COLIN N. REINHARDT, Ph.D.

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Atmospheric Propagation Branch, Communications & Networks Department
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Department of Electrical and Computer Engineering
University of Washington, Seattle, WA

KEYWORDS
computer vision methods: classical/modeled and learned
physics-based modeling & simulation for machine learning
Intelligent edge computing: GPU/accelerators and HW+SW architecture and design
GPU computing and parallel software algorithm engineering
active/passive imaging/video and hyperspectral remote sensing systems, sensors, software, and algorithms: 3D Flash Lidar, light field sensors, event cameras, neuromorphic cameras
optical communications and laser systems engineering
uncertainty quantification, statistical error analysis, sensitivity analysis
verification & validation
electromagnetic wave/field propagation theory, computational electromagnetics

OVERVIEW

During my decade-and-a-half as an US Navy engineer within the US Department of Defense Research Development Test & Engineering (RDTE) infrastructure, I have developed and led multiple multi-service efforts (Army-Navy-AirForce-Marines), and have worked with various Intelligence Community (IC) agencies. Examples include:

● TrueView EO/IR/hyperspectral simulator, technical lead and program manager: 2015-present, (> $10M budget, distributed development & engineering team of ~10 engineers/scientists/software developers/data scientists),
● US appointee to several NATO Science & Technology Organization (STO) task groups: 2016-present
● Navy lead for the tri-Service DOD Supercomputing Resource Center (DSRC) High-Performance Computing Modernization Program Office (HPCMPO) Institute for Imaging Sensor Exploitation (IISE): 2017-2020
● US Navy co-lead for multi-Service/Agency OUSD(R&E) electro-optical (EO) Artificial Intelligence (AI) Hub DOD-wide AI/ML infrastructure program, 2022-present
● Program Committee member, SPIE Defense + Commercial Sensing conference: Synthetic Data for Artificial Intelligence and Machine Learning: Tools, Techniques, and Applications

As an affiliate professor in the Department of Electrical and Computer Engineering (ECE) at the University of Washington in Seattle, in 2016 I developed two new course curricula: GPU-Accelerated Computing and Interactive Accelerated Scientific Visualization. These were adopted by the UW ECE Professional Master's Program (PMP). In 2021 the PMP program requested that I extend the GPU curriculum offering to a 3-quarter certificate track which we call GPU-Accelerated Computing and Visualization, so I developed a third course curriculum: Advanced GPU-Computing and Visualization. This upcoming academic year 2024-2025 we are offering the 2nd series of the popular GPU certificate program, which has successfully lead to graduates gaining employment in top-tier tech industry positions such as: NVIDIA, Intel, Apple, Unity, Google, Microsoft, and others.

EDUCATION

2010 ***Ph.D. Electrical Engineering***
Electromagnetics and Remote Sensing Laboratory, Department of Electrical Engineering, University of Washington, Seattle
Thesis: "Atmospheric channel modeling and estimation for free-space optical communications systems in adverse visibility using radiative transfer theory."
ASEE/DOD SMART Fellow

2005 ***B.S. Physics and B.S.E.E., double major***
Focus areas: applied electromagnetics, EM theory, signal processing, communications theory
University of Washington, Seattle

1994 ***B.A. English, with Honors***
University of Hawaii, Manoa

SKILLS

- End-to-end machine learning (ML) engineering including: dataset preparation (synthetic, real, hybrid), network architecture design, model development, training, testing and evaluation of machine learning networks and algorithms for computer vision (CV) applications such as image and video detection/recognition/identification, classification, object tracking, segmentation. Research, design and development of novel ML/DL methods/models/techniques. Experience with CNN, vision transformers, state-space models (SSM), diffusion models, auto-encoders, embedding space theory, contrastive learning, reinforcement learning, agentic architectures.
- Electro-optical (EO), infrared (IR), and hyperspectral (HS) sensors and systems: optical design, signal post-processing, sources and detectors, BRDF/OTF/PSF/PSD modeling and engineering, advanced optimized ray-trace and physics-based propagation and rendering theory, (PBRT) methods, modeling and analysis of communication systems and protocols, link budget and system performance analysis. Practical lab/work-bench experience, troubleshooting, field test design and execution. Computer vision applications: object detection, segmentation, tracking.
- Target and background EO/IR/HS signature modeling and simulation, analysis, measurement, and characterization.
- Wave propagation in random media: theoretical methods and applications. Visible, Infrared (IR), ultraviolet (UV), radio-frequency (RF). LIDAR and RADAR fundamental theory, standard and novel algorithms, signal and wavefront coding, systems engineering and analysis. Imaging and propagation through atmospheric turbulence, aerosols, and refractive effects. Diffraction theory. Polarization effects, coherence theory.
- Statistical signal processing: classical detection and estimation theory, Kalman and particle filtering, adaptive filtering, pattern recognition, regression/classification, system identification.
- Stochastic process modeling and analysis: random signals in noise, Gaussian/non-gaussian noise modeling and analysis, Bayesian analysis, distribution estimation.
- Applied analytical and numerical mathematical methods: convex and nonlinear optimization, machine learning, SVD/PCA/KLT, partial differential equation and integral equation methods, eigen-analysis, compressed sensing.

