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Preparing for the future….
Never forgetting the past!

Office of Naval Research Code 30
Thrust Area Willful Intents
FY12 - FY13

Willful Intent - Detection

Current Capability:
- Single/dual modality sensor systems capable of performing a single function
- Manual employment and operation
- Minimal automated target recognition

FY	Desired Capability	S&T Challenge	S&T Solution
Near Term **FY12-FY15**	Explosive hazards: • Mounted detection & confirmation at sufficient distance and tactical speeds to safely avoid. P(d) >75%, low false alarms (<2 per mission). • Improved handheld detection with no-metal cueing & detecting irregularly shaped IEDs. Reduced self-calibration requirements & calibration times.	Explosive hazards: • Detection through concealing layers (varying dielectrics) and high-conductivity materials. • Extremely low vapor pressure of explosives. • Sensor height & sweep speed not available for handheld GPR to improve algorithms. Radar efficiencies. • Clutter returns similar to target signal. • Automated target recognition using k-nearest neighbor image analysis is computationally inefficient & requires library of signals (comparing targets to all other library signatures).	Explosive hazards: • Leverage US Army detection of disturbed earth (spectral and thermal with automated target recognition). • Detection of electronic signatures when available. • Digital GPR algorithms relying on detection of known/learned impedance patterns vs. signal shape. • Mathematical or contextual rejection of clutter features. • Development of sensor tracking and image reconstruction for handheld GPR/metal detection. Analysis of time domain vs. step frequency domain radars in CREW environment. • Trace remote detection of explosives; improvements in number of analytes detected and sampling system/preconcentrator.
Mid Term **FY15-FY20**	Explosive hazards: • Standoff detection and confirmation of threats at sufficient time & distance to allow the maneuver unit to engage with minimal impact to the unit's operational tempo. P(d) >85%, low false alarms (<1 per 10 km).	Explosive hazards: • Signal loss from forward-looking radar (reflection); trade between penetration and resolution. • Interpretation of noisy radargrams. • Extremely low vapor pressures of explosives (ppt to ppq). • Autonomy algorithms capable of complex searching & perceiving behaviors (object recognition with surface variance (shape, shadows, etc), contextual analysis, learning behavior). • Real time fusion of multiple signatures due to bandwidth requirements and noisy & contradictory data. • Effective low cost sensors & complexity of autonomy & cooperative behavior algorithms. • Limited backscattered signal with with forward looking radar regimes.	Explosive hazards: • Use rule based, fuzzy logic & neural networks to fuse data (disturbed earth, metal detection, GPR, trace chemical detection) & assess data trust. • Leverage ONR efforts in semi-autonomous platforms with cooperative behavior. • Forward looking GPR at Brewster's angle to reduce ground reflections by optimizing transmission. • Standoff spectroscopy/detection of explosive reagents, byproducts & impurities with greater signatures than explosives (e.g., HNO_3) (Raman, hyperspectral & other) • Forensic trace detection of explosives or explosive metabolites on insurgents.

Willful Intent – Detection Cont.

Far Term **FY21-FY25**	Explosive hazards: • Standoff detection and confirmation of threats outside min. safe distance. P(d) >90%, low false alarms (<1 per mission).	Explosive hazards: • Very low signal (photons) from trace vapor and trace residue due to low cross sections. • Atmospheric attenuation (scattering, absorption). • Subtended solid angle from point source (signal diminishes $1/r^2$); effect more acute at greater standoff. • Target signal variance. • Fusion of data with varying statistics and trust. • Achieving effective sensing modalities and algorithms in a computationally efficient manner to achieve full autonomous behavior.	Explosive hazards: • Leverage ONR efforts in fully autonomous platforms with optimal cooperative behavior. • Standoff spectroscopic methods utilizing greatest cross sections; target manufacturing/storage sites. • Distributed detection systems. • Multiple sensor autonomous airborne platforms. • Multi-modal system with sensor/data fusion. • Vehicle mounted on-the-move systems integration • Unmanned detection. • Improved multimodal airborne systems for imaging for tactical unit operation • Multiple systems integration for tactical unit operation of above appropriate fused sensor modalities.
Endstate: • Enable forces to maintain operational tempo through a range of enemy threats by creating a family of systems that increases the stand-off distance for detection of kinetic or non kinetic, surface or subsurface, manned or unmanned threats to a distance that provides the commander with a series of options ranging from bypassing the hazard to neutralizing the threat.			

