



Through-the-Wall Sensors for Law Enforcement

Market Survey

October 2012



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Table of Contents

1.0	Executive Summary.....	1
2.0	Introduction	3
2.1	Basic Principles of Operation	3
2.2	FCC Regulations	6
3.0	Commercially Available Equipment (FCC-Certified).....	9
3.1	Continuous Wave (CW) Systems.....	9
3.1.1	Rex-Plus (STI)	10
3.2	Pulse Wave Systems	11
3.2.1	Range-R (L-3 Communications CyTerra Corporation)	11
3.3	Ultra-Wide Band (UWB) Pulse Instruments.....	12
3.3.1	Xaver 100 (Camero-Tech)	12
3.3.2	Xaver 400 (Camero-Tech)	13
4.0	Comparison of Commercial Systems (FCC-Certified)	15
5.0	Additional Uncertified TTWS Systems	17
5.1	InSight (Raytheon).....	17
5.2	Eagle5 Series (TiaLinx)	18
5.2.1	Eagle45-W (TiaLinx).....	19
5.2.2	Eagle5-N (TiaLinx)	19
5.3	Xaver 800 (Camero-Tech).....	20
5.4	Prism 200 (Cambridge Consultants).....	20

5.5 SuperVision 1600 (Yiwu Tianying Optical Instrument Co., Ltd.).....	21
5.6 ACU-CPR4 (Acustek).....	22
6.0 Prototype TTWS Systems Under Development	25
6.1 ASTIR (AKELA)	25
6.2 ImpSAR (Eureka Aerospace).....	25
6.3 STORM Portable Unit (VAWD Engineering).....	26
6.4 Range-R 2D (L-3 Communications CyTerra Corporation).....	27
7.0 Conclusions.....	29
Appendix: Acronyms and Abbreviations.....	31

List of Figures

Figure 2.1-1 Attenuation properties of common building materials.....	4
Figure 3.2.1-1 L3-CyTerra Range-R.....	11
Figure 3.3.1-1 Xaver 100 (Pre-Production Version).....	12
Figure 3.3.2-1 Xaver 400.....	13
Figure 5.1-1 Raytheon InSight STTW (Demonstration Unit)	17
Figure 5.2-1 Eagle5-P.....	18
Figure 5.2.1-1 Eagle45-W	19
Figure 5.2.2-1 Eagle5-N and Eagle5-NL.....	19
Figure 5.3-1 Xaver 800.....	20
Figure 5.6-1 ACU-CPR4	22
Figure 6.1-1 ASTIR Prototype	25

List of Tables

Table 4-1 Commercially Available TTWS in the U.S.	15
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1.0 Executive Summary

The National Institute of Justice (NIJ) Sensor, Surveillance, and Biometric Technologies (SSBT) Center of Excellence (CoE) has undertaken a market survey of through-the-wall sensors (TTWS) certified by the Federal Communications Commission (FCC) for operation by law enforcement and first responder agencies in the United States. These devices generally use a form of radar to detect small amounts of movement behind barriers; in some cases, the movement associated with normal breathing is enough to allow detection. TTWS allow for enhanced situational awareness during operations when knowledge of the presence of individuals behind opaque barriers would be of benefit, during law enforcement operations requiring forced entry, in hostage situations, in building sweeps by firefighters or when locating individuals in rubble during search-and-rescue operations. Some devices provide a range to the moving target and others, a two-dimensional (2D) graphical display of multiple targets.

The FCC governs TTWS use and generally requires devices to be certified prior to use by law enforcement and first responder agencies. In addition to FCC-certified equipment, this report also identifies several systems not currently certified by the FCC. Some non-certified systems are in late stages of development, several devices initially intended for military use are being reengineered and repurposed for civilian law enforcement use, and others in use in other countries have not undergone certification for use in the United States.

The intended use of a TTWS device dictates requirements. This report provides an unbiased survey of available equipment and its operational capabilities and limitations (as reported by manufacturers). This information provides individuals and organizations with a better understanding of the capabilities and limitations of available equipment. In conjunction with the agency's requirements for intended use, the information provided in this report will help individuals and organizations identify a more optimal system based on their particular needs and requirements.



2.0 Introduction

The NIJ-sponsored Sensors and Surveillance Technology Working Group (TWG) has identified a technology need for first responders to be able to sense the presence of persons through visually obscure barriers. The ability to sense the presence of individuals through common building materials can be useful during rescue operations, law enforcement operations and other tactical scenarios. Firefighters could use the ability to detect individuals to more quickly clear dangerous areas (e.g., buildings that are on fire could be more quickly checked for trapped survivors), rescue personnel could use TTWS to more easily locate survivors after a building collapse and law enforcement personnel could use TTWS to enhance situational awareness during tactical operations (e.g., building clearance, hostage threat situations).

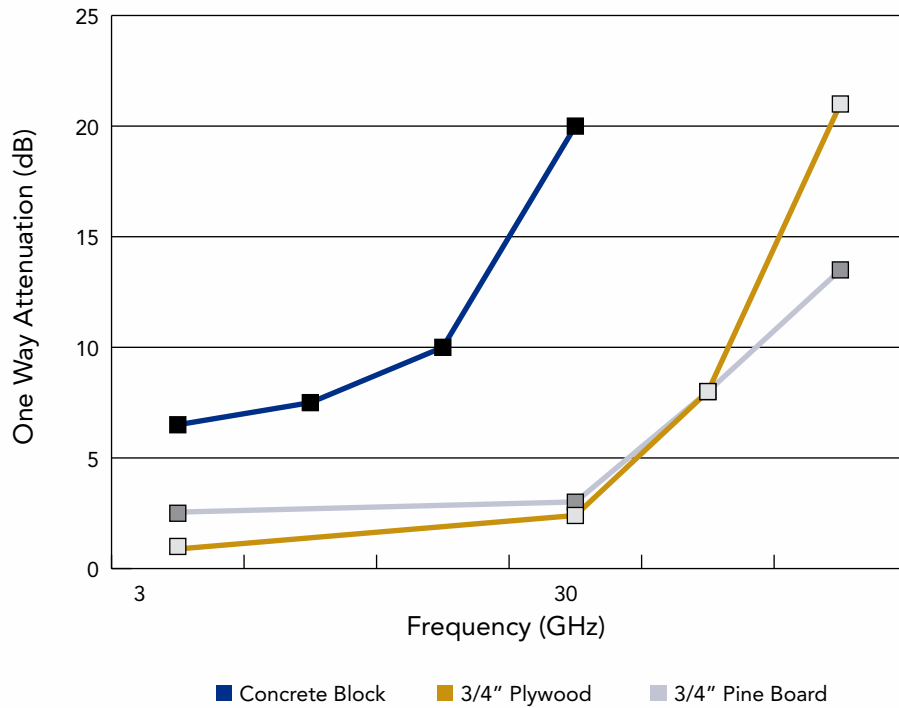
TTWS can display a variety of information, from the simple “movement detected” to a 2D graphical representation of detected movement in relation to the sensor. Devices may also provide additional information such as a graphical representation of repetitive movement (as would be expected in detection of breathing). Some data interpretation is straightforward (such as the display of “movement detected”) and other data interpretation may require training on the instrument for optimal use. The amount of training needed depends on the amount, quality and level of data presented by the instrument.

