# (1) Intelligent System for Materials Discovery (NTE 20 Pages)

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## \*Summary

Aptamers are single-stranded oligonucleotides that binds to compounds with high affinity and selectivity. [[1]](#endnote-1) Aptamer-molecular bonds form by hydrogen bonds, van der Waals interactions or electrostatic coupling, with picomolar range dissociation constants (Kd).[[2]](#endnote-2) Aptamers are excellent contenders for targeted therapeutics[[3]](#endnote-3) (Figure 1) due to the specificity, stability at high temperature, scalability via *in vitro* synthesis, adaptability, and for its lower immunogenicity.[[4]](#endnote-4) Conjugated nanoparticle and nucleic acid coupled aptamers are used in creating targeted cancer drugs.[[5]](#endnote-5),[[6]](#endnote-6) Prostate Specific Member Antigen (PSMA) is a class of aptamer which is conjugated with biomarkers to treat prostate cancer.[[7]](#endnote-7) Paclitaxel is another aptamer drug to treat cancer cells which express the mucin-1 protein.[[8]](#endnote-8) Aptamers are a likely replacement for mono- or poly-clonal antibodies for drugs to treat infectious and viral diseases. Compared to antibodies, aptamer are more streamlined for pharmaceutical processes due to its capability to better recognize membrane-immortalized protein via Western blotting technique, and has a higher compliance to enzyme-linked immunosorbent assay (ELISA) protocols.[[9]](#endnote-9)





Figure . Aptamers used in target-cancer therapy. Drugs are bound to the aptamer via a covalent to non-covalent interaction.

The discovery and synthesis of aptamers with high-specificity and high-affinity to a target compound is a complex, expensive and time consuming process. The fundamental understanding of the chemical interaction between a target molecule and an aptamer is incomplete. This inhibits the capability to accurately predict and custom design aptamers with high specificity and selectivity for a given compound.[[10]](#endnote-10) The state-of-art method of aptamer discovery is via an *in vitro* method called Systematic Evolution of Ligand Exchange by Exponential Enrichment or SELEX.[[11]](#endnote-11),[[12]](#endnote-12) The primary drawback of the SELEX is that it take months, or in some cases, several years to discover an aptamer with the required specificity, affinity to create therapeutics. The long development time increases the overall cost of the drug, and is also delays entry to the market. Hence, there is a crucial need for a cheaper, faster and a more intelligent route for the discovery of highly specific aptamers for a given target molecule.

We propose to develop a computational method which discovers and classify aptamers which demonstrate high degree of affinity and specificity to a given target molecule group, making aptamer based targeted drug discovery cheaper and faster. Voxtel put forwards an interdisciplinary group of experts with experience in the field of biochemistry, bioinformatics, and machine-learning (ML), to design and produce a machine learning driven data-mining algorithm for aptamer-molecular functional classification. We propose to train, validate and cross-validate the proposed algorithm, using a library of currently discovered target molecules and the specific aptamers bound to these targets.

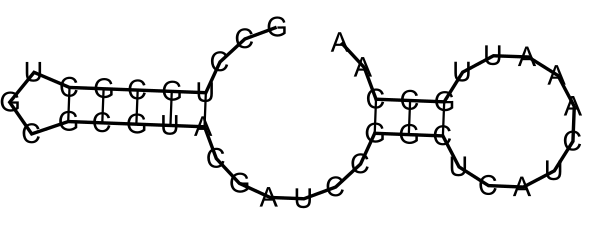
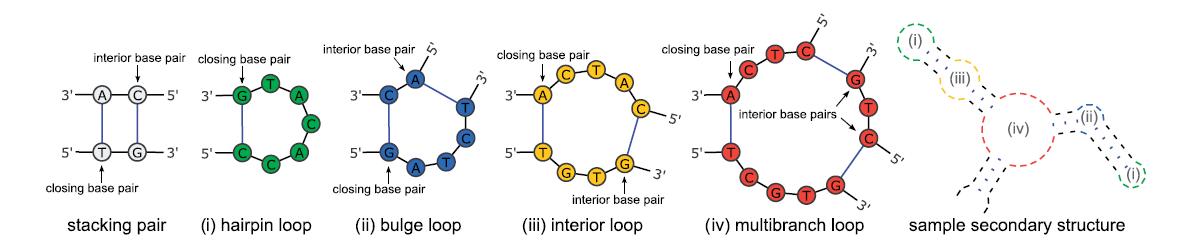


Figure . Components of RNA secondary structure. In this study, bulge loops and interior loops are treated similarly. Despite the fact that one is a degenerate version of the other, they represent substructures of different flexibility. Optimum folding pattern of *GCCUGCGCUGCGCGUACGAUCCGGCUCAUCAAAUUGCCAA* oligonucleotide sequence with 2 hair pin structure.

We will develop the proposed aptamer-molecule classification engine using a selective suite of molecular descriptors which showcase the constitutional, topological, geometric, thermodynamic, physico-chemical, electrostatic, quantum-chemical and symmetry point-group attributes of the target molecules used in the input. Apart from the molecules, the 2D and 3D quantitative structure activity relation (QSAR) of the aptamers will also be expressed using single-nucleotides descriptors of “a”, “c”, “g” , “u|t”, di-nucleotides descriptors of “aa,” “ac,” “ag,” “au(t),” “ca,” “cc,” “cg,” “cu(t),” “ga,” “gc,” “gg,” “gu(t),” “u(t)a,” “u(t)c, ” “u(t)g,”, “u(t)u(t)”, and a new class of Voxtel developed, secondary motifs (Figure 2) descriptors (SMDs). Central to the success in Voxtel’s approach is the use of the SMDs to quantify and group stacking pairs, hair pin loops, bulge loops, interior loops and multi branches based aptamer homologs. The secondary motifs in an aptamer strongly influence and to a large degree determines the molecular-aptamer specificity.[[13]](#endnote-13) We believe that using a finite number of highly relevant 2D and 3D QSAR descriptors for both the target molecules and the aptamers, it would be possible to classify aptamers with strong affinity to the given compound, with higher accuracy than a state-of-art computational algorithms. After a rigorous validation processes, our classification output will be used as a library for combinatorial aptamer development to create therapeutics.

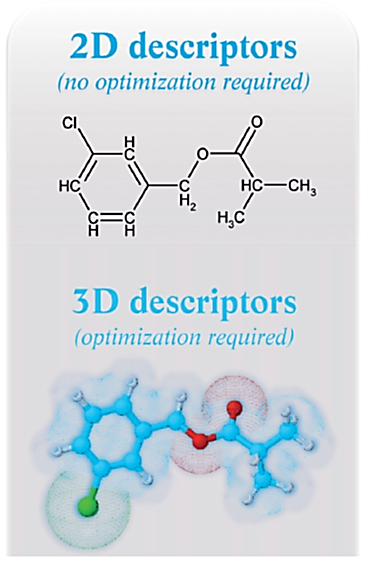


Figure . Different type of QSAR descriptors used in computational drug discovery.

The team lead by Voxtel have unique capability and experience of conducting the work proposed. We have more than a decade of experience in working with nanomaterials and small-molecules, and multiple years of experience in developing aptamers and antibodies for various programs funded under the DOD. We plan to collaborate with a machine-learning experts at the University of Oregon **Neuroinformatics Center**, who have extensive experience with high performance computing resources and data-mining. Our proposed aptamer-molecule classification algorithm will be a high value tool which will be licensed to stake holders in drug development, threat analysis, bio sensors and bio markers industries.

## Technical Rationale

### Fundamentals of computational drug discovery

*In silico* approach to drug discovery is faster, cheaper, and ethically less contentious to *in vivo* or *in vitro* methods of drug discovery. The first step *in silico* drug discovery starts by determining the rules regarding how the attributes of a molecule are related to its chemical functionality. This is defined as QSAR function of the molecule, and has been explored in the area of computational chemistry and combinatorial drug discovery, for the past several decades. The basis of QSAR is quantifying and grouping the properties of molecules using various markers called *descriptors*. A descriptor gives a continuous numerical score quantifying an attribute of a molecular. Depending on the complexity of the attributes, the molecular descriptors can be either 2D or 3D, as given in Figure 3. Based on the descriptor values the responses (functionality) of the molecular group is classified. As an examples, the toxicity such as carcinogenicity or mutagenicity, or the binding affinity to a target molecule, are the functional classifications of a molecule obtained by grouping descriptor values. Data mining is the process of determining the rules of how the descriptor values gets linked to the functionality such as the toxicity and carcinogenicity providing the classification.[[14]](#endnote-14) Descriptors comes in various classes. These include *constitutional* (i.e. number of atoms, molecular weight), *topological* (i.e. types of bonds between atoms such as H bonds), *physico-chemical* (i.e. *Log P* or partition coefficient between octanol and water), electronic (i.e. charge of an atom, polarity), thermodynamic, or quantum-chemical (i.e. energy of the highest occupied molecular orbital, HOMO or lowest unoccupied molecular orbital, LUMO) descriptors. Typically, there can be thousands of descriptors reported for molecules, used *in silico* computational drug discovery. For accurate classification only a handful of descriptors are typically in use. Principal component analysis (PCA) or maximum relevance and minimum redundancy (mrMR) methods are proposed to reduse the degree and reducing the number of descriptors for efficient data mining via effective and robust classification.

#### Creation and down selection of a molecular descriptors

Out of the many thousands of descriptors defined by 2D and 3D QSAR, a basic set of uncorrelated descriptors (i.e. < 10) need to be selected for efficient data mining. Noise in the classification increase with the number of input descriptors or due to the correlation among the descriptors. This results in over-fitting where the classification works extremely well for the training set of data, but works poorly for a completely new and untrained molecular input. The chosen descriptors have to be functionally relevant to the response, which is being classified. As an example, classification of the toxicity is highly dependent or relevant on the partition value between water and an organic solvent (octanol) defined by Log P. However, toxicity has little dependence on the quantum-chemical type HOMO/LUMO descriptors. Therefore, *log P* is a descriptor highly relevant for the classification of toxicity. Hence, a large number of starting descriptor needs to be systematically down selected to obtain a finite set of uncorrelated and highly-relevant descriptor set for the molecules.

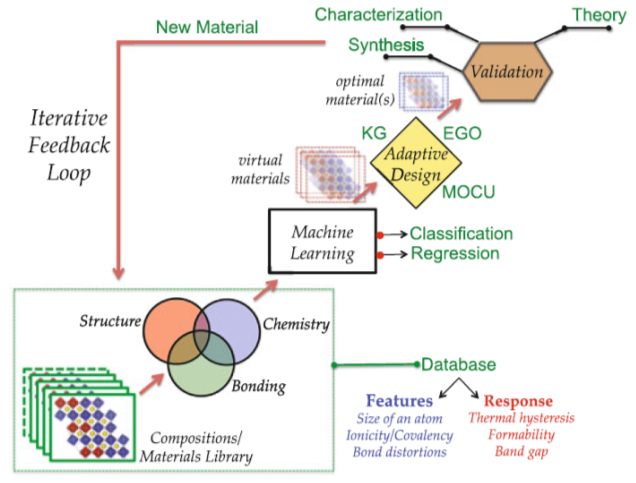


Figure . Schematic of the design process showing different stages of machine learning and adaptive design strategies with an iterative feedback loop for in silicon design of novel materials.

##### Maximum relevance and minimum redundancy (mrMR) method of descriptor selection

Maximum relevance and minimum redundancy (mrMR) of a descriptor is chosen using a score defined by the mutual information (I) calculated by equation[[15]](#endnote-15),

,

Where x and y represents two variable function with p(x,y) is the joint probability function and p(x), p(y) are the marginal probability functions. In a sample with N number of descriptors, the number of descriptors with the maximum relevance is given by the ones with the highest mutual information value.

The degree of redundancy of a descriptor R(d) is calculated using equation,  
,

Where Ωs is the set with already selected descriptors. I(d,di) is the mutual information between a new descriptor *d* and already selected descriptor *di*. The minimum R gives minimum redundancy among the descriptors. Therefore, a set of descriptors with maximum I(x,y) and minimum R(d) will be used in classification algorithm for drug discovery.

##### Principal component analysis based selection of descriptors

Principal component analysis (PCA) reduces the dimensionality of the data while retaining most of the variation in a data set.[[16]](#endnote-16) Dimensions are reduced by identifying directions, known as principal components (PCx) in which the variance of the data is maximized. In the orthogonal direction, the variance will be extremely small. The PCx directions are given as linear combination of the descriptors defined as,

,

Where αk­ are scaler coefficients. As the data is plotted in direction of the principal components, grouping of the data becomes simplified and the dimension of the data is reduced. An example of the use of PCA is give in Figure 5, in which PC1 and PC2 are defined as the principal components of the descriptors XBP1 and GATA3, to classify the expression level of estrogen response (ER). It is seen that once the ER level is projected in to the PC1 there is extremely clear grouping of the data, even though the number of descriptors fell by half.

### DATA Mining using machine learning

Data mining is based the three components: the concept, the instance and the attribute. The concept defines the rule in which the inputs are related to the output and is found through the process of data mining. The instance defines an example of the input data. The attribute defines a specific aspect of the input. Data mining is either a *classification* process or a *numerical* prediction process. Classification is used when the output is a nonnumeric value. Discrimination analysis, classification and regression analysis[[17]](#endnote-17) (CART), k nearest neighbor (KNN)[[18]](#endnote-18), fuzzy logic, Bayesian statistics, self-organization maps and support vector machines[[19]](#endnote-19) are types of classification methods. Multivariate analysis (MVA), partial least squares (PLS), neural networks (NN), and genetic algorithms are examples of regression type data mining. In MVA type regression analysis a linear relationship is defined between the descriptors (di) and the continuous response (R) data, given by R, where *ai* are the weighting parameters found by least squares method.

The predictability is defined using a R2 value defined as:

,

Where is the predicted value, is the experimentally measured value, and is the average predicated value. Classification and regression is done with and without supervision. In supervised learning, the response data is used to improve the data mining process, with each training iteration. In unsupervised learning, pattern recognition is done only using the input descriptor values.

#### Validation of the classifier

A classifier algorithm has to be validated in order to quantify if the predication of an unknown molecule is possible in the classifier method. This is done using a cross validation (leave one out or LOO method), bootstrapping, or by Y-scrambling method. In LOO all the input except one is used in define the model. The unused component is then predicted by the classification model trained using the remaining instances. The predictability of the LOO is given as a Q2 parameter. Bootstrapping is a statistical procedure of sampling with replacement. The dataset with replacement is used as the training set for the classification engine. A dataset with n instances is sample n times, with replacement, gives another dataset of n instances. Typically a 0.632 bootstrap is used. The predictability of all the instances are averaged to gives a more statistically rigorous method of cross validating the classifier.

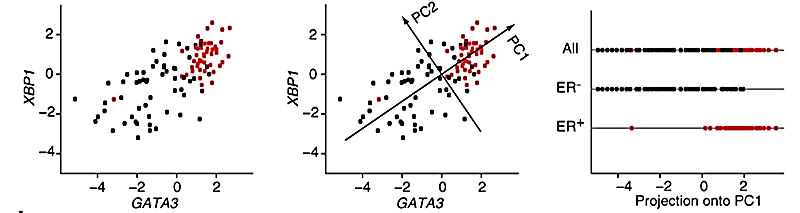


Figure . Use of principal component analysis. Each dot represents a breast cancer sample plotted against its expression levels for two genes.(left most) Samples are colored according to estrogen receptor (ER) status: ER+, red; ER- , black). PCA identifies the two directions (PC1 and PC2) along which the data have the largest spread.(middle) Samples plotted in one dimension using their projections onto the first principal component (PC1) for ER+, ER- and all samples separately.

#### Evaluation of a classification based data mining

The accuracy and the sensitivity of the classifier with a binary output (i.e. true or false) is measured using a confusion matrix. The outcomes of the classifier can be a true positive (TP), true negative (TN), false positive (FP) and false negative (FN) value. Using TP, TN, FP and FN the accuracy and the sensitivity of the classifier is valued as following:

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,

,

SN and SP are not perfect measurements because as each only partly use TP, TN, FP, and FN. As a solution MCC is defined which is a more balanced measurement of the accuracy of the classification.[[20]](#endnote-20)

### State of art methods of applying machine learning for Aptamer discovery

Computational based approaches are being explored to boost the discovery of aptamers in the field of therapeutics. The thus far the computational approaches use primarily oligonucleotide sequences and attempts to recognition of patterns between the sequences and molecules.[[21]](#endnote-21) Minimum redundancy and maximum relevance (mRMR) technique is one example of sequence based aptamer-compound selections method.[[22]](#endnote-22),[[23]](#endnote-23) We believe that sequence alone will not enable the classification of the olegonucleotides. Apart from sequence information, the secondary structure[[24]](#endnote-24) of the oligonucleotides (i.e. motifs) need to be used in the computational discovery of aptamers. The secondary motifs are unique folding patterns of the oligonucleotides formed by Watson-Crick or GU base-pair bonds (i.e. A-T and C-G) created in the oligonucleotides.[[25]](#endnote-25) Secondary motifs include stacking pair, hair pin loops, bulge loops, interior loops, multi branch loops as given in Figure 3.[[26]](#endnote-26) The target molecules (i.e. apatopes) are primarily bound in these motifs which creates specificity and affinity. There are efforts to identify aptamers by statistically screening the secondary motifs which show affinity to the apatopes. In some cases, such numerical approaches can be combined with the experimental SELEX process steps to reduce the number of SELEX steps. In our approach the secondary structure of the oligonucleotides are also used for classification and will be a more potent than state-of-art machine learning algorithms.

Describe the work in SVM based technique used for molecular-aptamer classification.[[27]](#endnote-27)

## \*Technical Approach

### molecule and oligonucletoide attributes used for machine LEARNING

Constitutional, topological, thermodynamic, physico-chemical, electronics and quantum-chemical descriptors have been the primary types of descriptors explored in classification of molecular and oligonucleotide interactions. Thousands of primary descriptors are reduced to a basis set of uncorrelated and highly relevant descriptors. However, use of these basic descriptors have not given expected classification or predictability of finding aptamers which have high affinity to a given target molecules. This inefficiency in the classification is led from two primary causes. Firstly, the descriptors chosen for the molecules have been insufficient in capturing the true functional interactions between an oligonucleotide and a molecule. Secondly, the descriptors chosen for the oligonucleotide have been too simplistic to represent the constitutional, topological and conformation accuracy in a real aptamer.

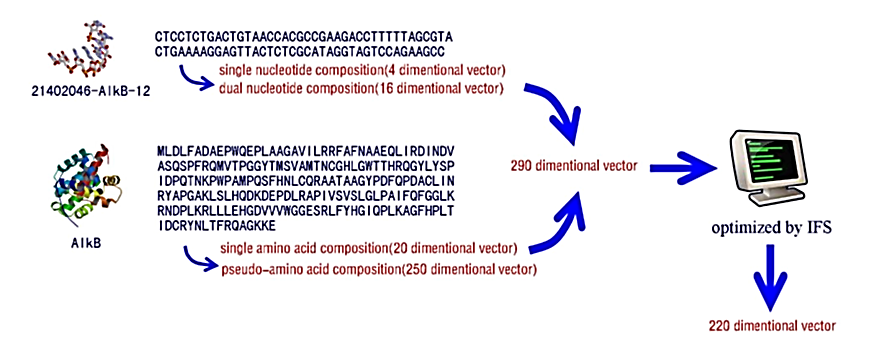


Figure . Machine learning based approach to aptamer discovery.

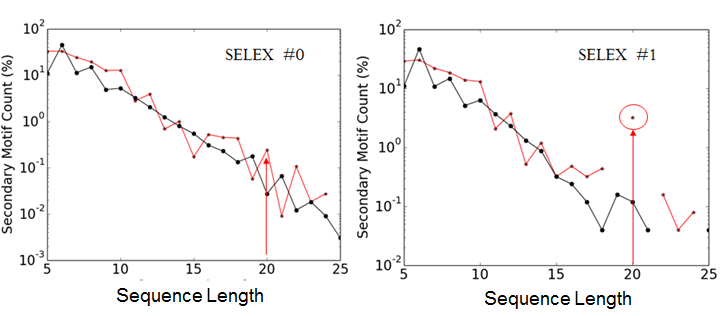


Figure 6. Probability distribution of all the thermodynamically optimum secondary sequences from two consecutive computationally derived SELEX steps. Going from SELEX #0 to SELEX #1 the probability of 20 Base HPs increase from 0.1% to 3%. The down selected SELEX #1 is created by taking SELEX #0 and making a sub population which is enriched with sequences with 20 BP HPs as well as also containing every 100th sequence in SELEX #0. This numerical SELEX test case is mimics the down selection which happens in experimental SELEX processing.

Voxtel, has experimental and computational experience in looking at molecular and aptamer interactions stemming from past work done in a DOD funded DTRA program. We will use the knowledge gained as a basis theoretically defining molecular and aptamer descriptors which are functionally more suitable for the use in a classification method. We have done significant work in computationally analyzing the HTSELEX data to correlate the secondary motif population to evaluate the functional element between aptamers and target molecules such as dimethylmethylphosphonate (DMMP) and ricin.

Molecular descriptor to quantify van der Waal interaction in a molecule

van der Walls forces are extremely important in the aptamer-molecule interactions. However, current approaches have not used a descriptor to capture the van der Walls forces explicitly in the aptamer-molecule classification algorithms. The vW force () between two spheres is given as:

,

Where R1, R2 are the radii of the spheres and r is the separation. In a molecule, the vW force is well defined by the Lenard Jones force[[28]](#endnote-28) and we proposed to use it as a molecular descriptor to quantify van der Walls interactions in our classification algorithm. The Lenard Jones force (FLJ) is calculated using:

,

Where ε, σ and r are the depth of the potential well, distance where the inter-particle potential is zero and the separation distance. For water ε = 0.31 nm and σ = 0.65 respectively.

