



WPI

Mathematical Sciences at WPI

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Mathematical Sciences
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What do Mathematicians Do?

"The universe cannot be read until we have learned the language and become familiar with the characters in which it is written. It is written in mathematical language, and the letters are triangles, circles and other geometrical figures, without which means it is humanly impossible to comprehend a single word. Without these, one is wandering about in a dark labyrinth"

Galileo Galilei (1564-1642)

Through their work, Mathematicians build a language that allows us to experience in a quantitative and self consistent fashion the complexity of nature. The language is used by Physicists, Engineers, Economists,...

A powerful language: Calculus



Gottfried Wilhelm Leibniz (1646-1716)

Isaac Newton (1643-1727)



Math allows us to experience infinity

Normal numbers are special numbers in which every sequence of digits will sooner or later appear in their decimal representation.

For instance the number

0.12345678910111213....

has this property.

What do they have to do with understanding infinity?

Math allows us to experience infinity

This number contains any discrete data imaginable.

For instance... your SSN, all your credit card numbers...



Math allows us to experience infinity

This screenshot, is represented in the pdf file as a list of 0 and 1 and so it is encoded as a number which is contained in any normal number.

Any image that can be represented in this way is contained in any **normal** number...

Math allows us to experience infinity



This number contains any possible picture of you as a baby

... as well as all other babies in history

Math allows us to experience infinity



This number contains any possible sound, encoded as mp3 file. This means any performance of any song ...

... any piece of music that has ever been written

... Any tune you have ever whistled in the shower ...

Math allows us to experience infinity

Mathematicians can prove that **ALMOST EVERY NUMBER** (in a precise mathematical sense) has this property, but currently we do not have any algorithm to decide whether a given number, for instance π , is normal or not.

Why study Mathematics?

In 1960 Physics Nobel prize
Eugene Wigner wrote a famous
article in which he observed how
Mathematical Structures used to
model Physical Theories often
(and inexplicably) lead to further
advances in that theory.

COMMUNICATIONS ON PURE AND APPLIED MATHEMATICS, VOL. XIII, 001-14 (1960)

The Unreasonable Effectiveness of Mathematics in the Natural Sciences

Richard Courant Lecture in Mathematical Sciences delivered at New York University,
May 11, 1959

EUGENE P. WIGNER
Princeton University

*"and it is probable that there is some secret here
which remains to be discovered." (C. S. Peirce)*

There is a story about two friends, who were classmates in high school, talking about their jobs. One of them became a statistician and was working on population trends. He showed a reprint to his former classmate. The reprint started, as usual, with the Gaussian distribution and the statistician explained to his former classmate the meaning of the symbols for the actual population, for the average population, and so on. His classmate was a bit incredulous and was not quite sure whether the statistician was pulling his leg. "How can you know that?" was his query. "And what is this symbol here?" "Oh," said the statistician, "this is π ." "What is that?" "The ratio of the circumference of the circle to its diameter." "Well, now you are pushing your joke too far," said the classmate, "surely the population has nothing to do with the circumference of the circle."

Naturally, we are inclined to smile about the simplicity of the classmate's approach. Nevertheless, when I heard this story, I had to admit to an eerie feeling because, surely, the reaction of the classmate betrayed only plain common sense. I was even more confused when, not many days later, someone came to me and expressed his bewilderment¹ with the fact that we make a rather narrow selection when choosing the data on which we test our theories. "How do we know that, if we made a theory which focusses its attention on phenomena we disregard and disregards some of the phenomena now commanding our attention, that we could not build another theory which has little in common with the present one but which, nevertheless, explains just as many phenomena as the present theory." It has to be admitted that we have not definite evidence that there is no such theory. The preceding two stories illustrate the two main points which are the

¹The remark to be quoted was made by E. Wigner when he was a student in Princeton.

Medical imaging and math

- At the heart of every medical imaging technology is a sophisticated mathematical model of the measurement process and an algorithm to reconstruct an image from the data.
- Key Mathematical instrument is the inverse of the Radon Transform

Johann Radon (1887-1956)

Radon Transform introduced
In 1917. A long time before
The technology for medical
Imaging was developed.

This is an example of how
“pure” math becomes
“applied” math over centuries



J. Radon

Why study Mathematics?

- Because you are drawn to logical analysis, patterns and structure (you have the “math gene”).
- Because it is a powerful and beautiful language that can be used to model and predict systems from biology, physics, engineering, ...
- Because it opens up a wide range of appealing job opportunities...