2.1 Basic Principles of Operation

To detect the presence of an object, a TTWS device sends out an electromagnetic signal (i.e., radio waves). The signal propagates from the device and is then reflected by an object. Part of the reflected signal then travels to a receiver that detects the reflected signal. The receiver is typically (although not necessarily) in the same device as the transmission source. The reflected signal then indicates the presence of an object; the strength of the reflected signal may indicate the proximity and/or how reflective the object is (i.e., size, material composition). With advanced signal formation (e.g., pulses) and signal processing methodologies, other qualities of the target can be deduced, qualities such as the range to the target and whether the target is stationary or moving.

To sense an object on the other side of a wall, the TTWS signal must be able to penetrate through the wall, reflect off an object, travel back through the wall and finally reach the receiver. How easily the TTWS detects an object depends on the amount of signal returned to the receiver. This in turn depends on how much signal the object reflects and how well the signal passes through barriers (e.g., walls) between the object and the TTWS device. Loss of signal due to barriers is known as *attenuation*, and the amount of attenuation depends on the properties of the barrier materials and the thickness of the materials. Figure 2.1-1 shows the attenuation properties of several common building materials at different frequencies.

Figure 2.1-1 Attenuation properties of common building materials



A subset of data from SPIE, the international society for optics and photonics. (Frazier, L.M. Feb. 18, 1997. *Radar Surveillance through Solid Materials*. Bellingham, WA: SPIE, 2938: pp. 139-146).

From Figure 2.1-1, it can be seen that lower frequencies (i.e., longer wavelengths) tend to penetrate barriers better than do higher frequencies (i.e., shorter wavelengths), but there is a tradeoff. It is more difficult to detect slight changes in frequencies due to Doppler effects in longer wavelengths than it is for shorter wavelengths. Also, shorter wavelengths can provide better location data than longer wavelengths. In addition, it is possible that a barrier may attenuate a small range of wavelengths (a band) much more strongly than surrounding wavelengths. Note that in the above figure there are only three or four data points for each material

and a curve has been fitted to include the points. This may mask highly attenuating areas in between data points. In addition, the composition of building materials may vary significantly from manufacturer to manufacturer. The use of a wide range of frequencies for the signal will help to “probe” the frequency spectrum so that the device uses the best tradeoff of penetration to detection/localization. This can be accomplished by either changing the frequency of the signal (i.e., using a “frequency sweep,”) or by using a *wide band* signal that inherently contains a wide range of frequencies.

A very simplistic device would continuously emit radio waves of a single frequency and would be able to detect any changes in the strength of the reflected signal. For instance, a device may be situated near a wall in an effort to detect if someone walks by on the other side of the wall. If the TTWS uses a frequency that penetrates the wall and reflects off a target, when a target approaches the device, the TTWS reflects more and more signal. An increase of the reflected signal above a predetermined threshold triggers an alarm of some kind (e.g., audible, visual, recording device). The device would not be able to determine the distance to the reflective target and small movements may not be detected by a change in the reflective intensity. A consumer product, Rex-Plus, is intended to sound an alarm when individuals approach a residence, and it appears to operate in this manner (see Section 3.1.1). More advanced methods and technologies can be used to determine the distance to the reflecting object and to detect small movements such as chest expansion and contraction during breathing.

Although signal strength may be used to indicate relative distance from the transceiver, a much more accurate technique is to use pulsed methods. A *pulsed signal* travels toward an object, is reflected and returns to the receiver at the same speed. Since the pulse speed is known, the amount of time required for the pulse to make the round trip depends on the distance of the object from the transmitter/receiver. A pulsed system determines the distance to an object by measuring the time difference between transmission and reception of a pulse.

Higher sensitivity to movement is accomplished by the use of Doppler radar techniques. Doppler radar takes advantage of the fact that a reflected signal from a moving object will have a slightly different frequency than the initial signal sent out by the transmitter, whereas signals reflected from stationary objects will have the same frequency as the initial signal. The use of Doppler techniques allows for the detection of very small amounts of movement, such as the movement of a chest cavity during breathing.

Combining Doppler effects with pulsed systems can allow a system to detect very small amounts of movement and to determine the distance of an object from the transmitter/receiver. In addition to using a combination of the above techniques,

the use of a technology known as *ultra-wide band (UWB) radar* has several advantages over conventional techniques, including better penetration properties, better range determination and decreased signal detection by second/third parties. Many commercially available products use UWB, Doppler and/or pulse technologies to gather as much information as possible.

2.2 FCC Regulations

Note: Organizations and individuals should seek legal counsel before operating TTWS. The summary and interpretations of relevant FCC regulations are the opinions of the SSBT CoE and should not be taken as legal advice. They are provided here for informational and planning purposes only.

The FCC regulates interstate and international communications by radio, television, wire, satellite and cable.¹ The FCC governs all devices that emit radio waves and regulates the frequencies and power levels on which the devices are allowed to operate. The FCC also distributes licenses for the use of frequency bands to individuals and to organizations, if required.² TTWS fall under the categories of intentional radiators and radiolocators; some TTWS are also governed by UWB requirements. Key regulations from Title 47 of the Code of Federal Regulations (CFR) for TTWS include:

1. [Parts 15, 90] Intentional radiators are required to have FCC certification.³ FCC-certified devices will have an FCC Identification (FCCID) number associated with them and shall be labeled as such.⁴
2. [Part 15] UWB TTWS Operation is limited to law enforcement, emergency rescue or firefighting organizations.
3. UWB TTWS Operators (or the organization by which the operator is employed by or volunteers for) must have a license in the Public Safety Radio Pool under Title 47 Code of Federal Regulations, Part 90.