#### Molecular descriptor to quantify point group symmetry in the molecules

##### Point group symmetry and functionality relationship of a molecule

Symmetry in a molecule defines

#### Secondary motif based oligonucleotide molecular descriptors:

* Olegocucleotoide descriptors: Sequence, secondary motifs
* Ontology based information extraction from the secondary motif to create an oligonucleotide descriptor.[[29]](#endnote-29)
  + RNA structure alignment ontology.[[30]](#endnote-30)

### Formulation of the classification algorithm

### Measure of the success in the classification

## Anticipated Public Benefits

# \*(2) Phase I Technical Objectives

# \*(3) Phase I Statement of Work

## Scope

## Management Plan

## Work Breakdown Structure

Phase I will be conducted according to the following Work Breakdown Structure (WBS).

### WBS 1.0 Describe and formulate molecular and apatamer descriptors

#### WBS 1.1. Creation of training set of data

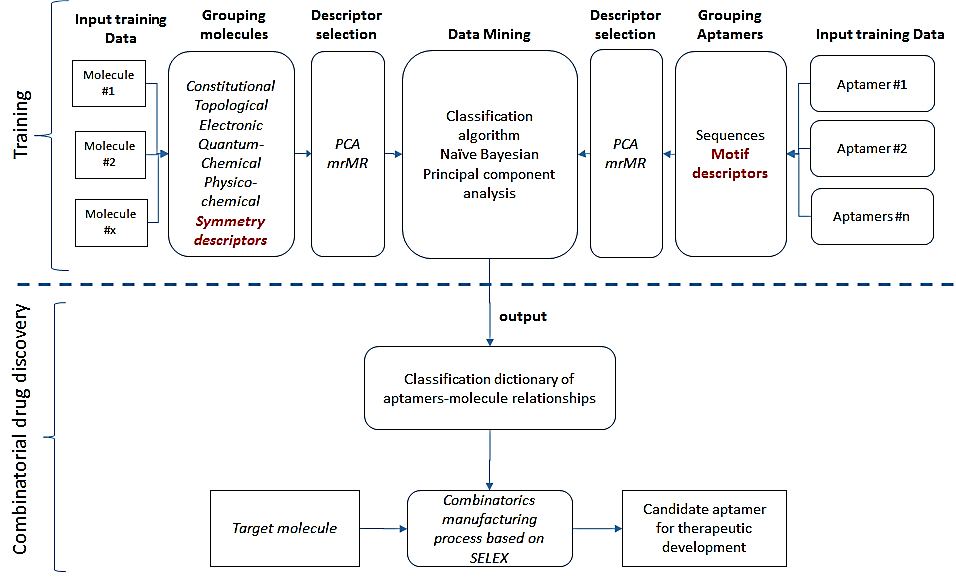


Figure . Voxtel proposed system of creating a machine learning based molecule-aptamer classification dictionary for combinatorics method of aptamer based therapeutic drug development. PCA, mrMR are the principal component analysis and minimum redundancy and maximum relevance based descriptor selection method.

* We will use canonical SMILES format to create a training molecular set.
* Attribute relation file format documents the attributes of a molecule.

#### WBS 1.2. Symmetry based molecular descriptors

* Defining a point group symmetry based molecular descriptor.
* Validating point-group symmetry of the target molecule as a 3D descriptor.

#### WBS 1.3. Secondary Motif based descriptors for the aptamers

* Defining ontology based method for creating a descriptor for secondary motifs
* Validating secondary motif descriptor for in the aptamers.

Define a table with the instances and the descriptors and the responses.

* Molecules are described by InCI[[31]](#endnote-31), Simplified Molecular Input Line Entry System (SMILES)[[32]](#endnote-32) or Structure Data Format (SDF)[[33]](#endnote-33) format.

### WBS 2.0 selection of the descriptors with lowest redundancy and highest relevance

### WBS 3.0 development of a custom classifier program for the project

### WBS 4.0 Training of the custom classifer and validation of the results

### WBS 5.0 testing the custom classifer and gauge the accuracy of the predictions

#### WBS 5.1. SELEX based testing

##### WBS 5.1.1 Metrics of testing

### WBS 6.0 PDR

## Performance Schedule

|  |  |
| --- | --- |
| Milestone | MARO |
| Complete requirements definition and develop specification |  |
|  |  |
|  |  |
|  |  |

## Deliverables

Voxtel proposes bimonthly reports detailing the technical program and incurred costs. A final report will be delivered at the end of the program. The reports will abide with the reporting requirements identified on the Federal Assistance Reporting Checklist and Instructions for RD&D Projects, DOE F 4600.2.

# (4) Related Work

## \*Examples of Voxtel’s Related Experience

|  |  |  |  |
| --- | --- | --- | --- |
| High-gain, Low-excess-noise APDs: Our industry-leading advanced APDs provide performance over the visible, NIR, and SWIR spectral regions. While common APDs have avalanche gain of *M* < 20 and are noisy, our APDs, characterized by *keff* = 0.02, offer low excess noise at gains of *M* > 5000, previously unprecedented in the NIR, providing superior sensitivity, resolution, and standoff. | | |  |
| Silicon Photomultiplier (SiPM) and Single-photon APD (SPAD) Detectors: We developed large-area solid-state digital SPAD detectors and a detector processes for commercial, high-volume CMOS that let us incorporate circuit function in the pixel, which pushes digital partitioning forward in the signal chain—into microcell elements. | | |  |
| Microminiature Eye-safe Laser Rangefinders (μLRF) and Components: To address the unmet need for a very low-cost, miniature eye-safe LRF capable of ranging from 1.5 km for scope- and rifle-mounted applications to 10 km and beyond for mounted and dismounted crew-served applications, we developed a μLRF that, in field demonstrations, shows 10-km ranging with better than 0.1‑m range accuracy. | | |  |
| Active and Active/Passive ROICs: The core competency of our ROIC design team is our ability to achieve low-noise, high-speed (e.g., GHz-rate) detector signal processing, including densely integrated analog and digital functionality, on a single full-custom CMOS integrated circuit. This unique capability offers tremendous leverage in highly sensitive active imaging, LADAR, and lidar applications, and many others where performance demands integral design of the detector and ROIC. | | |  |
| 3D Imaging, LADAR, and Active/Passive Imaging Cameras: To implement sophisticated functionality, our rugged cameras integrate our LADAR and active/passive FPAS with reconfigurable readout and data processing electronics to achieve < 25-ps accuracy in multichannel photon-detection instruments with applications in numerous markets. | | |  |
| 1024 x 1024 SWIR and MWIR Nanocrystal Imagers: We synthesize PbS (SWIR) and HgTe (MWIR) nanocrystals (8 nm) and, using automated electrostatic layer-by-layer deposition, we self-assemble superlattice infrared detectors directly on 200-mm wafers containing Voxtel-designed 15-μm-pixel, 1024 x 1024-format readout ASICs. Data readout at the 1-μm scale was correlated to quantum effects at the nanoscale. Shown are the SWIR imager and the image obtained. |  | | |
| High Density Micron-scale Nanoparticle Conductors: Using nanolithography and print deposition of Au and Ag nanoparticle (2 nm) inks, we assembled millions of < 1-µm-sized electrical vias at the wafer level (200 mm), which is not possible with current photolithographic techniques. Shown are 1-µm-dia. conductive metal pillars that are 1.5-µm high on a 5-µm pitch. These self-assemblies were developed to demonstrate next-generation infrared focal plane interconnection. |  | | |
| Inkjet-fabricated Freeform 3D GRIN Nanocomposite Optics: By modifying ligands for the select nanoparticle, we achieve optical polymers with a high loading density of ~10-nm-sized nanoparticles that do not aggregate. We inkjet-deliver these optical polymers with micron precision to fabricate large GRIN optics. Shown are a 45-mm GRIN lens (left), a 25-mm GRIN Wood lens integrating a pseudo aperture stop (center), and a GRIN lenslet array (right). |  | | |
| Hybrid Nanoparticle-Polymer Nanocomposite Optical Inks: We developed a series of 8-nm nanoparticle–monomer nanocomposite optical inks made from PbS, ZnO, SiC, ZnS, ZrO2, and TiO2, including heterogeneous mixes to perform color correction. We also demonstrated enhanced EO and NLO properties in the optical inks by implementing complex push-pull nanocomposite structures. These are delivered at 2.25M dps, with 1-µm accuracy to form freeform 3D GRIN optics. | |  | |
| Nanocrystal Devices[[34]](#endnote-34): Creating electrical and optical ensembles from confined nanoparticles requires understanding of individual and ensemble properties. Here, we showed—for the first time—delocalized quantum-confined states and localized sub-bandgap states via spatial mapping, shedding light on the mechanisms of surface-state formation, where under-coordinated surface atoms exist due to the steric hindrance between passivating ligands. | |  | |
| Phonon Filtering Nanocomposite Insulating & Thermoelectric Devices: We have used nanostructured material phononic filtering to discover the world’s most nonconductive materials,[[35]](#endnote-35) and we have used the same hierarchical structuring to achieve industry-leading thermoelectric materials using intercalated and exfoliated (BixSb1-x)2Te3 nanoplates (shown), to manufacture working thermoelectric devices with *ZT* > 1.69 (250 °C).[[36]](#endnote-36) | |  | |
| High-volume Commercial Fabrication of Nanocrystals: With over 15 years’ experience manufacturing nanocrystals, Voxtel has developed a high-rate (kg/hr) nanomaterial reactor, with which we can produce materials sized from about 1 nm to 100 nm, with better than 5% nonuniformity and better than 90% quantum yield. This technology has been licensed and scaled to production quantities, by Shoei Electronics, in a new 100K-sq.-ft. facility located in Eugene, Ore. | | \\nano.mbi.oregonstate.edu\projects$\ONAMI_Gap_Voxtel\Microwave Pictures\photo(4).JPG | |

## Partial List of Related Prior Contract Experience

New Awards to categorize:

Demonstration of High-dynamic-range Lidar Focal Plane Array, N162-112 Contract # N162-112-1121

Demonstrate highly sensitive high-dynamic-range lidar readout integrated circuit (ROIC) with dynamic range performance at least 6 bits beyond the existing lidar sensor used in the Airborne Laser Mine Detection System (ALMDS;

Hybrid Lidar/Radar Sensor for Improved Mine Detection, N162-113 Contract # N162-113-1147

Development of a hybrid lidar/radar (HLR) sensor that enables enhanced target detection and lower false alarm rates for airborne lidar mine-countermeasure (MCM) applications.

Large-format Low-false-alarm NIR SPAD Imager, SB162-010 Contract # D162-010-0324

Development of a near-photon-counting, high-dynamic-range, low-light multi-mode NIR-sensitive silicon single-photon avalanche-diode (SPAD) digital imager capable of high detection efficiency and low dark counts

Optically Transparent Tapered Resistive Elements, Aug16-Feb-17 (SOCOM 16-04) Contract # D16PC00218

Development of an innovative film and process that provides a tapered resistive layer across the film while remaining transparent in the visual and near-infrared optical bands for use in RF applications.

Covert Fiber-coupled Eye-safe Laser Rangefinder for Photonic Masts, Jul16-Dec16 (N161-033) N00024-16-P-4079

Development of a compact fiber-based low-power miniature LRF with superior ranging performance within the demanding size, weight, and power (SWAP) requirements of existing and planned photonics masts for submarines.

Nonlinear Optical Threat Protection Technologies for Daytime Cameras, Sep16-Mar17(A16-083) W56HZV-16-C-0147: Development of first-order (linear) and third-order (nonlinear) optical materials and systems to protect against continuous-wave and pulsed lasers of common daytime and low-light-level imaging cameras (400 – 1100 nm).

Large-Format High-Throughput SPC Imager, Jun16-Mar17 (DOE 7A; DE-FOA-0001417) DE-SC0015740

Development of a large-format single-photon-counting detector capable of capturing a single photon’s spatial location and time of arrival to better than 20 μm and 100 ps, respectively.

High-gain, Low-excess-noise APD Arrays for Near-single-photon-sensitive LADAR, Jun16-Jun17 (T9.01) NNX16CL66P

Development of a low-cost, high-pixel-density InGaAs electron-APD detector array sensitive from 0.5 μm to 1.7 μm spectral range with nearly noiseless avalanche gain at room temperature, based on a single-carrier multiplication (SCM) APD technology.

Robust, Low-SWAP Planetary Entry, Descent, and Landing System, Jun16-Dec16 (S4.01) NNX16CP68P

development of an entry, descent, and landing sensor—a high-dynamic-range, high-resolution LADAR detector focal plane array (FPA)—that works as an altimeter from ~~altitudes as high as 40 km, and at altitudes below 20 km, down to~~ 1 meter to 40 km.

Robust, Wafer-level 3D Electrical Interconnect Technology, Jun16-Dec16 (S1.03) NNX16CG19P

Demonstration of abilities to produce densely packed conductive sub-1-μm and larger nanometal pillars, to form low-resistivity 3D interconnects at a sub-3-μm pitch, to scale to 1-μm pitch and below, and to form 2.5D/3D stacked circuits to allow for 3D ICs, systems in a package, and stacked detector FPAs to be realized from dissimilar circuit and detector materials.

Wafer-scale Manufacturing of Nanocrystal Quantum Dot Focal Plane Arrays, Jun16-Dec17 (DARPA BAA 15-57), FA8650-16-C-7638: Development of non-bump-bonded, small-pixel-pitch, high-temporal-response imager with integrated immersion lens using automated, scalable colloidal quantum dot synthesis, layer-by-layer dip-coating, inkjet printing, & nano-resolution embossing.

High-Sample-Rate Analog-to-Digital Converters, Apr16-Jan17 (SB153-004) Army W31P4Q-16-C-0086

Development of a 40-GS/s ADC with at least six effective number of bits (ENOBs) for direct RF digitization of communications systems, instrumentation, and radar applications.

Multi-Wafer-Stack 3D Interconnect Manufacturing Technology, Jul16-Jan17 (N153-130) N68936-16-C-0067

Development of inkjet-print deposition and patterning of dielectric, electrical, and optical materials for use in electronics and sensor manufacturing for interconnecting a multi-layer wafer stack with high-density electrical and optical interconnection.

Radiation-hardened Reconfigurable Digital Dual-band Infrared ROIC, Apr16-Oct16 (MDA15-019), HQ0147-16-C-7037: Development of A 1280 x 1024, 12-micron-pitch format radiation-hardened dual-band digital infrared ROIC.

Low-Light Short-Wave Infrared Focal Plane Arrays, Dec15-Dec16 (MDA15-022) HQ0147-16-C-7529

Optimization, fabrication, and demonstration of a SWIR-sensitive linear-mode APD detector array—extensible to small pixel pitches and formats larger than 1024 x 1024—for space-based low-light imaging.

Adjustable-Focus Lenses for Respiratory Protection, Feb16-Aug16 (CBD152-001) W911SR-16-C-0010-A

Development—using 3D freeform gradient index materials—of a low-cost, adjustable optical-correction technology, for integration with AVON M50 and other respiratory protective masks, allowing for fast, adjustable vision correction.

Adaptive-Zoom Weapon Scope with Integral Ranging, Tracking, and Fire Control, Feb16-Aug16 (A152-095), W911SR-16-C-0010-B: Development of a small robust adaptable-zoom lens capable of wide focal-length change—from wide angle to telephoto in a fraction of a second—including design of the adjustable optic in a complete sighting, ranging, targeting, and fire control solution.

Alternative Interconnect Manufacturing—Printed SSL Optics, Feb16-Sept16 (7B, DE-FOA-0001366) DE-SC0015183

Develop method with improved efficiency for fabricating optics for LED lighting. Demonstration of inkjet-print fabrication of nanocomposite optical inks allowing for efficient, low-cost, and precise light extraction from LED lamps

Additive Manufacture of 3D Interconnects, Feb16-Nov16 (22E, DE-FOA-0001366) DE-SC0015187

Demonstration of method of using commercial inkjet print technology to deposit metals and dielectrics to form high-density traces and 3D electrical interconnections that allow circuits to be stacked on one another.

### Nanocomposite Optics

Monolithic Gradient Index Phase Plate Array, Jun14 – Dec14 (NASA 2014, S2.04) NASA NNX14CG41P

Delivered 3D freeform nanocomposite GRIN phase corrector plates, used by NASA to achieve diffraction-limited optics.

Fabrication of Aberration-free GRIN NLO Materials Processes, May14 – Nov14 (AF141-143) FA8650-14-M-5028

Fabricated inkjet-print manufacturing of nonlinear optical (NLO) nanocomposite materials, modulating third-order susceptibility.

High Index of Refraction Materials for Printed Applications, May14 – Nov14 (AF141-173) AFRL FA8650-14-M-5032

Demonstrated drop-on-demand inkjet-print processes of electro-optical (EO) materials in waveguide devices.

Manufacturable Gradient Index Optics (M-GRIN), Mar12 – Aug15 (DARPA BAA 11-57) FA8650-12-C-7226

Developed/demonstrated facile additive inkjet SFF process for large‐area 3D freeform GRIN optics, including color correction.

### Nanocrystal Detectors

Novel Flexible Sensor Array Integrated with a Flexible Display, Dec09 – Jun10 (A09-044) W911QX-10-C-0021

Developed nanocrystal-based IR detector that was fabricated in a process compatible with inkjet-printed backplanes.

Direct-Detection Nanocrystal-Based Pixelated X-ray Image Sensor, Jun10 – Feb15 (DOE 2010, 13A) DE-SC0004238

Demonstrated nanocrystal x‐ray detector arrays made from stable and reliable PbI2 nanocrystal films.

Innovative NIR/SWIR Sensor Development, Jun12 – Dec12 (SOCOM 12-002) H92222-12-P-0068

Optimized VIS-NIR, VIS-SWIR, and VIS-MWIR photoconductive (PC) and photovoltaic (PV) nanocrystal detector films.

Stretchable (Highly Conformable) PVs for Expeditionary Forces, Jun09 – Jan10 (N09-T020) N00014-09-M-0297

Developed a roll-to-roll nanocrystal PV technology based on a solid-state Gratzel architecture.

High-Count-Rate, Pixelated Direct X-ray Detection APDs, Jun06 – Aug10 (DOE 2006, 25C) DE-FG02-06ER84406

Developed a large-area, solution-processed nanocrystal x-ray detector using roll-to-roll processing on polymer films.

Wide-Spectral-Response Nanocrystal-Sensitized FPA, May12 – Jun15 (AF121-019) AFRL FA8650-13-C-1588

Optimized VIS-NIR, VIS-SWIR, and VIS-MWIR photoconductive (PC) and photovoltaic (PV) nanocrystal detector arrays.

CMOS-Compatible SWIR-Response Silicon Detectors, Nov11 – Nov12 (AF112-067) FA9453-12M-0039

Developed a low-cost, room-temperature, high-resolution active/passive SWIR imager, which can be fabricated at low cost.

### Nanomaterial Products

Covert Threat Functionalized Nanomaterials, Jan15 – Jan17 (DTRA 122-003) HDTRA1 -15-C-0021

Synthesized and demonstrated optical threat-reporting nanomaterials formed using threat-conjugating materials.

High-Efficiency Up/Down-Converting Infrared Nanoparticles, Apr12 – Jan13 (AF11-BT24) FA8650-12-M-5126

Developed series of optically transparent nanoparticles sensitive to 830-nm or 1064-nm laser illumination.

Optimization of Impact Ionization in Composite Nanocrystal PV (DOE 2007, 10C) DOE DE-FG36-GO18025

Developed nanocrystal photovoltaic arrays, demonstrating—for the first time—extraction of multiple exciton generated carriers.

Real-time Identification of Chemical, Biological, and Explosive (CBE), May10 – Aug10 EPA-D-10-045

Demonstrated biologically functionalized nanocrystal taggants for detection of *E. coli* or *Salmonella.*

Production of Monodisperse SW Carbon Nanotubes, May10 – Nov11 (N09-073) N00014- 10-C-0309

Developed manufacturing methods for synthesizing carbon nanotubes (CNTs) with known chirality.

Transparent High-Efficiency Upconverting Films, Jan09 – Apr13 (SB072-34) W31P4Q -10-C-0144

Developed a transparent NIR→visible nanocrystal upconverting film for helmet-mounted display applications.

Multifunctional Nanocrystal Microtaggants for Tracking, Aug06 – May14 (N06-T027) N00014 -08-C-0101

Developed spectrally coded covert optical nanotaggant for long standoff detection with covert stimulation and detection.

Standoff Detection of Functionalized Nanoparticles, Apr07 – Sep08 (AF073-047) AFRL FA8650-08-M-5908

Developed nanocrystal-based taggants for detecting CBE threat simulants (anthrax, ricing, etc.).

Nanoparticle Upconverting Films DARPA D072-034-587

Developed metal oxide-based nanoparticles for the upconversion of NIR light to a visible signature.

High-Efficiency Nanomaterials for Thermoelectrics, Jan06 – Aug09 (NASA 2005, S6.07) NASA NNM07AA27C

Developed nanoparticle thermoelectric (TE) materials; *ZT* > 1 was achieved using solution processing of nanocrystals.

Multifunctional Nanoparticles for Tracking Materiel, Aug06 – Feb07 (A06-T007) Army W911NF-06-C-0121

Developed a security ink invisible to the naked eye and with multiple tiers of encryption.