Why study Mathematics?

Competitive

Salaries

Statistics is #13, and
Applied Math is #16

Top Ten Majors
by Salary potential.
www.payscale.com 2018

Rank ▲	Major	Degree Type	Early Career Pay ?	Mid-Career Pay ?	% High Meaning ?
1	Petroleum Engineering	Bachelor's	\$94,600	\$175,500	65%
2	Actuarial Mathematics	Bachelor's	\$56,400	\$131,700	49%
3	Actuarial Science	Bachelor's	\$61,200	\$130,800	43%
4	Nuclear Engineering	Bachelor's	\$69,000	\$127,500	72%
5	Chemical Engineering	Bachelor's	\$70,300	\$124,500	57%
6	Marine Engineering	Bachelor's	\$73,900	\$123,200	68%
7	Economics and Mathematics	Bachelor's	\$60,000	\$122,900	36%
8	Geophysics	Bachelor's	\$54,100	\$122,200	N/A
9	Cognitive Science	Bachelor's	\$54,000	\$121,900	40%
10	Electrical Power Engineering	Bachelor's	\$68,600	\$119,100	70%
11 (tie)	Aeronautical Engineering	Bachelor's	\$65,300	\$118,800	61%
11 (tie)	Electrical & Computer Engineering (ECE)	Bachelor's	\$69,000	\$118,800	51%
13	Computer Systems Engineering	Bachelor's	\$72,000	\$118,000	N/A
14 (tie)	Bioengineering (BioE)	Bachelor's	\$61,600	\$116,800	68%
14 (tie)	Computer Science (CS) & Engineering	Bachelor's	\$70,900	\$116,800	42%

Salaries of 2017 WPI grads

- WPI wide employment rate is 91.7%
- WPI wide BS grads salary: \$66,983
- **Math Sciences grads: \$67,500 - Higher than the average.**
- **Math is ranked #9 among over 90 WPI majors and programs in terms of initial salary.**

Wall Street Journal Article

2014 Ranking of the Best and Worst Jobs



1. MATHEMATICIAN

Applies mathematical theories and formulas to teach or solve problems in a business, educational, or industrial climate.

2. STATISTICIAN

Tabulates, analyzes, and interprets the numeric results of experiments and surveys.

3. ACTUARY

Interprets statistics to determine probabilities of accidents, sickness, death, & property loss from theft & natural disasters.

Where do Mathematicians Work?

- Arts, entertainment, and recreation
- Education
- Finance and insurance
- Government
- Health care and social assistance
- Information technology
- Legal services
- Management of companies & enterprises
- Manufacturing
- Nonprofit
- Other science and technology
- Retail trade
- Transportation & warehousing
- Utilities