¹ Federal Communications Commission. *What We Do*. <http://www.fcc.gov/what-we-do>. Accessed July 3, 2012.

² Electronic Code of Federal Regulations. *Title 47: Telecommunications; Part 15 - Radio Frequency Devices*. <http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr;sid=1a11ffedc3fee3edd61c0b5bd6c0f66c;rgn=div5;view=text;node=47%3A1.0.1.1.16;idno=47;cc=ecfr>. Accessed July 2, 2012.

³ Electronic Code of Federal Regulations. *Title 47: Telecommunications; Part 15 - Radio Frequency Devices; Subpart C – Intentional Radiators*. <http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr;sid=bad3dcf075dd6e1571512a489dad02b2;rgn=div6;view=text;node=47%3A1.0.1.1.16.3;idno=47;cc=ecfr>. Accessed July 2, 2012.

⁴ Federal Communications Commission. *Equipment Authorization – Authorization Procedures*. <http://transition.fcc.gov/oet/ea/procedures.html>. Accessed July 2, 2012; 784748 *Part 15, Part 18, Labeling Guidelines, Labeling, Information to User, Information in M*. <http://apps.fcc.gov/oetcf/kdb/forms/FTSSearchResultPage.cfm?id=27980&switch=P>. Accessed July 2, 2012.

All three restrictions can be waived by the FCC under an Experimental License, which must be obtained by the operating organization. Companies conducting research and development (R&D) of TTWS and performing third-party testing and evaluation often require an FCC Experimental License.

Vendors may not be forthcoming about these FCC requirements. It behooves the purchaser to verify FCC certification of the device and that the intended operator or organization holds the proper license for operations before making a purchase. FCC certification can be verified by requesting the FCCID from the vendor and using the FCCID to search the FCC database for authorized equipment.⁵

It is also important to note that federal agencies do not fall under FCC jurisdiction and are instead governed by the National Telecommunications and Information Administration (NTIA). By default, NTIA regulations allow federal agencies to purchase and operate FCC-certified equipment (Part 90, Part 15); non-certified or experimental TTWS would require NTIA approval to operate.⁶

⁵ <http://transition.fcc.gov/oet/ea/fccid/>

⁶ Lazarus, M. Fletcher, Heald & Hildreth. "RE: FCC Regs for Operating UWB Through-Wall Systems." Personal e-mail to Lars Ericson, June 26, 2012.



3.0 Commercially Available Equipment (FCC-Certified)

Note: Prior to the preparation of this report, the SSBT CoE did not conduct any laboratory or field testing to verify the performance or features of specific devices or detection technologies. Assessments are based on subject-matter expertise, available literature and vendor materials.

Commercially available TTWS range from stationary sensors to more sophisticated portable equipment. Available stationary systems continuously emit a single frequency and only alarm when the reflected signal strength reaches a certain threshold, whereas available portable devices use a wide range of frequencies and can determine distances and/or movements (even small amounts of movement such as breathing).

The utility of the equipment depends on the ability of the emitted signals to pass through barriers, reflect off a target and return to the receiver. Figure 2.1-1 presents the attenuation of the signals by common building materials, but in addition, it should be noted that radio waves cannot penetrate continuous metal barriers such as cargo containers and the sides of metallic rail cars and trailers.

Law enforcement and first responders are bound by operating under FCC regulations when it comes to TTWS (see Section 2.2). As a result, knowledge about the breadth and depth of commercially available devices that can provide through-wall capabilities in tactical and emergency rescue scenarios is important so that the agency can choose the right tool for the right job. Generally, there are three categories of TTWS: continuous wave, pulse wave and UWB.

3.1 Continuous Wave (CW) Systems

CW instruments send out radio waves without breaks or pulses in the signal emission. These devices can be configured to take advantage of Doppler effects so that they can detect very small movements. However, they cannot provide accurate range data because the continuous nature of the signal does not allow for accurate timing between the transmission and reception of the signal.

In a typical CW system, the frequency of the signal is precisely controlled and essentially consists of a single frequency. When the transmitted signal reflects off a moving target, the frequency of the reflected signal will be slightly shifted from that of the transmitted signal. An audio analog of this effect can be heard as a car passes: the sound produced by the car is higher in tone as the car approaches and lowers after the car passes. Similarly, for CW radar, if the target is moving toward the transceiver, the frequency will be shifted slightly higher; if the target is moving away from the transceiver, the frequency will be shifted slightly lower. Also, the faster a target is moving, the more the frequency shifts. Even slight movements can be detected by this method.

3.1.1 Rex-Plus (STI)

Rex-Plus, by Safety Technology International, Inc. (STI), is a consumer device designed to be placed inside a residence and detect motion outside.⁷ The device demonstrates what can be achieved with basic components. It costs around \$100 and is comparatively low tech. When placed on one side of a wall, the device uses radio waves to detect motion on the other side. The device puts out a continuous signal at 2.4 GHz and will alarm once reflected energy is received. The alarm frequency and volume increase as the target gets closer. Therefore, as someone walks toward a wall, the signal reflects off the individual and back to the receiver. Once the signal reaches a certain threshold, the alarm starts to sound. As the individual gets closer to the wall, the reflected signal strength increases, and this triggers higher alarm rates and volume.

A device such as this may be useful for monitoring a low or very low traffic area, but the time required to set a reliable threshold level, the necessity for 120V AC and the potential for false alarms (both positive and negative) make it unsuitable for most applications that law enforcement or first responders would require.

Note that although the Rex-Plus was the only device of its class identified by the SSBT CoE – namely a commercial TTWS device marketed to civilian non-law enforcement – because the assessment’s focus is on security, defense and law enforcement technologies, others in this class may exist.

⁷ Safety Technology International, Inc. *STI Rex Plus*. <http://www.sti-usa.com/pdf/specs/ED50.pdf>. Accessed July 2, 2012; Rex Plus Electronic Watchdog ED-50. <http://www.sti-usa.com/product.asp?PartNo=ED-50>. Accessed July 2, 2012.

