSW products performed their missions much more efficiently than without. Furthermore, they felt that the potential for even greater advantage was very high and they provided numerous ideas on how to improve the next phase planned for January of 2001. The surprise is the fact that the oft predicted cognitive overload associated with a glut of information did not manifest itself. The soldiers seemed ready and willing to adjust preferences and useage to siphon that information they felt they needed most. They complete the smart aspects of the web in that all levels will employ processors and agents to transmit only the essential data and thus mininmize web congestion.

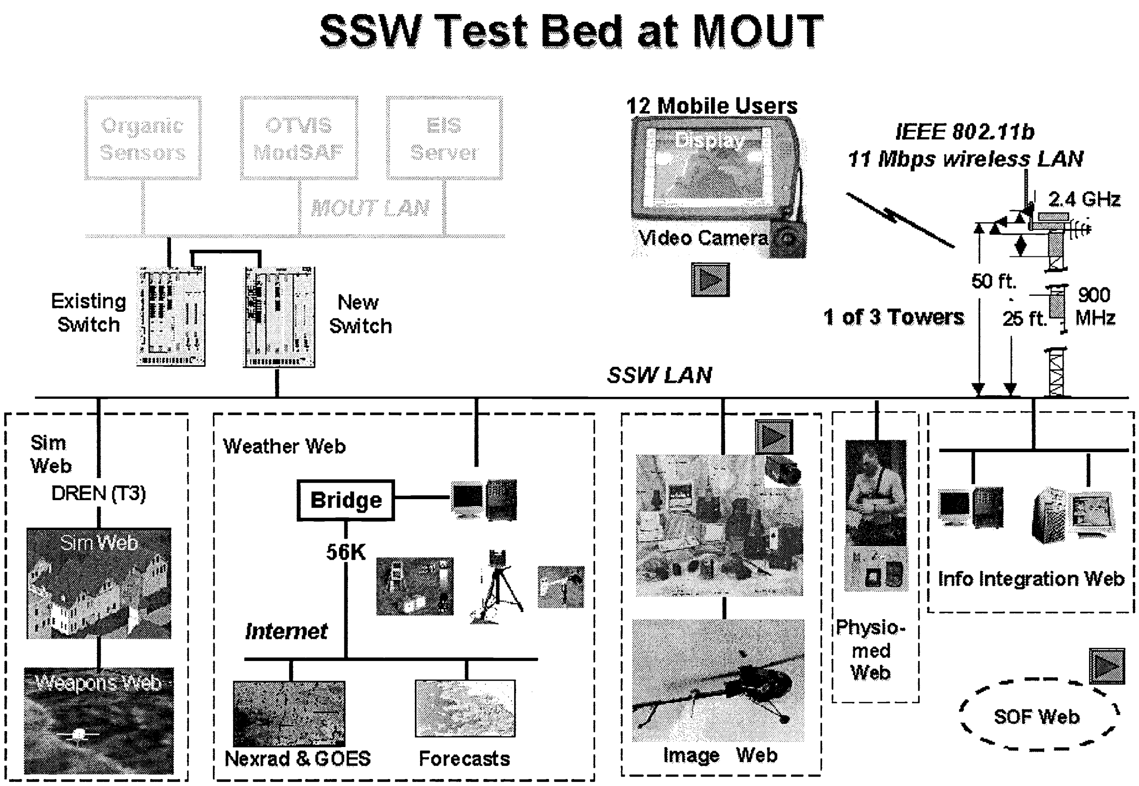

Figure 5. The first SSW experiment in August blended a mix of simulation and real systems in a wireless network that was tied locally to a control center at the MOUT site. Remote assets played in the operational scenarios via the DREN.

The Future. What can we expect as the concepts of Smart Sensorweb evolve and mature ? We can answer this question by reviewing the ultimate vision behind SSW. The key ingredients are :

- *Omnipresent local sensor fields.* These sensor fields will be deployed before, during, and after military operations by air, sea, and ground vehicles, and individual soldiers.
- *Layers of networks to move sensor data around the battlefield.* Information will passed around local and global networks just as is now emerging on the commercial internet.
- *Visualization tools to provide virtual presence to the user.* Users at all echelons will be immersed in 3-D displays that provide pre-mission training, planning, and realtime operational capability. Our forces will have the ability to 'be' and see nearly everything.
- *Distributed smart agents to refine the sensor data and infuse knowledge.* Users will be aided by invisible hoards of smart agents that perform automatic target detection, recognition, and identification, object and personnel tracking, planning advice, training scenarios, and weapons cueing, delivery.

Conclusion and Credits. The path to Smart Sensorweb will be evolutionary. Not all the pieces will arrive at the same time. But commercial and military technology will readily enable all of them in this decade. It will simply be a matter of using an acquisition strategy that allows this evolution to move smoothly and rapidly at reasonable cost. Since late 1997, the phenomenon of sensor webs has exploded. Many Service and DARPA programs have appeared that work various aspects of the concept. Several preceded the actual ARES conference and were in place as the Smart Sensorweb effort in OSD began. There are too many relevant efforts to mention here. The key elements for future sensor webs are now rapidly developing in excellent programs at DARPA and in the Services. The OSD program strategy has been to leverage these and fold them into the experiments. Special thanks are due to Professor Burton Richter of Stanford who chaired the first ARES and Professor S. Koonin of CALTECH who chaired the physics panel which developed the sensorweb concept. It is also important to acknowledge the enthusiastic support of MIT Lincoln Laboratory personnel: Walt Morrow, Al McLaughlin, and Al Gschwendtner.