- Thrives in dynamic challenging innovative multi-disciplinary work and research environments.
- Massively parallel GPU/CPU/heterogenous software design and engineering: expertise in C/C++/ C#, CUDA, OpenCL, OpenGL, Vulkan. MATLAB, various scripting languages. Object-oriented software architecture and programming. Familiarity with Python, NumPy, SciPy, R, assembly-language, UML. Embedded systems and firmware design & development. Full software engineering process lifecycle. Extensive experience with modeling and simulation of high-fidelity EO/IR/RF scenarios for system design, performance prediction, decision-support and analysis. Management of team of software engineers.
- Laser systems engineering: beam propagation modeling, beam shaping, beam quality analysis, coherence engineering, noise analysis, laboratory and field experiment design and execution, laser safety and optical hazard analysis, hands-on experience with class 3B/4 lasers. Navy laser-safety-certified engineer.
- Computational electromagnetics: FDTD, FEM, T-Matrix method, MoM, Computational Fourier optics and numerical wave-optics propagation methods, vector radiative transfer equation solution methods.
- GPU Computing and parallel software algorithm design and applied analysis. Performance tuning and optimization of highly parallel GPU algorithms. OpenCL, CUDA, OpenMP, Intel Cilk Plus, Intel Thread Building Blocks.
- Multi-spectral (MS)/Hyperspectral (HS) and IR imaging and remote-sensing techniques: time-series/image/video signal processing and analysis. Computer vision. Fourier/wavelet methods, dimensionality reduction, target detection/tracking and clutter mitigation algorithms. Ill-posed inverse problems and parameter retrieval. Novel emerging systems: 3D Flash LADAR, plenoptic imaging, range-gated imaging.
- Unique and valuable blend of advanced technical skills, applied project and process management experience with large-budget multi-year successful efforts, seasoned oral presenter and public speaker, outstanding proposal/report/technical writing skills. Able to 'see the whole forest' and also 'path-find through the weeds and undergrowth.' Adept at bridging communication gaps between technical and non-technical project participants and stakeholders.

CLEARANCE

- TOP SECRET (active)

EXPERIENCE / SELECTED HIGHLIGHTS

2011 - PRESENT PRINCIPAL ENGINEER / CHIEF SCIENTIST / PM / PI

Naval Information Warfare Center, Pacific (NIWC-PAC)
San Diego, CA, Atmospheric Propagation Branch

- TrueView Maritime Physics-Based EO/IR/HS Scene and Signature Modeling Team Lead
  - ROLES: Chief Scientist/Architect, TrueView EOIR Signature Model Team lead, PM
  - Responsible for all aspects of multi-year, multi-million dollar software engineering effort, project and financial execution, team management and leadership, relationship with multiple project sponsors, as well as primary technical contributor.

    - Design and develop an EO/IR/hyperspectral 3D scene simulator which we have been using to support multiple M&S efforts including work for many DOD agencies. TrueView provides physically-based thermal and radiometric modeling of atmospheric propagation and image generation of photorealistic environment scenarios. Physics-based fog, smoke, clouds, and general aerosol/particulate phenomenology modeling is a key capability area of TrueView.
- VAPM: Volumetric Atmospheric Participating Media
    - Applied Research 6.2
    - ROLES: PI, leading team of SSC engineers and APL-UW engineers/scientists
    - Responsible for all aspects of 2-YR $450K project execution and management, as well as primary technical contributor.
    - Novel applied research effort to develop a 3D spatio-temporal volumetric modeling prototype for future integration into TrueView EO/IR (hyperspectral) scene simulator, which will include volume-based participating media support for multiple-scattering aerosols, turbulence, and refractivity gradients
- SES : Single-Ended Atmospheric Sounding Capabilities in Non-cooperative Environments
    - Basic Research 6.1
    - Project Role: PI, leading team of 6
    - Responsible for all aspects of 2-YR $400K project execution and management, as well as primary technical contributor.
    - Project completed on-budget, on-schedule, with high acclaim.
    - Applied machine learning methods as part of novel image-analysis-based remote atmospheric sensing algorithm (patent-pending)
    - Concept, design, and breadboard-prototype (TRL-4) of novel single-ended hyperspectral active remote sensing/imaging device (patent-pending) with Raman inelastic scatter, multiple field-of-view, polarimetric discrimination.
    - Developed atmospheric imaging simulation laboratory testbed to simulate well-characterized aerosol distributions with a fog-aerosol chamber and turbulence effects using calibrated high-resolution spatial light modulators (SLM).
    - Achieved one of first published results of successful simultaneous turbulence and aerosol extinction parameter extraction from imagery, using feed-forward back-propagation Neural Network with Levenberg-Marquardt and Bayesian regularization.
- SSL-TM : Solid-State Laser Technology Maturation Program
    - Project Role: engineer, Test & Evaluation IPT, Atmospheric Sub-group
    - Designed, developed, tested calibrated instrument to simultaneously measure atmospheric path turbulence and extinction at several wavelengths (VIS/IR) over slant path geometries tracking dynamic targets (patent-pending)
    - Providing all atmospheric propagation instrumentation and modeling to support the maturation of next-generation high-energy laser weapon system capability for the Navy fleet.

