Imaging Science (Interdisciplinary PhD)

The PhD program in Imaging Science at Washington University in St. Louis is one of only two such programs in the U.S. and offers an interdisciplinary curriculum that focuses on the technology of imaging with applications ranging from cancer diagnosis to virtual reality.

What is Imaging Science?

Imaging Science is an interdisciplinary academic discipline that broadly addresses the design and optimization of imaging systems and the extraction of information from images. It builds on contributions from traditional fields including biomedical engineering, electrical engineering, and computer science, as well as from physics, applied mathematics, biology and chemistry.

What can you do with a PhD in Imaging Science?

The high demand for personnel with training in imaging science is reflected in government policy and funding opportunities. Many academic, industrial, and national laboratory positions exist for highly qualified candidates. Graduates of the program will be prepared for careers in academic research or in industry that requires expertise in the quantitative principles of imaging.

Curriculum Focus

- mathematical and computational principles of image formation
- image analysis
- image understanding
- image quality assessment

This interdisciplinary program is unique and brings together expert faculty from the School of Engineering & Applied Science and the School of Medicine to provide students the freedom and flexibility to learn from leading imaging experts and engage in impactful research.

History

Washington University has been a leader in the technology and advancement of imaging science for more than 125 years. In the 1920s, Washington University researchers were the first to use X-rays to view the gallbladder. In the 1970s, research by Michel Ter-Pogossian at the university’s Mallinckrodt Institute of Radiology led to the development of the PET scanner.

Website:  https://engineering.wustl.edu/departments-faculty/interdisciplinary-degree-programs/imaging-science/

Faculty

Mark Anastasio (https://engineering.wustl.edu/Profiles/Pages/Mark-Anastasio.aspx)  
Imaging Science Program Director  
Professor  
PhD, University of Chicago  
Biomedical Engineering  

Sam Achilefu (http://orl.wustl.edu/index.php?id=122)  
Michel M. Ter-Pogossian Professor of Radiology  
University of Nancy, France  
Radiology; Biomedical Engineering  

Hongyu An (https://www.mir.wustl.edu/research/research-laboratories/biomedical-magnetic-resonance-laboratory-bmrl/people/bio-an)  
Associate Professor  
PhD, Washington University  
Radiology; Biomedical Engineering  

Beau Ances (https://neuro.wustl.edu/research/research-labs-2/ances-laboratory/team)  
Professor  
MD, University of Pennsylvania  
PhD, University of Pennsylvania  
Neurology; Biomedical Engineering  

Martin Arthur (https://engineering.wustl.edu/Profiles/Pages/Martin-Arthur.aspx)  
Newton R. and Sarah Louisa Glasgow Wilson Professor of Engineering  
PhD, University of Pennsylvania  
Electrical & Systems Engineering  

Deanna Barch (https://psychweb.wustl.edu/people/deanna-barch)  
Gregory B. Couch Professor of Psychiatry  
PhD, University of Illinois  
Psychological & Brain Sciences; Biomedical Engineering  

Phil Bayly (https://engineering.wustl.edu/Profiles/Pages/Philip-Bayly.aspx)  
Lilyan and E. Lisle Hughes Professor of Mechanical Engineering  
PhD, Duke University  
Mechanical Engineering & Materials Science  

Aaron Bobick (https://engineering.wustl.edu/Profiles/Pages/Aaron-Bobick.aspx)  
James M. McKelvey Professor and Dean  
PhD, Massachusetts Institute of Technology  
Computer Science & Engineering
Frank Brooks (https://bme.wustl.edu/faculty/Pages/Frank-Brooks.aspx)
Research Assistant Professor
PhD, Washington University
Biomedical Engineering

Ayan Chakrabarti (https://engineering.wustl.edu/Profiles/Pages/Ayan-Chakrabarti.aspx)
Assistant Professor
PhD, Harvard University
Computer Science & Engineering

Hong Chen (https://engineering.wustl.edu/Profiles/Pages/Hong-Chen.aspx)
Assistant Professor
PhD, University of Washington
Biomedical Engineering

