NUS Computing
Any sufficiently advanced technology is indistinguishable from magic.

- Arthur C. Clarke

Computing’s Reach

The alarm rings, we reach for our mobile phones to turn it off and check for messages. At breakfast, we scroll through news headlines and social media news feeds. When we step out the door, an app tells us when the next bus will arrive. On our daily commute, we respond to emails, catch up on our reading or try to get to the next level of that addictive game. And then we get to work and turn on our computers...

We are living in the Age of Computing, and yet people seem unaware of how extensively we rely on Computing, how quickly it is developing, and its awe-inspiring potential to revolutionise every aspect of life as we know it. Computing is enjoyed by most, but understood by few. Everyone uses Computing to communicate, work, travel; spend, invest, heal, build, entertain… and every industry is using Computing to enhance performance and productivity. With its inevitable ubiquity, understanding Computing will be as critical as literacy, even if most people don’t realise it yet.

As did steam power, electricity, and the internal combustion engine before it, Computing is the new general purpose technology that is allowing us to re-imagine the way we live, work, connect, and create.
The All-Access Pass

With that kind of growth, and its pervasiveness, there is a massive demand for Computing talent across all industries, across the globe. Computing is one of the few disciplines that can blend with and complement any other field to potentially propel performance to new heights. No other discipline affords access into all industries like Computing does. The problem is that there just aren’t enough people who are trained with these skills today. There is a dearth of computing talent. Supply is not meeting Demand. Correspondingly, many Computing jobs are consistently listed, not only as the best paid, but also simply the best jobs to have in Singapore, and the world.

We are only just beginning to see Computing’s impact on our lives. The advent of autonomous cars and accurate computerised translations are only the first examples of the kinds of revolutionary technology that will emerge as Computing’s astounding exponential growth continues. Every day, Computing experts are revealing machines and software that are successfully performing tasks that were unachievable only a few years ago. Since Computing is fundamentally about helping people solve problems with technology, it can exist anywhere and in any field.
NOT JUST GEEKS
Because Computing can exist in and augment all industries, we need Computing experts of all types. Entrepreneurs, Math-Whizzes, Artists, Doctors, Builders, Business Executives, Scientists, Writers, Athletes, Musicians, Designers, Film-Makers, Conservationists, Farmers, Teachers, Inventors, Financiers... whatever your propensity, Computing will teach you how to think and equip you with the skills that will give you an edge in whatever you do.

When you enter one of our many comprehensive programmes, which range from Business Analytics to Computer Engineering, you will be part of a diverse community made up of enthusiastic, well-rounded, and versatile students, alumni, and faculty, of myriad personalities, aptitudes, and interests.

With Computing, you could write lines of code or design systems that will impact the lives of millions. Computing offers the fastest and simplest way to transform an idea in your mind into a physical, functioning product, and then share it with millions around the world, in a click. If you can create technology, you can change the world.

Some people say it’s the closest thing we have to a superpower.

Most people might have the misconception that computing students are made up of mostly nerds and geeks, and that’s not true! NUS Computing students really know how to have fun and are always actively participating in school activities. Sure, we know how to study hard, but also play harder!
We are consistently ranked among the world’s leading Computing schools.

Guaranteed Symonds World University Rankings by Subject
Times Higher Education World University Rankings by Subject

Degree Programmes

Bachelor of Computing in **Computer Science** (with Honours*)
- Turing Programme
- Von Neumann Programme

Bachelor of Computing in **Information Systems** (with Honours*)

Bachelor of Engineering in **Computer Engineering** (with Honours*)

Bachelor of Science in **Business Analytics** (with Honours*)
- Co-Operative Education Programme (Co-Op)

Bachelor of Computing in **Information Security** (with Honours*)
- Co-Operative Education Programme (Co-Op)

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**Double Bachelor’s Degree Programmes**

Bachelor of Computing in **Computer Science** / **Information Systems**
- Bachelor of Business Administration, with NUS Business School

Bachelor of Computing in **Computer Science** / **Information Systems**
- Bachelor of Business Administration (Accountancy**), with NUS Business School

Bachelor of Computing in **Computer Science**
- Bachelor of Science in Mathematics/Applied Mathematics, with NUS Faculty of Science