Nanostructured Materials with Improved Thermoelectric Properties, Jul06 – Dec06 OII-0611239

Developed a PbS/PbTe-based nanocrystal thermoelectric cooler.

High QE for Fast Readout of Scintillators for Gamma Rays, Mar07 – Sep07 (H-SB06.2-007) HSHQDC-07-C-0044

Developed a nanocrystal scintillator gamma ray detector.

Flexible, High-Performance Microlens Array Technology, May13 – Apr16 (NASA 2013, S1.03) NASA NNX14CG12C

Demonstrated ink-jet-printed solid-state free-form GRIN optical technologies for microlens array elements for IFS.

Low-Cost Nanostructured TE Materials for Low-Temp Power Generation, Jun11 – Mar12 (DOE 2011, 1B) DE-SC0006159

Developed novel (BixSb1−x)2Te3 nanoparticle thermoelectric power generator (TEG).

Quantum-Confined Nanocrystal Materials for Anti-Stokes Optical Coolers, Aug11 – May12 (AF 10-BT02) FA9550-11-C-0084

Developed nanocomposite laser cooling materials for a compact solid‐state cryocooler for space applications.

### Additive Manufacturing

Research Tool to Support Hybridized Additive, Jul15 – Nov18 (AF151-135) FA8650-16-C-5014

Develop print-compatible metal, optical, dielectric, magnetic, and structural feedstock materials and refine the capabilities of multi-material multi-jet-print manufacturing equipment. ~~Developed machine for the additive manufacturing (AM) multi-material 3D printing of heterogeneous materials.~~

Microchannel-Assisted Nanomaterial Deposition for PV DOE Solar Energy Tech.

Developed a process that reduces the energy and production cost of thin-film nanoparticle PV manufacturing.

Additive Direct-Print Fabrication of Nanocomposite Materials, Aug15 – Feb16 (AF15A-T07) FA9451-15-M-0532

Develop high-dielectric-nanocomposite high-voltage insulators/vacuum materials that hold off > 20 kV/mm per ASTM D149.

Magnetic Powders and Heterogeneous Gradient AM Techniques, Jul15 – Jan16 (N151-029) N00024-15-P-4545

Developed high-volume 3D inkjet AM manufacture process for known-quality, low-impedance, magneto-dielectric powders.

Atoms to Product, Jun15 – Jun17 (DARPA BAA 14-56) DARPA HR0011-15-C-0066

Develop multi-scale (nano-to-macro) products using a common covalent chemistry and DNA-like mediated self-assembly.

Hybridization Techniques for Ultra-Small-Pitch FPAs, Jun14 – Jul17 (AF141-196) AFRL FA8650 --15-C-1872

Developed process for hybridizing FPAs with < 5-µm-pitch interconnects by combining inkjet-print and nanoimprint nanometals.

### LIDAR and Active EO Systems

ADS Dual-Band IR Radiometer, Jan04 – Jan06 (N02-002B) USMC M67854-04-C-6000

Fabricated 2-color (MWIR/LWIR) ratio quantum-well IR photodetector (QWIP) radiometer for Active Denial System.

Hyperspectral 3-D LADAR Polarimeter (MDA 03-002) AFRL F19628-03-C-0108

Designed & simulated performance of a Stokes-vector LADAR polarimeter capable of staring hyperspectral imaging.

LADAR Spectro-Polarimeter (AF02-168) AFRL F08630-02-C-0052

Designed an active spectropolarimetric LADAR that aids in detection and identification.

Low-SWAP LIDAR Instrument for Arctic Ice Sheet, Feb13 – Apr16 (DOE 2013, 17A) DOE DE-SC0009577

Developed a gimbal-mounted LIDAR UAV-compatible instrument for measuring ice sheet mass balance.

Next-Generation Semi-Active Laser (SAL) and Mini Designator, Jul15 – Feb16 (AF151-112) FA8651-15-M-0225

Develop gun-hardened SAL seeker, including mini high-pulse-rate ~1540-nm laser designator, dual-mode FPA & multi-aperture optics.

Geo-Referenced, UAV-Based 3D Survey System for Precision Construction, Jun15 – Jul18 (DOE 2015, 32F) DE-SC0013835

Development of a mobile dual-mode laser scanner (lidar) instrument for construction and maintenance of nuclear power plants.

High-Peak-Power, Ultra-Sensitive Tx/Rx System on Board, Aug15 – Apr16 (A15A-T001) W31P4Q-15-C-0106

Development of a robust, highly integrated laser diode (or laser) and APD receiver for laser proximity sensors.

Optimized Taggant Delivery Systems, Sep11 – Jan15 (AF112-002) AFRL FA8650 -13-C-2319

Developed small, remotely piloted aircraft optical nanotaggant delivery system; covertly delivering taggants to targets.

### Active and Active-Passive Readouts, Focal Plane Arrays, and Cameras

Highly Sensitive Flash LADAR Camera, Jun15 – Sep18 (NASA 2015, T9.01) NASA NNX16CS78C

Development of a highly sensitive 640 x 480-element flash LIDAR camera capable of 100 Hz with better than 5-cm range precision

Extended-SWIR Targeting Sensor, Nov12 – Mar16 (AF112-096) FA8651-12-M-0069 / FA8651-13-C-0021

Development of the Multi-spectral Night-and-day Image and Laser spot imaging sensor with highly functional ROIC.

High-Res Asynchronous Day/Night Timespot NIR-SWIR Imager, Jul15 – Dec15 (A15-039) W909MY-15-C-0018

Development of a compact, low-power dual-mode imager with passive SWIR and asynchronous laser spot detection.

Ultra-High-Time-Resolution Laser Radar (LADAR) Receiver, Jan08 – Jul13 (A07-080) ARMY W15P7T-09-C-P005

Developed 5GHz-bandwidth linear-mode InGaAs APD receiver with ray with < 500-ps pulse-pair resolution.

Improved Hyperspectral ROIC and FPA, Nov11 – Apr15 (AF112-135) FA8650-13-C-1501

Developed a high-dynamic-range hyperspectral FPA, including custom ROIC and InGaAs array, with greater than 31 bits of DR.

ROIC & FPA for High-Rate Tracking of Energetic Threats, Jan11 – Jun16 (AF103-188) FA8650 -12-C-1365

Developed active/passive MWIR FPA with passive imaging and hyper-temporal readout of threats (small arms, MANPADs, etc.).

High-Sensitivity InGaAs LIDAR Receiver for UAS, Feb11 – Feb12 (NASA 2011, T4.01) NASA NNX11CI17P

Developed single-photon-sensitive InGaAs linear-mode APD receiver to discriminate single photon from dark event.

Linear-Mode Single-Photon Flash LADAR Receiver, Jan11 – Sep15 (AF103-182) FA8650-12-C-1359

Developed 128 × 128-format single-photon-sensitive APD array capable of about 10 photon NEI and mm range resolution.

Ultra-Compact Low-Power NIR Flash LADAR Receiver, Jan06 – Jul06 (NASA 2005, X1.03) NASA NNG06LA37C

Developed a NIR-sensitive germanium LADAR receiver.

Single-Photon-Counting FPA for Missile Seekers (MDA04-020) SMDC W9113M-04-P-0052

Developed a linear-mode SWIR HgCdTe APD LADAR achieving single-photon sensitivity.

High-Rate Single-Photon-Sensitive Coded APD Lasercom Receiver, May10 – Dec14 (MDA09-038) HQ0147-11-C-7751

Developed high-speed, asynchronous, random access, InGaAs APD receiver.

Multi-Mode LADAR Camera for Enhanced Interceptor Seekers, May11 – Dec11 (10-016) HQ0147-11-C-7627

Developed a large-format InGaAs LADAR focal plane array for space missile interceptor applications.

High-Sensitivity Sampling 3D LIDAR Imagers for SZ Mine Detection, May10 – Jul16 (N101-083) N00014-15-C-0149

Developed a 256 x 256-element APD FPA capable of GHz-rate full-waveform LIDAR sampling.

Coherent Holographic LADAR Applications, Jan11 – Nov15 (AF103-186) AFRL FA8650-12-C-1363

Developed high-quantum-efficiency, highly uniform, high-rate InGaAs FPA for coherent holographic LADAR.

Enhanced Capability Point Combined Bio and Chem Sensor, Jul07 – Aug11 (CBD 07-105) W911SR-08-C-0065

Designed DISC LIDAR system based on LWIR HgCdTe APDs. Developed HgCdTe APD-based spectrometer for DIAL LIDAR.

Solid-State SOI CMOS LIDAR, Dec04 – Sep08 (N04-209) NSWC N00178-06-C-3024

Developed solid-state linear 128-channel, nsec-rate full-waveform-recording LIDAR for underwater mine detection.

Airborne Laser Detector Technology (BAA AL2003-01) AFRL F33657-03-C-2043

Designed a 1.0–1.7-μm, 32 × 32-element InGaAs APD wavefront sensor with 10K fps, 6-photon NEI, and 1-ns pulse resolution.

Ultra-Sensitive Detector, Apr05 – Apr06 (BAA AL 2005-01) MDA FA8632-05-C-2456

Developed a 32 x 32-element sub-ns-response single-photon linear-mode InGaAS APD FPA operating at 10K fps.

Airborne Laser (ABL) Detection Sensor Improvements, May07 – May11 (MDA06-054) MDA W9113M-08-C-0167

Developed single-photon-sensitive InGaAs ranging cameras to upgrade the ABL’s image tube ranging cameras.

Future Night Vision System, Apr05 – Apr07 (AF04-061) AFRL FA8650-05-C-6532

Developed helmet-mounted, solid-state 100-degree night vision googles with visible and SWIR response.

Adaptive Multi-Waveform LADAR FPA, Jun07 – Mar08 (AF071-236) AFRL FA8750-07-C-0173

Demonstrated encoded laser waveforms for single-photon-sensitive LADAR.

High-Sensitivity High-Bandwidth Multi-Access Optical Comm. Receiver, Feb10 – Sep10 (AF093-043) FA8750-10-C-0094

Developed eye-safe (1.0 to 1.7 µm) high-sensitivity laser communications receiver using ultra‐low-excess-noise APD arrays.

### Lasers

Ultra-Miniature High-Power Pulsed Microchip Lasers, Jun15 – Jun16 (NASA 2015, T9.01) NASA NNX15CS55P

Developed ultra-compact, high-pulse-energy, high-pulse-repetition-frequency (PRF), diode-pumped solid-state (DPSS) laser.

### Passive Solid-State Imaging Arrays anD Detectors

Radiation-Hardened HDTV Sensors, Feb11 – May16 (NASA 2010, O3.05) NASA NNX12CA89C

Developed a 1980 x 1280 rad-hard back-illuminated HDTV SOI CMOS imager for the international space station (ISS).

High-Definition (HD) Low-Light-Level Detector, Jan08 – Oct08 (AF073-043) AFRL FA8650-08-M-5405

Developed a back-illuminated SOI CMOS image sensor.

Commercial 200-mm SOI CMOS Imager Process Development, Jun10 – Aug14 (DOE 2010, 49D) DOE DE-SC004236

Developed rad-hard event-driven SOI CMOS imager architecture for charged-particle detectors.

Rad-Hard Metamorphic InGaAs Detector Arrays, Feb11 – Aug11 (NASA 2010, S1.04) NASA NNX11CF32P

Developed a UV-SWIR-sensitive metamorphically grown InGaAs detector architecture.

Rad-Hard SOI CMOS Active-Precision Agile Star Tracker, Jul09 – Apr10 (DOE 2009, 48D) DOE DE-SC0002421

Developed a 1024 x 1024-element, agile, back-illuminated, fully depleted CMOS image sensor for star trackers.

Next-Generation Architecture for Night Vision Imaging, Apr06 – Jan07 (AF06-022) AFRL FA8650-06-M-6672

Developed helmet-mounted backside-illuminated SOI CMOS imager technology.

Back-Illuminated CMOS Detector Arrays, May06 – Feb07 (N06-073) NAVY N00014-06-M-0089

Developed a back-illuminated charge-coupled device (CCD) for missile warning systems.

Ultra-Low-Noise, High-Bandwidth, 1550-nm HgCdTe APD, Jan03 – Jan07 (NASA 2003, S5.03) NASA NNG05CA28C

Developed a large-area (>1 mm2) NIR-sensitive HgCdTe APD receiver with sub-ns response, high gain, and low-noise.

Improved Reliability EBCCD Sensors (MDA03-028) AFRL F29601-03-M-0249

Developed a back-thinned CMOS imager with high electron-bombarded-silicon (EBS) gain and minimum dead space.

Large-Format Rad-Hard CMOS Imager for Star Trackers, May10 – Nov10 (MDA09-014) MDA HQ0006-10-C-7360

Developed rad-hard ROIC architecture for star-tracking applications.

Interceptor Seekers, Aug10 – Mar15 (MDA 08-002) HQ0147-10-C-7284

Developed a small-sized InGaAs APD array and ROIC for two-color LADAR interceptor systems.

Solid-State Night Vision Sensor, May08 – Feb09 (AF081-007) ARMY FA8650-08-M-6883

Developed a 10-µm-pixel-sized InGaAs SWIR imager and ROIC.

Radiation-Hard, High-Precision, Agile Star Tracker, Apr07 – Sep10 (AF063-002) MDA W9113M -07-C-0155

Fabricated a 2k × 2k FPA, radiation-hardened CMOS array for star tracking.

Uncooled, Long-Life Wavefront/Tracking Sensor, Feb05 – Sep08 (MDA04-105) AFRL FA9453-05-M-0066

Developed a 32x32 InGaAs array and ROIC capable of < 20 e- RMS noise and 20K fps operation.

Enhanced Focal Plane Array, Apr05 – Dec09 (AF05-291) USAF FA9200 -C-0322

Developed a 10-micron-pitch high-rate snapshot NIR-sensitive germanium detector array for HEL radiometric imaging.

Revolutionary Photoreceivers, May05 – May07 (AF04-214) AFRL FA-8750-05-C-0041

Developed a high-bandwidth germanium photodetector.

SOI CMOS Star Tracker (BMDO-02-003D) DTRA DTRA01-02-P-0185

Designed a CMOS star tracker with radiation mitigation circuitry for navigation in harsh environments.

Low-Swap Multispectral Sensor for Low-Light & Laser Imaging, Jul11 – Apr12 (N111-003) M67854-11-C-6543

Developed hi-res integrated multispectral sensor incorporating day/night vision & multispectral laser spot imaging.

NIR InGaAs Wavefront and Tracking Sensor, May04 – Nov04 (MDA04-068) AFRL FA9453-04-M-0265

Developed design of a 1024 × 1024-element NIR imager for wavefront sensing, sensitive at 1030 nm and 1064 nm.

High-Frame-Rate Wavefront Camera for Acq., Tracking, & Pointing, May11-Dec11 (10-005) HQ0147-11-C-7626

Developed a high-rate InGaAs FPA for adaptive optics and wavefront control.

High-Efficiency Large-Area 1550-nm InGaAs Photodiodes, Jun09 – Jul13 (NIST 9.12.02-1.R) NIST SB134110CN0052

Developed an InGaAs photodiode with greater than 85% QE. Developed single-photon-sensitive InGaAs optical receiver.

Multi-Modal LWIR/VLWIR Focal Plane Array (MDA03-036) AFRL F29601-03-M-0246

Optimized a two-color HgCdTe LWIR/VLWIR sensor.

Active/Passive Two-color Infrared Focal Plane (MDA03-088) SMDC DASG60-03-P-0295

Optimized design of monolithic, active/passive, two-color (S/MWIR) APD and MWIR passive photodetector.

Radiation-Hard Stacked LADAR Circuits (MDA03-013) AFRL F19628-03-C-0103

Developed small rad-hard LADAR ROIC based on 3D wafer-stacked SOI CMOS ICs.

Rad-Hard Back-Illuminated SOI CMOS Star Tracker, Jul04 – Jul06 (MDA03-051) W9113M-04-C-0070

Developed rad-hard, 2048 x 2048 SOI CMOS star tracker with high-frame-rate windowing and nondestructive readout.

Non-Avalanche Gain Detector for Hi-Res Single-Photon & Dual Mode, May10 – Nov10 (MDA09-002) HQ0006-10-C-7376

Designed non-avalanche linear-mode InGaAs photodiode detector array with GHz count rate and sub-Poissonian shot noise.

### Single-Photon-Counting Detectors, Detector Arrays, and Readouts

Compact High-Res, Time-Resolved Intensified Image Sensor, Jun15 – Dec15 (NASA 2015, S1.06) NASA NNX15CM54P

Develop hybrid pixelated image sensor with timestamping of photon events at counts per second ranging from a few to billions.

Linear-Mode Single-Photon Avalanche Photodetector, Feb11 – Aug11 (NASA 2010, O1.04) NASA NNX11CF20P

Developed InGaAs/InP hole-avalanche linear-mode APD capable of high-rate photon counting.

Large-Area High-QE Linear-Mode APD NASA NNG09LM25P

Developed SWIR and MWIR HgCdTe APDs for single-photon-counting LIDAR applications.

Single-Photon-Sensitive MWIR HgCdTe APD Detector, Jun09 – Oct09 (NASA 2005, S6.02) NASA NNX08CA29C

Delivered an MWIR HgCdTe APD LIDAR receiver with single-photon-sensitivity in the MWIR that demonstrates no excess noise.

Efficient Low-Dark-Count Detector for Photon Counting, Aug08 – Jun12 (NIST 9.03.1-4.R) NIST SB134109CN0079

Developed a NIR-sensitive linear-mode InGaAs single-photon-counting receiver for quantum information processing.

NIR Photon-Counting APD (NIST 8.18.2T) NIST 50-DKNB-0-90090 / SB1341-02-C-0015

Developed high-speed, large-area, single-photon-sensitive, Geiger-mode APDs and active quenching circuits.

Single-Photon Lasercom ROIC, Jun15 – May 18 (NASA 2015, H9.01) NASA NNX16CP11C

Developed a high-dynamic-range Geiger-mode single-photon-counting (SPC) freespace optical communications readout.

Wafer-Scale Geiger-Mode Silicon Photomultiplier, Jun11 – Aug16 (DOE 2011, 61A) DOE DE-SC0006157

Developed/fabricated high‐density Si Geiger‐mode APD arrays on 200‐mm wafers using high‐volume CMOS process.

Large-Area, Low-Dark-Count, VIS-UV, Solid-State Photomultiplier, Feb12 – Nov12 (DOE 2012, 31C) DE-SC0007536

Demonstrated improved performance of large-area linear-mode and Geiger-mode AlGaAs APD.

Digital Silicon Photomultiplier Readout Circuit, Feb13 – Apr15 (DOE 2013, 42B) DOE DE-SC0009575

Developed a digital ROIC for use with large-area, silicon, Geiger-mode APD arrays.

High-Count-Rate Single-Photon-Counting Detector Array, Jun14 – Dec14 (NASA 2014, H9.02) NASA NNX14CP53P

Developed linear-mode single-photon InAlGaAs APD using impact ionization in multiple cascaded gain stages.

High-Count-Rate, High-Resolution, Single-Photon Detector, Feb13 – Nov13 (DOE 2013, 26B) DOE DE-SC0009576

Developed solid‐state ROIC optimized for increased photon count rate and time-resolved cross-strip (XS) photon detectors.

Large-Area, UV-Optimized, Back-Illuminated SiPM Arrays, Feb11 – Apr16 (NASA 2010, S1.05) NASA NNX12CA38C

Developed large-area, back-illuminated SiPM array technology using a domestic 200-mm CMOS fab.

Highly Stable Large-Format EUV Imager (NASA 2003, S1.06) NASA NNG04CA63C

Developed design of a back-illuminated CMOS imager with improved extreme-ultraviolet (EUV) sensitivity and surface stability.

High-Efficiency, High-Speed Si Gamma-Ray Detectors, Jun07 – Jan11 (DOE 2007, 10C) DOE DE-FG36-GO18025

Developed arrays of silicon APDs for detecting blue scintillators.

Digital SiPM Array Readout Integrated Circuits, Jun11 – Mar12 (DOE 2011, 63A) DOE DE-SC0006158

Designed digital ROIC for high‐count‐rate silicon photomultipliers (SiPMs) and silicon Geiger-mode (Gm) APDs.

High-Performance Geiger-Mode 1.06-micron APD Array, Aug04 – Aug06 (MDA 03-088) SMDC W9113M-04-C-0103

Developed NIR-sensitive, 32 x 32, Geiger-mode APD array with high probability of detection and low dark counts.

Optimized UV Solar-Blind GaN/AlGaN Avalanche Photodiode FPA (BMDO-00-003C) DASG60-02-P-0120

Developed a GaN-based photon-counting UV solar-blind imager.

### X-ray Photon and Charged-Particle Detectors

High-Dynamic-Range Rad-Hard Time-Resolved X-ray Photon Detector, Jul09 – Aug13 (DOE 2009, 6C) DE-SC0002430

Developed event-driven, time-resolved correlating x-ray detector array and camera.

Picosecond-Rate X-ray Photon-Counting Detector, Feb12 – Nov12 (DOE 2012, 9A) DOE DE-SC0007542

Demonstrated custom-fabricated InSb pixelated waveform recorder w/psec x-ray timing resolution.

Charged-Particle Imaging Foundry Source, Jun10 – Aug15 (DOE 2010, 44D) DOE DE-SC004237

Developed a domestic SOI CMOS fabrication source for high-performance back-illuminated imagers.

