Using Low-Cost Cryptographic Hardware to "Rob a Bank"

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Presented at: MCS Oxford,
7th February 2002

Summary

- Keys and Ciphers
- The IBM 4758 Cryptoprocessor
- How PIN values work
- The low-cost hardware “DES cracker”
- How to extract 3DES keys from a IBM 4758
- Mike Bond’s “API attacks”

Keys and Ciphers

- Kerckhoff’s doctrine (1883)
  - the security of a system should depend upon its key and not upon its design remaining obscure
- If there is no shortcut then the security of a system depends upon its key length
  - trying all possibilities @ 33 million keys/sec
    - 2^{40} = 9 hours
    - 2^{56} = 69 years
    - 2^{80} = 1.1 billion years

A History of Tamper Resistance

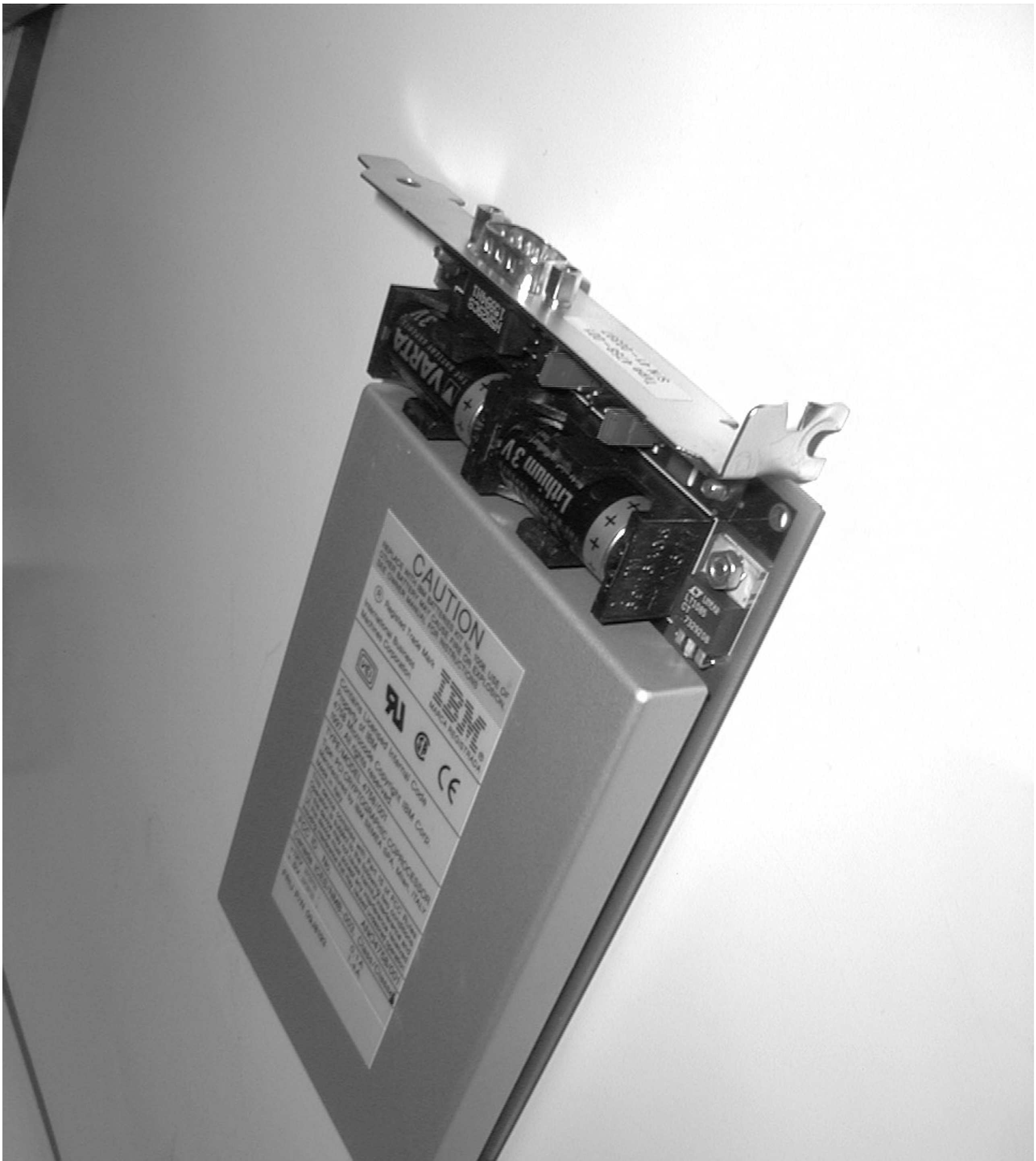
Problem: another program on the same machine can access your sensitive data

- Put keys into separate microprocessor
- Put microprocessor into a tin box
- Photocells and tilt detection
- Epoxy “potting”
- Tamper detecting barriers

The IBM 4758

- Protective barrier with wires of chemically similar compound
- Detectors for temperature & X-Rays
- “Tempest” shielding for RF emission
- Low pass filters on power supply rails
- Multi-stage “ratchet” boot sequence

= STATE OF THE ART PROTECTION!