<http://www.ams.org/early-careers/>

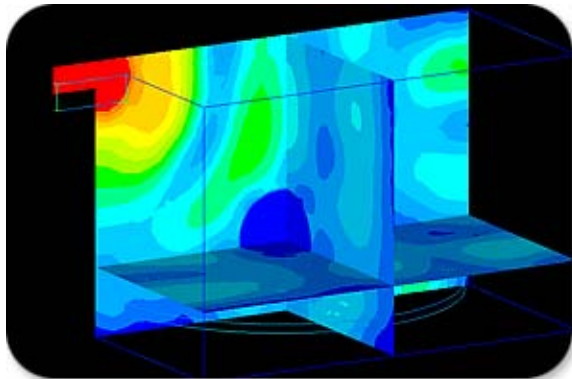


AMS

American Mathematical Society

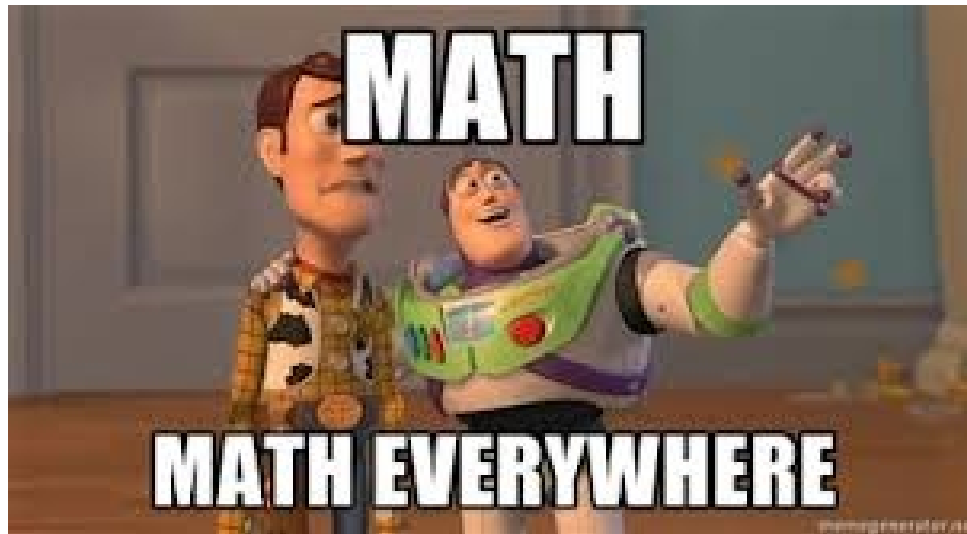
Mathematics and Big Data

Analysis of large sets of data, be they genetic markers (220 millions base pairs) or Netflix preferences (matrix composed of 50 millions rows and about 20,000 columns), is carried out through an intense use of mathematics and statistics.



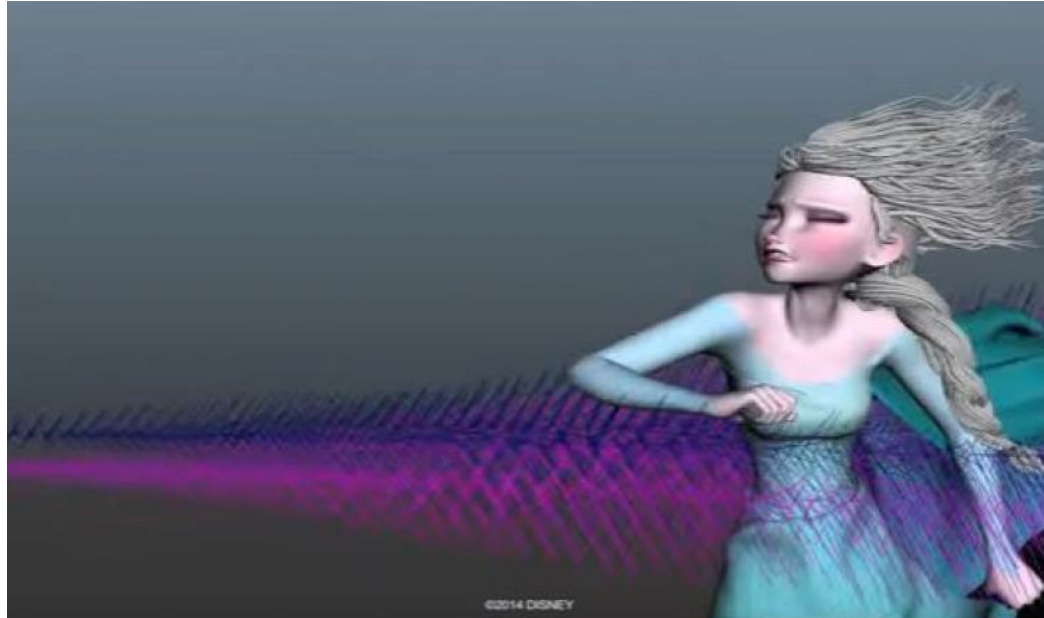
WPI's DATA SCIENCE
program blends Math, CS
and business

Mathematics in Entertainment



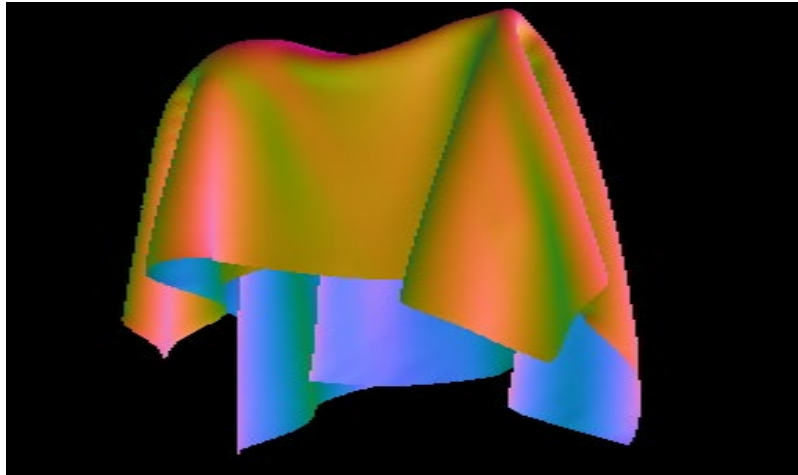
100 powerful supercomputers perform geometrical, algebraic and calculus-based calculations to animate Pixar's characters.