Dual-Threshold High-Count-Rate Silicon Pixel Array Detector, Feb12 – Apr16 (2012, 23A) DOE DE-SC 0007543

Developed a rad-hard, dual-threshold, dual‐counter, x‐ray photon‐counting pixel array (DUPREA) detector.

Rad-Hard SOI CMOS Active-Pixel Sensor for Charged-Particle Detection DOE DE-PS02-08ER08-34

Developed a backside-illuminated depleted SOI CMOS imager with sparse readout for x-ray detection.

Time-Resolved, X-ray Photon Detector Array (DOE 2007, 14A) DOE DE-FG02-07ER84927

Developed large-area silicon APD arrays to record the time of arrival of x-ray photon events.

Large-Area SiPM Arrays for Cherenkov Calorimetry, Jun07 – Aug10 (DOE 2007, 34A) DOE DE-FG02-07ER84918

Developed large-area Geiger-mode silicon APD arrays to measure Cherenkov scintillators.

15-micron Pixelated SOI CMOS Vertex Sensor, Jun07 – Aug10 (DOE 2007, 34A) DOE DE-FG02-07ER84919

Developed thin, back-illuminated SOI CMOS vertex detectors for the international linear collider.

High-Speed Direct-Electron-Microscopy Detector Array (DOE 2006, 25B) DOE DE-FG02-06ER84405

Developed the design of a CMOS imaging array for direct electron imaging.

Improved Vertex Focal Plane Array for Linear Colliders (DOE 2006, 41B) DOE DE-FG02-06ER84489

Developed a thin (15-μm) back-illuminated sensor with time-of-arrival statistics to improve pulse pile in the ILC.

Germanium X-ray Photon Counting Focal Plane Array, Jun10 – Aug15 (DOE 2010, 18C) DOE DE-SC004235

Developed a germanium (Ge) x-ray photon counting detector array for synchrotron science experiments.

### Signal-Processing Platforms and Time-to-Digital Converters

High-Channel-Count Lasercom TDC and Pulse Processor, Jun15 – May18 (NASA 2015, H9.01) NASA NNX16CP01C

A 256-1024 channel FPGA-based TDC with better than 30 ps time resolution for readout of SPAD optical communications arrays.

Programmable, Reconfigurable Si Photodiode Array Module, Feb14 – Nov14 (DOE 2014, 34A) DOE DE-SC0011290

Developed a reconfigurable detector processor with heterogeneous processing platform.

Low-Cost Reconfigurable Multi-Channel Pulse-Processing Platform, Jun10 – Feb15 (DOE 2015, 59B) DE-SC004234

Developed 64-channel FPGA-based TDC with time-over-threshold (TOT) & multi-TOT pulse processing.

Onboard Data Processing for Fast Detectors, Feb15 – Nov15 (DOE 2015, 9B) DOE DE-SC0013185

Developed reconfigurable processing platform with heterogeneous processing allowing massively parallel I/O detector arrays.

DLS Instrumentation Using FPGA-Based DPS, Jun07 – Jan10 (NIST 9.12.12-5) NIST SB134109SE0599

Developed multi-channel FPGA-based TDC with real-time auto/cross-correlation and GigaE communication\*

# (5) Relationship with Future Research or Research and Development

# \*(6) Commercialization Strategy (EXCEPTION: DARPA-leave out info here; use 5 PP Comm Template)

## Success Commercializing SBIR and Government S&T Funded Technologies

Voxtel is well qualified to conduct this effort, manufacture the resulting product, and successfully commercialize the technology. The proposed development directly aligns with our strategic plan and product development roadmap. We have a very successful history commercializing technologies, including those developed under SBIR funding. Voxtel is a spinoff of a spinoff from Tektronix. We spun out the CCD group from Tektronix in 1993, forming SITe and PixelVision and, while developing the first scientific-grade CCD imagers that are still on the Hubble Space Telescope today, we innovated solid-state imaging in digital photography, x-ray medical and dental imaging, astronomy, and other markets. Now, at Voxtel and for over 10 years, we have developed the world’s foremost staff of detector and ROIC designers. Some successes commercializing government S&T funded technologies include:

**Military Rangefinding (LRF) and Laser Radar (LADAR):** First under an MDA BAA, then under an AFRL SBIR, Voxtel developed a novel, low-noise APD architecture, which we developed into a product line of LADAR and LRF products. These technologies now form a business unit that accounts for 50% of Voxtel revenue. Under a Phase III SBIR, Voxtel is now being considered as the source for over 100,000 LRF units over the next three years. The higher performance and lower cost of these LRFs is expected to provide the Army a 40-fold return on its SBIR investment.

**Gesture Recognition and Human Computer Interfacing:** We consolidated many of detector and ROIC technologies we developed, partially under U.S. government S&T and SBIR funding, in a business unit to address next-gen gaming interfaces and human computer interfaces. The business unit is expected to reach sales of $25M in three years.

**Production Nanocrystal Reactors:** To develop nanomaterial products, we recognize the need for control and mastery of nanomaterials across scales and, about a decade ago, we began developing automated nanoscale continuous flow reactor technologies that can economically mass-produce diverse nanomaterials with the quality required for product development. We have shown our continuous flow nanomaterial reactors capable of producing kg/hr quantities of monodisperse nanomaterials, with quality not obtainable using common hydrothermal batch methods. Our existing laboratory inkjet assembly systems deliver nanostock in submicron-scale drops at 35M dps. Our material quality and delivery precision have enabled us to achieve the rapid scientific advancements that have eluded the research community.[[37]](#endnote-37) As part of a Phase I U.S. Navy SBIR, we developed the concept for our microwave-enhanced continuous flow reactor that, with investment from Japanese materials supplier Shoei Electric, in 2013, spun out as a U.S. subsidiary division of Shoei. The two-year investment in this technology is approximately $16M.

**Inkjet-printed Nanocomposite Optics:** Voxtel has created a new company, Vadient Optics, LLC, which will commercialize inkjet-printed nanocomposite optics. The technology was initiated by a DARPA BAA call.

**Licensing:** A number of our patents result from SBIR efforts. We licensed four patents in 2013 alone.

### Publication and Presentation

We routinely disseminate information through publication and present designs and trade shows and conferences. Since 1993, we average 4 – 10 publications per year, most peer reviewed. As industry leaders, we routinely participate in National Academy of Sciences (NSC), National Research Council (NRC), and military review panels.

### Customers and Past Performance

Our current customers include: *consumer products* providers, such as Google, Facebook, Apple, Samsung, etc.; *industrial and medical system integrators*, such as Trimble, GE, Philips, etc.; *military system suppliers*, including Lockheed Martin, DRS, BAE, Raytheon, and L3; and *government agencies*, including the U.S. Navy, U.S. Army, U.S. Air Force, DARPA, NIST, NOAA, NASA, and U.S. Secret Service.

### Intellectual Property

Innovation is our lifeblood, so we have a system and strategy to maintain tight control over Voxtel-developed IP, which includes the short-term protections afforded by unique knowledge/abilities in our technological specialties.

We have our *own full-time patent attorney on staff* to handle the significant IP created by our staff. We currently have over 15 granted and 24 pending patents. In 2014 alone, we filed 36 provisional patent applications. We work regularly with several outside patent firms, including Klarquist Sparkman, LLP, Lumen Patents, and Chernoff Vilhauer LLP. We license technology through our business law firm, Ater Wynne, and we litigate using Tonkin Torp, LLC.

As novel processes and technologies are developed, we assess costs/benefits of patents and trade secrets. In all our projects, discussions regarding patenting/publishing are ongoing between our CEO and project managers.

## Strategy

## Market

## Quantitative Commercialization Results

Required. Jen confirmed against solicitation on 5/19.

# (7) Key Personnel

## George Williams, System Engineering

##### MSEE, Northeastern Univ, 1989; MBA, Va Tech, 1993; BSEE, Union College, 1985

As president of Voxtel, Inc., Mr. Williams oversees Voxtel’s R&D/commercial product development, technical strategy, and market channel development. Mr. Williams also contributes technically in engineering X‑ray, UV, visible, NIR, infrared, night vision, and multi-spectral EO systems. He has researched, designed, and manufactured image sensors, imaging systems, and image processing algorithms for more than 27 years. His specific technical expertise include active/passive EO system design and modeling, silicon CCDs and CMOS imagers, InGaAs imagers, image-intensified detectors, and HgCdTe detector design and manufacturing. He also leads development of Voxtel’s technologies related to nanocomposite optics, nanocrystal-based photovoltaics and infrared detectors, thermoelectric coolers, and upconverting/downconverting nanocrystal film devices. Previously, as executive VP and general manager of PixelVision, Inc. and its sister company, SITe, Inc., he managed the teams that designed, manufactured, and delivered CCD technology to commercial and government programs, including imagers for the Space Telescope Imaging Spectrograph (STIS) and Advanced Camera for Surveys (ACS) installed on the Hubble Space Telescope, the Solar and Heliospheric Observatory (SOHO), the Space Shuttle, the Chandra X-ray Observatory, as well as other important NASA and DoD missions; and led the commercialization of the first science-grade CCDs used in digital photography, x-ray mammography, dental imaging, spectroscopy, and microscopy. While at ITT Night Vision, he developed considerable experience in image-intensified night vision goggles (NVGs) and infrared detector design and development, and led commercialization of the night vision technology in the NightMariner and NightEnforcer product lines. Mr. Williams is a U.S. citizen and holds a DoD Top Secret security clearance.

##### Selection of Relevant Publications

* “Pixelated Detector with Photon Address Event Driven Time Stamping and Correlation,” G. M. Williams Jr., J. Rhee, A. O. Lee, and S. D. Kevan, Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC), 2013 IEEE.
* “Dual Threshold X-ray Photon Counting Pixel Array Detector,” A.O. Lee, J. Rhee, G.M. Williams, S.D. Kevan, IEEE NSS‐MIC-RTSD Conference Record, submitted Nov. 27, 2013.
* “Instantaneous Receiver Operating Characteristic Performance of Multi-gain-stage APD Photoreceivers,” G. M. Williams, D. A. Ramirez, M. Hayat, A. S. Huntington, J. Electron. Devices, vol. 1, no. 6, pp. 1-9, June 2013.
* “Discrimination of Photon- and Dark-Initiated Signals in Multiple Gain Stage Avalanche Photodiode Receivers,” G. M. Williams, D. A. Ramirez, M. Hayat, A. S. Huntington, J. Electron. Device, vol. 1, issue 4, pp. 1-12, 2013.
* “Multi-gain-stage InGaAs Avalanche Photodiode with Enhanced Gain and Reduced Excess Noise,” G. M. Williams, M. Compton, D. A. Ramirez, M. Hayat, A. S. Huntington, J Electron Device, vol 1, no 2, pp. 54-65, Feb. 2013.
* "Time resolved gain and excess noise properties of InGaAs/InAlAs avalanche photodiodes with cascaded discrete gain layer multiplication regions," G. M. Williams, D. A. Ramirez, M. M. Hayat, and A. S. Huntington, J. Appl. Phys., vol. 113, issue 9, p. 093705 , Mar. 2013.
* “Non-local Model for the Spatial Distribution of Impact Ionization Events in Avalanche Photodiodes,” D. A. Ramirez, A. S. Huntington, G. M. Williams, and M. M. Hayat, Appl. Phys. Letter., submitted for publication, 2013.
* “Increased gain InGaAs avalanche photodiode with reduced excess noise achieved through asymmetric carrier modulation,” G. M. Williams, et al, J. Appl. Physics, accepted for publication, 2013.
* “Linear-mode single-photon APD detectors.” A Huntington, M Compton, G Williams. *Proc SPIE* 6771.
* “Improved breakdown model for estimating dark count rate in avalanche photodiodes with InP and InAlAs multiplication layers.” A. Huntington, M. Compton, G. Williams. *Proc SPIE* 6214, 2006.
* “Probabilistic analysis of linear-mode vs. Geiger-mode APD FPAs for advanced LADAR-enabled interceptors.” G. Williams, A. Huntington. *Proc SPIE* 6220, 2006.

##### Selection of Relevant Patents

* US 8724214 B2, WO 2014039347 A1: Broadband optical upconversion by energy transfer from dye antenna to upconverting crystal
* US7160753 Silicon-on-insulator active pixel sensors.
* US8207484 Streak image sensor and method of operating
* US7919018 Photoactive taggant materials comprising semiconductor nanoparticles and lanthanide Ions.
* US7994421 Photovoltaic devices having nanoparticle dipoles for enhanced performance and methods for same.

## Dr. Andrew Huntington, Detector and Focal Plane Engineering

##### PHD, MATERIALS, UNIV. CALIF. SANTA BARBARA, 2003; BS, CHEM., CALTECH, 1997

Dr. Huntington manages Voxtel’s detector development group and is responsible for Voxtel’s advanced development efforts relating to semiconductor devices, material growth, device modeling, and detector design and development efforts. He invented and patented Voxtel’s advanced high-gain, low-excess-noise SCM-APD technologies, and has supported the development of this important device through Monte Carlo modeling and experimental extraction of material properties. He has also managed the development of Voxtel’s array process and APD-based commercial products. The detector projects Dr. Huntington has conducted include Geiger- and linear-mode SOI CMOS and InGaAs-based APDs for the NIR spectrum; HgCdTe APDs for the SWIR, MWIR, and LWIR spectra; and silicon-based linear APDs for visible and X‑ray applications. Most recently, his work has included silicon photomultiplier (SiPM), silicon single photon avalanche photodiodes (SPADs), and infrared nanocrystal detectors. He has a number of publications detailing this work. Prior to joining Voxtel, Dr. Huntington performed his doctoral studies in materials at the University of California, Santa Barbara (L. Coldren Group), where his dissertation work included development of low-noise and broad-area InGaAs/InAlAs APDs. That work was conducted in collaboration with Professor Joe Campbell of the University of Texas, Austin, who is widely recognized as a leader in the field. Conducting this work, Dr. Huntington developed his expertise in the production of APD wafers by molecular beam epitaxy, with particular emphasis on understanding the relationship between growth conditions, material quality, and device performance. Dr. Huntington is a US citizen and holds a DoD Secret security clearance.

##### Selection of Relevant Publications

* “Linear-mode single-photon APD detectors.” A. Huntington, M. Compton, G. Williams. Proc SPIE 6771, 2007.
* “Improved breakdown model for estimating dark count rate in avalanche photodiodes with InP and InAlAs multiplication layers.” A. Huntington, M. Compton, G. Williams. Proc SPIE 6214, 2006.
* “Probabilistic analysis of linear-mode vs. Geiger-mode APD FPAs for advanced LADAR-enabled interceptors.” G. Williams, A. Huntington. Proc SPIE 6220, 2006.
* “Relationship of growth mode to surface morphology and dark current in InAlAs/InGaAs avalanche photodiodes grown by MBE on InP.” A. Huntington et al. J Crystal Growth 267(3–4), 458–465, 2004.
* “Long-wavelength In0.53Ga0.47As/In0.52Al0.48As large-area avalanche photodiodes and arrays.” X. Zheng, J. Hsu, X. Sun, J. Hurst, X. Li, S. Wang, A. Holmes Jr., J. Campbell, A. Huntington, L. Coldren. IEEE Journal of Quantum Electronics, vol. 40, no. 8, pp. 1068–1073, 2004.
* “A 12 × 12 In0.53Ga0.47As/In0.52Al0.48As avalanche photodiode array.” X. Zheng, J. Hsu, X. Sun, J. Hurst, X. Li, S. Wang, A. Holmes Jr., J. Campbell, A. Huntington, L. Coldren. IEEE Journal of Quantum Electronics, vol. 38, no. 11, pp. 1536–1540, 2002.
* “Low-noise impact-ionization-engineered avalanche photodiodes grown on InP substrates.” S. Wang, J. Hurst, F. Ma, R. Sidhu, X. Sun, X. Zheng, A. Holmes Jr., A. Huntington, L. Coldren, J. Campbell. IEEE Photonics Technology Letters, vol. 14, no. 12, pp. 1722–1724, 2002.

##### Patents

* USPTO: 7432537: Dr. Andrew Huntington, “Avalanche Photodiode Structure.” Nov 23, 2005.
* U.S. Patent Application (filed by UCSB). “Heterogeneous Composite Semiconductor Structures for … Semiconductor Lasers…” Serial No. 09/953,576. Co-Inventor: Jin K. Kim.

## Dr. Vinit Dhulla, Solid-State Device Engineering

##### PHD, EE, STONY BROOK UNIV, 2007; MSEE, STONY BROOK UNIV., 2006; BSEE, UNIV MUMBAI, 2001

Dr. Dhulla is a senior engineer and the principal investigator responsible for Voxtel’s silicon photomultiplier (SiPM) device and product development efforts, as well as the development of Voxtel’s FPGA-based high-resolution (~25‑ps) time-to-digital (T2D) converter/correlator modules and LADAR electronics. Dr. Dhulla joined Voxtel after serving as an intern during his graduate studies, during which time he characterized SiPMs as high-speed single-photon counters and published the first experimental demonstration of their application to DNA sequencing. He designed, implemented, tested, and characterized a novel high-speed quenching circuit for single-photon avalanche diodes (SPADs). Dr. Dhulla’s technical capabilities include system-level design, implementation, and characterization of multi-channel photon counting systems. He has participated in the design, prototyping and testing of support electronics modules for many detector system projects.

##### Selection of Relevant Publications

* “Silicon Photomultiplier: Detector for Highly Sensitive Detection of Fluorescence Signals.” V. Dhulla et. al. CLEO/QELS, San Jose, California, May 4–9, 2008.
* “Single Photon Counting For Ultra‐weak Fluorescence Detection: System Design, Characterization and Application to DNA‐Sequencing,” Vinit Dhulla, PhD Thesis, Stony Brook U., Dec 2007. <http://gradworks.umi.com/3337615.pdf>.
* “Single Photon Counting Module Based on large area APD and novel logic circuit for quench and reset pulse generation,” V. Dhulla et. al. *Selected Topics in Quantum Electronics*, (IEEE Journal) pp. 926–933, Volume: 13, No. 4, July/August 2007.
* “32-channel single-photon counting module for ultra sensitive detection of DNA sequences,” G Gudkov, V Dhulla, et al., Conference on Advanced Photon Counting Techniques, Proc of SPIE, vol 6372, 63720C, Boston Oct 1–4 2006.
* “Single Photon Detection Module for Multi-Channel Detection of Weak Fluorescence Signals,” V Dhulla, et al., *Proc SPIE* 6007, 600719-1, pp. 1–9, Boston Oct 23–26 2005.

## Jonathan L. Marson, Laser Transmitter Product Engineering

##### BS, PHYSICS (OPTION: OPTICAL PHYSICS), OREGON STATE UNIVERSITY, 2002

Mr. Marson is Voxtel’s lead product engineer in the laser transmitter group. Previously, he was a product engineer at nLIGHT, where he was part of the engineering teams that developed and transferred multiple diode-pumped solid-state lasers from prototype to production, including the Microlaser M30. Prior to nLIGHT, Marson held a lead position at Phoseon Technology, where he designed optical systems and developed manufacturing processes for the FireEdge, FireFly, FireLine, StarFire and FireFlex products. He also played a key role in developing the global market for industrial UV LED curing—working side-by-side with engineering groups throughout the world to identify and resolve technical problems in transitioning from mercury arc lamps to UV LEDs through innovation, education, and key partnerships. His seven patents and patent applications helped Phoseon develop a strong IP position in the UV LED curing market. Mr. Marson is a U.S. citizen.

##### Patents and Publications

* 8,465,172: Lighting module with diffractive optical element
* 8,330,377: Monitoring voltage to track temperature in solid state light modules
* 8,328,390: High irradiance through off-center optics
* 8,110,804: Through substrate optical imaging device and method
* 8,080,812: Multi-attribute light effects for use in curing & other applications…
* WO 2011059558 A3 / EP 2498981 A2 / US 20110116262 A1: Economical partially collimating reflective micro optical array
* WO 2010077828 A1 / EP 2382666 A1 / US 20100165620 A1: Reflector channel

## Dr. Drake Miller, Focal Plane and Camera Engineering

##### PHD, EE, OSU, 2011; BS, COMPUTER ENG., EMBRY-RIDDLE AERONAUTICAL U, 2004

Dr. Miller is an imaging scientist at Voxtel, where he develops silicon and InGaAs avalanche photodiodes (APDs), single-photon avalanche photodiode (SPAD) FPA products, high-yielding detector manufacturing processes, reliable solder bump-bond hybridization, and camera integration. Before joining Voxtel, he was a device/product engineer and a characterization and modeling engineer at SiOnyx, where he was responsible for developing innovative silicon detector products with enhanced near‐IR detection. At SiOnyx, he performed TCAD/FDTD simulation of 4T pixel architectures using IR‐enhancing structures, developed image sensor packages and the functional test infrastructure for imager test chips, modeled and simulated silicon photodiode image sensors, performed electro‐optical characterization, and modeled noise of PIN photodiodes. He is a U.S. citizen.