3.2 Pulse Wave Systems

As mentioned in the introduction, the use of pulses in radar allows the determination of distance. Because the signal is pulsed and not continuous, it is possible to measure the amount of time it takes for the signal to make the round trip from transmitter to target and back to receiver, and therefore calculate the distance based on the radar signal speed.

3.2.1 Range-R (L-3 Communications CyTerra Corporation)

The Range-R is made by L-3 Communications CyTerra Corporation (FCCID: YKD-25TWD3000).⁸ Although the Range-R technically uses CW and scans a wide range of frequencies, it is placed in the pulse-based equipment category because it uses a technology known as Stepped Frequency Continuous Wave (SFCW). In



Figure 3.2.1-1 L3 CyTerra Range-R
Photo courtesy of NLECTC SSBT CoE

SFCW, a frequency range is swept by using quick, discrete changes in the wavelengths. The change in frequency creates a synthetic pulse that determines range by examining the length of time needed for the synthetic pulse to make the trip from transmitter to object to be detected and back.⁹ Sweeping a wide range of frequencies improves the probability that the signal penetrates barriers and still provides enough sensitivity to detect targets. The Range-R uses Doppler techniques to detect motion, even the slight motion associated with breathing. When the Range-R detects a moving object, the instrument displays a numerical value for the range of the detected object. The Range-R also indicates to the operator whether the detection was based on target movement or on breathing. Detection is within a 160-degree field of view and the Range-R can detect movement at 15.25 meters without barriers. The detection range will decrease depending on the attenuation properties of any barrier between the target and the device. The Range-R costs approximately \$6,000.

⁸ L3 Communications CyTerra Corporation. *Range-R; Handheld Through-Wall Sensor*. <http://www.range-r.com/documents/RANGER.PDF>. Accessed July 2, 2012.

⁹ Jol, H.M., ed. 2009. *Ground Penetrating Radar Theory and Applications*. Amsterdam, The Netherlands: Elsevier B. V., p. 76.

An upgraded version of the Range-R, called Range-R Link, incorporates wireless communications capability for remote monitoring and scan control.¹⁰ The unit includes a wireless module along with a fixture for attaching a monopod stand. The operator can then control the unit via a peer-to-peer connection through an iOS application (Android app version is finished and standing by for release). Operators can initiate scans and receive measurement signals through the mobile application. Range is limited to typical wireless signal strengths found in civilian electronic and computer devices. Existing Range-R systems can be upgraded by L-3 for approximately \$3,000, with the full Range-R Link system costing approximately \$9,000.

3.3 Ultra-Wide Band (UWB) Pulse Instruments

Although UWB techniques use a pulsed system, the emitted pulses differ significantly from those used by the instruments described in the previous section in both pulse width and frequency band used. As mentioned in the introduction, these properties can create advantages over normal pulse systems. UWB instruments create an extremely short (nanosecond) pulse that contains a wide range of wavelengths. The composite pulse enhances the probability that at least a portion of the wavelengths will be able to penetrate obstacles (such as walls) and reflect off the intended targets. The extremely short pulse duration may also allow for higher range resolution.



Figure 3.3.1-1 Xaver 100 (Pre-Production Version)
Photo courtesy of Camero-Tech. Used by permission.

3.3.1 Xaver 100 (Camero-Tech)

The Xaver 100 is made by Camero-Tech Ltd. and distributed in North America by Mistral Security, Inc. (FCCID: A42X100F).¹¹ The Xaver (pronounced “Saver”) series of TTWS uses UWB pulse technology to sense through walls. These devices are single-user handheld devices that detect movement (such as that from breathing)

¹⁰ L-3 Communications CyTerra Corporation, Meeting with SSBT CoE staff., Oct. 23, 2012.

¹¹ Camero-Tech Ltd. XaverTM 100. <http://www.camero-tech.com/product.php?ID=38>. Accessed July 3, 2012. Mistral Security, Inc. *Tactical Sense-Thru-The-Wall (STTW) Imaging Solutions*. [http://mistralsecurityinc.com/products/Tactical%20Equipment/Tactical%20Sense-Thru-The-Wall%20\(STTW\)%20Imaging%20Solutions/](http://mistralsecurityinc.com/products/Tactical%20Equipment/Tactical%20Sense-Thru-The-Wall%20(STTW)%20Imaging%20Solutions/). Accessed July 3, 2012.

through a wide range of normal construction material. The field of view is 120 degrees and the device has an 8-meter detection range. The instrument can be operated in stand-off mode, but as with most stand-off systems, it's best to have the device mounted to a stable mount (on a tripod, for instance) because even small movements by the operator can interfere with the operation of the device. An optional platform (XaverNet Rugged PDA platform) allows for wireless control and viewing of multiple units. The U.S. distributor for the Xaver 100, Mistral Security, ran an Early Adopter Program through May 2012 that made pre-production units available to interested organizations, and planned a fall 2012 release based on that program. According to Mistral Security, the pre-production and final devices differ only in external packaging and device orientation (horizontal vs. vertical). The final production Xaver 100 will retail for \$9,000.¹²

3.3.2 Xaver 400 (Camero-Tech)

The Xaver 400 (FCCID: A42X400F) is made by Camero-Tech and distributed in North America by Mistral Security.¹³ Compared to the Xaver 100 (see Section 3.3.1), the Xaver 400 is a larger two-handed device that provides additional information, such as approximate direction (azimuth) and tracking, for user interpretation.¹⁴ The Xaver 400 can detect living as well as static objects within a maximum range of 20 meters with a field of view of 120 degrees. The Xaver 400 operates in three modes (Tracker, Expert and High Penetration) and has three maximum detection ranges (4 meters, 8 meters and 20 meters). Because it can



Figure 3.3.2-1 Xaver 400
Photo courtesy of Camero-Tech. Used by permission.

¹² Mistral Security, Inc. 2012. *Early Adopter Program Brochure*. Bethesda, MD: Mistral Security.

¹³ Camero-Tech Ltd. *Xaver™ 400*. <http://www.camero-tech.com/product.php?ID=39>. Accessed July 3, 2012; Mistral Security. *Tactical Sense-Thru-The-Wall (STTW) Imaging Solutions*. [http://mistralsecurityinc.com/products/Tactical%20Equipment/Tactical%20Sense-Thru-The-Wall%20\(STTW\)%20Imaging%20Solutions](http://mistralsecurityinc.com/products/Tactical%20Equipment/Tactical%20Sense-Thru-The-Wall%20(STTW)%20Imaging%20Solutions). Accessed July 3, 2012.

