Secure Optical Data Communications Between Tactical Vehicles - *Light**Speed***™ Technology

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ABSTRACT

Modern military forces need an alternative to radio-frequency (RF) based communications between tactical vehicles. Free Space Optics (FSO) can provide that alternative but, to date, the design and form-factor of the equipment precluded considering it as a viable solution. Recent advances in FSO technologies are changing that and systems suitable for use in tactical field operations are currently being introduced into the battlefield by the special operations community. This paper explores some of the issues associated with adapting FSO to mobile vehicular applications and provides an overview of the current maturity and capabilities of these technologies.

INTRODUCTION

Various forms of optical communications have been used by military forces for thousands of years. A relative newcomer in this scene is Free Space Optics (FSO), an optical communications technology that uses light propagating in free space to transmit data between two points. Modern FSO became possible with the advent of small lasers in the 1950s and, more recently, the explosion of Light Emitting Diode (LED) technologies based upon inexpensive and relatively powerful emitter diodes. It is now possible to establish robust and reliable tactical communications networks using FSO and new products are being introduced that provide suitable performance in a form factor small enough for use by soldiers in tactical operations. Although much work is required, there is no reason that FSO technologies cannot be adapted to vehicular applications where it will provide reliable inter-vehicle communications under a variety of field conditions.

FREE SPACE OPTICS IN PERSPECTIVE

Radios are, unquestionably, the preferred solution for inter-vehicle, mobile communications and FSO is not suggested as a replacement for this flexible and robust solution. However, there are situations were radio frequency communication is undesirable or impractical and FSO provides an alternative with several advantages[i]:

- Ease of deployment
- Immunity from electromagnetic interference
- High bit rates
- Low bit error rate
- Very secure due to high directionality of emission
- License-free operation

Conversely, the inherent enabling aspect of a FSO system, transmission through the atmosphere, limits the range and effectiveness of the systems. When light is transmitted through a gaseous atmosphere, some of the radiated power is lost by scattering and some by absorption[ii]. Scattering is result of photons colliding with particles in the atmosphere whereby the photon energy is reradiated in all directions. Absorption is a fundamental quantum process where an atmospheric molecule absorbs the energy from some incident photon.[iii] Although atmospheric transmittance is a function of many variables: wavelength, path length, pressure, temperature, humidity and the composition of the atmosphere[iv], the realistic effect is that low-power FSO systems are limited in range to a few kilometers over most of the Earth's surface.

CONSIDERING VEHICULAR APPLICATIONS

The most significant issue affecting the viability of a FSO system on tactical vehicles is scattering from fog or dust in the atmosphere. The transmittance properties of fog are fairly well known and a FSO system can be engineered to minimize this attenuation by selecting an optimal frequency[v]. Transmittance through dust is not well documented, in part because it varies according to the size of the particle versus the frequency. Dust is not uniform in size so a significant amount of research is required to thoroughly document its effects worldwide.

However, when considering the practicality of FSO systems in tactical vehicle applications, it may be reasonable to apply some experienced based rules-of-thumb instead of theoretical transmittance tables. In this regard, TPL has found that its LED-based FSO design functions suitably in fog and dust at distances of roughly twice what the human eye can see. In other words, if foggy/dusty conditions allow a driver to see 400 meters, then we expect 800 meters effective range from our FSO system. Although we continue to seek solid data on transmittance in dusty conditions, we believe that a range of 2x visible is practical in most situations encountered by operational soldiers.

SOME TACTICAL APPLICATIONS

Torrey Pines Logic's ("TPL"'s) *Light**Speed*** technology is an optical LED communication system built as an attachment to any existing binocular, scope, gun scope or stand-alone allowing point to point, high speed, eye safe, secure, non-RF communications.

Alternative configurations for *Light**Speed*** are in the form fitting any hand-held light source, such as Surefire hand or weapon-mounted attachment, stationary Navy shipboard configurations or advanced fiber design systems described below.

TPL has created a portable link for Military Use and Civilian Law Enforcement teams making safe non-RF communications possible, including transmission of audio and live video. Distances of up to 10km with variable field of view can be implemented.