CAUTION
IBM
VARTA
Lithium 3V

CCA and PIN values

- Common Cryptographic Architecture
  - runs on many IBM platforms
  - available for free to run on a 4758
- A PIN value (in the CCA world) is the account number encrypted with (112 bit) 3DES key and last few bytes made decimal
- Changing a PIN => changing an offset

Key Entry under CCA

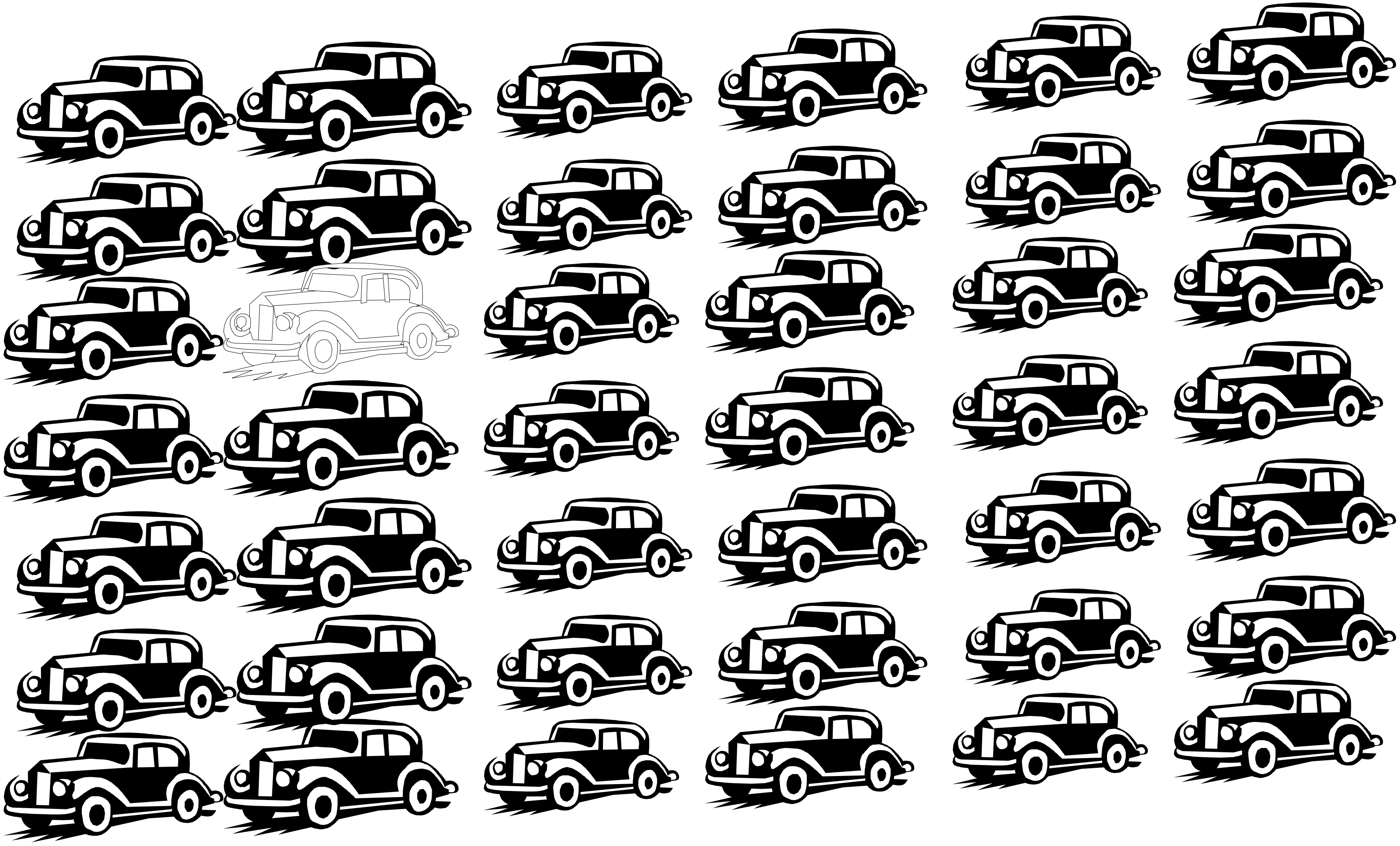
- Each key is loaded in two parts, which are then XORed together
  - XOR means that knowing one part tells you NOTHING about the final key value
- Two security officers, “trusted” not to collude, are given one part of the key each.
  - They authenticate themselves and then separately load these into the 4758.
- This makes the key entirely secure...