**subject to meeting CAP requirements after first year**

**Concurrent Bachelor’s & Master’s Degree Programmes**

Bachelor of Computing in **Information Systems**
- Master of Science in Engineering & Technology Innovation Management, with Carnegie Mellon University

Bachelor of Computing in **Computer Science** / **Information Systems**
- Master of Science (Management), with NUS Business School in Management

**Bachelor’s & Double Master’s Degree Programmes**

Bachelor’s & Master’s degrees in **Computer Science** / **Information Security** / **Computer Engineering** / **Business Analytics**
- French Grandes Écoles Diplôme d’Ingénieur

*subject to meeting requirements*
**Double Majors & Minors (Direct Entry)**

**Bachelor of Computing in Computer Science**
- a second major in Mathematics, with Faculty of Science
- a second major in Statistics, with Faculty of Science
- a minor in Interactive Media Development, with Faculty of Arts & Social Sciences
- a minor in Entrepreneurship, with NUS Business School
- a minor in Management, with NUS Business School
- a minor in Mathematics, with Faculty of Science
- a minor in Statistics, with Faculty of Science

**Bachelor of Computing in Information Systems**
- a second major in Economics, with Faculty of Arts & Social Sciences
- a minor in Economics, with Faculty of Arts & Social Sciences
- a minor in Interactive Media Development, with Faculty of Arts & Social Sciences
- a minor in Entrepreneurship, with NUS Business School
- a minor in Management, with NUS Business School

**Bachelor of Engineering in Computer Engineering**
- a second major in Management, with NUS Business School
- a second major in Innovation & Design, with Faculty of Engineering
- a second major in Systems Engineering, with Faculty of Engineering
- a second major in Mathematics, with Faculty of Science
- a second major in Statistics, with Faculty of Science
- a minor in Economics, with Faculty of Arts & Social Sciences
- a minor in Entrepreneurship, with NUS Business School
- a minor in Management, with NUS Business School
- a minor in Financial Mathematics, with Faculty of Science
- a minor in Statistics, with Faculty of Science

**Bachelor of Science in Business Analytics**
- a second major in Economics, with Faculty of Arts & Social Sciences
- a second major in Mathematics, with Faculty of Science
- a second major in Statistics, with Faculty of Science
- a minor in Economics, with Faculty of Arts & Social Sciences
- a minor in Entrepreneurship, with NUS Business School
- a minor in Information Security, with School of Computing
- a minor in Real Estate, with School of Design & Environment
- a minor in Financial Mathematics, with Faculty of Science
- a minor in Statistics, with Faculty of Science

**Bachelor of Computing in Information Security**
- a second major in Mathematics, with Faculty of Science
- a second major in Statistics, with Faculty of Science
- a minor in Entrepreneurship, with NUS Business School
- a minor in Management, with NUS Business School
- a minor in Financial Mathematics, with Faculty of Science
- a minor in Mathematics, with Faculty of Science
- a minor in Statistics, with Faculty of Science

Alternatively, pair any non-Computing NUS degree programme with a second major or minor in Computer Science / Information Systems / Business Analytics / Information Security.

You know that this is the Age of Computing and it permeates all fields, from the sciences, like medicine and agriculture, to the arts, like law and music. To have an edge over everyone else in your field, it makes sense to capitalise on this ubiquitous technology and pair it with your interests; it makes sense to speak the language—the lingua franca—of the modern economy.

Imagine what you could do with a killer combination like that.
Scholarships, Awards & Financial Aid

NUS Scholarships & Aid
School of Computing Scholarship
Kwan Im Thong Hood Cho Temple Computing Scholarship
Lim Hong Chin Memorial Scholarship
Asia Fusion Technology Scholarship
LBKM Future Economy Scholarship
National Infocomm Scholarship
Singapore International Pre-Graduate Award
NEW Scholarship
SingTel Analytics/Cyber Security Undergraduate Scholarship
SNCF Co-Operative Scholarship
SoC Pay-It-Forward Bursary
Computing Alumni Assistance Award
Computing Student Development Fund

Internships

Advanced Technology Attachment Programme (ATAP)
Student Internship Programme (SIP)
Industry Internship Programme (IIP)
Co-Operative Education Programme (Co-Op)

Enrichment Programmes

NUS Overseas College (NOC)
Student Leadership Programme (SLP)
University Scholars Programme (USP)

Industry Exposure

SoC Term Project Showcase
SoC Career Fair
Orbital: Independent Software Engineering (Summer) Project
ADMISSIONS REQUIREMENTS

Please refer to NUS Office of Admissions (www.nus.edu.sg/admissions) for complete admissions requirements and subject prerequisites.