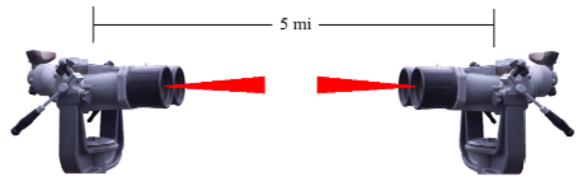
Recent developments in *Light**Speed*** optical communication technology presently in Gen 6 make this possible with systems providing up to 2Mbps data stream and parallel 64Kbps voice channel.

Relay Stations and Wearable Units are currently in design as well as TPL is starting to manufacture an integral binocular communication system.

*Light**Speed*** technology is available for secure links via external Encryption link.

Advanced *Light**Speed*** versions can be miniaturized for body worn, stationary or on the move applications.

It should be noted that original development of the *Light**Speed*** system was partially supported by ONR for the concept of communicating between Navy ships using the attachment and Big Eyes binoculars present on every vessel.

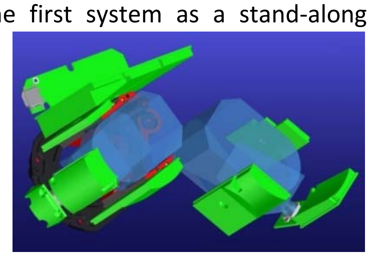


Using these attachments ships could easily communicate at distances exceeding 5nm. The system provided ship to ship, ship to shore and ship to deployed craft scenarios communications.

CURRENT TECHNICAL APPROACH

Torrey Pines Logic has leveraged its knowledge and previously built devices to create Generation 6 of Optical Communication systems. The devices use eye-safe LED communication platform to provide tactical forces with non-RF solution for EOD, covert and emergency response scenarios.

In this section we will outline the form factors and overall packaging of the three variants of the system. We can consider the first system as a stand-along binocular with complete Optical Communications system embedded in boards wrapping the prisms as show below.



The development of the embedded Generation 6 hardware enabled integrated binocular development and B20 unit has been introduced in early 2009 with full scale production commencing Summer 2009.

The second implementation of the system is in hand-held of tripod mounted version named R10. R10 is a small stand-alone system enabling full LightSpeed protocol including Ethernet communications (B20 binocular unit above supports USB as a power or data port).

The integral Ethernet adapter and small form factor allow R10 to be used as vehicle to vehicle or dismounted operator at distances exceeding 2km. In comparison B20 operates at distances exceeding 3km.

Finally, the third key component of *Light**Speed*** product line is a G10 gun scope (or spotting scope) adapter with the same communication capabilities as B20 and R10 above. The G10 can be attached to a variety of scope and does not change the operational use of either the gun or spotting scope. Due to the facts that scopes are generally have narrow field of view, distances at which G10 is operational greatly exceed the B20 performance.

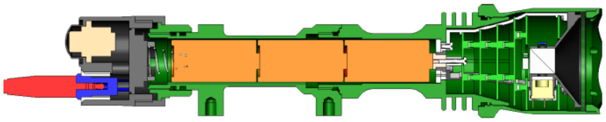
A Tactical Operations kit may consist of:

- 2 Binoculars with A10 LightSpeed binocular attachments or B20 binoculars and headsets
- 2 R10 *Light**Speed*** self-contained hand-held or tripod mounted units with headsets
- 2 G10 *Light**Speed*** gun/spotting scope attachments with headsets
- All units will contain a data connection in the form of either Ethernet or USB port
- 2 small tripods to establish hands free communications between interoperable units

Current development has built upon 7 years of design and development of *Light**Speed*** technology. While the original concept was developed and built solely by TPL, in the later stages of the system design Navy, ONR and components of SOCOM have participated in funding specific design goals. TPL has recently completed the Generation 5 of the A10 binocular attachment with improved characteristics in terms of size, weight and range. This unit can substitute one of the components in the Tactical kit.

There is a number of advanced *Light**Speed*** implementations that merit additional discussion. During 2006/2007 TPL proposed and built a prototype optical *Light**Speed*** full duplex audio system housed in a M92/M97 SUREFIRE hand-held light system. The goals of the implementation were:

- Externally there are no discernable difference from an original light
- Audio transmission is optical at or around 1550nm light frequency
- System is based on LED light source and be completely eye safe
- Audio is full duplex voice at 16Kb sampling rate
- Audio link at 1-2 km
- The system operates on 3 CR123 Lithium for 8 hrs



Surefire project hardware was located purely in the head of the flashlight. The cross-section of the flashlight is shown here.