The Meet-in-the-Middle Attack

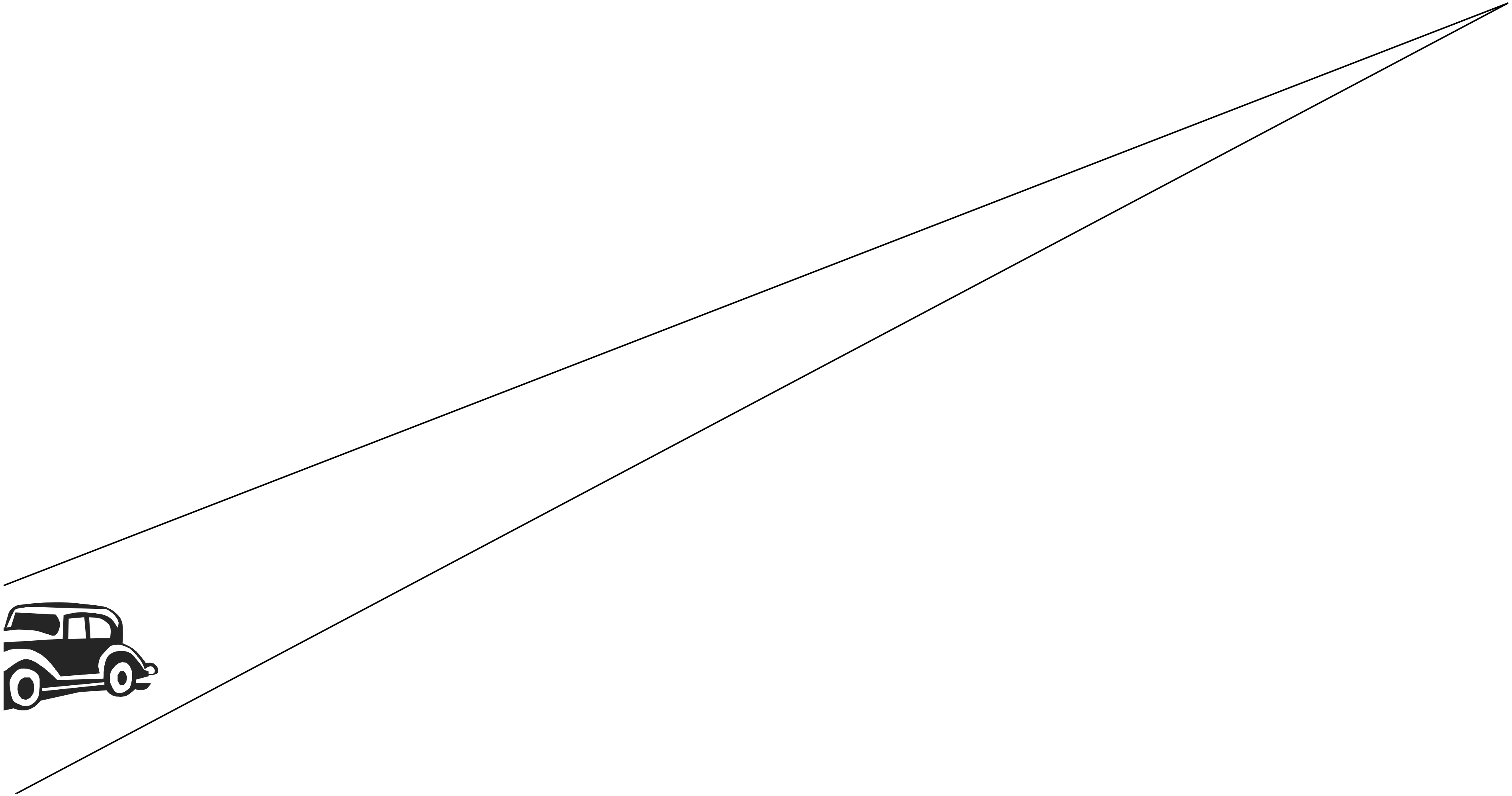
- A thief walks into a car park and tries to steal a car...

- How many keys must he try?