Bachelor of Computing in:

Computer Science (CS)

or

Information Security (ISC)

- Singapore-Cambridge ‘A’-Levels:
  - H2 pass in Computing or Mathematics or Physics;
  - OR a good pass in H1 Mathematics
- Polytechnic Diplomas: All Diplomas
  (except Advanced Diplomas/Specialist Diplomas/Certificate Courses)
- NUS High School Diploma:
  - A good major CAP in Mathematics or Physics
- International Baccalaureate Diploma:
  - Pass in HL Computer Science/Mathematics/Physics;
  - OR a good pass in SL Mathematics

Bachelor of Computing in:

Information Systems (IS)

- Singapore-Cambridge ‘A’-Levels:
  - H2 pass in Computing; OR a good pass in H1 Mathematics
- Polytechnic Diplomas: All Diplomas
  (except Advanced Diplomas/Specialist Diplomas/Certificate Courses)
- NUS High School Diploma:
  - A good major CAP in Mathematics
- International Baccalaureate Diploma:
  - Pass in HL Computer Science; OR a good pass in SL Mathematics

Bachelor of Engineering in:

Computer Engineering (CEG)

(jointly offered with fHSE)

- Singapore-Cambridge ‘A’-Levels:
  - H2 pass in Mathematics and either Physics*, Computing or Chemistry
- Polytechnic Diplomas:
  - Please refer to NUS Office of Admissions
- NUS High School Diploma:
  - A good major CAP in Mathematics and either Physics* or Chemistry
- International Baccalaureate Diploma:
  - Pass in HL Mathematics and either HL Physics or Chemistry

*Students without H1 or H2 Physics need to have an O-Level pass in Physics or its equivalent and would be required to take Physics bridging module(s).

#Students without Major subject in Physics need to have ‘O’ level Physics or equivalent and would be required to take specified Physics bridging modules.

Bachelor of Science in:

Business Analytics (BA)

(an interdisciplinary programme in collaboration with BIZ, FAS, FASS, FAdS)

- Singapore-Cambridge ‘A’-Levels:
  - H2 pass in Mathematics
- Polytechnic Diplomas:
  - Please refer to NUS Office of Admissions
- NUS High School Diploma:
  - A good major CAP in Mathematics
- International Baccalaureate Diploma:
  - Pass in HL Mathematics
I chose to study Computer Science because I strongly believed in taking up the challenge of possibly a very demanding, but highly rewarding undergraduate course. My advice to future undergraduates is to come in with an open mind and lots of perseverance. As they say, ‘Don’t limit your challenges, challenge your limits’.

WHAT YOU COULD BE

Software Engineer at Google
Applications Developer at Barclays Capital
IT Security Specialist at DSTA
Application Programmer at Ubisoft
Software Developer at successful start-ups like Viki or Garena
Start-up Founder
Graduate Student at UC Berkeley, CMU, MIT or Stanford

SNEAK PEEK

You’re halfway into your third year and are in your favourite class, CS3216 Software Product Engineering for Digital Markets. Today’s guest speaker is an NUS Computing alumnus who describes how he studies in artificial intelligence, computational geometry, and human computer interaction allowed him to develop an intuitive gesture system for an iPad game while he was a student here. You listen with interest as he describes how he founded a company to develop the game into a highly profitable, chart topping mobile app. After class, you chat with your project teammate about your idea to reduce manpower needs in restaurants by using customers’ mobiles for ordering and billing. You discuss your concerns about the potential trade-off between customer service and manpower savings while you are rushing to your next class, CS3244 Machine Learning. While the professor is describing the hidden Markov model, you feel a tap on your shoulder. It’s your teammate, and she whispers, “Why not have the phone learn the customer’s preferences so that they can order easily?” Brilliant! Instead of compromising on service, your app may end up improving the dining experience. You realise that your class project may turn into a real, money-making product.

Sampler of Modules

CS1101S Programming Methodology
Experience our unique ‘gamified’ introductory programming course where you take on challenging missions to level up and occasionally meet Sumbots, Jedi Knights, and Darth Vader.