Please note that 2.5mm standard audio jack is inserted into the back of the light next to the on/off switch. All the boards (shown in green) and optical assembly are contained in one pluggable module (shown at right in comparison with the US quarter coin).

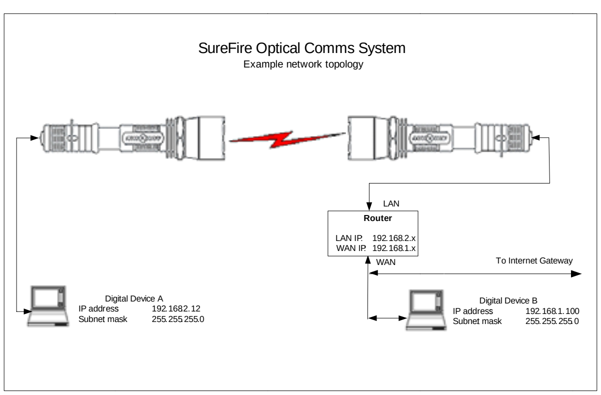
While the audio communication is the first and most important step in the tactical context, clearly the most desirable extension is full data mode. TPL has implemented a full Ethernet transmission mode internally inside the communication system utilizing Xilinx Virtex4 FPGA technology. In case of the hand-held device we have add an Ethernet plug to the power and audio jack as seen above in R10 version.

It is important to note that audio is functioning separately and concurrently with data.

In the case of data communications, optical transmission capabilities opens up currently limited RF tactical communications to a plethora of optical links with LPD and LPI capabilities. Below we discuss some of the potential network arrangements using *Light**Speed*** equipment.

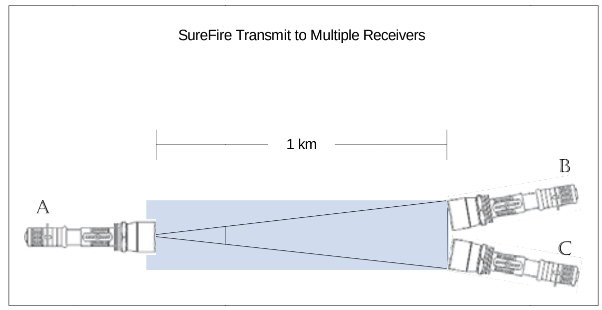
Basic Network Topology

Using the R10 Surefire predecessor as a placeholder, a remote computing device can be connected to a LAN via the SOCS.



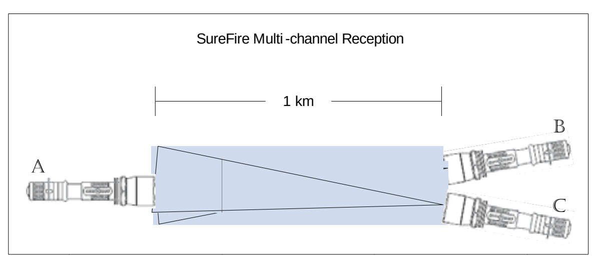
Device A can access network resources available to Device B, which can include access to the Internet. Again, both *Light**Speed*** Controller Systems must be on the same subnet; also, Device A and the Router LAN port must also be on this subnet.

Connect the adapter to the rear of an SOCS communicator to allow direct connection to a twisted-pair Ethernet network. The adapter includes indicators for network presence and activity, along with communication lock. The adapter can also be configured to operate with all indicators off.



SOCS optical transmitters have a beam width of 8-10 degrees; thus, for example, at a range of 1 km, the transmit signal will cover 80 to 100m of horizontal distance. Thus it is possible for multiple units at long range to receive signal from a single transmitter, as shown in the figure above. In this scenario, units B & C receive the transmission from A, as they are both in the field-of-view of A's transmitter.

With a single optical communication channel, difficulties arise if B and C attempt to transmit to A simultaneously. As depicted in Figure below, A receives information from both B & C; these two signals will either interfere with one another, or the weaker signal may be ignored entirely.