The Meet-in-the-Middle Attack



The Meet-in-the-Middle Attack



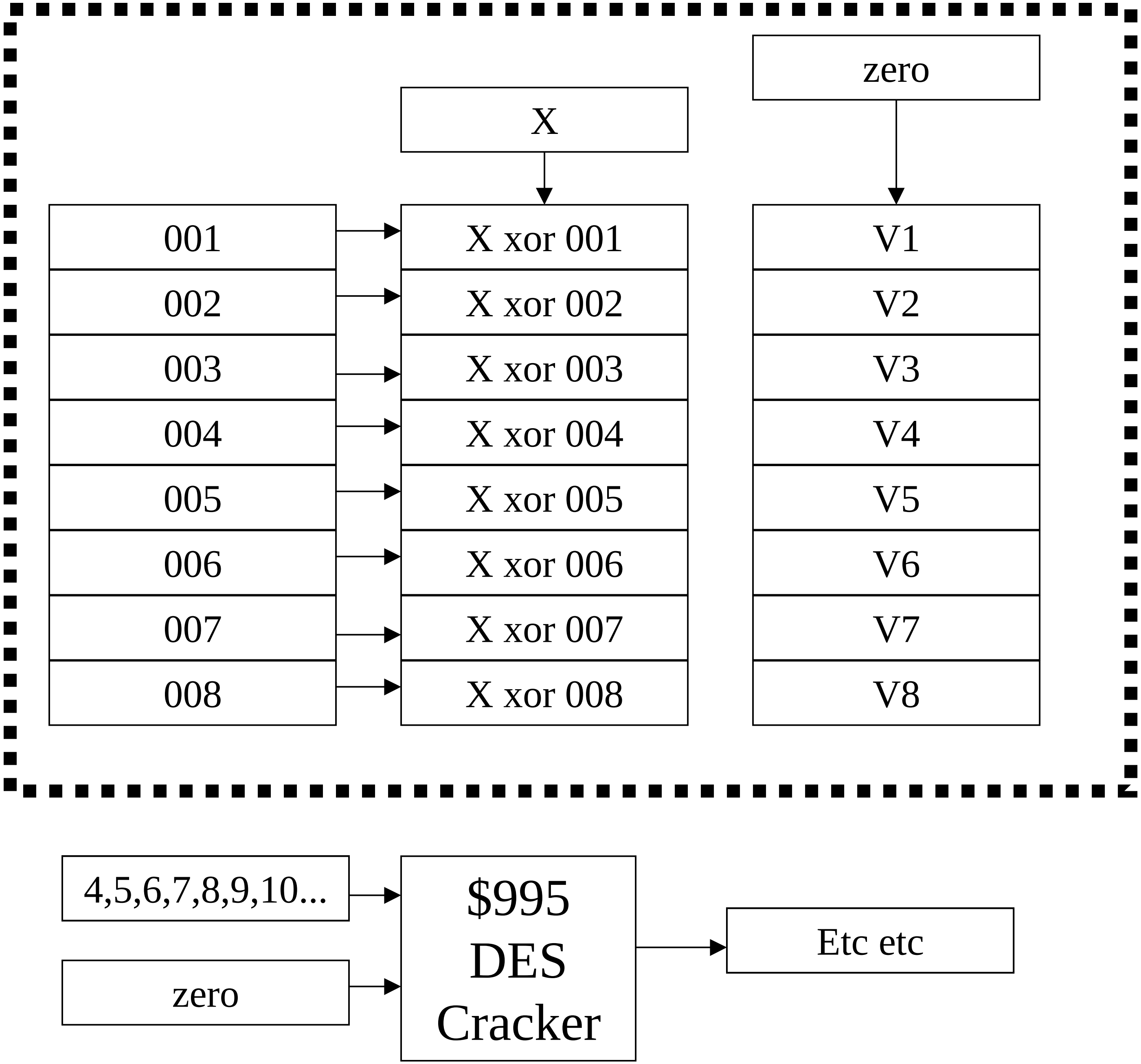
The Meet-in-the-Middle Attack

Idea: Attack multiple keys in parallel

- Encrypt the same plaintext under each of the multiple keys to get a “test vector”
- Attack by trying all keys in sequence but check for a match against any test vector value (check is faster than encrypt)
- Typical case: A 2^{56} search for one key becomes a 2^{42} search for 2^{14} keys

Attacking the CCA : Part 1

- Create unknown DES key part
- XOR in “...001”, “...002”, “...003” etc
- Encrypt zero value under each key
- Repeat to get 16384 (2^{14}) results
- Some complexity because of parity issues, but essentially simple & takes 10 minutes.
- Use “brute-force” attack to get the DES key



zero

X

001	X xor 001	V1
002	X xor 002	V2
003	X xor 003	V3
004	X xor 004	V4
005	X xor 005	V5
006	X xor 006	V6
007	X xor 007	V7
008	X xor 008	V8

4,5,6,7,8,9,10...