¹⁴ Camero-Tech Ltd. *Xaver™ 400: Compact, Tactical Through-Wall Imaging System Product Data Sheet*. <http://www.camero-tech.com/files/files/Xaver400.pdf>. Accessed July 3, 2012.

detect static objects, the Xaver 400 can provide information about room dimensions and major infrastructure elements. Image quality in cluttered environments is improved by the use of image reconstruction algorithms. An optional internal wireless video transmitter is available for remote display. Camero-Tech states that the Xaver 400 has been widely deployed with leading military and law enforcement users around the world.¹⁵ The device is available from the U.S. distributor, Mistral Security, at a price of approximately \$47,500.

¹⁵ Camero-Tech Ltd. *Xaver™ 400: Compact, Tactical Through-Wall Imaging System Product Data Sheet*. <http://www.camero-tech.com/files/files/Xaver400.pdf>. Accessed July 3, 2012.



4.0 Comparison of Commercial Systems (FCC-Certified)

This chapter provides a summary of the commercially available FCC-certified TTWS systems suitable for law enforcement or emergency response applications for ease of reference and comparisons. Key characteristics and parameters are assembled in Table 4-1.

Table 4-1 Commercially Available TTWS in the United States

Product Name ¹	Mfr.	Unit Cost	Training	Operating Range ² (meters)	Field of View (degrees)	Weight (lbs)	Battery Life	Frequency (GHz)
Range-R	L3	\$6,000 ⁴	Included	15.25	160	1.2	400 uses	3.18 – 3.42
Xaver 100	Camero-Tech	\$9,000	Included	8	120	1.2	3 hrs	3 – 10
Xaver 400	Camero-Tech	\$47,500	Included	20	120	7	2.5 - 4.5 hrs ³	2 – 10

¹ The Rex-Plus is a consumer residential product and has not been included because it is unsuitable for law enforcement or emergency response applications.

² The effective operating range to a target through a barrier is dependent on the barrier material composition, signal composition/shape and output frequency(s).

³ Dependent on the number of batteries installed in the system during operation.

⁴ Range-R Link with wireless monitoring and control costs \$9,000.

Key

- **Unit Cost** in U.S. dollars of a single unit with supporting material (if needed) for operating the device in the field.
- **Training** included for the operation of the instrument.
- **Operating Range:** Manufacturer stated the range in which the device can detect a target without attenuating barriers, unless otherwise noted. *Without attenuating barriers* was chosen as the base for this parameter because signal frequencies, barrier properties and signal properties all affect range in differing dependencies.

- **Field of View** indicates the angular width at which the device can detect targets.
- **Weight** of the device when operated.
- **Battery Life** (where applicable): The length of operational time that the device can be operated on one set of fully charged (or fresh) batteries.
- **Frequency** or frequency range that the device uses to form the signal used for target detection.



5.0 Additional Uncertified TTWS Systems

This report mainly focuses on equipment certified by the FCC for operation in the United States by law enforcement and first responder agencies. However, since manufacturers of non-certified devices may consider certification in the future, this section identifies non-certified devices. Some of these devices are based on units that have been in use by the military for years, but are being adapted for civilian law enforcement use; other devices were developed outside the United States and are currently in use in other countries. The following list is not a comprehensive one of non-certified devices, but rather includes devices encountered during our investigations that may be of interest to the law enforcement community.

5.1 InSight (Raytheon)

The InSight is a handheld TTWS made by Raytheon for military use.¹⁶ This small handheld device weighs 3.3 pounds and can operate for 3.5 hours using rechargeable batteries. The device has a 100-degree, two-dimensional (2D) field of view with an operating range of up to 40 meters. The device is able to detect walls as well as moving targets, including slight motion (although not motion associated with breathing). The InSight operates between 2.9 and 3.5 GHz, and is expected to cost in the \$10,000 to \$15,000 per unit price range for large orders.¹⁷



Figure 5.1-1 Raytheon InSight STTW (Demonstration Unit)

Photo courtesy of NLECTC SSBT CoE

¹⁶ Raytheon Company. 2009. *Insight Sense Through The Wall (STTW) Product Brochure (rev 3)*. Ft. Worth, TX: Raytheon.

¹⁷ Cook, Carl. *Sense Through The Wall (SSTW) Technology and Raytheon InSight Product Demonstration*. Presentation at the Sensors and Surveillance Technology Working Group meeting, Arlington, Va., April 19-20, 2011.

The manufacturer designed InSight for military use but is currently seeking FCC approval for civilian law enforcement use. Under the Criminal Justice Technology Information and Sensor Systems CoE (Award# 2009-IJ-CX-K113), operated by SCRA, several domestic police departments evaluated the device with favorable reviews. One department had on hand another TTWS, Radar Vision by Time Domain (a device no longer produced) and compared the performance of the two devices, finding the InSight to be superior in portability and ease of use (Radar Vision is a much larger, two-handed device). However, the older device was able to better detect and track targets through interferences such as glass, steel supports and sheet rock.¹⁸

5.2 Eagle5 Series (TiaLinx)

The Eagle5 line of TTWS is offered by TiaLinx, Inc.¹⁹ This line of TTWS features stand-alone sensors that use UWB pulses centered on a frequency of approximately 5 GHz. The device uses a 2D image of reflective objects constructed by advanced algorithms using signal delay and amplitude information. The Eagle 45-W is a wrist-mounted device with an extended battery attached to the belt of the operator and a monacle display unit.

The Eagle5 N is a stand-off device intended to be used for surveillance, intrusions and area/perimeter monitoring.

It should be noted that in addition to these stand-alone devices, TiaLinx has incorporated its TTWS technologies into unmanned aerial vehicles (UAV), unmanned ground vehicles (UGV) and a ground-penetrating radar device. The Phoenix 50-H is a UAV and the Cougar Family consists of small robotic UGVs. Both the UAV and the UGV family use UWB pulse technologies for detection of targets. The main advantage is that in hostile environments, the vehicles eliminate the necessity of humans entering and placing equipment in high-profile and/or dangerous situa-



Figure 5.2-1 Eagle5-P Searching for culverts or tunnels

Photo courtesy of TiaLinx. Used by permission.

¹⁸ Raytheon. Dec. 6, 2011. *Final Report for Sense Through The Wall (STTW)*. Ft. Worth, TX: Raytheon.