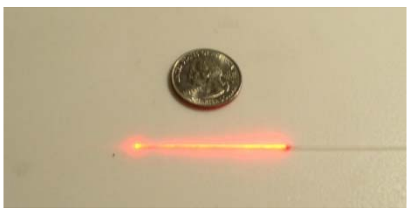


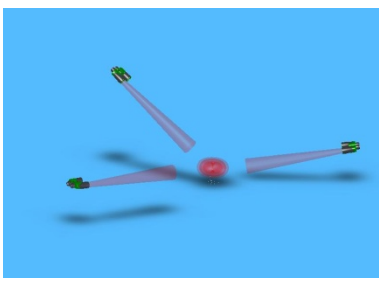
By adding multi-channel capability to the receiver, both signals could be received simultaneously. In addition, the operator at A may choose to select reception from B or C individually, using a simple rocker switch attached to the rear of the Surefire device. Please note that multi-channel capability will be a later separate addition after the initial effort is done and thoroughly tested.

Optical Beacon

A device that transmits in a wide optical angle or omni-directionally can be employed as a optical beacon. This beacon could be visible form several receivers at large distances from the beacon source. Provided they are pointed at the beacon, optical receivers A, B, and C all receive the information transmitted by the beacon.

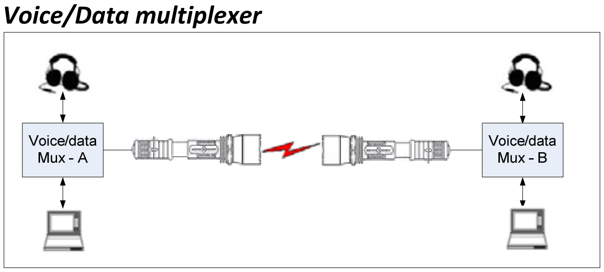
The omni-directional beacons are technology being currently developed by TPL. It is expected that variety of omni-directional devices and associated hardware will become available within the next 12-24 months matching the performance of current systems and providing extended capabilities for blue force track, equipment tracking, search and rescue operations.





An alternative implementation is a micro-beacon: a small localized optical transmitter visible from any direction. Such a micro-beacon could be worn by an individual as an optical identifier, for example. A Surefire communicator pointed at the individual wearing the ID tag from any angle would detect the optical transmission of the micro-beacon.

Voice/Data multiplexer

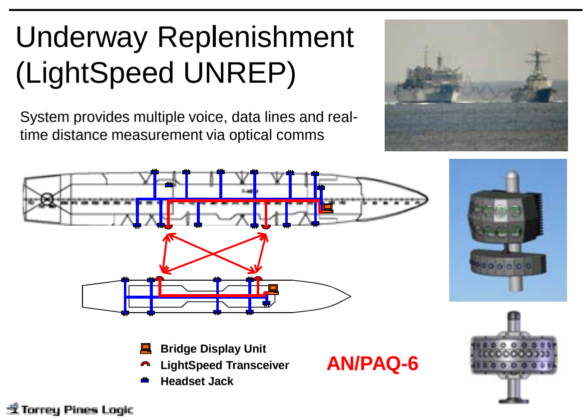


A voice data multiplexer, or combiner, would allow voice and data to be transmitted simultaneously. This module could likely be incorporated into an external Ethernet adapter module with would provide both a voice and data interface.

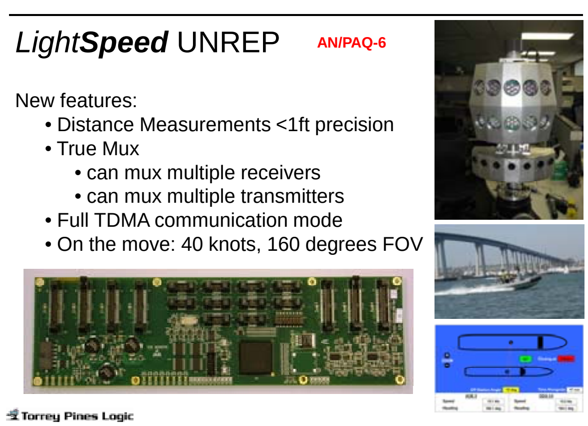
CURRENT AND PRIOR DEVELOPMENTS

It should be noted that *Light**Speed*** technology has been developed in stages with some projects being funded in part by Navy, Army and SOCOM.

Beyond systems mentioned above, one of the key developments being currently worked on is the UNREP project. Underway Replenishment ("UNREP") stands for a device mounted on the side of the ships during re-fueling operation at sea. Such a device will provide not only voice and data communications but also a distance measurement function between hulls.