Willful Intent – Detection Cont.

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- Single/dual modality sensor systems capable of performing a single function
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FY	Desired Capability	S&T Challenge	S&T Solution
Near Term **FY12-FY15**	Air Defense: • On-the-halt detection of low radar cross section (RCS) threats consistent with classified CDD values to support low altitude air defense. • Man-in-the-loop visual identification of unmanned aerial system (UAS) targets.	Air Defense: • Low radar cross sections limit power received & results in low SNR. • Visual identification at significant standoff through turbulent atmosphere (scintillation, absorbance, scattering).	Air Defense • Leverage airborne active electronically scanned array (AESA) radars for ground use to support neutralization programs. • Begin development of adaptive optics for high energy laser system.
Mid Term **FY15-FY20**	Air Defense: • Low cost on-the-move detection of low radar cross section threats consistent with classified CDD values to support low altitude air defense. • Fusion of multiple targets. • Automatic visual identification of targets. Guided rockets, artillery, mortars & missiles: • Detection of incoming targets with sufficient time to warn troops & defeat incoming rounds. • The functions of detect and neutralize will begin to be integrated into one system. • Integrated air defense and counterfire radar on-the-move. • Improved clutter rejection & additional target detection capabilities.	Air Defense: • Further reduced radar cross section threats and potential future incorporation of absorbing materials. Guided rockets, artillery, mortars & missiles: • Maintaining desired radar performance while reducing system cost, complexity & increasing ruggedization. • Utilizing ultrawideband, frequency agile technologies. • Precise range and Doppler for long distance high speed targets.	Air Defense: • AESA radar detection of low RCS threats, integrated ground/air command and control, & track handoff to laser weapon. • Adaptive optics/wavefront correction to support long range visual identification. • Potential effort with ONR-31 for low cost solid state Doppler radar capable of detecting low RCS threats. Guided rockets, artillery, mortars & missiles: • Leverage advanced counterfire radar efforts. • True dime domain correlation receivers.

Willful Intent – Detection Cont.

Far Term **FY21-FY25**	Air Defense: • On-the-move detection of low radar cross section threats consistent with classified CDD values to support low altitude air defense in a low cost radar. • Automatic visual identification of targets. Air Defense, guided rockets, artillery, mortars & missiles: • Rugged, low cost, low power detection of incoming targets with sufficient time to warn troops & defeat incoming rounds. Increased detection range (ground track and altitude). Improved integrated air defense/counterfire performance. • Greatly improved clutter rejection.	Air Defense: • Further reduced threat radar cross section & improved standoff from improved sensors reducing system SNR. Air Defense, guided rockets, artillery, mortars & missiles: • Fundamental power limitations from solid state emitters.	Air Defense, guided rockets, artillery, mortars & missiles: • Leverage Army efforts & potential efforts with ONR-31.

Endstate:

- Enable forces to maintain operational tempo through a range of enemy threats by creating a family of systems that increases the stand-off distance for detection of kinetic or non kinetic, surface or subsurface, manned or unmanned threats to a distance that provides the commander with a series of options ranging from bypassing the hazard to neutralizing the threat.

Willful Intent – Detection Cont.