¹⁹ TiaLinx, Inc. *Eagle Family*. Accessed July 3, 2012. Link no longer valid.

tions. The Eagle5-P is a ground-penetrating radar system intended for location of buried objects, tunnels and movement within tunnels.²⁰

5.2.1 Eagle45-W (TiaLinx)

The Eagle45-W is a wearable UWB device with the transmitter/receiver worn on the arm, leaving the hands free. The display unit can be a monacle or integrated with glasses or goggles. The Eagle45-W has an unobstructed detection range of approximately 18 meters with a field of view of 120 degrees.²¹ The unit is portable, battery operated for up to 4 hours and capable of wireless communications up to 300 feet from the scanner unit. The unit is 7 inches x 6 inches x 5 inches and weighs approximately 5 pounds. (Pricing information withheld at the request of the manufacturer.)



Figure 5.2.1-1 Eagle45-W
Photo courtesy of TiaLinx. Used by permission.

5.2.2 Eagle5-N (TiaLinx)

The Eagle5-N is a stand-off device intended to be used for surveillance, intrusions and area/perimeter monitoring. The device normally is mounted on a tripod, but it can also be affixed to objects by use of customized fixtures. The Eagle5-N has a range of approximately 12 meters for detecting breathing behind a barrier.²² It has a 60-degree field of view, although modifications are available to allow



Figure 5.2.2-1 Eagle5-N and Eagle5-NL
Photo courtesy of TiaLinx. Used by permission.

²⁰ TiaLinx, Inc. Accessed July 2, 2012; Link no longer valid. *Motion detector behind a wall*. Accessed July 9, 2012. Link no longer valid.

²¹ TiaLinx, Inc. April 2012. *Core Products; Phoenix, Cougar, Lynx, and Eagle Family*. Newport Beach, CA: TiaLinx; Mohamadi, Fred, Chief Executive Officer, TiaLinx. "RE: Sense Through The Wall Devices." Personal e-mail to Chad Huffman, June 27, 2012.

²² TiaLinx, Inc. April 2012. *Core Products; Phoenix, Cougar, Lynx, and Eagle Family*. Newport Beach, CA: TiaLinx.

for a 20-degree field of view with a much longer (approximately 120 meters) detection range (Eagle5-NL).²³ The 8-inch x 8-inch x 4.5-inch unit is battery operated for up to 4 hours and weighs less than 5 pounds. (Pricing information withheld at the request of the manufacturer.)

5.3 Xaver 800 (Camero-Tech)

The Xaver 800 by Camero-Tech uses the same UWB technology as the Xaver 100 and the Xaver 400, but the Xaver 800 can provide a three-dimensional (3D) representation of detected objects (both moving and static).²⁴ The device displays the location of moving and stationary targets as well as approximate room dimensions and major infrastructure components. It has a maximum range of approximately 20 meters and a field of view of 80 degrees in both azimuth and elevation. The Xaver 800 weighs 32 pounds (including batteries), folds up for transport to a size of 19 inches x 19 inches and expands to 33 inches x 33 inches during operation.

The main power source for the Xaver 800 is rechargeable batteries that operate the device for 2 hours. Currently, Camero-Tech has no plans to have the Xaver 800 certified by the FCC.²⁵



Figure 5.3-1 Xaver 800
Photo courtesy of Camero-Tech. Used by permission.

5.4 Prism 200 (Cambridge Consultants)

The Prism 200, produced by Cambridge Consultants, is an UWB-based system made in the United Kingdom.²⁶ It operates between 1.6 and 2.2 GHz, with a detection range of about 20 meters. The Prism 200 is 12 inches x 17.7 inches x 8.25 inches and weighs about 12.5 pounds, including an internal rechargeable

²³ Mohamadi, Fred, Chief Executive Officer, TiaLinx. "RE: Sense Through The Wall Devices." Personal e-mail to Chad Huffman, June 27, 2012.

²⁴ Camero-Tech. *Tactical Through-Wall Imaging Solutions; Xaver 800*. <http://www.camero-tech.com/files/files/Xaver800.pdf>. Accessed July 2, 2012.

²⁵ Levontin, Josh. "RE: Permission for use of Camero images...." Personal e-mail to Chad Huffman, July 1, 2012.

²⁶ Cambridge Consultants. *Prism 200*. <http://www.cambridgeconsultants.com/projects/prism-200-through-wall-radar>. Accessed July 3, 2012.

battery that can operate the instrument for 4.5 hours when fully charged. It has a viewing angle of 120 degrees in azimuth and 90 degrees elevation, and can display data in both 2D and 3D.²⁷ Advanced signal processing can highlight moving objects and people in cluttered environments. The device has an interface option available for laptop connection so remote viewing and recording can be performed. It is designed to track multiple people,²⁸ and is in use by national security agencies, security services, emergency services, the military and special forces throughout the world.²⁹ The system is also available through Westminster International LTD under the product name WG Covert Intelligence Through-wall Radar, with the same NATO stock number as the Prism 200 (5840-99-679-8569).³⁰

With a lower operational frequency than most other devices, the Prism 200 can be expected to have superior penetration capability, but it would be expected that Doppler shifts of the lower frequencies (and therefore small movements) would be difficult to detect. Note that the manufacturer does not state that motion due to breathing is sufficient for detection.

5.5 SuperVision 1600 (Yiwu Tianying Optical Instrument Co., Ltd.)

The SuperVision 1600 by Yiwu Tianying Optical Instrument Co., Ltd. (Tianying) is an UWB handheld TTWS manufactured in China.³¹ It operates between 1 and 3 GHz with a detection range of 16 meters. According to product descriptions by the vendor, the system has a unique antenna configuration that allows for a large field of view: vertical 120-degree and horizontal 90-degree planes. It can combine sensor measurements to produce a 2D map of object location and motion tracking. In addition, the TTWS reports to detect targets through 40 cm (15.7 inches) of concrete and possess high enough sensitivity to detect breathing and differentiate between a target lying face down or lying on the side. The SuperVision claims to also be able to determine whether a signal is a human or animal target.

²⁷ Cambridge Consultants. *Covert Intelligence Through-wall Radar*. <http://www.cambridgeconsultants.com/documents/download/fe345ceafb540735523b22fda67604354f8ebacdcf97c>. Accessed July 2, 2012.