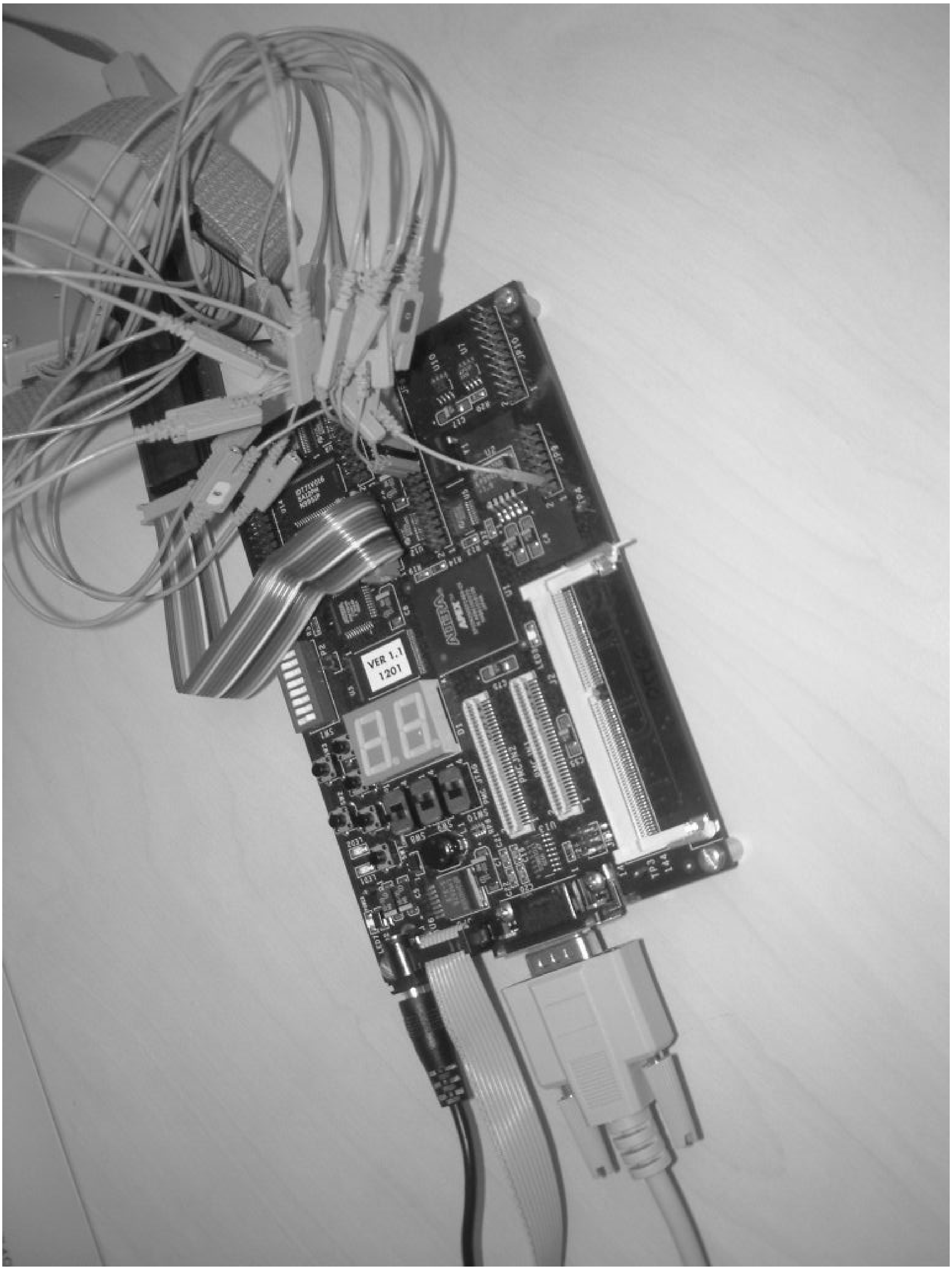
zero

$995 DES Cracker

Etc etc

Low-cost DES Cracker

- $995 Excalibur kit (Altera 20K200 FPGA)
  - chip cost is ~$5 (in volume; $178 one-off)
- 33MHz pipeline (& 60MHz possible)
- 2^{25} keys/second
  - 56 bit DES = 69 years
- However... look for 16384 keys in parallel
  - with average luck find first key in 25.4 hours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Attacking the CCA : Part 2

- Recall we had 16K related DES keys
- We can crack one of these in ~1 day
- Now create 16K related 3DES keys with “replicate” halves and “exporter” capability
  - 3DES = EncryptA; DecryptB; EncryptA
- Export the DES key under the 3DES keys
- Since replicate can also crack in ~1 day

Attacking the CCA : Part 3

- Create non-replicate 3DES key by combining two unequal halves with the replicate halves that we’ve now determined
- Export all the CCA keys under this key
- Download list of PIN offsets
- Use magnetic stripe writer to create cards
- Use any ATM to extract money from accounts
- Go to Bermuda!

Michael Bond’s “API attacks”

- New type of attack: use standard API in non-standard way to cause dumb things
  - Overloaded key types
  - Unauthorised type casting
  - 3DES binding attack
  - Related keys

Mike’s PhD topic targets formal methods that will detect (and avoid) these problems

Who am I?