Joe Culver (https://www.mir.wustl.edu/research/research-laboratories/optical-radiology-laboratory-orl/people/joseph-culver)
Professor
PhD, University of Pennsylvania
Radiology; Biomedical Engineering

James Fitzpatrick (http://neurosci.wustl.edu/people/faculty/james-fitzpatrick)
Associate Professor
PhD, University of Bristol, United Kingdom
Cell Biology & Physiology; Biomedical Engineering

Michael Gach (https://radonc.wustl.edu/faculty/michael-gach)
Associate Professor
PhD, University of Pittsburgh
Radiation Oncology; Biomedical Engineering

Roch Guérin (https://engineering.wustl.edu/Profiles/Pages/Roch-Gu%C3%A9rin.aspx)
Harold B. and Adelaide G. Welge Professor of Computer Science
PhD, California Institute of Technology
Computer Science & Engineering

Dennis Hallahan (https://wuphysicians.wustl.edu/for-patients/find-a-physician/dennis-e-hallahan)
Elizabeth H. and James S. McDonnell III Distinguished Professor of Medicine
MD, Rush University
Radiation Oncology; Biomedical Engineering

Tim Holy (http://neurosci.wustl.edu/people/faculty/timothy-holy)
Alan A. and Edith L. Wolff Professor of Neuroscience
PhD, Princeton University
Neuroscience; Biomedical Engineering

Geoff Hugo (https://radonc.wustl.edu/faculty/geoffrey-hugo-phd)
Professor
PhD, University of California, Los Angeles
Radiation Oncology; Biomedical Engineering

Abhinav Jha (https://engineering.wustl.edu/Profiles/Pages/Abhinav-Jha.aspx)
Assistant Professor
PhD, University of Arizona
Biomedical Engineering; Radiology

Tao Ju (https://engineering.wustl.edu/Profiles/Pages/Tao-Ju.aspx)
Professor
PhD, Rice University
Computer Science & Engineering

Ulubek Kamilov (https://engineering.wustl.edu/Profiles/Pages/Ulugbek-Kamilov.aspx)
Assistant Professor
PhD, École Polytechnique Fédérale de Lausanne, Switzerland
Computer Science & Engineering; Electrical & Systems Engineering

Gregory Lanza (https://cardiology.wustl.edu/faculty/gregory-m-lanza-md-phd-facc)
Oliver M. Langenberg Chair, Distinguished Professor of the Science and Practice of Medicine
MD, Northwestern University
PhD, University of Georgia
Medicine; Biomedical Engineering

Associate Professor
PhD, University of Laval, Canada
Radiology

Matthew Lew (https://engineering.wustl.edu/Profiles/Pages/Matthew-Lew.aspx)
Assistant Professor
PhD, Stanford University
Electrical & Systems Engineering

Harold Li (https://radonc.wustl.edu/faculty/harold-li)
Associate Professor
PhD, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany
Radiation Oncology; Biomedical Engineering

Hua Li (https://radonc.wustl.edu/faculty/hua-li-phd)
Assistant Professor
PhD, Huazhong University of Science and Technology, China
Radiation Oncology; Biomedical Engineering
Daniel Marcus (https://www.mir.wustl.edu/research/research-support-facilities/neuroimaging-informatics-analysis-center-niac/our-staff/niac-staff-dan-marcus)
Associate Professor
PhD, Washington University
Radiology; Biomedical Engineering

Sasa Mutic (https://radonc.wustl.edu/faculty/sasa-mutic)
Professor
PhD, University of Missouri-Columbia
Radiation Oncology; Biomedical Engineering

Arye Nehorai (https://engineering.wustl.edu/Profiles/Pages/Arye-Nehorai.aspx)
Eugene and Martha Lohman Professor of Electrical Engineering
PhD, Stanford University
Electrical & Systems Engineering

Jody O’Sullivan (https://engineering.wustl.edu/Profiles/Pages/Joseph-O’Sullivan.aspx)
Samuel C. Sachs Professor of Electrical Engineering
PhD, University of Notre Dame
Electrical & Systems Engineering