##### Selection of Relevant Patents

* US2012/0146172 A1 High speed photosensitive devices and associated methods
* US 2011/0220971 Photosensitive imaging devices and associated methods.
* US2012/0112251 A1 Reduction of random telegraph signals (RTS) and 1/f noise in silicon mos devices, circuits, and sensors

## Fred Sahebi, Reconfigurable Signal Processing and Camera System Engineering

##### MS, ELECTRICAL AND COMPUTER ENGINEERING, PORTLAND STATE UNIVERSITY, 1992; BSEE, PSU, 1989

At Voxtel, Mr. Sahebi works on reconfigurable signal processing and camera system engineering. He has extensive experience in: High-speed digital circuit design, High frequency sub-micron MOS transistor modeling, extraction, and simulation; Wire and interconnect design and modeling in sub-micron processes; Low Power/High Frequency (4GHz+) Dual Vt circuit IC design, and methodology development; High Performance static and dynamic logic design, transistor level as well as gate level; HLM and RTL programming languages: iHDL, and Verilog; Balanced clock distribution network; Pipeline design, Partitioning, and Load Balancing; Static and dynamic timing analysis, convergence, and closure; Power estimation and analysis; Area estimation; Noise, Coupling, and Signal Integrity analysis, simulation and measurement. Extensive Lab work on Microprocessor’s Debug and validation. Excellent software skills to make hardware debug work more efficient.

Before joining Voxtel, Fred was the senior digital design engineer for Sionyx, working on advanced low light level image sensors and cameras, and MagnaChip Semiconductor’s Advance Pixel Research Center, where he was responsible for digital circuit development, RTL (Verilog) coding, synthesis, floor planning, place and route, and FPGA programming (Xilinx Virtex 4) for (pixel vehicle test) CMOS image sensor timing controller. Previously, he was a hardware design development engineer in Hewlett-Packard’s ASIC development group, where he was involved in design and development of ASIC chips used for high end printers. At HP, he was responsible for RTL (Verilog) development, coding, debugging, pipeline balancing, logic implementation, unit and system level verification, testing, code coverage, and FPGA and CPLD programming. He has also held staff design at Intel Corporation, where he participated in the digital design of high-speed on-die caches for Intel Microprocessors and designed circuits for the *MD-6, Willamette (3GHz+) and Northwood (4GHz+) Microprocessors*

His extensive experience and training in engineering software and EDA tools includes: Cadence—OPUS (schematic entry), DLS (layout), NCSIM (VHDL-Verilog simulation and debug); Avant!—HSPICE, Apollo, STARRC; SYNOPSYS—PrimeTime, Design Compiler (WLM and Topographical), Astro (Place & Route), Formality; Xilinx—XST & ISE; Mentor Graphics—ModelSim; EPIC—PathMill (timing analysis), PowerMill (power analysis); Intel—DLS (layout), Galaxy (layout), Genesys (layout), Processing Simulations; Matlab, MathCAD, and AutoCAD. Fred is well experienced with many electronic test instruments, including Various Agilent(HP) Network Analyzers, Tektronix and Agilent Oscilloscopes, signal and power sources, GPIB interfacing, SUN and HP workstations. He is fluent in DOS, UNIX and LINUX Operating Systems, X-Windows, and Microsoft suites.

## John Kent, Software Engineering

##### MASTERS COURSEWORK, CALI. STATE U., CHICO, 1992; BS, COMP. SCI., OREG. STATE U, 1986; AB, BUSINESS ADMINISTRATION, MT. HOOD COMMUNITY COLLEGE, 1984

Mr. Kent is a software engineer at Voxtel with nearly three decades of experience. Mr. Kent cofounded the successful iPhone company savageApps.com. His experience includes successful management of software consulting business and exceptional design and coding skills across numerous platforms and languages.

Previously, Mr. Kent has held software engineer, senior software engineer, quality engineer positions at: Navis, where he created a mobile application that runs on both iOS and Android platforms to manage guest stays at vacation rentals and hotels; Oregon Mutual Insurance, where he implemented a cloud-basedweb service rating systems with the most current aut rates; FEI, where he created a new scanning electron microscope product for wafer and grid sample preparation; Welch Allyn, where he worked with a design team to verify and validate a multi-parameter medical monitoring sytem; Inovixe Medical, where he worked with a development team to quickly bring a new and exciting ECG heart sound analysis product running on a PDA to market; Willamette Valley Software Solutions, where he designed and built a cutting edge ultrasonic imaging system to provide diagnostic 3D images to physicians screening women for breast cancer using a superior solution to traditional mammography; and Hewlett Packard, where he successfully procured and integrated an IrDA stack into the product, which made communicating with the defibrillator simple and yet very powerful.

Expertise highlights include: Microsoft C#, C, C++, VB, Obj-C; RTOS (WinCE, VxWorks, INTime embedded systems); WPF, WF, XML, HTML, Asp.NET; Innovative UI designs; Database MS SQL, MySQL; System architecture leadership; UML design patterns; XCode, Microsoft Visual Studio; Windows, Linux, OSX; Agile development methodologies. Mr. Kent has four patents. He is a U.S. citizen.

##### Patents

* 6,438,417: Defibrillator test system with wireless communications
* 6,405,083 Defibrillator with wireless communication of ECG signals
* 6,381,492: Defibrillator with mode changing infrared communications
* 6,141,584: Defibrillator with wireless communications

## Dumitru Mitaru‐Berceanu, Packaging Engineering

##### BS, CHEM (MINOR: PHYSICS), UNIVERSITY OF OREGON, 2014

Dumitru Mitaru-Berceanu is a packaging engineer at Voxtel, Inc. Previously, while studying Chemistry at the University of Oregon, he interned for Voxtel’s nanotechnology division, performing detector work that improved IDE production and characterization processes.

Mr. Mitaru-Berceanu graduated from the University of Oregon, Magna Cum Laude, with a BS in Chemistry and a minor in physics. At the University of Oregon, under Dr. James Hutchison, he conducted work to enhance lanthanide ion sensing capabilities of gold nanoparticles; and, under Dr. Marina Guenza, he conducted work developing a theory of polymers. He received the Materials Chemistry Achievement Award. Mr. Mitaru-Berceanu is a U.S. citizen.

## Archie Barter, Analog Engineering

##### MS, ENGINEERING MANAGEMENT, PORTLAND STATE UNIVERSITY, 1997; BS, APPLIED SCIENCE, PSU, 1965

Mr. Barter has more than 35 years of high-speed camera engineering experience, and is responsible for Voxtel’s thermoelectrically cooled CMOS camera and NIR LADAR receiver development, including high-speed NIR photon counting instruments. Prior to Voxtel, he worked for PixelVision of Oregon, Inc. and for Scientific Imaging Technologies, where, at both companies, he was a senior engineer for CCD cameras, designing and developing circuitry for their primary product lines. Prior to this, Mr. Barter worked for more than 26 years for Tektronix, Inc., as a product engineer, designing and developing measurement systems and components within their television, CRT, labs, avionics, and engineering computing divisions. Mr. Barter holds five circuit patents, received while at Tektronix. He is a U.S. citizen.

##### Patents

* US 5500615: Low power CCD driver with symmetrical output drive signal
* US 4464709: Current and voltage protection for a power supply circuit
* US 4442458: CRT Video drive circuit with beam current stabilization
* US 4431949: Lateral convergence correction system
* US 4241296: Horizontal deflection circuit including protection for output transistor

##### Publications

* “[Dual-band MWIR/LWIR radiometer for absolute temperature measurements,”](http://scitation.aip.org/vsearch/servlet/VerityServlet?KEY=FREESR&smode=results&maxdisp=10&possible1=george+williams&possible1zone=article&fromyear=1893&frommonth=Jan&toyear=2009&tomonth=Mar&OUTLOG=NO&viewabs=PSISDG&key=DISPLAY&docID=4&page=0&chapter=0) George M. Williams and [Archie Barter](http://scitation.aip.org/vsearch/servlet/VerityServlet?KEY=FREESR&possible1=Barter%2C+Archie&possible1zone=author&maxdisp=25&smode=strresults&aqs=true), Proc. SPIE 6205, 62050M (2006)

## Adam O. Lee, Group Lead, Readout Integrated Circuits and Imagers

##### MSEE, 2003, Iowa State Univ; BSEE, 2000, Iowa State Univ

Mr. Lee is the group lead of Voxtel’s readout integrated circuit (ROIC) and CMOS imager design group. In that role, he manages a design group, develops ROIC architectures, and participates in the development of active and active/passive ROICS, including LADAR, laser rangefinding and see-spot circuits, high-resolution CMOS and SOI CMOS ROICs—including radiation-hardened designs, with performance ranging from extremely low-noise video-rate imaging to those requiring ps-scale time-of-flight and GHz-bandwidth temporal sampling, such as are used in active/passive imaging and LADAR FPAs. His designs have included event-driven readout, waveform sampling, and thresholded active TOF/passive imaging features in small-unit-cell linear and 2D imaging formats. He is familiar with a broad range of CMOS processes at both domestic and foreign foundries. He is actively involved in the optical/electrical test of high-performance imaging arrays and ROICs at both room and cryogenic temperatures. Prior to Voxtel, Mr. Lee worked was an IC design engineer in the imaging division of Teledyne Imaging/Rockwell Scientific, LLC, where he was responsible for monolithic CMOS image sensors using the 0.13‑μm pinned PD (4T) process, with a focus in low-noise switched-capacitor amplifiers, programmable-gain amplifiers, analog output drivers, and horizontal and vertical scanners. He was previously an analog IC design engineer in the high-speed interface division of LSI Logic Corporation, where he was responsible for gigabit-rate transceiver design in the 0.13‑μm CMOS process for USB, Fibre Channel, and SCSI interfaces. Mr. Lee is a US citizen and holds a DoD Secret security clearance.

##### Selection of Relevant Publications

* “Pixelated Detector with Photon Address Event Driven Time Stamping and Correlation,” G. M. Williams Jr., J. Rhee, A. O. Lee, and S. D. Kevan, Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC), 2013 IEEE, Oct. 27, 2013 – Nov. 2, 2013, Seoul, Korea, pp 1-10.
* “Dual Threshold X-ray Photon Counting Pixel Array Detector,” A.O. Lee, J. Rhee, G.M. Williams, S.D. Kevan, IEEE NSS‐MIC-RTSD Conference Record, submitted Nov. 27, 2013.
* “Comparison of Global Shutter Pixels for CMOS Image Sensors.” S. Lauxtermann, A. Lee, J. Stevens, A. Joshi. International Image Sensor Workshop, Ogunquit, ME, 06/2007.
* “LWIR Heterodyne Detection 3D LADAR Camera.” D. Gulbransen, D. Lee, A. Petersen, A. Lee, M. Xu, M. Milkov, A. Joshi, L. Kilmer. MSS Proceedings, Orlando, FL, 2006.

**Patents**

* US 7755689 B2: Lauxtermann et al. “Imaging System with Low Noise Pixel Array Column Buffer” Jul 13, 2010.
* US 7852124 B2: Stevens et al. “Low Noise Correlated Double Sampling Amplifier for 4T Technology” Dec 14, 2010.

## Dr. Mike Munroe, Function

##### PHD, OPTICAL PHYS., U. OF OR, 1995; MS, PHYS., U. OF OR, 1990; BS, APPL. PHYS., HARVEY MUDD COLL., 1989

Dr. Munroe is Voxtel’s Title responsible for X. He has two decades of experience in lasers and optical communications as an individual contributor, principal investigator, technical manager, and mentor. He is an expert in: optical, electro-optic, and laser engineering and design with specialties in solid-state lasers, ultrafast pulsed laser systems, and harmonic generation; design and modeling of optical systems (ZEEMAX, OSLO, SNLO), fiber systems (Optsim, LAD, VPI), and general systems (MATLAB, MiniTab); optical metrology, laboratory techniques, and test automation (LABVIEW); system engineering principles and tools (Jama, DOORS), and development of requirements, specifications, and tests. Before joining Voxtel, Dr. Munroe was a principal systems engineer at Raydiance, Inc., responsible for the design and production of the company’s femtosecond laser product. Previously, as a senior laser scientist contracting at nLight Photonics, he led the design, prototype assembly, and characterization of a one-micron picosecond fiber laser system and as the director of research and development for Deep Photonics Corporation, he directed a team of engineers and scientist in the development of high-power nanosecond and picosecond fiber laser products. He has also held positions including manager of optical systems engineering for Mahi Networks, Program Manager for Templex Technology, and National Research Council Postdoctoral Researcher for NIST. Dr. Munroe Dr. Munroe is an inventor on 21 issued U.S. patents and has authored or co-authored 17 publications in the fields of optics and lasers. He is a U.S. citizen.

## Jon McGuire, Program Role

##### MS, OPTICS, U. CENTR. FLA., COLL. OF OPTICS AND PHOTONICS, 2010; BSE, OPTICAL SCI. ENG., UCLA DAVIS, 2005

Mr. McGuire is Voxtel’s Title responsible for X. With over a decade of experience, he is an expert in optical, electro-optical and laser system development, and related fields, including program planning and management, business development, laser design, optical fabrication, optical design, and development of electro-optical laser systems in both R&D and high-rate production. His focus includes technical and business leadership in development of single and multiband laser solutions for IRCM, rangefinding, target designation, SWIR illumination, LIDAR, directed energy, and industrial applications through qualification, efficacy testing, and high rate production; business case development for new market engagement, including: definition of existing and burgeoning markets in DoD and commercial segments, opportunity qualification, funnel management, and final sales; experience with laser diodes, solid state lasers, nonlinear optics, QCL's, fiber lasers, and optics from the visible to Mid-IR bands, and their applications; and relations with corporate and U.S. government technical personnel and program management concerning multiple laser systems and related projects, and suppliers of subcomponents to military lasers. Before joining Voxtel, he held business development manager, applications manager, and product engineer roles at nLIGHT, where he oversaw the development of applications for high-power fiber laser systems and enged new and existing DOD markets in man-portable laser rangefinder, marker, illuminators, LIDAR, and directed-energy fields, both for existing laser technologies and new laser development efforts. Previously, he held systems engineer and optical/laser engineer positions at Northrop Grumman, where he focused on next-generation IRCM laser systems. Mr. McGuire has served as a panel expert or advisory board member for manufacturing quality for electro-optical systems and other standards-related topics. He is the author or co-author of five publications and is an inventor of a patent for a resonator mounting assembly for isolation of resonator defining optics. He held a DOD SECRET security clearance from 2005 to 2013. He is a U.S. citizen.

## Grigory Kogan, Principal Mixed Signal IC Design Engineer

##### MS, Semiconductor Physics, State University, Novosibirsk (Former USSR)

Mr. Kogan has 30 years of experience in mixed signal IC design. Before joining Voxtel in 2011, as a principal IC design engineer responsible for high-bandwidth sampling readout integrated circuit, he spent almost 25 years at Tektronix as an integral member of the IC design team. As a part of the IC design team at Tektronix, he pioneered the field of high-speed mixed-signal design, developing ICs for industry-leading oscilloscope and signal-sampling electronics. Mr. Kogan was the technical leader for four generations of logic analyzer chip sets, working on various technology nodes including 40-nm and 65-nm CMOS. His group designed the first chips and assisted in the development of several generations of the IBM BiCMOS process. His designs include a 50 GS/s per channel oversampling receiver with PLL, a digital filter, a data compressor, state machines, SRAMs, skew adjust PLLs, and a 1.6 GB/s LVDS source synchronous transceiver; and he has supervised the designs of large custom data paths. Other designs he has worked on include: ramp-based time-to-digit converters based on LC QPLLs; a 12.5GS/s 7-bit ADC (10-ps resolution) on the 130-nm CMOS process; a 12.5 GS/s 8-bit ADC convertible to 25 GS/s (2.5-ps resolution) on the 65-nm and 40-nm CMOS processes; and a PLL-DLL-based picosecond-resolution programmable delay line on the 65-nm CMOS process. He is a U.S. citizen.

## Brent Jensen, Principal Integrated Circuit Design Engineer

##### BSEE, Portland State University, 1988

Mr. Jensen has 22 years of IC design experience. At Voxtel, he is responsible for focal plane design engineering, specializing in high-speed RF circuits and low-noise applications, with a focus on the design of laser-based rangefinders and multichannel LADAR readout integrated circuits. In this work, Mr. Jensen has been involved in the development of low‐noise, high‐sensitivity, high‐bandwidth LADAR receivers with formats ranging from a single element to 128 x 128 receivers. Before joining Voxtel, Mr. Jensen worked at Quantance, Inc., where he worked in RF power amplifiers. He was also a principal engineer at Cypress Semiconductor, where he was lead RF and analog design engineer for 2.5 GHz DSSS Wireless USB chips. He also worked at Maxim Integrated Products, where he designed GHz-class power amplifiers, and Tektronix, where he designed video ICs for a line of video broadcast test and operational equipment. He is a U.S. citizen.

##### Patents

* 20110018351; Jensen, et al; High Bandwidth Power Supply System with High Efficiency and Low Distortion
* 6,819,185; Jensen, Brent; Integrated RF amplifier biasing method that prevents de-biasing
* 6,842,710; Jensen, et al; Calibration of integrated circuit resistor-capacitor time constants
* 6,949,935; Jensen et al; Method and system for built in testing of switch functionality of tunable cap arrays
* 5,677,561; Jensen, Brent; Temperature compensated logarithmic detector
* 5,672,961; Jensen et al; Temperature stabilized constant fractional voltage controlled current source
* 5,724,003; Jensen et al; Methods and apparatus for signal amplitude control systems
* 7,660,563; Jensen et al; Apparatus and method for calibrating mixer offset

## David Fink, Sensor Integrated Circuit Physical Layout Engineer

##### BS, Computer Engineering, Iowa State University

Mr. Fink has over 20 years of industry experience including 15 years of CAD design and test processes for mixed-signal high-speed RF applications. At Voxtel, he performs CMOS imager and readout integrated circuit (ROIC) IC mask design for 0.13-micron, 0.18-micron, and 0.25-micron CMOS and bipolar processes. These responsibilities include verification, schematic capture, and netlist translation. Additional responsibilities include PCB, DRC and LVS rule programming, CAD tool support, QA, and network administration. Prior to Voxtel, Mr. Fink performed design work at Cascade Microtech (Beaverton, Oregon) where his responsibilities included parts specification, schematic design, layout, auto-route, DRC, bus SI constraints, impedance control, DFT, DFM, high signal count, high-speed (1-20 gHz), digital and RF applications, as well as project planning, status communication, approval, and review. He also served as a CAD Engineer at Triquint Semiconductor (Hillsboro, Oregon), where he programmed and debugged DRC rule sets and LVS verification for ICED layout tools for HBT, MESFET, PHEMT and other non-silicon IC process flows. At Maxim Integrated (Beaverton, Oregon), he performed IC CMOS and bipolar floor planning layout on analog and mixed signal designs, as well as executed DRC, LVS verification, and parasitic analysis for internal and external customer layouts, reticle creation, and tape-out. He is a U.S. citizen.

## Haifeng Zou, Senior Mixed-Signal Pixel Designer

##### MSEE, Univ. of South. Cal.; BSEE, Northwestern Polytech. Univ. (Xi’an, China)

At Voxtel, Mr. Zou is responsible for analog and non-linear integrated circuit design, specializing in low-noise, high-bandwidth amplifier circuits. Prior to joining Voxtel, he worked at Newport Media, Inc., as an RFIC design engineering, where he worked on temperature-stable low-noise amplifier (LNA) designs, filers, and sigma-delta DAC systems for high-volume commercial wifi applications. He is a U.S. citizen.

## Dr. Jehyuk Rhee, Sr. Readout Integrated Circuit Engineer

##### PhD, EE, Arizona State Univ, 2006; MSEE, Arizona State Univ, 2002; BSEE, Hanyang Univ, 2000

Dr. Rhee is a Senior Engineer and principal contributor to Voxtel’s integrated circuit design group. His projects at Voxtel include development of low-noise, small-pixel-pitch readout architectures. Prior to Voxtel, at MagnaChip Semiconductor, he performed pixel test vehicle development, investigated architectures for low-noise applications, and simulated and verified various proprietary analog blocks for next-generation product development. His graduate work focused mainly on the development of wide-dynamic-range CMOS active-pixel imaging sensors with low switching noise and pixel-level analog-to-digital conversion. He is a U.S. permanent resident authorized to work on ITAR-restricted projects.

