**Imaging Science (Interdisciplinary PhD)**

The PhD in Imaging Science program at Washington University in St. Louis is one of only two such programs in the United States. This program offers an interdisciplinary curriculum that focuses on the technology of imaging with applications that range 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 such as 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 in that it brings together expert faculty from the McKelvey School of Engineering (https://engineering.wustl.edu/pages/home.aspx) and the School of Medicine (https://medicine.wustl.edu/) to provide students with the freedom and flexibility to learn from leading imaging experts and to engage in impactful research.

**History**

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

**faculty**

**Jody O’Sullivan**

Co-Director

Samuel C. Sachs Professor of Electrical Engineering

PhD, University of Notre Dame

Electrical & Systems Engineering

**Joe Culver**

Co-Director

Professor

PhD, University of Pennsylvania

Radiology; Biomedical Engineering

**Michel M. Ter-Pogossian**

Associate Professor

PhD, University of Nancy, France

Radiology; Biomedical Engineering

**Hongyu An**

Associate Professor

PhD, Washington University

Radiology; Biomedical Engineering

**Beau Ances**

Professor

MD, University of Pennsylvania

PhD, University of Pennsylvania

Neurology; Biomedical Engineering

**Deanna Barch**

Gregory B. Couch Professor of Psychiatry

PhD, University of Illinois

Psychological & Brain Sciences; Biomedical Engineering

**Phil Bayly**

Lilyan and E. Lisle Hughes Professor of Mechanical Engineering

PhD, Duke University

Mechanical Engineering & Materials Science

**Aaron Bobick**

James M. McKelvey Professor and Dean

PhD, Massachusetts Institute of Technology

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

Hong Chen (https://engineering.wustl.edu/faculty/Hong-Chen.html)
Assistant Professor
PhD, University of Washington
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/faculty/Roch-Guerin.html)
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/faculty/Abhinav-Jha.html)
Assistant Professor
PhD, University of Arizona
Biomedical Engineering; Radiology

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

Ulugbek Kamilov (https://engineering.wustl.edu/faculty/Ulugbek-Kamilov.html)
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/faculty/Matthew-Lew.html)
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

Daniel Marcus (https://www.mir.wustl.edu/research/research-support-facilities/niac/our-staff/niac-staff-dan-marcus/)
Associate Professor
PhD, Washington University
Radiology; Biomedical Engineering

Sasa Mutic
Professor
PhD, University of Missouri-Columbia
Radiation Oncology; Biomedical Engineering

Arye Nehorai (https://engineering.wustl.edu/faculty/Arye-Nehorai.html)
Eugene and Martha Lohman Professor of Electrical Engineering
PhD, Stanford University
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 (https://oto.wustl.edu/people/jonathan-e-peele-phd/)
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/faculty/Yoram-Rudy.html)
Fred Saigh Distinguished Professor of Engineering
PhD, Case Western Reserve University
Biomedical Engineering

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

Kooresh Shoghi (https://www.mir.wustl.edu/research/research-laboratories/radiological-chemistry-and-imaging-laboratory-rcil/people/biotemplate-rcil/kooresh-shoghi/)
Associate Professor
PhD, University of California, Los Angeles
Radiology; Biomedical Engineering

Monica Shokeen (https://www.mir.wustl.edu/research/research-laboratories/optical-radiology-laboratory-ortl/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

Richard Wahl (https://wuphysicians.wustl.edu/for-patients/find-a-physician-richard-leo-wahl/)
Elizabeth E. Mallinckrodt Professor of Radiology
MD, Washington University
Radiology

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

Pam Woodard (https://www.mir.wustl.edu/research/research-laboratories/precision-radio-theranostics-translational-laboratories-prt2/people/pam-woodard/)
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

Jie Zheng (https://www.mir.wustl.edu/research/research-laboratories/cardiovascular-imaging-laboratory-civil/people/civil-faculty/bio-jie-zheng/)
Associate Professor
PhD, University of Cincinnati
Radiology; Biomedical Engineering

Quing Zhu (https://engineering.wustl.edu/faculty/Quing-Zhu.html)
Professor
PhD, University of Pennsylvania
Biomedical Engineering

Professor Emeritus

Newton R. and Sarah Louisa Glasgow Wilson Professor of Engineering
PhD, University of Pennsylvania
Electrical & Systems Engineering
Degree Requirements
PhD in Imaging Science

Requirements
To complete the PhD in Imaging Science, students must do the following:

- Maintain an average grade of B (3.0 grade-point average) 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 their administrative home department

Courses
Required core courses (22 units):

- BME/CSE/ESE Mathematics of Imaging Science (3 units)
- BME 593 Computational Methods for Imaging Science (3 units)
- ESE 506 Seminar in Imaging Science and Engineering (1 unit)
- 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 601C Research Rotation (3 units) (refer to the Research Rotations section later on this page)

Elective imaging courses from any of the following categories (at least 12 units):

- Computational Imaging & Theory
- Imaging Sensors & Instrumentation
- Image Formation & Imaging Physics
- Translational Biomedical Imaging
- Medical Physics

Progression of Courses (Typical)
First Semester

Second Semester

Third Semester

Fourth Semester

Elective Options

Elective Courses — Computational Imaging & Theory
- BME/CSE Adaptive Imaging
- BME/CSE Wave Physics and Applied Optics for Imaging Scientists
- CSE 501N Programming Concepts and Practice
- 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 524 Detection and Estimation Theory
- ESE 588 Quantitative Image Processing

Elective Courses — Imaging Sensors & Instrumentation
- BME Imaging Instrumentation

Elective Courses — Image Formation & Imaging Physics
• BME 494 Ultrasound Imaging
• BME 591 Biomedical Optics I
• 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

Elective Courses — Translational Biomedical Imaging
• BME Therapeutic Applications of Biomedical Imaging

Elective Courses — Medical Physics
• BME 507 Radiological Physics and Dosimetry
• BME 5071 Radiobiology
• BME 5072 Radiation Oncology Physics
• BME 5073 Radiation Protection and Safety

Approved Life Science Courses
• BME 503A Cell & Organ Systems
• BME 530A Molecular Cell Biology for Engineers
• BME 538 Cell Signal Transduction
• BME 5902 Cellular Neurophysiology
• Biol 404 Laboratory of 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 5053 Immunobiology (4 units)
• 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 548 Nucleic Acids and Protein Biosynthesis
• Biol 5488 Genomics
• Biol 5571 Cellular Neurobiology (4 units)
• Biol 5651 Neural Systems
• 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 (3 units) with program faculty mentors. The research rotations 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 the student’s second year of graduate school. The examining committee, which will develop and grade the exam, will consist of three members of the Imaging Science PhD Program Committee. The director of the graduate program will approve the committee, the members of which will be suggested by the thesis adviser.

Students will choose three out of the following 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 their stipend, tuition, health insurance and student fees. The thesis adviser must be a faculty member on 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 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 who have been accepted by letter.
Research Presentation/Thesis Proposal

Before the end of their 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 of the Imaging Science PhD Program Committee, and this individual 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 typically be between 15 and 30 pages in length, and it 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 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 the student 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 (https://teachingcenter.wustl.edu/events/). 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.