- 2nd Year PhD student at the Computer Laboratory, University of Cambridge, Age:22
- Studied “Computer Science” as an undergraduate at Cambridge, before that KSB
- Studied Maths, Physics, Chemistry, DT, IT etc… at A-Level
- Currently live in Cambridge, a mile or so from town centre & computer lab

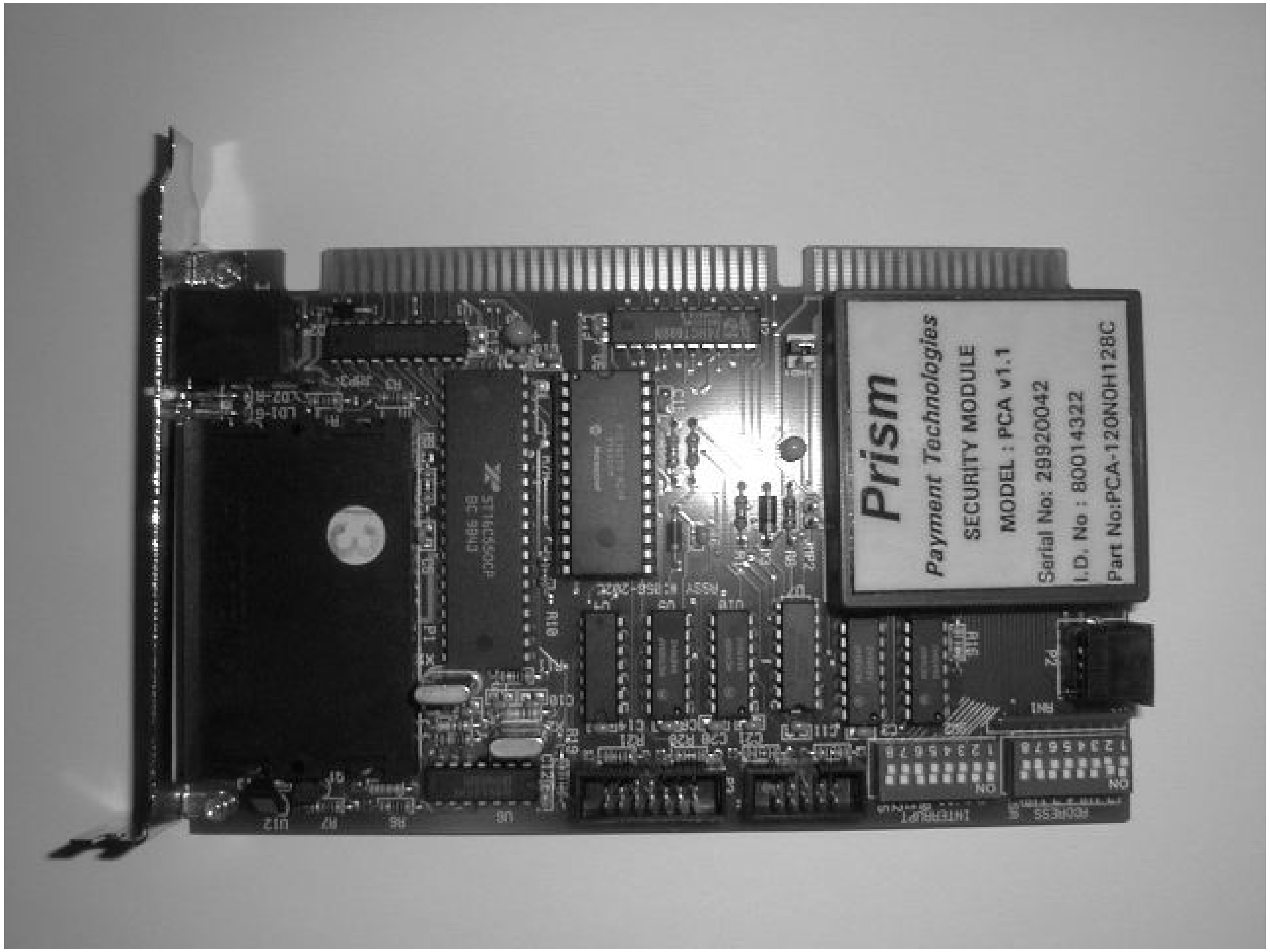
What is a PhD?

- In theory:
  - “an original and significant contribution to the general body of knowledge in the chosen subject” – a thesis of 40,000-100,000 words
- In practice:
  - three years of supervised research into a particular topic as a member of a research group studying similar topics
- **Y1**: Explore, **Y2**: Understand, **Y3**: Write-up