CS2104 Programming Language Concepts
How do you design a programming language? How do you get the same program to run on different hardware? Delve into the languages of the future.

CS2106 Introduction to Operating Systems
Understand how different processes and up in a deadlock via the adventures of dining philosophers who starve because they cannot coordinate the use of their chopsticks.

CS2107 Introduction to Information Security
How are websites hacked? Are there unbreakable codes? How are human vulnerabilities exploited in social engineering attacks? Decipher and master the intricacies of IT security.

CS3230 Design & Analysis of Algorithms
How do you design blazing fast applications? Can some well-known problems be solved quickly? Prove or disprove that and you will win the first Millennium Prize and a million dollars.

CS3243 Introduction to Artificial Intelligence

CS3247 Game Development
Learn the underlying principles and theories that you will use to make the next great game that captures the world’s imagination!
I chose to pursue a course in Information Systems because it amazes me how technology can continue to progress and evolve, making the world a better place. I did a diploma in Business Studies back in Polytechnic, and there are so many different ways companies can use IT to run their businesses much more effectively and efficiently. The curriculum offered in Information Systems allows me to equip myself with the necessary skills and knowledge to contribute to the Business-IT sector.

**WHAT YOU COULD BE**

- Finance Analyst at Goldman Sachs
- Manager at International Enterprise Singapore
- Consultant at Accenture
- Associate Consultant at KPMG
- IT Specialist at IBM (Global Technology Services)
- Developer Evangelist at Microsoft
- Technology Associate at Singapore Exchange

**SNEAK PEEK**

You are close to completing your project for IS4103 Information Systems Capstone Project. You and your teammates have been enthusiastically developing a hospitality management system for an integrated resort chain. While you have always enjoyed participating in hackathons, developing an enterprise-level system in a team is a completely different challenge.

You check if you have your tie for the IS4103 project presentation today. You want to look sharp, and present with confidence! After your presentation, you meet with representatives for whom you are setting up and managing a retail company’s Facebook fan page, as part of your IS3150 Digital Media Marketing project. You are enjoying the experience of a real-life industry project that needs not only computer coding skills, but also an in-depth understanding of the retail business, as well as marketing aspects on social media platforms. Thanks to Information Systems, you have developed the confidence to innovate business with IT solutions that you can design, acquire, and market. You have no doubt that the rigorous education you are receiving now will put you in good stead for a career as a business leader with deep technology insights.

**SAMPLE OF MODULES**

- **IS2102 Enterprise Systems Architecture & Design**
  Learn the critical skillsets of architecting and designing modern large-scale Enterprise Systems that are complex, scalable, distributed, component-based, and mission-critical.

- **IS3103 Information Systems Leadership & Communication**
  Gain a deep understanding of the key drivers of strategic innovation, effective leadership, and communication skills to integrate novel technologies with business objectives.

- **IS3150 Digital Media Marketing**
  Develop the skills and know-how for social media analytics, market analysis, consumer behaviour, and customer relationship management for successful digital marketing campaigns.

- **IS3251 Principles of Technology Entrepreneurship**
  Explore current developments in entrepreneurship and learn to use tools, techniques and frameworks to develop game-changing entrepreneurial businesses.

- **IS4151 Pervasive Technology Solutions & Development**
  Study computer and network architectures for pervasive computing, wearable technologies, Internet of Things, mobile computing, and security techniques such as for user authentication.

- **IS4243 Information Systems Consulting**
  Develop comprehensive skills in management and IS consulting practices, and experience a real-life field consulting project with an organisation.

- **IS4302 Blockchain & Distributed Ledger Technologies**
  Gain cutting-edge knowledge and technical skills to implement blockchain and distributed ledger technologies that have disrupted the financial industry.

- **IS4303 IT-Mediated Financial Solutions & Platforms**
  Learn how to tap into the capabilities of new FinTech innovations that transform the provision of payment, loan, credit, and investment services.
I always wanted to learn about interfaces between hardware and software and what I have learnt in Computer Engineering has exceeded my expectations. Some of the modules are technical, but it has been truly fun and I am certain these valuable experiences will help mould my career. What I like most about being part of NUS Computing is that everyone is driven and willing to help each other achieve their objectives.