²⁸ *Financial Times*. "Winners – East of England – FT.com." <http://www.ft.com/intl/cms/s/0/595f4ffa-6aa1-11e0-80a1-00144feab49a.html#axzz1z709iSIV>. Accessed June 26, 2012.

²⁹ Cambridge Consultants. *Prism 200 through-wall radar now available in the US*. <http://www.reuters.com/article/2008/06/30/idUS125568+30-Jun-2008+BW20080630>. Accessed July 2, 2012.

³⁰ Westminster International Ltd. *WG Covert Intelligence Through-wall Radar*. http://www.wi-ltd.com/security/CCTV_and_Surveillance/Covert/WG_Covert_Intelligence_Through-wall_Radar. Accessed Sept. 7, 2012.

³¹ Tianying. *SuperVision 1600 Through-Wall Radar Life Detector*. <http://www.nightvisioncn.com/sdp/625512/4/cp-5246844/0.html>. Accessed Sept. 7, 2012.

The system includes a display controller for remote viewing and control of the TTWS. The SuperVision 1600 retails for just under \$100,000.³²

The SuperVision 1600 is included here for completeness; it is neither affordable to law enforcement nor certified for domestic U.S. operation. It is currently not certified by the FCC, and based on its operating frequencies, would not qualify for certification under CFR Title 47, Part 90 (1.990 – 10.600 GHz).³³ This system may be in use by foreign security, military or law enforcement agencies.

5.6 ACU-CPR4 (Acustek)

The ACU-CPR4 by Acustek, a single-frequency, continuous wave TTWS device manufactured in Ireland,³⁴ detects motion by Doppler signature of moving objects. The movement of the chest cavity during breathing provides sufficient motion to detect an individual who is intentionally remaining motionless or is unconscious. The ACU-CPR4 is a recent upgrade of the ACU-CPR3 and detects the direction of motion and estimates range to the moving target through the use of proprietary methods. The ACU-CPR4 detects motion at a range of 25 meters without attenuating barriers and weighs approximately 1.3 pounds with a battery life of up to 10 hours. Several devices (up to seven) can be linked to a single computer by Bluetooth or to Android-based devices.³⁵



Figure 5.6-1 ACU-CPR4
Photo courtesy of Acustek. Used by permission.

³² Tianying. *SuperVision-1600 Through Wall Rada Life Detector*. http://www.nightvisioncn.com/sdp/625512/4/pd-3235797/5016779-1745273/SuperVision-1600_Through_Wall_Radar_Life_Detector.html. Accessed Sept. 7, 2012.

³³ Electronic Code of Federal Regulations. *Title 47: Telecommunications; Part 15 - Radio Frequency Devices; Subpart C – Intentional Radiators* <http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr;sid=bad3dcf075dd6e1571512a489dad02b2;rgn=div6;view=text;node=47%3A1.0.1.1.16.3;idno=47;cc=ecfr>. Accessed July 2, 2012.

³⁴ Global TSCM Group, Inc. *ACU-CPR3: See Through Wall Human Detector*. <http://kn2c.us/app/download/6701666704/ACU-CPR3+Human+Detector.pdf>. Accessed July 2, 2012.

³⁵ Carwood, Alasdair. Acustek. Personal interview with Chad Huffman, June 15, 2012.

The ACU-CPR4, a CW device, uses a set frequency of 10.525 GHz as the standard frequency, although there are other frequencies available (9.35, 9.90, 10.587 and 10.687 GHz).³⁶ These frequencies are on the higher end of typical frequencies used, and may be susceptible to significant attenuation, especially by concrete and/or thick stone. On the other hand, the use of higher frequencies provides for better Doppler sensitivity, and therefore better target detection. The ACU-CPR4 also has the ability to determine the direction of movement (toward or away from the user) and can be reconfigured in the field by the use of a USB port.³⁷ The device costs approximately \$9,250 from the distributor, Global TSCM Group.³⁸

The unit is in use by authorities in the UK and India, and by search and rescue personnel in Taiwan and the Turkish Ministry of Interior.³⁹

Note that although the ACU-CPR4 and CPR3 are sold in the United States, the devices do not appear to be FCC-certified for domestic law enforcement use.

³⁶ Global TSCM Group. ACU-CPR4; *Handheld "See Through Wall" Human Movement Detector*. http://www.hik-consulting.pl/files/ACUSTEK-ACU-CPR4_ENG_dq4f7i97.pdf. Accessed July 2, 2012.

³⁷ Carwood, Alasdair. Acustek. Personal interview with Chad Huffman, June 15, 2012.

³⁸ Kim, D., Director/Technical Sales. Global TSCM Group, Inc. "RE: Information request on ACU-CPR3." Personal e-mail to Chad Huffman, June 8, 2012.

³⁹ Carwood, Alasdair. Acustek. Personal interview with Chad Huffman, June 15, 2012.



6.0 Prototype TTWS Systems Under Development

6.1 ASTIR (AKELA)

The AKELA Standoff Through-wall Imaging Radar (ASTIR) is a portable TTWS device currently being developed by AKELA under NIJ R&D funding. The prototype device is built within a protective carry case for direct deployment on a tripod. It is operated by an external power supply and laptop computer. ASTIR uses a (relatively) large spaced antenna array to gather location data and detect motion. It operates by scanning between 3,101 – 3,499 MHz with a maximum output power of 50 mW (10 dB antenna gain mid band).⁴⁰ The ASTIR operating range is 30 meters and it detects moving and stationary objects with enough sensitivity to detect motion associated with breathing.⁴¹ The SSBT CoE is conducting a detailed evaluation of ASTIR in fall/winter 2012.



Figure 6.1-1 ASTIR Prototype
Photo courtesy of AKELA, Inc.

6.2 ImpSAR (Eureka Aerospace)

The Impulse Synthetic Aperture Radar (ImpSAR) by Eureka Aerospace is primarily intended as a vehicle-mounted system for through-the-wall and underground imaging.⁴² The device is intended to remotely view personnel, weapons and other objects of interest at a stand-off range of up to 50 meters (plans for an airborne system would have a range in excess of

⁴⁰ Taylor, Paula. AKELA. "RE: ASTIR Output Power & Freq." Personal e-mail to Lars Ericson, July 11, 2012.

⁴¹ AKELA. *AKELA Standoff Sense-Through-the-Wall Imaging System, Product Information Sheet*. Santa Barbara, CA: AKELA.