Philip Payne (https://publichealth.wustl.edu/scholars/philip-r-payne)
Robert J. Terry Professor
PhD, Columbia University
Medicine; Biomedical Engineering

Jonathan E. Peelle (http://oto.wustl.edu/About-Us/Faculty-Physicians/Jonathan-E-Peele)
Associate Professor of Otolaryngology
PhD, Brandeis University
Otolaryngology

David Piston (https://pistonlab.wustl.edu)
Professor
PhD, University of Illinois
Cell Biology & Physiology; Biomedical Engineering

Yoram Rudy (https://engineering.wustl.edu/Profiles/Pages/Yoram-Rudy.aspx)
Fred Saigh Distinguished Professor of Engineering
PhD, Case Western Reserve University
Biomedical Engineering

Joshua Shimony (https://sites.wustl.edu/nillabs/people/joshuas-shimony)
Professor of Radiology
PhD, University of Tennessee
Department of Radiology

Associate Professor
PhD, University of California, Los Angeles
Radiology; Biomedical Engineering

Monica Shokeen (https://www.mir.wustl.edu/research/research-laboratories/optical-radiology-laboratory-orl/people/bio-page-template/monica-shokeen)
Assistant Professor
PhD, Washington University
Radiology

Associate Professor
PhD, University of California, Los Angeles
Radiology; Biomedical Engineering

David Van Essen (http://dbbs.wustl.edu/faculty/Pages/faculty_bio.aspx?SId=1569)
Alumni Endowed Professor
PhD, Harvard University
Neuroscience; Biomedical Engineering

Elizabeth E. Mallinckrodt Professor of Radiology
MD, Washington University
Radiology

Yong Wang (https://reproductive.wustl.edu/people/yong-wang)
Assistant Professor
PhD, Washington University
Obstetrics & Gynecology; Radiology; Biomedical Engineering

Professor
MD, Duke University
Radiology; Biomedical Engineering

Deshan Yang (https://radonc.wustl.edu/faculty/deshan-yang-phd)
Associate Professor
PhD, University of Wisconsin-Madison
Radiation Oncology; Biomedical Engineering

Tiezhi Zhang (https://radonc.wustl.edu/faculty/tiezhi-zhang-phd)
Assistant Professor
PhD, University of Wisconsin-Madison
Radiation Oncology; Biomedical Engineering

Associate Professor
PhD, University of Cincinnati
Radiology; Biomedical Engineering
Quing Zhu (https://engineering.wustl.edu/Profiles/Pages/Quing-Zhu.aspx)
Professor
PhD, University of Pennsylvania
Biomedical Engineering

Degree Requirements
PhD in Imaging Science

Requirements
- Maintain an average grade of B (GPA 3.0) for all 72 units (up to 24 graduate units may be transferred with approval)
- Complete courses with no more than one grade below B-
- Complete at least one semester-long research rotation
- Become integrated with a research group
- Pass a qualifying exam
- Successfully defend a thesis proposal
- Present and successfully defend a dissertation
- Complete the mentored teaching experience required by the student’s administrative home department

Courses
Required Core Courses (22 units)
- BME/CSE/ESE, Mathematics of Imaging Science (3 units)
- ESE 506, Seminar in Imaging Science and Engineering (1 unit)
- BME 593, Computational Methods for Imaging Science (3 units)
- ESE 589, Biological Imaging Technology (3 units)
- BME/ESE 5907, Theoretical Imaging Science (3 units)
- BME/CSE/ESE, Image Analysis and Data-Driven Imaging (3 units)
- BME/ESE/CSE, Practicum in Computational Imaging (3 units)
- BME 601, Research Rotation (3 units) (refer to Research Rotations (p. 5) section)
- Elective (3 units)

Second Semester
- BME 593, Computational Methods for Imaging Science (3 units)
- ESE 589, Biological Imaging Technology (3 units)
- Elective (3 units) or optional Second Research Rotation – BME 601 (3 units)