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- Single/dual modality sensor systems capable of performing a single function
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FY	Desired Capability	S&T Challenge	S&T Solution
Near Term **FY12-FY15**	Sniper, RPG, ATGM Detection: • Pre-shot detection at maximum effective weapon range, fixed & mobile sensors that includes detection of surveillance devices. • Semi-automated multi-modality detection of multiple signatures while on the move in sequence with low false alarms. • The capability should be integrated into select platforms, have limited remote manual employment and operation, and have a near real time automated data interpretation/ analysis with human decision interface.	Sniper, RPG, ATGM Detection: • Low optical cross-sections of threat targets at certain wavelengths and associated absorbance. • Absorbance windows of threat optics. • Atmospheric scintillation of reflected laser light. • Specular reflection from innocuous & natural objects. • Detection at eye safe laser frequency/power pairings. • Low beam quality at certain wavelengths due to fiber chemistries. • Atmospheric absorbance vs. desired frequency & technical maturity at certain radar bands. • Overcoming shape, shadow an other optical object variances.	Sniper, RPG, ATGM Detection: • Leverage post-shot efforts. • Optical augmentation (OA) using optimized wavelengths/pulse width/repetition rate for detection and clutter rejection. • Incorporation/fusion of human detection spectral efforts (from ISR) with OA. • Initial efforts using starring pre-shot sniper radar optimized for barrel and weapon detection. Algorithms detecting binary strings of impedance mismatches running on fast, self-generating finite state machines for computational efficiency.
Mid Term **FY15-FY20**	Sniper, RPG, ATGM Detection: • Pre-shot detection outside maximum weapon range using handheld, fixed & mobile sensors that includes detection of surveillance devices. • Automated multi-modality detection of multiple signatures while on the move in sequence with low false alarms. • Real time automated data interpretation/ analysis with human decision interface.	Sniper, RPG, ATGM Detection: • Clutter rejection day/night in all environments. • Computational demands.	Sniper, RPG, ATGM Detection: • Improved clutter rejection algorithms for optical augmentation techniques. • Scanning pre-shot sniper radar optimized for barrel and weapon detection. Algorithms detecting binary strings running on finite state machines for computational efficiency. • Fusion of optical (shape recognition, radar, & optical augmentation techniques).

Willful Intent – Detection Cont.

Far Term **FY21-FY25**	<u>Sniper, RPG, ATGM Detection:</u> • Pre-shot detection outside weapon maximum effective range using handheld, fixed & mobile sensors that includes detection of surveillance devices. • Automated real time multi-modality (cavity, radar, shape, human) detection of multiple signatures while on the move with low false alarms. • Real time automated data interpretation/ analysis with human decision interface. • The functions of detect and neutralize will be integrated into one system.	<u>Sniper, RPG, ATGM Detection:</u> • Time/distance challenges and computational efficiency on a chip.	<u>Sniper, RPG, ATGM Detection:</u> • Multimodal detection modalities with computationally efficient detection algorithms.
Endstate: • Enable forces to maintain operational tempo through a range of enemy threats by creating a family of systems that increases the stand-off distance for detection of kinetic or non kinetic, surface or subsurface, manned or unmanned threats to a distance that provides the commander with a series of options ranging from bypassing the hazard to neutralizing the threat.			

Willful Intent - Neutralization

Current Capability:
- Expensive & bulky predetonation capabilities.
- Current efforts with precise delivery of canister launched shape charge munitions.
- Slew-to-cue detection and neutralization of snipers post shot

FY	Desired Capability	S&T Challenge	S&T Solution
Near Term **FY12-FY15**	Explosive hazards: • Spot & small area neutralization at distances up to 150m for known hazards. • Predetonation outside of a safe distance when mounted in armor protected vehicle.	Explosive hazards: • Penetration of inches of soil overburden to a specific diameter/velocity to achieve detonation. • Accurate standoff delivery (achieving low circular error of probability) with environmental, vehicle & system variability. • Coupling electromagnetic (EM) energy into targets through absorbers (function of waveform, polarization, angle & etc.) • Near earth environmental losses (channels, moisture, scatterers, effect of wind/turbidity). • SWAP limitations associated with directed energy systems (power, cooling, and DE sources/antennas) due to device efficiency. RF driven by dielectrics and generation and circulation of electrons. • Emulating complex magnetic, seismic and IR signatures from small nodes	Explosive hazards: • Pneumatic launched canister delivered, airbag deployed shape charge netted arrays < 2m wide. • Target device (IED) susceptibility measurements to radio frequencies (RF). • Environmental characterization of RF propagation near surface of earth. • High-power multiple beam inductive output tubes. • Increased power, reduced size with non-linear transmission lines. • Coordinate Joint Counter Remote Control Improvised Explosive Device (JCREW) efforts with ONR-31.
Mid Term **FY15-FY20**	Explosive hazards: • Spot & small area neutralization at distances up to 200m for known hazard location with reduced circular error of probability. • Predetonation well outside of a safe distance when mounted in armor protected vehicle.	Explosive hazards: • Further reduction in circular error in probability. • Coupling electromagnetic (EM) energy into targets through absorbers (function of waveform, polarization, angle & etc.) • SWAP limitations associated with directed energy systems (power, cooling, and DE sources/antennas) due to device efficiency. RF driven by dielectrics and generation and circulation of electrons. • Electromagnetic interference with C2 systems. • Semi autonomous platforms with cooperative behavior.	Explosive hazards: • Tunable/wideband sources • HPM solid-state sources • Planar arrays • Conformal arrays • Multifunctional arrays • Airborne integration of pulsed systems • Semi autonomous platforms with cooperative behavior. • Electronically steerable HPM arrays