My PhD

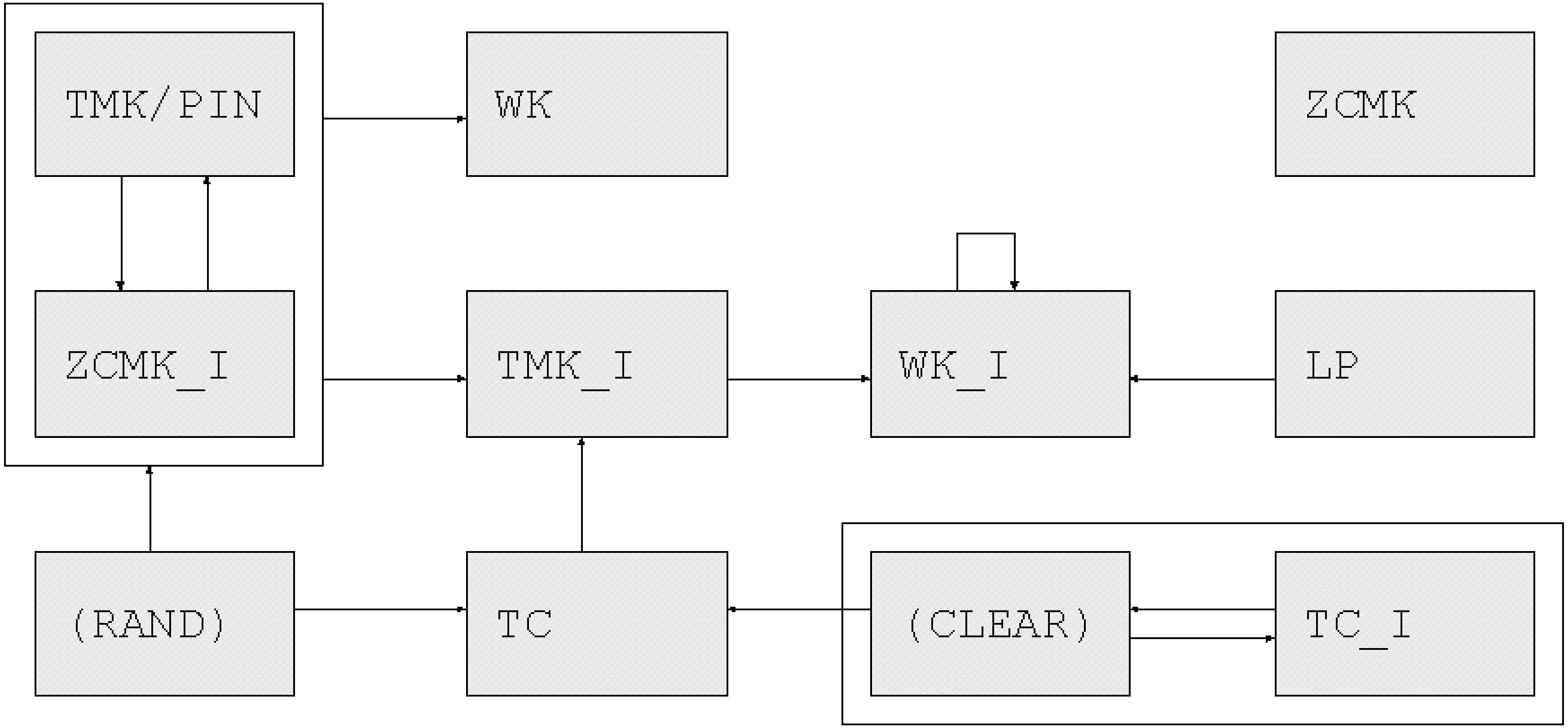
- “Understanding Security APIs”
- Security API = Software interface to a processor performing security functions, usually tamper-resistant hardware
- Year 1 : Analysed 6 different cryptoprocessors, published academic papers explaining attacks
- Year 2 : Producing design rules, and building analysis tools
- Year 3 : ….

The PRISM Security Module



The Visa Security Module

VSM Type Diagram



Example Security API Commands

U->C : $\{ A \}_{KM}$, $\{ B \}_{KM}$

C->U : $\{ A+B \}_{KM}$

U->C : GUESS , $\{ ANS \}_{KM}$

C->U : YES (if GUESS=ANS else NO)

U->C : $\{ X \}_{K1}$, $\{ K1 \}_{KM}$, $\{ K2 \}_{KM}$

C->U : $\{ X \}_{K2}$

UNIVERSITY OF CAMBRIDGE

Computer Laboratory

- 30 academic staff = teaching/research
  40 research assistants = research on lab money
  80 research students = research on grant money
  + 300 undergraduate students
- Groups: Security, Graphics & Hardware, Systems Research, Natural Languages,
  Theory …