Mathematics in Entertainment



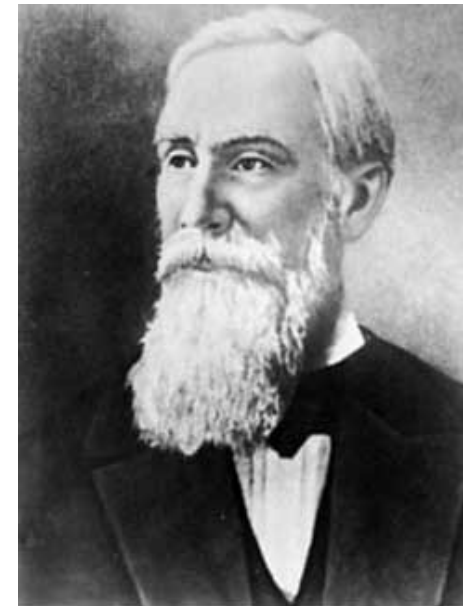
Aleka McAdams, a mathematician working at Disney Studios used math modeling and computational physics to do realistic hair simulations in the movies Tangled and Frozen

Mathematics in Entertainment



The laws of physics that describe the dynamics of fabric movement are modeled by mathematicians and used in computer graphics and in animations.

Pafnuty Chebyshev



What is Math Used For?

- Automobile and aircraft design
- Oil recovery
- Understanding cardiovascular diseases
- Understanding the spread of diseases
- Bringing architectural design to reality
- Understanding movement of bird flocks
- Predicting climate and weather
- Figuring out the best way to board an airplane
- Manufacturing better eyeglass lenses
- Finding the effects of voting procedures on election results
- Computer graphics and animation
- Internet encryption
- Data storage on CDs and DVDs
- Designing efficient water purification systems

<http://www.ams.org/mathmoments>



AMS

American Mathematical Society

Mathematical Sciences @WPI

- Mathematical Sciences Major
 - Mathematics; Statistics (MA degree)
 - Actuarial Mathematics (MAC degree)
- Mathematics minor
- Statistics minor

- It is also a required foundation for studying engineering, physics, technology, management, finance,...

Mathematical Sciences Department

- 105+** Undergraduates
- 110+** Graduate students (MS and PhD)
- 29+** Tenured & Tenure-Track Faculty
- 8** Postdoctoral Scholars
- 8** Teaching Professors

In recent years:

10 NSF research awards, 2 NIH awards, 1 Air Force award, 1 NSF REU, 1 NSF MPI, and several others.

3 NSF CAREER Fellows

2015 Trustees' Award for Outstanding Service to the Community

2010, 2015 Trustees' Award for Outstanding Research & Scholarship

2007, 2008, 2010 Trustees' Award for Outstanding Teaching

2008 Kalenian Award for Entrepreneurship & Innovation

2007, 2016 Trustees' Award for Outstanding Academic Advising

Mathematical Sciences Program

Mathematical Sciences

- *Algebra/Discrete Mathematics*
- *Math Modeling/Applied Math*
- *Mathematical Biology.*
- *Analysis, Calculus of Variations, Computational Mathematics.*
- *Financial Mathematics*
- *Statistics-Probability*

Actuarial Mathematics

Joint Programs

- Bioinformatics
- Data Science

BS/MS Programs

- *Applied Math*
- *Applied Statistics*
- *Financial Math*
- *Industrial Math*

Minors in Math or Statistics

Faculty Research

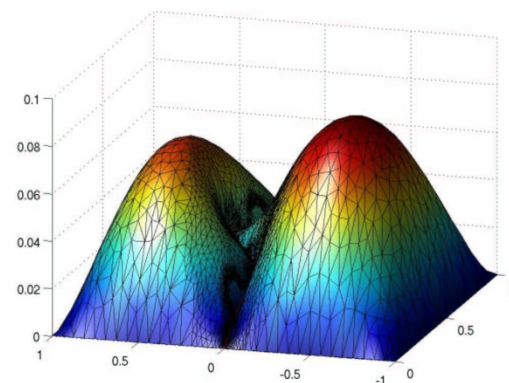
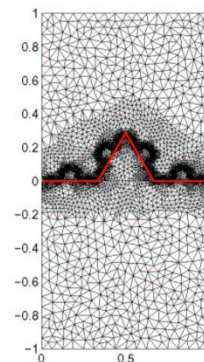
Actuarial Mathematics