Willful Intent – Neutralization Cont.

Far Term **FY21-FY25**	Explosive hazards: • Neutralization of explosive hazards, out to 2500m. • Family of systems will now be a fully integrated multi-modality family of systems performing multiple functions (i.e. detect then neutralize) automatically • Distributed and expeditionary capabilities for cooperative neutralization at required operational speeds • The functions of detect and neutralize will begin to be integrated into one system.	Explosive hazards: • Atmospheric & soil attenuation (scattering, absorption), near earth ground effects & $1/r^2$ losses with electromagnetic radiation. • Fully autonomous platforms with cooperative behavior. • Precise timing required to spatially combine distributed lower power phased arrays for neutralization effects.	Explosive hazards: • Distributed phased array neutralization systems that can temporally & spatially combine on the target. • Fully integrated detection & neutralization systems to reduce demands on neutralization. • Ultra wide-band amplifiers and antennas

Endstate:

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Willful Intent – Neutralization Cont.

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FY	Desired Capability	S&T Challenge	S&T Solution
Near Term **FY12-FY15**	Air Defense: • Hard kill (complete failure) & soft kill (sensor denial/defeat) of UAS at tactically relevant distances. Rockets, artillery, mortars: • Study vulnerability of threats to directed energy.	Air Defense: • Laser beam quality for TEM_{00} single mode fiber at high power from optical (largely thermal) distortions. • Nonlinearities in power scaling (stimulated Brillouin and Raman scattering) • Slope efficiencies (output to pump power) of current chemistries (improving spectroscopies and pump schemes). • Ruggedization of optical components from high g insults and high frequency rms vibrational noise. Rockets, artillery, mortars: • Measuring the fluence for desired effects of spinning threats in aerodynamically conditions.	Air Defense • Begin development of a rugged, mobile high energy laser system with good beam quality in FNC leveraging HEL-JTO programs. Rockets, artillery, mortars: • Leverage joint efforts in scaling up RELI laser to 100kW.
Mid Term **FY15-FY20**	Air Defense: • High energy laser to complement gun & missile defeat of low cost UAS <10kft altitude & <6km ground range. Guided rockets, artillery, mortars and missiles: • Rapid low cost per kill laser weapon system.	Air Defense: • Ruggedization of high energy laser architectures, reduction in jitter, effective wavefront correction & obtaining near diffraction limited beam quality in far field spot, increasing system efficiency. Guided rockets, artillery, mortars and missiles: • Power scaling single mode fiber lasers (Brillouin & Raman scattering) and slab lasers while maintaining beam quality, & obtaining very high power densities in far field.	Air Defense: • Rugged 25 KW class solid state laser system with λ/D ~1.3-1.5, jitter < 2.5 μrad, & automated aimpoint selection algorithms. Integration on lightweight tactical vehicle. • Adaptive optics/wavefront correction to support long range visual identification. • Establish potential effort with Code 31 for low cost solid state Doppler radar capable of detecting low RCS threats. Guided rockets, artillery, mortars and missiles: • Monitor HEL-JTO solid state laser power scaling efforts and Army efforts to develop mobile 100 KW class solid state laser.