- OCCIMA: Optical Channel Characterization in Maritime Atmospheres
    - Project Role: task-area lead, team of 4
    - Leading full-spectrum tradespace characterization task area, covering VIS through LWIR wavelengths and molecular, aerosol, and turbulence modeling for system performance prediction and analysis.
    - Also participating in radiometry and turbulence simulation task areas as technical contributor.
- EO/IR target & background signature modeling and analysis
    - Project Role: Co-PI
    - Technical lead for effort to provide high-resolution, near-realtime validated EO/IR modeling capability for target and background signatures in littoral environments
    - Involves high-performance parallel-computing software/hardware architectures with GPU arrays and shared/non-shared memory cluster systems.
    - Advanced physics-based light transport, rendering and global illumination, ray-tracing, importance sampling, BRDF/BSDF, acceleration data structures.
    - Including high-fidelity atmospheric propagation effects and sensor models
    - Probability of detection, image quality analysis, vulnerability analysis
- STEAP: Shipboard Turbulence Extinction and Aerosol Profile
    - Project Role: Co-PI
    - Developed slant-path atmospheric profile model for vertical optical turbulence, integrating Monin-Obukhov similarity-theory surface-boundary-layer model with empirical free-troposphere/stratospheric models
    - Model is undergoing extensive field verification & validation efforts, and is actively used in multiple Navy project efforts.

2017 - PRESENT AFFILIATE ASSISTANT PROFESSOR

Department of Electrical and Computer Engineering
University of Washington, Seattle, WA

- GPU-Accelerated Computing & Visualization: Master's track and certificate program
- refer to faculty webpage: https://faculty.washington.edu/colinrei

2004 - 2010 STUDENT/RESEARCH-ASSISTANT

University of Washington, Seattle

- 2005: Worked as research-assistant/software-engineer for Prof. Jeng-Neng Hwang in EE Dept. on real-time distributed messaging/collaboration framework.
- 2006: Graduate research-assistant with Center for Industrial & Medical Ultrasound (CIMU). Worked on characterization of high-intensity focused ultrasound (HIFU) therapy delivery remote monitoring using acoustic transducer arrays and wavelet decompositions.
- 2007-2010: SMART Fellow, funded research-assistant with Electromagnetics and Remote Sensing laboratory (ERSL). Worked on propagation channel estimation inverse problems for free-space optical laser communication to improve system performance in adverse atmospheric conditions (fog, haze, rain).

2000 – 2003 Lead Software Engineer, Cascade Engineering Services - Redmond, WA

- Contracted to Microsoft Broadband Networking division
- Embedded firmware design and development, digital audio signal processing and codecs
- C/C++, assembly language programming

1998 – 2000 Chief Software Architect, TranSenda Corporation - Redmond, WA

- Lead the design and development of distributed middleware business framework using C/C++ and COM/ATL/MFC SDK frameworks and VAT Tax filing systems.
- Led transition to new DOT-NET and C# development framework
- Lead team of up to 12 software-engineers through multiple development cycles

1997 – 1998 Lead Software Engineer, Catapult Inc. (IBM Subsidiary) – Bothell, WA

- Design/develop computer-based interactive training simulations using C/C++/Java/Visual Basic

1995 – 1997 Software Engineer/IT Consultant, Keane Inc. – Seattle, WA

- Microsoft Windows 3.x/NT/XP client & server operating system and networking support team
- TCP/IP network protocol packet analysis, OS crash analysis and debugging

PATENTS

- Atmospheric channel characterization system and method using target image information, 2019
  - US #10,249,025
- Computer modeling system and method for plenoptic scene simulation, 2018
  - US #10,102,317
- Atmospheric Transmissometer using a Modulated Optical Source, 2016
  - US #9,236,939
- Method for characterizing an atmospheric channel, 2015
  - US #9,129,369

AWARDS

- Honorable mention for 2013 research publications and conference proceedings, SPAWAR
- ASEE/DOD SMART Fellowship recipient, 2006-2010

SELECTED PUBLICATIONS (full listing available upon request - also see Google Scholar profile)

Colin N. Reinhardt, Sarah Brockman, Rusty Blue, Brian Clipp, and Anthony Hoogs; Toward quantifying the real-versus-synthetic imagery data 'reality gap': analysis and practical applications. Proc of SPIE. Vol. 13035, Synthetic Data for Artificial Intelligence and Machine Learning: Tools, Techniques, and Applications II (2024).