##### Selection of Relevant Publications

* “Pixelated Detector with Photon Address Event Driven Time Stamping and Correlation,” G. M. Williams Jr., J. Rhee, A. O. Lee, and S. D. Kevan, Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC), 2013 IEEE, Oct. 27, 2013 – Nov. 2, 2013, Seoul, Korea, pp 1-10.
* “Dual Threshold X-ray Photon Counting Pixel Array Detector,” A.O. Lee, J. Rhee, G.M. Williams, S.D. Kevan, IEEE NSS‐MIC-RTSD Conference Record, submitted Nov. 27, 2013.
* “Analysis and Design of a Robust Floating Point CMOS Image Sensor,” J. Rhee, D. Park, Y. Joo, IEEE Sensors Journal 9(5), 578–585 (2009). [DOI: 10.1109/JSEN.2009.2016595]
* “Wide Dynamic Range and High SNR Self-Reset CMOS Image Sensor Using A Schmitt Trigger,” D. Park, J. Rhee, Y. Joo, Proceedings of IEEE: Sensors 2008, 294 (2008). [DOI: 10.1109/ICSENS.2008.4716439]
* “A Wide Dynamic Range CMOS Image Sensor Using Self-Reset Technique,” D. Park, J. Rhee, Y. Joo, IEEE Electron Device Letters 28(10), 890–892 (2007). [DOI: 10.1109/LED.2007.905396]
* “Dual-Mode Wide Dynamic Range CMOS Active Pixel Sensor,” J. Rhee, Youngjoong Joo, Electronics Letters 41(24), 1322 (2005). [DOI: 10.1049/el:20053477]
* “CMOS Image Sensor Array for Surface Plasmon Resonance Spectroscopy,” J. Rhee, D. Wang, N. Tao, Y. Joo, Proceedings of SPIE 5301, 34–41 (2004). [DOI: 10.1117/12.527131]
* “Wide Dynamic Range CMOS Image Sensor with Pixel Level ADC,” J. Rhee, Y. Joo, Electronics Letters 39(4), 360–361 (2003). [DOI: 10.1049/el:20030246]
* “A new low-switching-noise CMOS logic circuit for single-chip CMOS imaging system,” H. Chung, J. Rhee, Y. Joo, Proceedings of IEEE: Sensors 2003 v.2, 1136–1140 (2003). [DOI: 10.1109/ICSENS.2003.1279122]
* “A New Wide-Dynamic-Range ADC for FPA applications,” Jehyuk Rhee, Youngjoong Joo, Proceedings of SPIE 4796, 263–270 (2003). [DOI: 10.1117/12.458064]

## Charles Myers, Electrical Engineer -Analog And Mixed Signal Ic Design

##### MSEE (MIXED SIGNAL DESIGN), OREGON STATE UNIVERSITY 2004; BSEE, OREGON STATE UNIVERSITY, 2002

Mr. Myers conducts analog and mixed-signal design at Voxtel. Prior to Voxtel, Mr. Myers was a Staff IC Design Engineer for Aptina Imaging (previously Micron, Avago, Agilent). There, he was the team lead for analog development and completion of a second-in-series sensor design. A seven member design team completed the project on-schedule, and the product is now in production. He designed and built a SAR-Ramp ADC for an image sensor. This design is used in several products that are now entering the engineering sample phase. Previous ADC work included a Cyclic ADC that was successfully built on a test chip and Sigma-Delta/Cyclic hybrid ADC. Mr. Myers also: designed current generation column memories with built in subtraction and accumulation modes, and analyzed and modified the previous generation’s column memory design and removed errors and improved design robustness; developed a robust differential sense amp enabling readout of large arrays at high speed; developed a row noise filtering algorithm and worked with digital designers to implement it with minimal gate count, resulting in a new company record for silicon row noise metric; developed circuits for switched capacitor gain, clamping, current sources, test circuits, analog muxes, decoding circuitry, and buffer drivers, the layout of which was built as an array with aggressive pitch constraints and several production chip generations are based on Mr. Myers work in this area; designed a row decoder with row selection and boosted signal multiplexing for controlling pixels in image sensor; developed a matched reference pixel strategy for measuring and subtracting row noise from images that was first implemented in an automotive sensor, resulting in significantly improved camera sensitivity; and performed silicon analysis of existing booster design and implemented an improved design with more boost charge capacity.

Expertise include: Image Sensor Design, ADCs, DACs, Amplifiers, Switch-Capacitor Circuits, Arrayed Circuit Design, References, DC¬DC Converters (boost), Analog and Digital Filters, DSP Image Processing, Advanced Layout (arrayed systems, matching, process insensitivity). Tools: HSPICE, Spectre, Cadence, Skill, Hercules, Calibre, Verilog, Matlab, C, Perl, sed/awk.

## Booshik Ryu, Firmware Engineering

MS, ELEC & COMP ENG, PORTLAND STATE U, 2015; MS, ELEC & COMMS ENG, DAEGU U, GYEONGSAN, KOREA 2009

Mr. Ryu is a firmware engineer at Voxtel, focused on real-time image processing architectures. He is skilled in digital circuit design in high-level synthesis, hardware debug using oscilloscopes, data acquisition, system-level software (real-time multi-task, test applications) in embedded environment. Before joining Voxtel, Mr. Ryu was a student at Portland State University. At PSU, his research projects included: the MCECS-Bot Robot Project, for which he designed a program to monitor an electric current through ADC; the FPGA Project, for which he designed a Euclidean distance equation with five-stage pipeline in two technologies: SRAM and RRAM and drew comparisons between the two designs; High-performance Digital Systems, for which he optimized registers for a a given sequential digital circuit by using a designed program in C for the re-timing procedure, and formatted data structures for the given circuit; Image Processing in FPGA, for which he designed object (face) detection logic in an FPGA and designed an image converter, and *integral image* generator, and a VGA controller; the SOC Project in FPGA, for which he implemented an eight-bit video maze game in FPGA and programmed a PicoBlaze CPU using assembly code to find a way in the maze, and improved VGA resolution over the 640 x 480 achieved by other teams to 1204 x 768. Mr. Ryu’s expertise include programming languages (VHDL, Verilog, C, C++, Python, MS Basic, Assembly, ASP, PHP, SQL, HTML), embedded platforms (Spartan6/3, PicoBlaze, ARM, Cortex M4, AVR, TI DSP Processor), software [Xilinx Vivado/ISE/System Generator for DSP, MS Visual Basic/Visual C++/Embedded VC, QT, Arduio IDE, Codevision/AVR Studio, WinAVR, Code Composer Studio C, Matlab/Simulink, Python(Pandas, Numpy], and operating systems (Windows NT series, Linux, Windows CE/Pocket PC, DOS). Mr. Ryu has three professional publications on the subjects of adaptive noise cancellation and implementation of embedded systems. He has co-authored three professional publications.

##### Publications

* “Hardware implementation of an Adaptive Noise Canceller in an automobile environment”, A. Boo-Shik Ryu, Joonwan Kim(IEEE Electrical Design of Advanced Packaging and Systems Symposium, Seoul, S. Korea). Dec 2008.
* “The Performance of an adaptive noise canceller with DSP processor", A. Boo-Shik Ryu, Jae-Kyun Lee, Joonwan Kim, Chae-Wook Lee (SSST 2008. 40th Southeastern Symposium). Apr 2008.
* “Implementation of the Embedded System for Visually-Impaired People” , A. Si-Woo Kim, Jae-Kyun Lee, Boo-Shik Ryu, Chae-Wook Lee (DELTA 2008. 4th IEEE International Symposium). Mar 2008.

## Devin Wolfe, Systems Engineering

##### COURSEWORK TOWARD MS, MASEEH COLLEGE OF ELEC. & COMP. ENG.; BS COMP. ENG., PORTLAND STATE U.

Mr. Wolfe is a systems engineer at Voxtel, focused on sensor and camera system integration. Mr. Wolfe is skilled in computer hardware, architecture and programming. Before joining Voxtel, as a student, he completed projects in areas such as FPGA-based design and synthesis, driver development, flight control with inertial sensor fusion AHRS, parallel computing (CUDA), PCB design, GUI programming and more. He is proficient in the use of microcontrollers for prototyping such as the Intel Edison, Teensy, Arduino, etc., both running custom C/C++ software, or in the case of the Edison, running C/C++ and Python programs on Yocto Linux to make use of serial, GPIO and other board capabilities. He has interfaced many different kinds of sensors and human input devices on such boards. For instance, working on a Bamboo Glider Autopilot project he took plans for a model airplane and added working control surfaces moved by micro servo motors. The servos are controlled autonomously using software running on an Intel Edison microcontroller/SOC. Also, working on a Game pad project, he designed a game pad that provided analog movement control using a keyboard-style interface. As his senior project, Mr. Wolfe was part of a four-person team that was paired with Symantec to create a system to measure and improve a user’s balance in response to changing visual stimuli. The team developed a testing methodology and criteria for assessing visual balance, and designed, built, and tested the hardware and software for administering the test and measuring the test results. The test administration hardware was a custom servo-actuated robot that could be manually controlled through the GUI the team designed, or loaded with behavioral scripts. The test measurement hardware was a custom-designed PCB board with accelerometer sensors, which fed its data out through USB to the test program. Mr. Wolfe’s responsibilities included designing the driver code for the hardware and writing the program for test administration, interpreting and displaying test measurements, and designing and integrating the robotics for the test administration hardware. Mr. Wolfe is practiced in many programming languages, including C, C++, Java, Android, Verilog, Python, and ARM Assembly; and is proficient at using technical simulation software, such as LTSpice and MatLab/Simulink, including programming functions and routines of intermediate complexity for MatLab. He is a U.S. citizen.

## Joseph LaChapelle, Business Development

##### BS, Engineering Physics, Oregon State University

Mr. LaChapelle is Vice President of Business Development at VoxtelOpto. Before Voxtel, he was vice president of business development for laser products at nLight Photonics. Before nLight, he co-founded and served as CEO and chairman of Deep Photonics, an ultrafast fiber laser company. Immediately before co-founding Deep Photonics, Mr. LaChapelle was vice president and division general manager of a Silicon Valley semiconductor capital equipment company. Mr. LaChapelle has a career history of multiple technology startups including Techné Systems, a semiconductor wafer inspection company that was acquired in December 1997, and Lucidyne Technologies Inc., a machine vision company. Mr. LaChapelle has multiple relevant patents issued in the field of semiconductor manufacturing automation and laser technology. He is a U.S. citizen.

##### Selection of Relevant Patents

* US7852549 Method and apparatus for pulsed harmonic ultraviolet lasers
* US7764719 Pulsed fiber laser
* US7848012 Method and apparatus for continuous wave harmonic laser
* US7782911 Method and apparatus for increasing fiber laser output power
* US7733922 Method and apparatus for fast pulse harmonic fiber laser
* US5818953 Optical characterization method
* US5892808 Method and apparatus for feature detection in a workpiece
* US4924088 Apparatus for reading information marks
* US2009/0107962 A1 Method and apparatus for a hybrid mode-locked fiber laser
* US13/339037 Hybrid laser amplifier system including active taper

## Madison Compton, Receiver Test and Characterization

##### MSEE, Portland State University 2005; BS, Physics and Astronomy, Haverford College, 1999

Mr. Compton is responsible for all facets of component and systems testing at Voxtel. In addition, he assists in test system design and executes experimental procedures for APDs and support circuitry. While in graduate school, Mr. Compton was a teaching and research assistant at Portland State Univ., from 2003 to 2005, where he assisted with undergraduate electromagnetism courses, conducted recitations, designed and instructed lab course work, setup the APD test lab, and conducted DC and noise tests on APDs. He is a U.S. citizen.

## Paul Spicer, Product Manufacturing Engineering

##### MS, Optoelectronic and Laser Devices, Heriot-Watt University; BS, Physics, Liverpool University

Mr. Spicer is Voxtel's director of manufacturing. Prior to joining Voxtel, he was a senior process engineer for new product introduction at nLight, where he transitioned products from the design and development cycle into production, including laser range finders for drone and rifle-mounted applications for the defense industry and a pulsed fiber for commercial applications. Mr. Spicer began his career as a senior process engineer at Fibre Systems/Metals Research Semiconductors, where he developed optical fiber manufacturing processes and equipment and oversaw installation and commissioning of manufacturing plants abroad, as well as training at those plants. During the 1990s, he managed Hewlett-Packard/Agilent Technologies' large technical team that supported 24/7 production lines, where he successfully implemented the world's first CO2 laser fiber lensing machine. In the early 2000s, as an engineering manager for Flextronics Photonics, after helping with the setup of a high-volume manufacturing facility in Europe, he was charged with leading the engineering team for a novel cell phone auto-focus camera module line. He is a U.S. citizen.

## Tram Pham, Lead Operator, Manufacturing

##### ESL & MATH STUDIES, WEST VALLEY COLLEGE (CA), 1996 – 1999

Ms. Pham is a manufacturing technician with 15 years of experience. Before joining Voxtel, at nLight Photonics, she handled small delicate components and used ESD practices and clean room protocol to conduct die bonding, wire/ribbon bonding, VSR, Test, optical fiber alignment, lidding, soldering, epoxies, and inspection/microscopy. Previously, at Tektronix, she operated the electronic beam evaporating machines and conducted electronic metal plating and evaporating (TI, NI and AU), and gained experience handling sulfuric acid as well as hydrofluoric acid, neutralizing sodium peroxide, using P.H meter to control acid and caustic solutions, and following safety procedures. She has also held positions at Flextronics Photonic, where she was an operator line leader with extensive experience in fiber attach (pigtail) and component attach (laser, die, themo-electric cooler, substrate, etc.); working with epoxy, soldering, and flux; lid seam-sealing, tube sealing, and plasma cleaning; dage wire pull and die shear machine, burn-in and ME test and fine leak test; gross leak test; manual and automated wire-bonding, ball-bonding, and ribbon bonding; quality assurance inspection; and functional test experience in particle impact noise detectors, vacuum solder reflows, and final tests. She also has four years of experience with the 80 µm, 125 µm polarized and single-mode optical fibers. Other skills include cleaving and splicing, lensing and polishing (conical, wedge, hyperbolic, bevel, and radiusing). Ms. Pham is a certified IPC specialist.

## Austin McGlone, Manufacturing Test Engineering

##### BS, ELECTRICAL ENGINEERING & PHYSICS, PORTLAND STATE UNIVERSITY, 2015

Mr. McGlone joined Voxtel after receiving his BS in electrical engineering and physics from Portland State University. At PSU, he led a project to build a three-phase soft-start motor where, instead of using a wye configuration, a delta configuration was used after a preset time delay. Also at PSU, he built a spectrogram function that could take audio input and display the frequencies in real-time streaming. The project used MatLab for the coding and GUI function. Finally, he also used assembly language to control an arm processor, which incorporated the creation of a button push input to turn on and off an LED and an internal timer to turn on and off an LED using an interrupt. At Oregon State University, Mr. McGlone’s coursework included microelectronics, electromagnetism, microprocessors, Fourier analysis, and power systems. Mr. McGlone’s hardware skills include circuit work, three-phase motors, and high-voltage systems; his software skills include assembly language, basic C, basic java, Matlab, LTspice, Verilog , AutoCAD Electrical, Powerworld, Excel , and Microsoft Word.

## Ren Earl, Program Role

Mr. Earl is Voxtel’s manufacturing device engineer. With over 20 years of experience, he is instrumental in improving process flows and identifying potential effects of changes in processes or implementation of new processes. Before joining Voxtel in 2015, he was a product engineering manager at TSI Semiconductor, where he advanced quality while mitigating impact to production throughput and complexity by initiating both corrective and supportive action plans. To blend new products with existing production line mix, he developed productivity and tool utilization models. Previously, he was a senior engineer for process development and performance analysis at SiOnyx, where he developed a leading-edge process for a novel CMOS imaging device that improves quantum efficiency at near-infrared wavelengths, and established process performance metrics in cooperation with the foundry, which improved device reliability without generating additional complexity. In addition to SiOnyx, he has held senior engineer positions at MagnaChip Semiconductor, Micron Technology (yield enhancement and failure analysis engineer), and Advanced Transistor Development. Mr. Earl has a BS in electrical engineering technology from DeVry University and an AS in medical science from Clackamas Community College. He is a U.S. Citizen.

##### Patents

* Self-Aligned Trenchless Reflecting Imager Scheme, US 6765250, Issued July 20, 2004
* Self-Aligned GMR Spacer Scheme, US 6358756, Issued March 19, 2002

## Paul Harmon, Program Manager

##### MSME, Stanford, 1989; BSME, U. of Washington, 1981

Mr. Harmon is the general manager and lead of VoxtelNano, Voxtel’s nanotechnology company. Mr. Harmon has wide experience making inventions real, ranging from technology conception to final product delivery and production. At Voxtel, he is developing infrared nanocrystal imagers and nanocrystal threat detectors. In 2013, he was responsible for the sale to Shoei Chemical of FlowSynth, Voxtel’s continuous flow nanocrystal reactor business; and is currently leading the effort to spin out Vadient Optics LLC, from Voxtel; Vadient’s charter is to commercialize inkjet-printed nanocomposite optics. Previously, he was variously director of technology development, engineering, and manufacturing operations for Trimble Mobile Computing Solutions' $50M high-mix/low-volume product line from 2005 through 2011. He created partnerships with internal divisions and other companies to develop rugged outdoor mobile computers and software applications for targeted markets. Before working with Trimble, Mr. Harmon was a section manager in the Advanced Research Lab of the Hewlett Packard InkJet Business Unit. His staff developed technology for thermal inkjet pens, inks, supplies, and writing systems. Research in this section led to HP's first mass-produced photographic-quality printers and provided the foundation for TIJ4, which is the technological basis upon which HP's inkjet business now rests. Research into creating new technology based on inkjet capital equipment and processes in Paul's section created HP's Atomic Resolution Storage, the derivative world leading "Richter" MEMs accelerometer, interferometric displays (later produced by Qualcomm), and the page-wide array inkjet architecture now used by HP's Digital Press. Mr. Harmon holds 43 issued patents worldwide. Representing HP, he was elected vice-chairman, International SemaTech Executive Steering Council in late 2004. He was a key designer of the original series of DeskJet printers while earning his MSME from Stanford University. He is a U.S. citizen.

##### Selection of Relevant Publications

* US4728963 Single sheet inkjet printer with passive drying system
* US4853717 Service station for inkjet printer
* USD314209 Inkjet print cartridge
* US5491502 Thin pen structure for thermal inkjet printer
* US5880748 Ink delivery system for an inkjet pen having an automatic pressure regulation system
* US6000787 Solid state inkjet print head
* US6997538 Inkjet printing with air current disruption

## Dr. Charles Dupuy, Nanoparticle Engineering

##### PhD, Physical Chem., Columbia U.; BS, MS Chem. eng., SwIss Federal Institute of Tech. (EPFL)

Dr. Dupuy is an expert in chemistry, physics, and molecular biology, using ultrafast lasers and custom optical detection systems. He has developed a variety of nanocrystal products and is leading the development of inkjet-printed nanocomposite optics. Prior to Voxtel, at HP (Corvallis), he worked in new product development, including system integration and accelerated life testing of dyes and inkjet inks; he worked on six different product releases. Additional experience includes high-volume manufacturing in excimer laser micro-machining of electronic materials. Prior to HP, Dr. Dupuy was the manager of opto-electronic systems at Applied Optronics Corp. (NJ), where he managed the development and production of fiber-coupled diode laser systems for medical applications. His other experience includes work at the David Sarnoff Research Center and the Research Institute of Scripps Clinic, where he performed time-resolved fluorescence measurements of the structure and mobility of fluorescent-tagged DNA polymerases and other biomolecules. In a two-man effort, Dr. Dupuy developed a laser system and computer automation for single-photon counting. He is the co-author on six granted patents and two pending patents, as well as 28 publications and conference proceedings. He is a U.S. citizen.

##### Selection of Relevant Patents

* US 6673140 B2: Ink-jet inks and ink sets providing excellent gamut, image quality, and permanence
* EP 1616916 B1: Inkjet ink formulation
* EP 1646694 B1, WO 2005010111 A1: Magenta ink-jet inks
* US 7105045 B2: Mixture of a phthalocyanine dye and a rhodamine magenta dye in an ink vehicle, combination of dyes gives a chroma C\* value of 60, light fastness
* EP 1648971 A1, WO 2005010110 A1: Dye sets and ink sets for ink-jet ink imaging
* EP 1497383 B1, WO 2003078533 A1: Ink-jet inks and ink sets providing excellent gamut, image quality, and permanence
* US 7188943 B2: Ink set for inkjet printing
* US 8724214 B2, WO 2014039347 A1: Broadband optical upconversion by energy transfer from dye antenna to upconverting crystal

## Dr. Ngoc Nguyen Thanh, Nanoparticle Chemistry

##### PhD, Chem, U. Or, 2007; MS, Mat. Sci., Intl. Training Inst. for Mat. Science (Hanoi, Vietnam), B.S. Chem, Vietnam Nat’l Univ.

Dr. Nguyen is an expert in the synthesis and characterization of thin film compounds. He has been a key technical member of the group responsible for the success in Voxtel’s previous Bi2Te3 / Sb2Te3 thermoelectric device and nanocrystal detector device developments. His previous work has included the development of multiple heating zone furnaces to control doping and diffusion in thin films. As a graduate from Professor David Johnson’s group at the University of Oregon, Dr. Nguyen has experience in the deposition and characterization of solid-state thin films, including: high-vacuum deposition, ALD, and sputtering, and has characterization experience using x-ray diffraction, elemental analysis using microprobe and x-ray photoelectron spectroscopy, secondary ion mass spectroscopy, transmission electron microscopy (TEM), scanning electron microscopy (SEM), ellipsometry, and electron backscattering diffraction (EBSD) detection methods. Dr. Nguyen is the author of more than 10 papers in the field of thermoelectric materials development and thin film reactivity. He has been active in NASA research applying Voxtel’s VIRGO process to creating a lenslet array solution for NASA’s Platform Independent Software Components for the Exploration of Space (PISCES) program, creating TiO2-based VCX optical inks. He is U.S. permanent resident authorized to work on ITAR-restricted projects.

##### Selection of Relevant Publications

* “Vapor Annealing as a Post-Processing Technique to Control Carrier Concentrations of Bi2Te3 Thin Films,” A Taylor, C Mortensen, R Rostek, N Nguyen, D Johnson, J Electron. Mater. 2010, 39(9), 1981.
* “X‑ray Charact­erization of Low-Thermal-Conductivity Thin-Film Materials,” P Zschack, C Heideman, C Mortensen, N Nguyen, M Smeller, Q Lin, D Johnson, “J. Electron. Mater. 2009, 38, (7), 1402.
* “Low Thermal Conductivity in Nanoscale Layered Materials…,” C Chiritescu, D Cahill, C Heideman, L Qiyin, C Mortensen, N Nguyen, D Johnson, R Rostek, H Bottner, J.Appl. Phys., 2008, 104, 033533.
* C Heideman, L Qiyin, N Nguyen, J Hanni, S Duncombe, D Johnson, J. Solid State Chem., 2008, 181, 1701.
* “Designed Synthesis of Families of Misfit-Layered Compounds,” L Qiyin, C Heideman, N Nguyen, P Zschack, C Chiritescu, D Cahill, D Johnson, European J. Inorg. Chem., 2008, 15, 2382.
* S Kim, J Zuo, N Nguyen, D Johnson, D Cahill, J. Mater. Res. 2008, 23(4), 1064.
* N Nguyen, B Howe, J Hash, N Liebrecht, D Johnson. Chem. of Materials, 2007, 19(8), 1923.
* “In-Plane Thermal Conductivity of Disordered Layered WSe2 and (W)x(WSe2)y Superlattice Films,” A Mavrokefalos, N Nguyen, M Pettes, D Johnson, L Shi, Appl. Phys. Lett. 2007, 91, 171912.
* “Ultra-low Thermal Conductivity of Disordered, Layered WSe2 Crystal,” C Chiritescu, D Cahill, N Nguyen, D Johnson, A Bodapati, P Keblinski, P Zschack, Science 2007, 315, 351.