Third Semester
- BME 5907, Theoretical Imaging Science (3 units)
- BME/CSE/ESE, Image Analysis & Data-Driven Imaging (3 units)
- Elective (3 units)

Fourth Semester
- BME/ESE/CSE, Practicum in Computational Imaging (3 units)
- Elective or doctoral research (3 units)
- Elective or doctoral research (3 units)

Electives Courses — Computational Imaging & Theory
- BME/ESE, Adaptive Imaging
- BME/ESE, Wave Physics and Applied Optics for Imaging Scientists
- CSE 501N, Programming Concepts and Practice
- CSE 512A, Statistical Computing for Scientific Research
- CSE 511A, Introduction to Artificial Intelligence
- CSE 513T, Theory of Artificial Intelligence & Machine Learning
- CSE 515T, Bayesian Methods in Machine Learning
- CSE 517A, Machine Learning
- CSE 519T, Advanced Machine Learning
- CSE 543T, Algorithms for Nonlinear Optimization
- CSE 546T, Computational Geometry
- CSE 554A, Geometric Computing for Biomedicine
- CSE 555A, Computational Photography
- CSE 559A, Computer Vision
- CSE 566S, High Performance Computer Systems
- ESE 523, Information Theory
- ESE 588, Quantitative Image Processing
- ESE 524, Detection and Estimation Theory
- ESE 518, Optimization Methods in Control

Electives Courses — Imaging Sensors & Instrumentation
- CSE 568M, Imaging Sensors
- BME, Imaging Instrumentation
Electives Courses — Image Formation & Imaging Physics

• BME 591, Biomedical Optics I
• BME 592, Biomedical Optics II
• BME 494, Ultrasound Imaging
• BME 5XX, Advanced Topics in Ultrasound Imaging (To be developed)
• BME 5XX, Magnetic Resonance Imaging (To be developed)
• BME 5XX, Imaging in Nuclear Medicine (To be developed)
• ESE 582/BME 5820 Fundamentals and Applications of Modern Optical Imaging

Electives Courses — Translational Biomedical Imaging

• BME, Therapeutic Applications of Biomedical Imaging
• BME 502, Cardiovascular MRI-Physics to Clinical Application

Electives Courses — Medical Physics

• BME 5071, Radiobiology
• BME 5072, Radiation Oncology Physics
• BME 507, Radiological Physics and Dosimetry
• BME 5073, Radiation Protection and Safety

Approved Life Science Courses

• BME 530A Molecular Cell Biology for Engineers
• BME 503A Cell & Organ Systems
• BME 538 Cell Signal Transduction
• BME 5902 Cellular Neurophysiology
• Biol 4071 Developmental Biology
• Biol 4580 Principles of Human Anatomy & Development
• Biol 4810 General Biochemistry
• Biol 4820 General Biochemistry II
• Biol 5068 Fundamentals of Molecular Cell Biology
• Biol 5319 Molecular Foundations of Medicine
• Biol 5051 Foundations in Immunology (4 units)
• Biol 5053 Immunobiology (4 units)
• Biol 5062 Central Questions in Cell Biology
• Biol 5146 Principles and Applications of Biological Imaging
• Biol/Chem 5147 Contrast Agents for Biological Imaging
• Biol 5224 Molecular, Cell, and Organ Systems
• Biol 5285 Fundamentals of Mammalian Genetics
• Biol 5352 Developmental Biology
• Biol 5488 Genomics
• Biol 5571 Cellular Neurobiology (4 units)
• Biol 5651 Neural Systems
• Biol 5581 Neural Basis of Acoustic Communication
• Biol 404 Laboratory of Neurophysiology
• Biol 548 Nucleic Acids and Protein Biosynthesis
• Biol 5663 Neurobiology of Disease

Approved Mathematics Courses — Any graduate-level course within the Department of Mathematics and Statistics is approved.