WHAT YOU COULD BE

Applications Developer at Facebook
Enterprise Lead at Palantir Technologies
Software Engineer at Garena
Engineer at Agilent Technologies
Software Developer at Lucasfilm
Start-up Founder
Graduate Student in Computer Science or Electrical Engineering

SNEAK PEEK

You are in the design studio with your CG1111 Engineering Principles and Practice teammates. For the past three exciting weeks you have been working together to build an autonomous vehicle, an integral part of any Smart and Sustainable City. Today, you are adding the final module that will allow your vehicle to navigate with only the guidance of its built-in sensors. In the near future, the use of these autonomous vehicles will make everyone more productive on the go. But wait, you also want to save the world. Now you and your team mates are enhancing your autonomous car with intelligent navigation and vision algorithms to find and rescue people trapped in rubble. Not only are you going to be saving lives, but you will also keep rescuers safe from the dangers of having to search among hazardous and unstable concrete debris. Things have never been more exciting for you. Computer Engineers are riding the wave of the computing industry’s unprecedented growth, and employment surveys indicate that you are among the best paid professionals in the country.

SAMPLE OF MODULES

CS1010 Programming Methodology
The app industry has exploded and programmers are enjoying soaring salaries and high demand for their talents everywhere. This is where your journey as a highly sought after developer.

EE2026 Digital Design
Do you ever wonder what lies under the hood of the amazingly cool iPhone? How does a collection of transistors become the powerful mobile processor giving life to your smartphone? Learn about the wonderful world of processor design here.

CS2113 Software Engineering & Object-Oriented Programming
Writing a single program is challenging, yet the sense of achievement that comes from having a working application is indescribable. Now imagine building complete systems for large corporations!

CG2271 Real Time Operating Systems
Airplane computers manage many complicated factors like air density, altitude, and navigation to keep you in the air. Now imagine that computer suddenly displaying the Blue Screen of Death. Learn how operating systems are made reliable enough so that lives can actually depend on them.

CS3243 Introduction to Artificial Intelligence

CS3247 Game Development
Learn the underlying principles and theories that you will use to make the next great game that captures the world’s imagination!

CG4002 Computer Engineering Capstone Project
Over the past three years, you have learnt how to build a computer, deploy a customised operating system that guarantees performance, and build large complex software systems. Now put all of your knowledge together and engineer complex systems that solve real world problems!
Business Analytics is the perfect programme that marries technology and business through big data. I've grown to appreciate and enjoy doing data-related projects, and wouldn't have it any other way. NUS Computing provides a holistic learning environment, where I not only acquire technical skills, but also grow as an individual. I absolutely love that there are abundant opportunities to participate in hackathons, internships, and overseas exchange programmes here.

Elissa Lim Yanting

You are currently conducting extensive data analyses of a major shopping mall’s customer loyalty programme for BT3101 Business Analytics Capstone Project, and enjoying it. You are always seeing things in the news about data analysts and data scientists being in high demand. Indeed, the Harvard Business Review reported that the Data Scientist is the “sexiest job” of the 21st century! Meanwhile, you are glad that you are taking BT4211 Data-Driven Marketing, where you can learn to code and estimate models that can predict customer choice behaviours and advertising responses. You finally learnt how Amazon figures out what you want even before you do! In your BT4221 Big Data Techniques & Technologies class, you discover how to conduct a linear regression statistical analysis of five billion airline transactions records in just two minutes, using Hadoop-based technology. With the ever-growing amount of consumer and business data available, you can’t help wondering about the exciting, lucrative career opportunities that lie ahead in the field of business analytics. Through this programme, you are confident that you will be well prepared with ample business domain knowledge and powerful data analytics skills.

WHAT YOU COULD BE

Web Analyst at AC Nielsen
IT Business Analyst at Citibank Singapore
Monetization Analyst at Facebook
Data Mining Specialist at Symantec
Market Research Analyst at Singtel
Business Analyst at Deloitte Analytics
Data Scientist at Singapore Press Holdings
Healthcare Analyst at Khoo Teck Puat Hospital, Alexandra Health System

SNEAK PEEK

BT2101 Decision Making Methods & Tools
Learn how to integrate decision making models with sophisticated technologies (neural networks, genetic algorithms, and support vector machines) to support evidence-based business decision making.

BT2102 Data Management & Visualisation
Gain practical knowledge and an understanding of data management, data warehousing, visual perception and design principles, and visualisation techniques for temporal and spatial data.