Willful Intent – Neutralization Cont.

Far Term **FY21-FY25**	Air defense & Air defense & guided rockets, artillery, mortars and missiles: • Inexpensive cost per kill defeat of low cost UAS at <10kft altitude & <10km ground range. • Rapid subsequent defeat of swarming targets and barrages.	Air defense & guided rockets, artillery, mortars and missiles: • Further power scaling high energy laser technology outside of typical Nd:YAG laser media. • Physical limitations due to quantum defects, maximum efficiency, and scattering in laser medium. • Atmospheric effects and thermal blooming.	Air defense & guided rockets, artillery, mortars and missiles: • Integration of an efficient 100-KW class fiber laser with exceptional beam quality on MTVR-class vehicle. • Increased power & beam quality allows defeat of multiple swarming threats. • Use of eye safer laser wavelengths to reduce eye hazards (e.g., holmium, thulium, & other laser media). • Reduced laser dwell time.
Endstate: • Enable forces to maintain operational tempo through a range of enemy threats by creating a family of systems that increases the stand-off distance for detection of kinetic or non kinetic, surface or subsurface, manned or unmanned threats to a distance that provides the commander with a series of options ranging from bypassing the hazard to neutralizing the threat.			

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FY	Desired Capability	S&T Challenge	S&T Solution
Near Term **FY12-FY15**	Sniper, RPG, ATGM: • Coordinate slew-to-cue capabilities with Maneuver & Fires. • Coordinate RPG/ATGM defeat activities with Army and Maneuver.	Sniper, RPG, ATGM Detection: • Truncated times from detection to neutralization. • Potential collateral damage to dismounted troops and friendlies.	Sniper, RPG, ATGM Detection: • Dazzlers / optical jamming. • Slew-to-cue gun systems.
Mid Term **FY15-FY20**	Sniper, RPG, ATGM: • Improved slew-to-cue defeat of snipers (with Fires). • Low collateral damage defeat of incoming RPGs & ATGMs.	Sniper, RPG, ATGM: • Increased standoff in weapon employment. • Increased tactical rates of advance challenging time to respond. • System jitter.	Sniper, RPG, ATGM: • Leverage Fires efforts in improved gun mounts / systems.
Far Term **FY21-FY25**	Sniper, RPG, ATGM: • Rapid kill on-the-move with little collateral damage.	Sniper, RPG, ATGM: • System jitter / stabilization requirements. • Processing demands.	Sniper, RPG, ATGM: • Leverage Fires efforts in improved gun mounts / systems.

Endstate:

- Enable forces to maintain operational tempo through a range of enemy threats by creating a family of systems that increases the stand-off distance for detection of kinetic or non kinetic, surface or subsurface, manned or unmanned threats to a distance that provides the commander with a series of options ranging from bypassing the hazard to neutralizing the threat.

Willful Intent - Mitigation

Current Capability:

- High strength ballistic p-aramid and olefin fibers which are resistant to environmental conditions, durable and time tested
- Hot pressed boron carbide and silicon carbide monolithic ceramics
- Monolithic layered plies of fabric balancing performance, cost and manufacturing