## Bradley Hermens, Writing Systems Engineering

##### BS, PHYSICS, OREGON STATE UNIVERSITY, 2014

Mr. Hermens is Voxtel’s writing systems engineer, printing lenses for the manufacturable gradient refractive index (MGRIN) effors, such as the DARPA and NASA programs. Mr. Hermens joined Voxtel after earning his BS from Oregon State University in 1994. As an undergraduate, he was a teaching assistant, undergraduate researcher, Python developer, and microcontroller developer, all at OSU. As a teaching assistant, he assisted with upper-level laboratory classes focused on electronics and instrumentation and lectured on topics about electrical components, integrated circuits, and programming languages. As an undergraduate researcher, he worked on a Python library to control a digital micrmirror array. As a Python Developer, he added features and improved stability of software used for classes and laboratory and he designed algorithms to acquire and analyze data. As a microcontroller developer, he implemented a linear motor control system using the chipKit Uno32 from Digilent. Mr. Hermens has expertise in: programming languages, including Python, C/C++, and Verilog; revision control software, including Git and Mercurial; and operating systems, including Windows, Linux Mathematics: Linear Algebra, Multivariable Calculus. He is a U.S. citizen.

## Dr. Sean Keuleyan, Nanocrystal Invention, Functionalization & Device Modeling

##### PHD, PHYSICAL CHEM., BROWN, 2013; MS, CHEM., BROWN, 2009; BS, CHEM., TEMPLE, 2008

Dr. Keuleyan is a nanomaterials chemist working on the development of quantum dots for optoelectronics at Voxtel. As lead photonic detector nanoparticle chemist, invents photonic detector films made from nanocrystals and ligands and integrates them analytically and empirically into detector devices for commercial and DOD NIR-MWIR applications. Previously, Dr. Keuleyan worked with Prof. E. Borguet at Temple University on charge transport in self-assembled monolayers of porphyrins and PNA, a DNA analogue, as well as thin film deposition for hydrogen sensors. Dr. Keuleyan received his MS in 2009 and his Ph.D. in 2013 at the University of Chicago. There, Dr. Keuleyan worked under Prof. Philippe Guyot-Sionnest learning world-leading HgTe synthesis for mid wave IR detection. Working with Prof. Guyot-Sionnest, he developed new syntheses and applications of narrow-gap colloidal quantum dots in mid-infrared applications. Dr. Keuleyan was the recipient of the Richard Asher Paclin Prize in Chemistry (Temple Univ.) and the Elizabeth R. Norton Prize for Excellence in Research in Chemistry (Univ. of Chicago).

Dr. Keuleyan’s expertise include colloidal and vapor-liquid-solid inorganic syntheses, air-free methods, device fabrication; infrared, UV-Vis, and Fluorescence Spectroscopies, NMR, sum frequency generation, low-temperature spectroscopy and transport measurements; scanning probe and electron microscopies, EDX, EELS, electrochemistry, thermal-gravimetric analysis, XRD; LabView, Origin, Mathematica. Dr. Keuleyan has over 20 professional publications and presentations, and a patent pending for mid-infrared photodetectors. He is a U.S. citizen.

## Peter J. Polesnak, Program Role

##### BS, BIOCHEM, GROVE CITY COLLEGE, 2011; MS, BIOTECH, UNIVERSIDAD DE LAS AMERICAS PUEBLA, 2014

Mr. Peter Polesnak is a bio-chemist responsible for nanoparticle functionalization chemistry with Voxtel at our CAMCOR labs. Peter is synthesizing new quantum dot ligands for taggant applications in biological and security applications for Voxtel.

Prior to joining Voxtel, Mr. Polesnak’s master’s thesis, "An Imobilization of DENV-1 monoclonal antibodies on the surface of SPIONs" was aimed to help create a new purification to better test for dengue fever, an epidemic in southern Mexico. Further research led to an internship at Pennsylvania State University's renowned MATSE program where he designed laboratory protocol for carbon nanotube assisted delivery of dsRNA.

##### Publications

* “Immobilization of a NS1 dengue protein specific antibody on a magnetic (Fe3O4) nanoparticle for magnetic purification and immunological detection,” PhD thesis, Faculty Advisor: Dr. Miguel Ángel Méndez Rojas, 2014.

## Justin Antolin, Detector Test and Metrology / Assembly Processes

##### MS, APPLIED PHYS., U. OF OR, 2015; BA, MATH & PHYSICS (CONCENTRATION: NANOTECH) CALIF. U. OF PA, 2014

Mr. Antolin develops and runs test and metrology for detectors as well as self-assembly processes for nanomaterials. Before joining Voxtel, he was a master’s candidate and physics and chemistry teaching assistant. His research projects include: laser calibration (honor’s thesis), where he build a handheld class IV laser from basic components and designed a new system using calorimetry to detect power output of laser within 3% of actual power; bioterror detection (intern), where he worked with a research group creating a microfluidic channel mounted on electrical circuit to trap and distinguish live and dead cells, and streamlined a process for graphing data for analysis to reduce bottlenecks on time-sensitive projects for the Department of Defense by condensing data functions into one powerful platform using MATLAB; and DNA Lab on a Chip, where he conducted material modification/characterization and testing of NMT structures and materials. Mr. Antolin is a skilled computer programmer, with expertise in Fortran, C+, Matlab, R, and JMP. He is trained on the: four-point probe, LCR, FESEM, sputtering tool, metal evaporator, profilometer, ellipsometer, tube furnace, spin coater, RIE, AFM, Class 1000/10000 clean room. He is a U.S. citizen.

## Dr. Peter Hugger, Test Engineering

##### PhD, U. Oregon, Mat. Sci., Photovoltaics, 2011; BSC, Physics, Va Military Inst, 2003

Dr. Hugger is responsible for test and characterization of nanoparticles, nanocomposites, and nanoproduct devices. Prior to joining Voxtel, in his post-doctoral fellowship at the University of Oregon, Dr. Hugger worked with an interdisciplinary team of both physicists and chemists to identify multi-exciton phenomena at ZnS/Si interfaces using methods such as microwave photoconductivity and pump/probe carrier lifetime measurements.  His graduate work included several material development research studies. With Dr. J. D. Cohen, he developed solar cells for United Solar with different nanocrystalline silicon with a range of crystallite fractions and growth rates.  He characterized the opto-electronic properties of these devices. He is an expert in junction-capacitance-based characterization techniques for structural functional relationships in polymorph semiconductors. Dr. Hugger worked with an industrial team to scale up the process of making high-efficiency nc-Si:H and a-SiGe:H multi-junction solar cells from small-area to square-meter scale production. His work is published in eight papers in journals such as *APL* and *MR*S. He is a U.S. citizen.

##### Selection of Relevant Publications

* “Material properties of a-SiGe:H solar cells as a function of growth rate,” P.G. Hugger, J. Lee, G. Yue, X. Xu, B. Yan, J. Yang and S. Guha, Mater. Res. Soc. Symp. Proc. 1245, A07-03 (2010)
* “High Efficiency Large Area a-Si:H and a-SiGe:H Multi-junction Solar Cells Using MVHF at High Deposition Rate,” X. Xu, D. Beglau, S. Ehlert, Y. Li, T. Su, G. Yue, B. Yan, K. Lord, A. Banerjee, J. Yang, S. Guha, P. Hugger, and J. David Cohen, Phys. Stat. Sol. 7, pp.1077-1080 (2010)
* “Relationship of deep defects to oxygen and hydrogen content in nanocrystalline silicon photovoltaic materials,” P.G. Hugger, J.D. Cohen, B. Yan, G. Yue, J. Yang and S. Guha; Appl. Phys. Lett. 97, 252103 (2010).
* “Insights and challenges toward understanding the electronic properties of hydrogenated nanocrystalline silicon,” P.G Hugger, J David Cohen, B. Yan, J. Yang and S. Guha; Philo. Mag. 89, pp 2541-2555 (2009).
* “Junction Capacitance Study of a-SiGe:H Solar Cells Grown at Varying RF and VHF Deposition Rates,” P.G. Hugger, J. Lee, J. David Cohen, G. Yue, X. Xu, B. Yan, J. Yang and S. Guha; Mater. Res. Soc. Symp. Proc. 1153, A07-12 (2009)

## Dr. Peter K. B. Palomaki, Inorganic Chemistry

##### PhD, Chemistry, Rensselaer Polytechnic Institute, 2012; BS, Chemistry, Muhlenberg College, 2007

Dr. Palomaki is Vadient’s lead inorganic chemist, responsible for developing nanocrystals and nanocrystal surface chemistries for advanced detector and optical device applications. Dr. Palomaki earned his Ph.D. from Rensselaer in 2012, after which he did post-doctoral work as a nanomaterial chemist for the National Renewable Energy Laboratory in Colorado. His primary focus at Vadient is on the synthesis, characterization, surface functionalization, and photophysical control of nanocrystals. He is the primary chemist for photosensitive nanomaterials. He has worked extensively with silicon, germanium, and III-V and II-VI nanocrystals. Dr. Palomaki’s work has led to improved synthesis of tightly controlled size and purity for nanocrystals to establish and control unique optical properties, and he has applied this work to nanocrystal-polymer composites. In his research, he pioneered a novel porphyrin molecular layer-by-layer thin film fabrication method and tested the photovoltaic properties in a dye-sensitized solar cell. In earlier research, he developed a working fuel cell for use with liquid hydrocarbon fuels—the first proof-of-concept for the Energy Frontier Research Center led by GE Global Research. In particular, he optimized formulations and methods for catalytic ink deposition on membrane electrode assemblies. Dr. Palomaki’s work has been published in 11 refereed papers in scientific journals such as the *Journal of the American Chemical Society*, *ACS Applied Material Interfaces*, and *Journal of Physical Chemistry*. He is a U.S. citizen.

##### Selection of Relevant Publications

* D. A. Kislitsyn, C. F. Gervasi, T. Allen, P. K. B. Palomaki, J. D. Hackley, R. Maruyama, and G. V. Nazin, “Spatial Mapping of Sub-Bandgap States Induced by Local Nonstoichiometry in Individual Lead Sulfide Nanocrystals,” *J. Phys. Chem. Lett.*, vol. 5, pp 3701–3707, Oct. 2014.
* “Low temperature hydrosilylation of silicon nanocrystals,” Palomaki, P. K. B.; Neale, N. R., 2013 manuscript in preparation.
* “Control of plasmonic and interband transitions in colloidal indium nitride nanocrystals,” Palomaki, P. K. B.; Miller, E. M.; Neale, N. R., J. Am. Chem. Soc. 2013 ASAP doi:10.1021/ja404599g
* “Photocurrent enhancement by multilayered porphyrin sensitizers in a photoelectrochemical cell,” Palomaki, P. K. B.; Civic, M. R.; Dinolfo, P. H., ACS Appl. Mater. Interfaces 2013 5 (15), 7604-7612.
* “Structural analysis of porphyrin multilayer films on ITO assembled using copper(I)-catalyzed azide alkyne cycloaddition by ATR IR,” Palomaki, P. K. B.; Dinolfo, P. H., ACS Appl. Mater. Interfaces 2011, 3 (12), 4703-4713.
* “Thickness, surface morphology, and optical properties of porphyrin multilayer thin films assembled on Si(100) using copper(I)-catalyzed azide-alkyne cycloaddition,” Palomaki, P. K. B.; Krawicz, A.; Dinolfo, P. H., Langmuir 2011, 27 (8), 4613–4622.
* “A versatile molecular layer-by-layer thin film fabrication technique utilizing copper(I)-catalyzed azide-alkyne cycloaddition,” Palomaki, P. K. B.; Dinolfo, P. H., Langmuir 2010, 26 (12), 9677-9685.
* “Preliminary testing of liquid hydrocarbons in fuel cells,” Palomaki, P. K. B.; Soloveichik, G. L., 2010 General Electric internal report 2010GRC936.

## Thomas Allen, Test Engineering

##### MS, CHEMISTRY, 2006, U. OREGON; BS CHEMISTRY/PHYSICS, U. OREGON, 2005

Mr. Allen is a skilled synthetic chemist with focus on synthesis of various metallic and semiconducting nanomaterials for optoelectronic and thermoelectric applications. He is an expert in materials characterization and structural determination using a variety of techniques. His materials test and characterization experience includes X-ray diffraction, differential scanning calorimetry, atomic force microscopy (AFM), field emission scanning electron microscopy (FESEM), transmission electron microscopy (TEM) , UV-VIS-NIR-FTIR optical spectroscopy, fluorescence, PLQY, Hall effect measurements, Seebeck effect measurements, cyclic voltammetry, four- point probe and Van der Pauw resistivity measurements. His device test experience includes IPL, photovoltaic measurements of solar cells, thin-film transparent FET testing and characterization. Mr. Allen also has 10 years of welding and machinist experience and is capable of fabricating complex testing platforms and adapting existing equipment to current needs. His other responsibilities at Voxtel include project engineering, interfacing with CAMCOR and the Lokey Labs, and technician management. His research experience began under Dave Johnson at the University of Oregon, developing kinetically controlled approaches to the synthesis of new solid-state materials and correlating physical properties with structure and bonding using modulated elemental reactant technique. He also developed an electroless deposition technique of metal phosphides for use as diffusion barriers in microelectronic circuits. Mr. Allen continues to use his expertise to develop novel nanostructures used in a bottom-up fabrication of tomorrow’s devices. He is a U.S. citizen.

##### Patents

* US 8724214 B2, WO 2014039347 A1: Broadband optical upconversion by energy transfer from dye antenna to upconverting crystal
* Publications
* D. A. Kislitsyn, C. F. Gervasi, T. Allen, P. K. B. Palomaki, J. D. Hackley, R. Maruyama, and G. V. Nazin, “Spatial Mapping of Sub-Bandgap States Induced by Local Nonstoichiometry in Individual Lead Sulfide Nanocrystals,” *J. Phys. Chem. Lett.*, vol. 5, pp 3701–3707, Oct. 2014.

## Dr. Sang-Ki Park, Program Role

##### PHD, MS OPTICAL SCIENCES, U. ARIZONA, 2006, 2003; MS, BS, PHYSICS, KOREA UNIV., 1994, 1994

Dr. Sang-ki Park, a Senior Optical Scientist, is our lead VIRGO optics designer and metrologist. He is creating lenses for commercial applications, for NASA in searching for exoplanets, by AFRL to limit the intensity of light seen by detectors. Prior to joining Voxtel, Dr. Park was a senior principal optics engineer for II-VI Laser Enterprise, where he: designed optics for high-power laser diode assemblies with outputs including fiber-coupled diodes, collimated beams, homogenized line sources, and semi-collimated beams; specified optics per design requirements and negotiated specifications with vendors; characterized and validated designs; and designed and built characterization tools including divergence, beam size, LIV, and spectrum, and stations including submicrometer level motion control and beam diagnostics. Previously, he was a graduate research associate at Optical Sciences Center, University of Arizona.

##### Publications

* “Advanced Lens Design for Bit-wise Volumetric Optical Data Storage,” Jpn J Appl Phys Vol 43(7B), 2004, 4929
* “Near-Field Solid Immersion Lens (SIL) Microscope with Advanced Compact Mechanical Design”, Proc. SPIE, Vol. 5380, 2004, 634
* “Master and Slave Servo Technique for Bit-wise Volumetric Optical Data Storage”, Jpn. J. Appl. Phys. Vol. 44, No. 5B, 2005, 3442

##### Patents

* USP8,003,187, “Optimized media structure for bit-wise multi-layer optical data storage”
* USP8,553,737, “Laser emitter modules and methods of assembly”
* USPA20110103056, “High brightness diode output methods and devices”
* USPA20130058124, “Homogenization of far field fiber coupled radiation”
* USPA20130258469, “Spatial beam combining for multiple diode laser elements”

## Dr. Nanditha Dissanayake, Program Role

##### PHD, ELECTRICAL ENGINEERING, U. OF SURREY, ENGLAND, 2009; BSEE, U. OF MORATUWA, SRI LANKA, 2002

Dr. Dissanayake leads the successful completion of VoxtelNano research into photonic detectors, atomic level assembly into products, bio-functionalized nanotaggants, and thermal electric generation nanoscale materials and devices. He also currently assists the vice president of Nanotechnology with the commercialization of technology in our portfolio. The key objective is growing revenue through exceptional teamwork and insight into technical opportunities that meet the needs of key customers within markets selected by Voxtel management. Before joining Voxtel, Dr. Dissanayake was a research associate for sustainable energy technologies at the Brookhaven National Lab. There, his work focused on: light capture in ultrathin organic PVs using optical waveguide modes; spatially resolved optoelectronic measurements in hybrid PVs; grazing incidence wide-angle x-ray scattering in polymer thin films; spectroscopic ellipsometry study of ultrathin polymer composites; charge extraction under linearly increasing voltage analysis of PVs; admittance spectroscopy and capacitive-voltage profiling of PVs; x-ray fluorescence and x-ray beam induced current measurement in PVs; hot-carrier effects in graphene and quantum dot hybrid PVs; optical and e-beam lithography for nanoscale device fabrication; EBIC and LBIC techniques for high-resolution device characterization; and synthesis and characterization of CuInxGa(1-x)S2 nanocrystalline PVs. Previously, he was a post-doctoral researcher in the solid-state electronics lab at the University of Michigan (Ann Arbor) and a C++ Software Engineer for Millennium Information and Technologies, Sri Lanka. Dr. Dissanayake’s work has been featured as an inside-cover 2013 journal article in *Advanced Energy Material*, and he won the *Best Poster* award for his 2011 presentation at the 37th IEEE Photovoltaic specialist conference in Seattle. His SWNT and polymer nanojunction PV work has been highlighted in SPIE Web and, in 2006, he was a runner up for the *Obducat AB* prize (Sweden) for nanoimprint lithography. Dr. Dissanayake has authored or co-authored 4 patents and 16 professional publications.

##### Patents

* 2011 Carbon Nanotube Hybrid Photovoltaics (U.S. Application #13/179,88)
* 2012 Thin-film Photovoltaic Device with Optical Field Confinement (PCT/US2013/041631)
* 2014 Building Integrated Photovoltaic Devices (U.S. Application #61/762,899)
* 2015 Novel Hole Blocking, Electron Transporting and Window Layer for Optimized Culn1-xGaxSe2 (U.S. Application 61/968,873)

##### Selection of Recent Publications

* D.M.N.M. Dissanayake, et al., “A Scalable, In Situ, and Spontaneously n-Doped Graphene Schottky Diode,” (submitted, April 2015).
* A. Ashraf, D.M.N.M. Dissanayake, and M.D. Eisaman, “Measuring charge carrier mobility in photovoltaic devices with micron-scale resolution (Accepted, Applied Phys. Letts.)
* A. Ashraf, D.M.N.M. Dissanayake, M.D. Eisaman, “Crystallinity and grain-size variation due to confinement and phase segregation in polymer:fullerene bulk heterojunction thin films,” submitted.
* D.M.N.M. Dissanayake and Z. Zhong, :Highly Rectifying Ensemble Single-Walled Carbon Nanotube Diodes,” Appl. Phys. Letts., 104, 123501 (2014).
* D.M.N.M. Dissanayake, A. Ashraf, Y. Pang, and M. D. Eisaman, “Mapping Spatially Resolved Charge Collection Probability within P3HT:PCBM Photovoltaics,” Adv. Energy Mater., DOI: 10.1002/aenm.201300525 (2013) (Inside Cover Article, February 2014 issue)
* D.M.N.M. Dissanayake, A. Ashraf, Y. Pang, and M.D. Eisaman, “Guided-Mode Quantum Efficiency: A Novel Optoelectronic Characterization Technique,” Rev. of Sci. Instr., 83, 114704 (2012).
* A. Ashraf, D.M.N.M. Dissanayake, D. S. Germack, C. Weiland, and M.D. Eisaman, “Vertical Phase Separation and Anisotropy in Ultrathin Polymer: Fullerene Bulk Heterojunctions,” ACS Nano, DOI: 10.1021/nn404172m (2013).
* D.M.N.M. Dissanayake, B. Roberts, and P.-C. Ku, “Angular Selective Backreflector for Semitransparent Photovoltaics,” Appl. Phys. Lett., 101, 063302 (2012).
* B. Roberts, D.M.N.M. Dissanayake, and P.-C. Ku, “Angular Selective Transparent Photovoltaics,” Opt. Express., 20, 045315 (2012).
* C. Liu, D.M.N.M. Dissanayake, S. Lee, K. Lee, and Z. Zhong, “Evidence of Direct Extraction of Hot Carriers from Graphene,” ACS Nano 6, 7172 – 7176 (2012).