Algebra/Discrete Mathematics

- Abstract Algebra
- Coding Theory and Cryptography
- Graph Theory and Combinatorics

Analysis/Differential Equations

- Calculus of Variations
- Free and Moving Boundary Problems
- Mathematical Physics
- Partial Differential Equations
- Stochastic Analysis



Faculty Research

Financial Mathematics

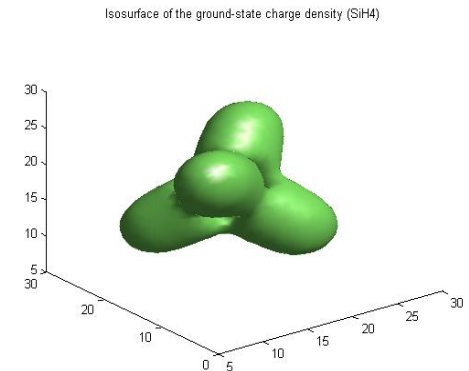
- Systemic Risk

Mathematics of Materials Science

- Composite Materials/Homogenization
- Fracture and Damage
- Mathematical Geophysics
- Porous Electrodes (fuel cells, batteries)

Numerical Analysis/Computational Modeling

- Computational Modeling
- Large Scale and Parallel Computing
- Numerical Analysis



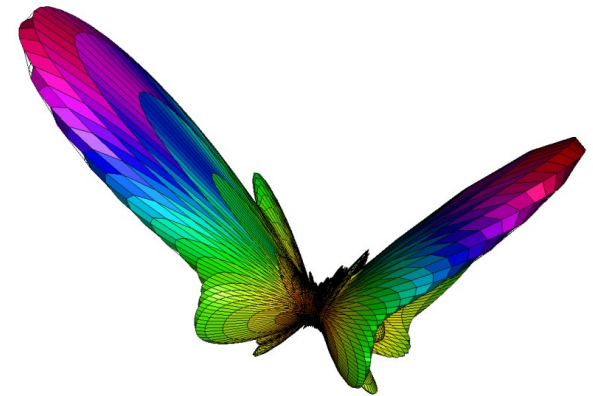
Faculty Research

Mathematical Biology

- Cardiovascular Modeling and Biomechanics
- Cell Motility
- Population Dynamics

Statistics

- Bayesian Statistics
- Biostatistics and Bioinformatics
- Statistical Decision Theory & High-dimensional Data Analysis
- Statistical Genetics
- Survey Methodology
- Time Series



Where our graduates go...

- Industry
 - Raytheon, Pratt & Whitney, General Mills ...
 - Microsoft, Alphatech, MathWorks, ...
 - Harrah's Entertainment, ...
- Actuarial and financial careers
 - Aetna, Allmerica, Sun Life, Hanover, Unum, ...
 - Fidelity Investments, Putnam, HIMCO, ...
- Consulting firms
 - Accenture, Towers-Perrin, SAIC, ...
- Graduate schools
 - Berkeley, Brown, Cambridge, Carnegie Mellon, Cornell, Duke, Harvard, Johns Hopkins, NC State, NYU/Courant, Princeton, Purdue, Stanford, U. Maryland, UC Santa Barbara, WPI ...

WPI Undergraduate Experience

- Flexibility with four terms per year
- Close interaction with faculty
- Collaborating with faculty active in fundamental research (MQP)
- Good job and graduate school prospects

WPI First Year Focus

- **Mathematics**
- **Science**
- **Humanities or Social Science**

First Year Mathematics

- Traditional Calc Sequence [MA1021-1024](#)
- Calculus with Review [MA1020, 1120](#)
- Analysis Sequence [MA1033-1034](#)
- Bridge to Higher Math [MA1971](#)
- Linear Algebra, Differential Equations, Probability, Statistics...