FY	Desired Capability	S&T Challenge	S&T Solution
Near Term **FY12-FY15**	• Tailorable, scalable modular personal armor designs. • 15% weight reduction for hard & soft armors; reduce parasitic weight. • Spread weight centralized on torso to protect vulnerable extremities. • Maximize fit, ergonomics & mobility. • Reduce battlefield casualties as a result of mild traumatic brain injury (mTBI) and Behind Helmet Blunt Trauma (BHBT). • Improve fire resistance & durability for Marine Corps Combat Uniform (MCCU). • Reduce injury from environmental effects. • Test surrogates that replicate the human body with good fidelity	• Optimizing energy transfer. • Different threats load materials differently (e.g., fragment vs 9mm response) (volume of response, energy profile as function of time). • Response varies with round (e.g., jacket stripping) & velocity (shattering vs. in tact & penetrating core). • Reducing areal density while maintaining or stiffening backface deformation. • Injury mechanisms & threshold injury criteria (dose/response curves) are not well understood or nonexistent. • Improving material purity & optimizing microstructure of hard armors. • Limited semi-parametric models & understanding of multi-component armor systems. • Requirements creep mitigating science; required to protect against high order level threats vs. most likely battlefield encounters. • Finite element modeling is computationally intensive	• Improvement of ceramic microstructure & fracture toughness via material processing and pre-sintering. • Use basic orthotropic materials like UHMWPE to provide wave spreading behavior. • Improved durability & environmental stability of PBO through new chemical processing techniques. • Improved soft armor modeling and simulation tools that optimize material properties and system architecture to defeat specific threats. • Flexible hard armor designs that improve mobility, limit crack propagation & increase multiple hit capability. • Shock mitigating materials & impulse spreading helmet shell/suspension systems that reduce the onset of mTBI. • Improved survivability prediction & virtual human performance models. • High bio-fidelity surrogates to accurately assess PPE equipment. • Develop fast running engineering survivability modeling & design tools
Mid Term **FY15-FY20**	• 30% weight reduction for hard & soft armors; reduce parasitic weight from baseline • PPE designed to minimize behind armor effects • Improved signature reduction against EOIR • Improved damage protection against environmental exposure, flames • Further mitigate mTBI battlefield casualties • Improve protection against DE threats • Test surrogates that replicate the human body with high fidelity	• Protecting at high strain rates and pressures with blast (>90 psi) doesn't typically provide low psi protection in TBI regimes (<20 psi) • Increasing van der waals interaction and/or hydrogen bonding for fibers. • Increasing crossligk density can embrittle • Need high fidelity Injury mechanisms & threshold injury criteria (dose/response curves) for various stress strain rates.	• Shockwave disruption/dissipation to improve defeat mechanism & energy dissipating designs and materials. • CNT reinforced ceramics for improved strike face properties. • Gradient hardness, diamond coating & improved nanostructure & tailored material/armor systems. • Improved hybrid fabric armor architectures & ceramic systems • Synergistic application of advanced materials & designs through modeling & simulation to meet weight and multi-threat goals. • Computational fluid dynamic assessment models for designing shock mitigating helmets. • Modeled designs optimized for specific mission scenarios • Bio-mechanics based operational predictive tools for PPE assessment. • Physics based high fidelity human performance model integrated with high fidelity survivability prediction model

Willful Intent – Mitigation Cont.

Current Capability:

- High strength ballistic p-aramid and olefin fibers which are resistant to environmental conditions, durable and time tested
- Hot pressed boron carbide and silicon carbide monolithic ceramics
- Monolithic layered plies of fabric balancing performance, cost and manufacturing

FY	Desired Capability	S&T Challenge	S&T Solution
Far Term FY20-FY25	• Mobility-enabled PPE • Further weight reduction (40%) • Scenario based adaptive multi-modality personal protective system • Prevention of detection throughout the EM spectrum • Active blast and ballistic protection • Eliminate damage from environmental exposure and sensory threats	• Significantly reduced areal densities require much more detailed behind armor effects knowledge. • High fidelity knowledge of injury dose/response curves for the human body at various stress and strain rates (10/s to 100/s to 10000/s) for a range of threats from automobile injuries to blunt trauma to blast. • Combining various energy spreading/absorbing modalities in one synergistic system. • Preventing detection throughout the EM spectrum found on the battlefield • Eliminating ceramics & using neutral buoyant or buoyant materials	• New ballistic anisotropic materials. • Combine energy absorption/spreading modalities (anisotropy wave spreading, compressive PV work, concentration gradients & interfaces, strength hardening, & layer optimization) • Nano-particle and fullerene materials providing lightweight ceramics, fibers, and composites reducing overall armor weight. • Scenario-based adaptive camouflage • Individual active countermeasures • Comprehensive system level predictive models • Fully integrated high fidelity human performance model including environmental, sensory, and survivability protection • Phase change materials against far term advanced DE threats

Endstate:

- Increased Naval Warfighter survivability, sustainability, comfort and overall quality of life while in combat environments and in post deployment by providing equipment and technology that ensures comprehensive protection and operational flexibility.