The device shown here is being tested at present and most likely will migrate to a program development enabling functionality not provided by any other equipment. Some of the technology specifically designed for UNREP, such as 180 degree receiver and mux capability will become crucial for follow on product developments.



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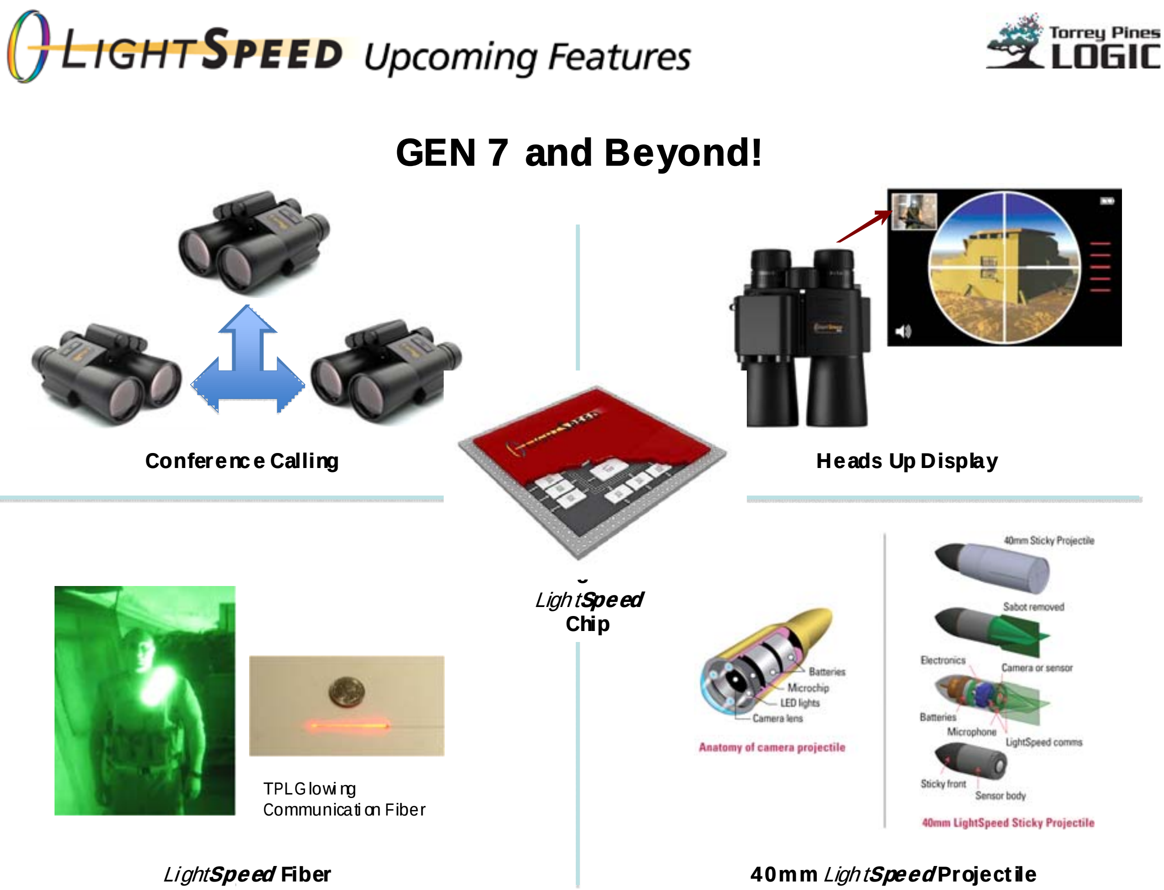

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[i] Garlington, Babbitt & Long; "Analysis of Free Space Optics as a Transmission Technology", US Army Information Systems Engineering Command, March 2005.

[ii] Burle, "Electro-Optics Handbook" Burle Technologies Inc. Copyright 1974, Reprinted 09-2005, Pg 81.

[iii] Driggers, Cox & Edwards, "Introduction to Infrared and Electro-Optical Systems", Copyright 1999, Artech House Inc; Pgs131-138

[iv] Burle, Ibid.

[v] Burle, Ibid, Fig 7-6 on pg 89.