“Traditional” Calculus MA1021-1024

- MA1021 – Derivatives and applications
- MA1022 – Integrals and applications
- MA1023 – Infinite Series, Parametric Curves, Vectors
- MA1024 – Partial Derivatives and Multiple Integrals

All are term-length courses for 1/3 unit credit

Calculus with Pre-Calculus Review

- **MA1020** – Derivatives and applications
 - Semester-long (14 weeks) course in the fall
 - Pre-Calculus Review!
- **MA1120** – Integrals and applications
 - Semester-long course in the spring

The Analysis Sequence

MA1033 in A term, MA1034 in B term,

- Rigorous treatment of calculus III and IV (with proofs)
- Appropriate for math majors and those who want the theory behind the calculus

MA1971: Bridge to Higher Mathematics

- Introduction to mathematical thinking
- Develop mathematical logic and reasoning skills
- Learn to explain, justify, defend, disprove, conjecture and verify mathematical ideas, both verbally and in writing
- Recommended for all Mathematical Sciences majors (MA & MAC)

Advanced Placement Credit

- **College Transfer Credit**
- **Advanced Placement (AP) Exam**
- **WPI Retroactive Credit**

AP Exam Credit

- 4 or 5 on AB exam
 - Credit for Calculus I and Calculus II
 - Take Calculus III in A term
 - Take Calculus IV in B term
- 4 or 5 on AB exam
 - Credit for Calculus I, II, and III
 - Take special Calculus IV in A term
 - Take special Differential Equations in B term
 - Take special Linear Algebra MA2072 in C term

Retroactive Credit

- Get free **credit for Calculus I** if*
 - Take and **pass Calculus II** in first year
 - Take and **pass Calculus III** in first year
- Get free **credit for Calculus I and II** if*
 - Take and **pass Calculus III** in first year
 - Take and **pass Calculus IV** in first year

* No changes and no substitutes, no math NRs

For Math Majors after the First Year

- Choose a Concentration... Transition Courses
 - Math Modeling with Differential Equations
 - Graph Theory, Combinatorics
 - Probability Theory
 - Linear Algebra II
- Upper Level Courses for breadth and depth
- Major Qualifying Project as a capstone

Some Mathematical Sciences MQPs

- Mathematical Model of Brain Tumors
- Differential power analysis side-channel attacks in cryptography
- Robustifying Logistic Regression for Nonresponse: An Application to BMI
- One-dimensional Viscoelastic Cell Motility Model
- Optimal Portfolio Analysis with Turnover Constraints
- Optimization of the Sierpinski Carpet Fractal Antenna
- An Investigation of Polya's Function
- Regulatory Network Models for Biology
- Thin-film Ferrofluidics
- Nanoionic Particle Composite Homogenization
- Network Anomaly Detection Using Robust Principal Component Analysis
- Calibration of an Optimal Bidding Model for the Mobile Advertisement Markets

BS/MS Programs

We have two BS/MS programs, which enable students to obtain both a BS and MS degree with 5 years of study:

- The 5-year BS/MS Program
- The “standard” BS/MS Program

The 5-year BS/MS Program

- Exclusive to Math Sciences Dept
- Apply when applying for admission as a freshman
- If accepted, progress reviewed in junior year
- Work as a PLA while an undergraduate
- 5th year is tuition-free; work as half-time TA
- Available for Financial Math, Industrial Math, Applied Math, & Applied Statistics MS programs.

“Standard” BS/MS Program

- Apply in junior year
- If accepted, can double-count courses to enable BS and MS in 5 years
- Available for the following Math Sciences MS programs:
 - Applied Mathematics
 - Applied Statistics
 - Financial Mathematics
 - Industrial Mathematics

Mathematical Sciences Minors

- **Can minor in Mathematics or Statistics**
- **Take 5 Courses + 1 Capstone**

Center for Industrial Mathematics and Statistics



- Build connections between academics and business and industry
- Students work on real-world projects that come directly from industry, government and finance

<http://www.wpi.edu/+CIMS>

PRATT & WHITNEY



UTRC



IBM T.J. Watson Research Center

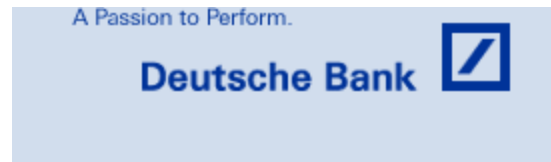


BOSE



CIMS Industrial Partners

200+ students have worked on
110+ industrial projects from
50+ companies



For More Information

<http://www.wpi.edu/+MATH>