Colin N Reinhardt, Derek Opel, Jeffrey Clark, Susan Shoemaker, Shibin Paramswaran; Preliminary results for a Deep Learning Atmospheric Radiative Transfer Emulator to accelerate predictive 3D scene simulation. Naval Applications of Machine Learning conference, San Diego, CA. (2024).

Colin N Reinhardt, Zachariah Ritsema, Jeffrey Clark, Derek Opel, Brian Young, Brian Teaney; Enhanced physics-based modeling of the electro-optical/infrared observation chain. Laser Communication and Propagation through the Atmosphere and Oceans V, Proc of SPIE Vol. 12106 (2022).

Colin N. Reinhardt, James A. Ritcey**;** Enhanced Sea-Surface Spectral Radiance Background Signature Modeling and Simulation. Proceedings of the Military Sensing Symposium. Paper CE-03. (2016).

Colin N. Reinhardt, Stephen M. Hammel, Dimitris Tsintikidis; Efficient physics-based predictive 3D modeling and image simulation of optical atmospheric refraction phenomena. Proc. SPIE 9979, Laser Communication and Propagation through the Atmosphere and Oceans V, 99790S (2016).

Colin N. Reinhardt, James A Ritcey; Efficient and physically accurate modeling & simulation of anisoplanatic imaging through the atmosphere: a space-variant volumetric image blur method. Proc. SPIE 9614. Laser Communication and Propagation through the Atmosphere and Oceans IV, 961408 (2015).

Colin N. Reinhardt; John S. Degrassie ; Joshua J. Rudiger ; Stephen M. Hammel; A reconsideration of the best wavelengths for free-space optics. Proc. SPIE 9224, Laser Communication and Propagation through the Atmosphere and Oceans III, 92240Q (October 7, 2014).

Colin N. Reinhardt; David T. Wayne ; Stephen M. Hammel; Simultaneous atmospheric extinction and scintillation estimation using a modulated beacon. Proc. SPIE 9224, Laser Communication and Propagation through the Atmosphere and Oceans III, 92240R (October 7, 2014).

C. Reinhardt, D. T. Wayne, and S. Hammel, "Range-Gated Intensified-CCD Imager for Atmospheric Characterization," in *Imaging and Applied Optics 2014*, OSA Technical Digest (online) (Optical Society of America, 2014), paper JTu2C.2.

C. Reinhardt, D. T. Wayne, K. McBryde, and A. Ascencio, "Machine Learning Methods for the Analysis of Turbulence- and Extinction-Degraded Imagery," in *Imaging and Applied Optics 2014*, OSA Technical Digest (online) (Optical Society of America, 2014), paper IM4C.4.

Stoneback M, Ishimaru A, **Reinhardt C**, Kuga Y; Temperature rise in objects due to optical focused beam through atmospheric turbulence near ground and ocean surface. Opt. Eng. 0001; 52(3), (2013).

Colin N. Reinhardt ; D. Wayne ; K. McBryde ; G. Cauble; Extracting atmospheric turbulence and aerosol characteristics from passive imagery. Proc. SPIE 8874, Laser Communication and Propagation through the Atmosphere and Oceans II, 88740F (September 25, 2013);

David T. Wayne ; **Colin N. Reinhardt** ; Kevin McBryde ; Galen Cauble; A novel method for measuring atmospheric transmission using a modulated laser source. Proc. SPIE 8874, Laser Communication and Propagation through the Atmosphere and Oceans II, 88740H (September 25, 2013).

Reinhardt CN, Tsintikidis D, Hammel S, Kuga Y, Ritcey JA, Ishimaru A; Atmospheric channel transfer function estimation from experimental free-space optical communications data. Opt. Eng. 0001; 51(3), (2012).

C. Reinhardt, Y. Kuga, S. Jaruwatanadilok, A. Ishimaru. Improving bit-error-rate performance of the free-space optical communications system with channel estimation based on radiative transfer theory. IEEE Journal on Selected Areas in Communications, 01/2010; ·3.12 Impact Factor

Colin N Reinhardt, Sermsak Jaruwatanadilok, Yasuo Kuga, Akira Ishimaru, James A Ritcey. Investigation of multilevel amplitude modulation for a dual-wavelength free-space optical communications system using realistic channel estimation and minimum mean-squared-error linear equalization. Applied Optics 11/2008; 47(29): 5378-89. · 1.69 Impact Factor