## Dr. Christopher D. Weber, Program Role

PHD, CHEM, U. OF OREGON, 2013; MS, CHEM., U OF O, 2009; BS, CHEM., RICHARD STOCKTON COLL. OF NJ, 2006

Dr. Weber assists the VoxtelNano lead with the commercialization of technology in our portfolio (nanotaggants, printed gradient refractive index optical structures, thermal electric generation devices, and photonic detectors). The key objective is developing new technology within designated research programs that advances Voxtel’s technical and scientific depth and breadth. Before joining Voxtel, Dr. Weber conducted postdoctoral research at the University of Oregon under a subcontract for the National Energy Technology Lab (NETL). This work focused on the development of ceria based infiltration catalysts for direct methane and carbon monoxide oxidation for solid oxide fuel cells (SOFC). This work includes synthetic control of infiltrate nanostructure, infiltration and deposition of nanoparticles within porous SOFC anode, and cell fabrication and testing. His doctoral research at the University of Oregon in the Department of Chemistry (Advisor: Mark Lonergan) focused on the role of ionic functionality on the charge injection processes of semiconductor conjugated polymers and molecules, as well as their effect on the properties of photonic devices fabricated from these materials. Dr. Weber was awarded the National Science Foundation: Integrative Graduate Education and Research Traineeship (IGERT) fellowship (2009 – 2011) and the University of Oregon Doctoral Research Fellowship (2012 – 2013). Dr. Weber is the author or co-author of more than 10 professional publications and presentations. He is a U.S. Citizen.

##### Publications

* Weber, C.D.; Bradley, C.; Lonergan, M.C. "Solution Phase n-doping of C60 and PCBM using Tetrabutylammonium Fluoride," J. Mater. Chem. A, 2014, 2, 303-307.
* Weber, C.D.; Bradley, C.; Walker, E.M.; Robinson, S.G.; Lonergan, M.C. " Increased Performance of Inverted Organic Photovoltaic Cells using a Cationically Functionalized Fullerene Interfacial Layer," Sol. Energy Mater. Sol. Cells, In Press April 2014
* Weber, C.D.; Robinson, S. G.; Stay, D.P.; Vonnegut, C. L.; Lonergan, M.C. "Ionic Stabilization of the Polythiophene-Oxygen Charge Transfer Complex," ACS Macro Lett., 2012, 1, 499-503
* Weber, C.D.; Robinson, S.G.; Lonergan, M.C. "Ionic Functionality and the Polyacetylene-Oxygen Charge Transfer Complex," Macromolecules, 2011, 44, 4600-4604
* Chase, D.T.; Fix, A.G.; Kang, K.J.; Rose, B.D.; Weber, C.D.; Zhong, Y.; Zakharov, L.N.; Lonergan, M.C.; Haley, M.M. "6,12-Diarylindeno[1,2-b]fluorenes: Syntheses, Photophysics, and Ambipolar OFETs," J. Am. Chem. Soc., 2012, 134, 10349-10352
* Chrostowska, A.; Xu, S.; Lamm, A.N.; Maziere, A.; Weber, C.D.; Dargelos, A.; Baylere, P.; Graciaa, A.; Liu, S. "UV-Photoelectron Spectroscopy of 1,2 and 1,3-Azaborines: A Combined Experimental and Computational Electronic Structure Analysis," J. Am. Chem. Soc., 2012, 134, 10279-10285
* Chase, D.T.; Fix, A.G.; Rose, B.M.; Weber, C.D.; Nobusue, S.; Stockwell, C.E.; Zakharov, L.N.; Lonergan, M.C.; Haley, M.M. "Electron -Accepting 6,12-Diethynylindeno[1,2-b]fluorenes: Synthesis, Crystal Structures, and Photophysical Properties," Angew. Chem. Int. Ed., 2011, 50, 11103-11106
* Rose, B.D.; Chase, D.T.; Weber, C.D.; Zakharov, L.N.; Lonergan, M.C.; Haley, M.M. "Synthesis, Crystal Structures, and Photophysical Properties of Electron Accepting Diethynylindenofluorenediones," Org. Lett., 2011, 13, 2106-2109
* Robinson, S.G.; Johnson, D.H.; Weber, C.D.; Lonergan, M.C. "Polyelectrolyte Mediated Electrochemical Fabrication of a Polyacetylene p-n Junction," Chem. Mater., 2010, 22, 241-246

##### Conference Presentations

* Weber, C.D. (2010, December). Asymmetric doping of polyacetylene polyelectrolyte pn-junctions. Presented at the UO Material Science Institute conference, Glenleden Beach, Oregon
* Weber, C.D. (2012, September). The Effect of Ionic Functionality on the Photooxidation of Conjugated Polymer Thin Films. Presented at the UO Materials Science Institute conference, Eugene, Oregon.

# (8) Foreign Citizens

None.

# (9) Facilities/Equipment

Founded in 1999, Voxtel Inc., is a profitable, privately held developer of advanced photodetectors and optoelectronics, specializing in time-of-flight 3D imaging, rangefinding, and photon-counting detectors and instruments, including those hardened for harsh radiation and environmental applications. Our advanced photodetectors, electro-optical systems, and optical instrumentation are implemented through a diverse array of industrial, commercial, research, and government applications. Our business systems and quality management system are designed to meet these customer demands.

## Facilities

Our corporate headquarters (Figure 1, left) are located in our 18,000-sq.-ft. facility in Beaverton, Oregon, in close proximity to Portland and to Tektronix and Intel’s Hillsboro, Oregon. Voxtel’s optoelectronics division, VoxtelOpto, is colocated with our headquarters in Beaverton. The cross-functional group of scientists, engineers and management professionals at VoxtelOpto, over 80% of whom hold advanced degrees, includes device design experts, process development engineers, CMOS ROIC designers, systems engineers, and test and integration experts.

Voxtel’s nanophotonics division, VoxtelNano is located in Eugene, Oregon (Figure 1, center). Our private wet labs are located at the 20,000 sq. ft. Lorry Lokey Laboratories, which include the highly specialized instruments necessary to manufacture nanophotonic devices. Over 80% of the employees of VoxtelNano hold PhDs in their respective disciplines. Our experience extends from nanocrystal fabrication and ligand functionalization to ink chemistry, nanocrystal-enabled detectors and photovoltaics, displays, inkjet-printed organic and inorganic device design, and organic chemical and biological detectors. Our work also includes molecular jet deposition integration for MEMS, modeling and integration work surrounding use of nanocrystals in emissive displays, and electrical characterization of inorganic oxide semiconductor materials for transparent displays.

Our subsidiary, Vadient Optics, focused on developing solid freeform fabrication (SFF) of 3D gradient index optics, is located at our facilities at the Microproducts Breakthrough Institute in Corvallis, Oregon (Figure 1, right).



Figure . Our administrative offices are in an 18,000 sq. ft. Voxtel-owned facility in Beaverton, Oregon, which we also use to design, manufacture, and test electro-optical devices and systems (left). Our private wet labs are located in Eugene, Oregon at the Lorry Lokey Laboratories underground facility (center). Our facilities for solid freeform fabrication of 3D gradient index optics are located at the Microproducts Breakthrough Institute in Corvallis, Oregon (right).

## Equipment

Voxtel has all the necessary equipment to conduct the work described in this proposal. A brief list of the equipment made available to this program is below.

### Analytical Instruments

* CAMECA SX50 Electron Microprobe
* ZEISS Ultra Scanning Electron Microscope (SEM)
* Philips CM12 Transmission Electron Microscope
* FEI Focused Ion Beam 611 System
* Nanoscope IIIa Atomic Force Microscope (AFM)
* Hysitron Nanoindentation System
* Perkin-Elmer Lambda 19 UV/VIS/NIR Spectrophotometer
* Bio-Rad Multiphoton Scanning Laser Fluorescence, Radiance 2001 Microscope
* Kratos HSI Monochromatized X‑ray Photoelectron Spectrometer (XPS) with UPS Capability
* CAMECA SX100 Electron Microprobe
* JEOL JSM-6300V Environmental/Var. Pressure SEM
* JEOL 6400F Field Emission SEM
* Balzer, BA 360M Freeze Etch/Freeze Fracture Equipment
* Woollam M44 Spectroscopic Ellipsometer
* Edinburgh Instruments UV/VIS/NIR Fluorometer
* Reichert Jung FC 4E Cryo-Ultramicrotome
* Phi Model 670 Scanning Auger Microscope
* Time-of-Flight Secondary Ion Mass Spectrometer (TOF-SIMS)

### Electrical Test and Measurement Equipment

* Source meters (Keithley, Agilent)
* HP 8970B Noise Figure meter
* Digital Osciloscopes , 500MHz-8GHz (Tektronix, Agilent)
* Boston Electronics 72BD capacitance meter
* Thermal Oven
* Function and signal generators (DC to 50 GHz) (Tek, HP, etc.)
* Automated (Cascade) and manual (2x Wentworth) wafer probe stations
* Semiconductor parameter analyzers (HP4145B, etc.)
* HP4248A LCR meter
* Various power sources
* Automated APD receiver test station
* Programmable (FPGA w/GUI) ROIC & FPA test station
* Alpha Omega TEC programmable controller
* Spectral Products CM110 fiber-coupled monochromator with ASBN-W-100-L tungsten-halogen lamp
* Portable Weather Station
* TSK UF200 Automated production & UF190A automatic wafer probes
* Agilent E5250A switch matrix

### Optical Test and Measurement Equipment

* Various optical tabletops, including Newport 36”x24”
* Oriel CS 1/4m 260 monochromator; 0.15-nm res
* Oriel 7400 monochromator
* Spectra-Physics UV line source for monochromator calibration
* Photo Research PR-670 SpectraScan spectroradiometer
* Laser beam profilometer
* Stanford Research SR620 counter
* Polycold Systems Cryotiger cryogenic chiller
* Spectra-Physics 7100 monochromator 6-Inch & 4-inch integrating spheres (12)
* PhotoResearch PR-880 automated photometer
* OZ Optics OZ-2000 stabilized diode
* Spectra-Physics 7100 monochromator
* Inspection scopes (Leica, Nikon, etc.)
* UV and NIR curing station
* Variable optical attenuators (OZ, Tektronix, JDS)
* Various laser sources (UV, VIS, SWIR, MWIR, LWIR) including: OZ Optics OZ-2000 stabilized diode lasers; 1064-nm and 1550-nm, 2-ns pulse laser; Litron S1290-20 200-mJ laser; Calmar 5-ps 1064-nm fiber laser; and PicoQuant PDL 800-B pulsed 45-ps laser
* Stanford Research SR400 gated photon counter
* Gen IV Intensified CCD Camera
* SUI 642 x 512 SWIR camera

### Manufacturing Equipment

* 1,500 clean room facility, 200 sq. ft. class 100
* Electro-optical assembly facility
* SET FC150 ROIC die bonder, 0.5-µm placement
* Manual die bonders
* Laser and APD burn-in stations
* Plasma etcher & PE-100 PlasmaEtch plasma cleaner
* Custom multi-head, multi-material (metal, polymer dielectric, optics) 3D inkjet printer w/1-µm precision
* Agilent Infinium oscilloscope
* Agilent 8116A pulse generator
* Ophir PE-9 Thermopile and Vega optical power meter
* Nikon SMZ1270 microscope
* Cascade Tek TFO-1 Oven
* Omano microscope
* Airclean 600 chemical work station
* Chicago electric ultrasonic cleaner
* Enlight ESpot-800 UV cure system
* Newport Conex-CC alignment system
* Explosion-proof hot plate
* MJB3 mask aligner
* Laurell WS-650-15B spin coater

### IC Design

We use Simucad and Tanner Research design tools to create schematics and simulate, layout, and verify IC designs.

***Schematic Capture:*** Simucad Gateway is used to graphically create, modify, and netlist hierarchical mixed-signal circuit schematics.

***Analog Circuit Simulation:*** Simucad SmartSpice is used to simulate transistor-level schematics in the DC, AC, and transient domains using foundry-supplied and verified models. The simulator supports both AC and transient noise simulations, as well as an integrated VerilogA simulator. The tool can be operated in single or multi-processor operating modes, allowing for fast simulation times of complex circuits. In addition to the SmartSpice tool, Voxtel also owns several Tanner Research T-Spice licenses that are routinely used to verify simulation results between tools.

***Digital Circuit Simulation:*** Simucad SILOS-X is an IEEE-1364-2001–compliant Verilog simulator that is used by the group to verify custom digital design.

***Mixed-Signal Circuit Simulation:*** Simucad Harmony combines the accuracy of the SmartSpice analog simulator with the fast simulation time of SILOS-X to perform true mixed-signal design simulations.

***Circuit Layout:*** Simucad Expert is used as our primarily hierarchical layout editor (mask design). Expert provides a high level of design assistance though Netlist Driven Layout (NDL) and parametric cell design (PCells). Voxtel also owns several Tanner Research L-Edit licenses that are used to perform mask designs for our large-feature-size detector arrays.

***Design Verification:*** Simucad Guardian is used to perform verification of the design database, including layout extraction, Design Rule Check (DRC), and Layout Versus Schematic (LVS). The tool supports hierarchical netlist extraction and LVS debugging.

***Parasitic Extraction:*** Simucad HIPEX is used to extract parasitic circuit parameters (resistance and capacitance) from hierarchical layouts. HIPEX can be configured to extract R, C, or RC in either lumped or distributed modes. Back-annotated netlists can be read directly into SmartSpice for post-layout design verification.

### Semiconductor Device Design Tools

Voxtel complements a suite of Silvaco device simulation tools with custom APD design software. Voxtel designs its APDs using a simulation program that is a Monte Carlo implementation of the dead-space multiplication theory (DSMT). This program, written by Dr. Huntington of Voxtel, computes both the spatial and temporal distribution of impact-ionization events for a large number of trials, for arbitrary 1-D APD layer structures.

### System Modeling and Simulation

Our staff have developed electro-optical device simulation and system modeling tools based on IDL, MATLAB, LabVIEW, and Mathematica. We use these tools with our device Monte Carlo models to integrate with the end-to-end physics-based simulation packages like DIRSIG that we use to design EO systems. We support these models with atmospheric models [MODTRAN, FASCODE, Mosart/Plexus, U.S. Army Electro-Optical Systems Atmospherics Effects (EOSAEL), etc.]. For system design and performance predictions, we also use a variety of industry-standard sensor models, including NVESD NVThermIP, SScamIP, NVLaserD, NVLRG, CN2, and IINVD, among others.

## Collaborators and Consortia

Voxtel is an active member of the Oregon Nanoscience and Microtechnologies Institute (ONAMI) and the Oregon Built Environment & Sustainable Technologies Center (Oregon BEST), which are university/industry collaboration networks established in the Pacific Northwest. Surrounding this core are Oregon’s four public research universities—Oregon State University, the University of Oregon, Oregon Health Sciences University, and Portland State University—as well as the Pacific Northwest National Laboratory (PNNL), the state of Oregon, and the regional business community. ONAMI and BEST offer matching funding to any academic performance on the program (20%). Voxtel is also a member of the Penn State EO Alliance

# (10) Subcontractors/Consultants

N/A

# (11) Prior, Current, or Pending Support

No prior, current, or pending support for proposed work.

# Bibliography & References Cited

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1. S. D. Jayasena, Aptamers: An Emerging Class of Molecules That Rival Antibodies in Diagnostics, *Clinical Chemistry* 45:9 1628–1650 (1999). <http://clinchem.aaccjnls.org/content/45/9/1628> [↑](#endnote-ref-1)
2. Nimjee, S.M.; Rusconi, C.P.; Sullenger, B.A. Aptamers: An emerging class of therapeutics. Annu. Rev. Med. 2005, 56, 555–583. [↑](#endnote-ref-2)
3. <http://www.nature.com/nrd/journal/v9/n7/full/nrd3141.html> [↑](#endnote-ref-3)
4. Biomedicines 2015, 3, 248-269; doi:10.3390/biomedicines3030248. [↑](#endnote-ref-4)
5. Brannon-Peppas, L.; Blanchette, J.O. Nanoparticle and targeted systems for cancer therapy. Adv. Drug Del. Rev. 2012, 64, 206–212 [↑](#endnote-ref-5)
6. http://www.nature.com/mtna/journal/v3/n8/pdf/mtna201432a.pdf [↑](#endnote-ref-6)
7. Farokhzad, O.C.; Cheng, J.; Teply, B.A.; Sherifi, I.; Jon, S.; Kantoff, P.W.; Richie, J.P.; Langer, R. Targeted nanoparticle-aptamer bioconjugates for cancer chemotherapy in vivo. Proc. Natl. Acad. Sci. USA 2006, 103, 6315–6320. [↑](#endnote-ref-7)
8. Yu, C.; Hu, Y.; Duan, J.; Yuan, W.; Wang, C.; Xu, H.; Yang, X.D. Novel aptamer-nanoparticle bioconjugates enhances delivery of anticancer drug to MUC1-positive cancer cells in vitro. PLoS ONE2011, 6, e24077. [↑](#endnote-ref-8)
9. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3890987/ [↑](#endnote-ref-9)
10. Maureen McKeague and Maria C. DeRosa, Challenges and Opportunities for Small Molecule Aptamer Development, Journal of Nucleic Acids Volume 2012, Article ID 748913, 20 pages. [↑](#endnote-ref-10)
11. <https://profiles.nlm.nih.gov/ps/access/PXBBCY.pdf> [↑](#endnote-ref-11)
12. <https://www.ncbi.nlm.nih.gov/pubmed/5492605> [↑](#endnote-ref-12)
13. https://academic.oup.com/bioinformatics/article/28/12/i215/267900/Identification-of-sequence-structure-RNA-binding [↑](#endnote-ref-13)
14. http://ebook.insilico.eu/insilico-ebook-orchestra-benfenati-ed1\_rev-June2013.pdf [↑](#endnote-ref-14)
15. https://www.hindawi.com/journals/bmri/2016/8351204/ [↑](#endnote-ref-15)
16. http://www.nature.com/nbt/journal/v26/n3/full/nbt0308-303.html [↑](#endnote-ref-16)
17. http://www.stat.wisc.edu/~loh/treeprogs/guide/wires11.pdf [↑](#endnote-ref-17)
18. http://www.saedsayad.com/k\_nearest\_neighbors.htm [↑](#endnote-ref-18)
19. http://www.cs.columbia.edu/~kathy/cs4701/documents/jason\_svm\_tutorial.pdf [↑](#endnote-ref-19)
20. https://www.hindawi.com/journals/bmri/2016/8351204/ [↑](#endnote-ref-20)
21. ShaoPeng Wang, Analysis and Identification of Aptamer-Compound Interactions with a Maximum Relevance Minimum Redundancy and Nearest Neighbor Algorithm, Volume 2016, Article ID 8351204, 9 pages. <https://www.hindawi.com/journals/bmri/2016/8351204/> [↑](#endnote-ref-21)
22. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0086729 [↑](#endnote-ref-22)
23. DOI:10.1371/journal.pone.0086729 [↑](#endnote-ref-23)
24. MICHAEL ZUKER, RNA SECONDARY STRUCTURES AND THEIR PREDICTION. Bulletin of Mathematical Biology Vol. 46, No. 4, pp. 591-621, 1984. [↑](#endnote-ref-24)
25. <http://albuquerque.bioinformatics.uottawa.ca/Papers/JournalPublication/1984_Zuker_Sankoff.pdf> [↑](#endnote-ref-25)
26. J. Honika, “Identification of sequence–structure RNA binding motifs for SELEX-derived aptamers”, *Vol. 28 ISMB 2012, pages i215–i223*. [↑](#endnote-ref-26)
27. http://www.sciencedirect.com/science/article/pii/S0169743914000987 [↑](#endnote-ref-27)
28. http://polymer.bu.edu/Wasser/robert/work/node8.html [↑](#endnote-ref-28)
29. https://www.cs.uoregon.edu/Reports/ORAL-200903-Wimalasuriya.pdf [↑](#endnote-ref-29)
30. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2743057/pdf/1623.pdf [↑](#endnote-ref-30)
31. The IUPAC International Chemical Identifier (InChI) - http://www.iupac.org/home/publications/

    e-resources/inchi.html [↑](#endnote-ref-31)
32. Daylight SMILES (Simplified Molecular Input Line Entry System) - <http://www.daylight.com/> dayhtml/doc/theory/theory.smiles.html [↑](#endnote-ref-32)
33. https://cactus.nci.nih.gov/SDF\_toolkit/ [↑](#endnote-ref-33)
34. [D.A. Kislitsyn](http://pubs.acs.org/action/doSearch?ContribStored=Kislitsyn%2C+D+A), Spatial Mapping of Sub-Bandgap States Induced by Local Nonstoichiometry in Individual Lead Sulfide Nanocrystals [↑](#endnote-ref-34)
35. C. Chiritescu, et al, Science 2007, 315, 351. [↑](#endnote-ref-35)
36. Ngoc Nguyen, [Solution Processible Nanoparticle Thermoelectric .](http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CB4QFjAA&url=http%3A%2F%2Fvoxtel-inc.com%2Ffiles%2F2012%2F07%2FSolution-Processible-Nanoparticle-Thermoelectric-Materials-8035-43.pdf&ei=qQJYVJ2nLYrvoAS-tIGQDA&usg=AFQjCNFVh_C595Rm0vZMojKL48kQZ3J60g&bvm=bv.78677474,d.cGE)SPIE [↑](#endnote-ref-36)
37. Sambur, Justin B., Thomas Novet, and B. A. Parkinson. "Multiple exciton collection in a sensitized photovoltaic system." Science 330.6000 (2010): 63-66. [↑](#endnote-ref-37)