In My Office

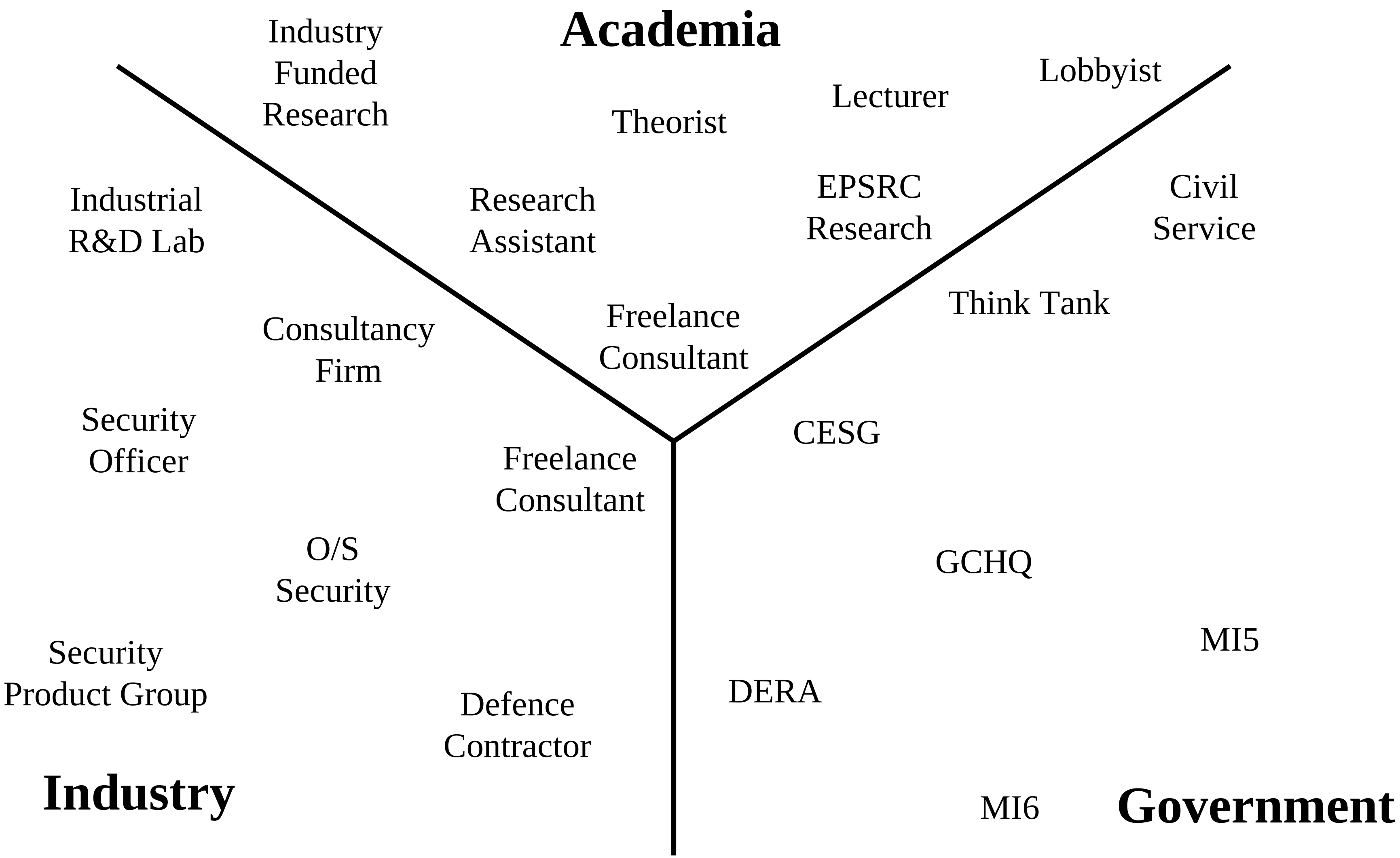
What is Computer Science?

- Practical and theoretical study of the details and principles of software, hardware and communications technology
- Cambridge course aims to be technology independent, split 50/50 between practice and theory
- Includes a 60 hour group project, and 500 hour individual project

Computer Security

- Cryptography, Anonymity, Protocols, Tamper-Resistance, Operating Systems, Copy-Protection
- Nowadays: Economics, Law, Politics
- Deals with fundamental conflicts of interest:
  - Good guys vs. bad guys
  - Competing corporations
  - International warfare
  - Personal privacy concerns

Computer Security Career Paths



Academia

Industry Funded Research

Theorist

Lecturer

Lobbyist

Research Assistant

EPSRC Research

Freelance Consultant

Think Tank

Civil Service

Industrial R&D Lab

Consultancy Firm

Security Officer

Freelance Consultant

O/S Security

Security Product Group

Defence Contractor

Industry

CESG

GCHQ

MI5

DERA

MI6

Government

Computer Hacking

- Not on the career path diagram?
- You can **really** hack hypothetical systems, and **really** hack real systems
- You need permission for the latter!
- “Black Hats” and “White Hats” can both hack legally – difference is ethics of disclosure
- Real hackers are just common criminals

More Info

- **How to hack a bank?**
  `http://www.cl.cam.ac.uk/~rnc1/descrack/`

- **How to apply to Cambridge?**
  `http://www.cam.ac.uk/cambuniv/undergrad/`

- **How to be like me?**
  `http://www.cl.cam.ac.uk/~mkb23/`

- **More questions – email us:**
  `Mike.Bond@cl.cam.ac.uk`
  `Richard.Clayton@cl.cam.ac.uk`