⁴² Eureka Aerospace. *Impulse Synthetic Aperture Radar: Through-the-wall and Underground Imaging*. <http://eurekaerospace.com/content/impulse-synthetic-aperture-radar-through-wall-and-underground-imaging>. Accessed July 2, 2012.

1,000 meters). The device would also provide information about interior walls, underground structures and mines, unexploded ordnance and improvised explosive devices (IEDs). The U.S. Department of Defense has provided financial and logistical support for the development of the technology, and Eureka Aerospace notes significant interest from different branches of the U.S. Department of Homeland Security as well as from law enforcement.

6.3 STORM Portable Unit (VAWD Engineering)

Sense Through Obstruction Remote Monitoring System (STORMS) by VAWD Engineering is a TTWS that can detect, track and discriminate human and other life form targets.⁴³ Designed as a stand-off system, STORMS can be vehicle-mounted, man-packed, portable or handheld. VAWD reports that STORMS has a detection range of up to 120 meters for the man-packed, portable and handheld systems, and up to 400 meters for the vehicle-mounted system.⁴⁴ Viewing angles are relatively small in relation to other systems (12 degrees for vehicle-mounted and 40 degrees for smaller systems). This may account for longer detection ranges through having a more focused emission. STORMS can detect moving and stationary targets and present data in 1D, 2D or 3D. STORMS can operate for 3 to 4 hours on a rechargeable battery pack. The units weigh up to 15 pounds for the smaller units and up to 70 pounds for the vehicle-mounted system.⁴⁵

The systems are based on a central technology that allows the company to work with a customer to configure the equipment for a specific application need. STORM operates between 3.3 and 3.8 GHz at low power levels (less than typical cell phones).⁴⁶ STORMS has not been FCC certified for civilian law enforcement applications; however, VAWD Engineering is aware of the FCC requirements for the equipment and is considering applying for a license so that the finished product can be offered for purchase.

⁴³ VAWD Engineering. *Sense Through Obstruction Remote Monitoring System (STORMS)*. <http://www.vawdengineering.com/stormsbrochure.pdf>. Accessed Sept. 12, 2012.

⁴⁴ Adams, Vinh, President and Chief Executive Officer. VAWD Engineering. Personal interview with Chad Huffman, Sept. 12, 2012.

⁴⁵ VAWD Engineering. *Products*. <http://www.vawdengineering.com/products.html>. Accessed Sept. 12, 2012.

⁴⁶ Adams, Vinh, President and Chief Executive Officer. VAWD Engineering. Personal interview with Chad Huffman, Sept. 12, 2012.

6.4 Range-R 2D (L-3 Communications CyTerra Corporation)

The Range-R 2D, by L-3 Communications CyTerra Corporation, is a late-stage prototype TTWS device that builds on the Range-R by adding 2D mapping and extending the operational range.⁴⁷ The system uses similar radar engineering as the Range-R (see Section 3.2.1), involving a stepped-frequency, continuous-wave radar transceiver operating over the 3,100-3,500

MHz band. However, the Range-R 2D exploits a wider portion of the band than the Range-R. The Range-R 2D has an effective detection range of 20 m, an accuracy of ± 2 m and a 120° field of view in both azimuth and elevation. It incorporates a rearward-facing antenna and advanced signal processing algorithms to compensate for operator-reflected signals and extraneous false positive signals to the sides of the area of interest. The Range-R 2D displays the active field of view, the initial wall of contact and a second rear wall, and can detect and track multiple targets simultaneously. The device also provides a warning if the radar signal is being blocked on the other side of the barrier (e.g., by a refrigerator or metal cabinet), and a warning if the device is jammed from outside interference. It can be used in a standoff mode by holding it braced on the ground or other solid object (e.g., hood of a car). L-3 anticipates FCC certification by summer 2013, with commercial availability shortly thereafter. On commercial release, the Range-R 2D will sell for \$15,000.⁴⁸



Figure 6.4-1 Range-R 2D

Photo courtesy of PEO Soldier

⁴⁷ L-3 Communications CyTerra Corporation. Meeting with SSBT CoE. Oct. 23, 2012.

⁴⁸ Don Wright, L-3 Communications CyTerra Corporation. "RANGER-2D MSRP." Personal e-mail to Lars Ericson, Nov. 26, 2012.



7.0 Conclusions

T TWS technology exists that can detect moving targets (e.g., persons) behind barriers that block normal visual detection. These devices can provide additional situational awareness and safety when operating in hostile environments or when deployed in emergency life-saving/rescue situations. There are only a handful of devices certified by the FCC. These devices vary in their level of sophistication and the level of information they can provide. Some devices detect only movement and provide a range to the moving target, while other devices provide a graphical representation of detected objects and building interiors.

The technological capabilities of the devices should be examined within the context of intended operational requirements. In some cases, an agency only needs to know if one or more persons are in a room, and in others, it needs to know the number of individuals, their relative positions and whether they are moving (for instance, in a hostage situation).

Only a handful of devices are currently FCC certified, but other devices have been fully developed for use by the military and new devices currently being developed may be FCC certified for use by state and local law enforcement organizations in the near future.

Overall, TTWS technologies offer a unique and important capability to law enforcement and first responders by providing information about their surroundings and tactical operations.

Appendix: Acronyms and Abbreviations

ACRONYM	DESCRIPTION
2D	Two-dimensional
3D	Three-dimensional
AC	Alternating Current
CoE	Center of Excellence
CW	Continuous Wave
DOJ	U.S. Department of Justice
FCC	Federal Communications Commission
FCCID	FCC Identification Number
GHz	Gigahertz
IED	Improvised Explosive Device
ImpSAR	Impulse Synthetic Aperture Radar
MHz	Megahertz
ManTech	ManTech Advanced Systems International, Inc.
NIJ	National Institute of Justice
SAR	Synthetic Aperture Radar
SFCW	Stepped Frequency Continuous Wave
SSBT	Sensor, Surveillance, and Biometric Technologies
STI	Safety Technology International, Inc.
STORMS	Sense Through Obstruction Remote Monitoring System
STTW	Sense Through-the-Wall
Tianying	Yiwu Tianying Optical Instrument Co. Ltd.
TTWS	Through-the-Wall Sensors
UAV	Unmanned Aerial Vehicle
UGV	Unmanned Ground Vehicle
UK	United Kingdom
U.S.	United States
UWB	Ultra-Wide Band