BT3102 Computational Methods for Business Analytics
Learn to apply computational methods and techniques, such as simulations, Monte-Carlo methods, Bayesian statistics, and spatial models, to address analytics challenges in business fields.

BT4211 Data-Driven Marketing
Learn marketing concepts, test designs, and analysis methods with statistical models to leverage on data sources, and use analytics to make more informed marketing decisions.

BT4221 Big Data Techniques & Technologies
Develop a deep understanding of how to design and apply scalable big data infrastructure, tools, and systems to support analysis of voluminous business data for corporations.

BT4222 Mining Web Data for Business Insights
Learn how to deploy and integrate text mining methodologies, web data mining techniques, social web data mining tools, and web analytics tools to accomplish business objectives.

BT4240 Machine Learning for Predictive Data Analytics
Apply machine learning methods, such as neural networks and support vector machines, to make accurate predictions of business outcomes.

IS4241 Social Media Network Analysis
Gain insights on how to navigate through densely intertwined corporations and human relationships through the use of social network analysis methods and tools.
I enjoy the challenge of learning technical subjects such as software engineering, machine learning, and information retrieval, and the sense of fulfillment in being able to see the applications in technologies being used in industry. The professors who have taught me have been passionate in their area of expertise and are not only good at research but also genuinely interested in imparting their knowledge and experience to students. Most importantly, computing students are keen to share what they have learned, and there are many events and clubs to showcase projects and share knowledge such as St3PS, HackLROA, Gamecraft, NUS Hackers, and NUS Greyhats.

**SNEAK PEEK**

You are in the Security Teaching Lab preparing your CS4238 Computer Security Practice assignment with your teammates. Your team is carrying out vulnerability scanning on another team’s server, and to your surprise, you discover a number of vulnerabilities with just the basic tools. You immediately realise that your team’s system must be fortified because it has the same underlying configuration. While fixing the problem, your teammates suggest that you all join NUS Greyhats to participate in an upcoming Capture-the-Flag competition. You will have to decide later because you need to get to your next class, CS4236 Cryptography Theory & Practice, to give a presentation about an attack on Bitcoin mining pools. The concepts behind the attack are tough, and you spent a lot of time working slides, so you’re satisfied when your classmates seem impressed. Later, as you are reading materials on legal analysis and the case of Charles vs Public Prosecutor for IFS4101 Legal Aspects of Information Security, you realise that, although the language used in legal writing is different than computer source code, logic is universal. The common froyer that you are studying in is becoming quite noisy due to preparations for this evening’s St3PS. The bustle reminds you that you should not miss your friend’s cool CS3235 Computer Security project demonstration about how keyboard keystrokes can be sniffed through their electromagnetic emissions. Your train of thought is interrupted by your ringing phone. It’s Ah Kong. He accidentally clicked on a link in a spam email and is worried that it has downloaded something into his computer. “Well, this is what it’s like being the security expert in the family,” you muse.

**WHAT YOU COULD BE**

- Forensic Investigator at Visa
- Computer Security Researcher at Defence Science Organisation (DSO)
- Cyber Analyst at OCBC
- Malware Analyst at Symantec
- Security Consultant at IBM
- Security Software Engineer at Centre for Strategic Infocomm Technologies (CSIT)

**SAMPLER OF MODULES**

**CS2107 Introduction to Information Security**

Should you proceed when you receive an “untrusted certificate” alert? Are there unbreakable codes? How are human vulnerabilities exploited in social engineering attacks? Learn the basics of IT security.

**CS3235 Computer Security**

Gain a broad understanding of security elements such as intrusion detection, e-mail security, and application, system and network security. Develop invaluable security technical skills and knowledge.

**IFS4101 Legal Aspects of Information Security**

What can an “electronic” signature certify? Are SPAM emails legal? Can a tuition centre share your email address with another centre? Learn how information security shapes laws from an NUS Law professor.

**IS4231 Information Security Management**

How do you manage information security in organisations? How do you obtain buy-in and compliance? Learn how to manage information security issues that can arise in enterprises.

**CS4236 Cryptography Theory & Practice**

Is it true that mobile call signals recorded from thin air can be decrypted? Discover the principles and concepts behind cryptography (think The Imitation Game) and the design of secure communication systems.