Research Rotations

During their first year, students are required to register for and complete at least one research rotation (for 3 units) with program faculty mentors. The research rotation(s) allow students to sample different research projects and laboratory working environments before selecting the group in which they will carry out the PhD dissertation research.

A rotation will be chosen in consultation with program faculty and must be mutually agreeable to both the student and the mentor. At the completion of each rotation, the student must submit to the mentor and director a written report approved by the mentor.

Qualifying Exam

A written qualifying exam will be administered during the spring of their second year of graduate school. The examining committee, who will develop and grade the exams, will consist of three members of the Imaging Science PhD Program Committee. The director of the graduate program will approve the committee, whose members will be suggested by the thesis adviser.

Students will choose three out of the four exam topics:

• Mathematics of Imaging Science
• Imaging Physics & Image Formation Methods
• Image Analysis & Data-Driven Imaging
• Theoretical Image Science

Finding a Thesis Research Mentor

Because the PhD is a research degree, the student is expected to become integrated within a research group. By the end of the first year of study, students should have found a thesis adviser who will oversee their PhD research and assume financial responsibility for stipend, tuition, health insurance, and student fees. The thesis adviser must be a faculty member in the Imaging Science PhD Program Committee with the title of professor, associate professor, or assistant professor. Failure to find a research adviser by May 1 will result in the student being placed on probation that can last up until August 31. During that time, the student must continue to seek a research adviser. Failure to find a research adviser by August 31 will lead to dismissal from the PhD program and termination of funding.

The student’s admission application should include transcripts and letters of evaluation. The Graduate Admissions Committee will review all applications and construct a ranked list of candidates. This list and the associated application packages will be forwarded to the dean of the Graduate School for approval for admission to the program. Following approval by the dean of the Graduate School and the director of the graduate program,
the chair of the Graduate Admissions Committee will notify the students accepted by letter.

**Research Presentation/Thesis Proposal**

Before the end of the student's third year, the student will give an oral presentation of their proposed PhD project, with the necessary background to support it, to the Thesis Committee. This committee will consist of six members. Four members must be members of the Imaging Science PhD Program Committee. At least one committee member must be chosen from outside the Imaging Science PhD Program Committee, and must be a tenured or tenure-track faculty member at Washington University. The committee will be chaired by the PhD mentor. At least two weeks prior to the presentation, the student will present to the Thesis Examination Committee a written document outlining the research background, proposed procedures, preliminary results, and plans for completion. The required document will be typically between 15 and 30 pages in length and must contain a comprehensive bibliography.

The student will be placed on probation if they fail to pass their Thesis Proposal by the sixth semester. The student will be given a second opportunity to pass the exam during their seventh semester. If the student passes the second exam and meets the other program requirements (e.g., grades), they may continue the program without prejudice. If the student fails the exam a second time, they will be terminated from the PhD program.

**Dissertation**

The student will prepare a written dissertation for examination by the Thesis Examination Committee and will defend the dissertation before this committee. Should a member of this committee be unable to participate, the director of the graduate program, in consultation with the PhD mentor, will choose a replacement. If the committee members feel that the dissertation has deficiencies, they may recommend that the candidate address them and send the revised dissertation to the committee members for approval. The committee may also recommend that the candidate present another oral defense of the modified work. The Thesis Committee will inform the director of the graduate program, and they will warn the student in writing that they must submit a revised dissertation and pass the oral defense (if recommended) in order to complete the PhD program. If, after revision and reexamination, the Thesis Committee still finds deficiencies and cannot reach unanimous agreement to approve the dissertation, the Graduate School's Policy on Dissenting Votes will apply.

**Teaching Requirements**

Students in the PhD program will receive formal pedagogical training by attending a minimum of two Teaching Workshops offered by the Washington University Teaching Center (http://teachingcenter.wustl.edu/graduate-students/workshops). They will be expected to fulfill the teaching requirements of their designated administrative home department. The teaching requirements must be completed before the student submits their doctoral dissertation to the Graduate School.

**Courses**

For information regarding courses, please refer to the Degree Requirements (p. 4) section of this page.