Cyber Security: Past, Present and Future

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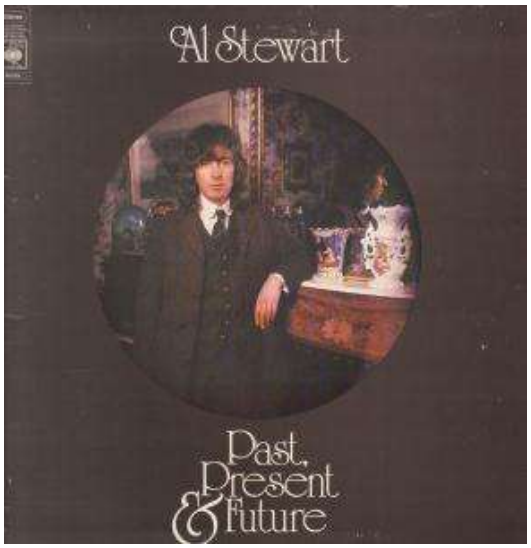

3

Agenda

- What is cyber security?
- The past
- The present
- The future …

4

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Defining cyber security

- There is no generally agreed definition for the term **cyber security**.
- Not so surprising since security itself is a very difficult word to define!
- I see cyber security as a simple extension of the existing notions of **information security** and **computer security** recognising the pervasive nature of modern ICT.
- Hence we are now dealing with a pervasive threat and one that government cannot ignore since it has impacts on almost every aspect of daily life.

CIA

- Long-standing definition of scope of *computer security* is as:
  - *Confidentiality* (preventing unauthorised disclosure of information);
  - *Integrity* (preventing unauthorised modification of information);
  - *Availability* (preventing denial of access by authorised parties to resources, including processing, communications, and information).
- Not such a bad definition for cyber security, although it omits a few issues.

Similar terms

- There are many widely used terms with similar (or more specialised) meanings, e.g.:
  - *Communications security*: protecting information sent via networks;
  - *IT (or ICT) security*: protecting information handled by, and resources associated with, IT (ICT) infrastructures;
  - *Critical National Infrastructure (CNI) security*: protecting countrywide infrastructures, such as electricity, gas and water supplies, road and rail networks, etc.
- Cyber security subsumes all this …

9

9

Why a new term?

- Why is yet another term needed?
- The
  - pervasiveness of ICT, and
  - ever-growing interdependence and complexity of systems,

  means that security is a government and public policy issue, rather than just an issue for individual citizens or corporate entities.
- I see emergence of cyber security as an indication of government recognising its responsibility for protecting the citizen (and not just in protecting its own infrastructure).

10

10

Public policy

- Security is no longer a private matter.
- Poor decisions made by all manufacturers and service providers could seriously affect safety of citizens (not just CNI – or perhaps everything is now a CNI).
- Public policy makers are a long way from being in a position to address this issue satisfactorily.
- We all hope that initiatives like the two new CDTs in cyber security will, in the long run, help to redress this imbalance.

Agenda

- What is cyber security?
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The academic subject

- Academic interest in cyber security has developed in independent strands since the 1970s, including:
  - cryptography;
  - computer security; and
  - network/protocol security.
- Of course, other topics have also grown up independently since then, including malware studies, intrusion detection, etc.
- Also, much of the work has been done jointly by academia and industry (and, to some extent, government agencies).
- Look at some of these strands (noting strong UK influence).

13

13

Cryptography

- Cryptography emerged from the shadows to become an academic subject in the 1970s.
- Number of important developments in 70s:
  - development of DES (public) standard block cipher;
  - invention of public key cryptography, RSA and Diffie-Hellman key agreement;
  - start of public discussion of design and analysis of ciphers, including stream ciphers.

14

14

DES

- DES arose as a result of a competition by NBS in the US for a block cipher.
- This has become a model for development of new international crypto standards
- NIST (successor to NBS) has led two competitions giving us AES (DES successor) & SHA-3 (hash-function successor to SHA-1/2).
- Other bodies now launching similar competitions (e.g. recent competition for an authenticated encryption scheme).

15

15

Public key crypto and RSA

- Diffie and Hellman (at Stanford) wrote *New directions in cryptography* in 1976, describing:
  - notion of public key cryptography (PKC), and
  - the Diffie-Hellman (DH) key agreement method.
- This stimulated Rivest, Shamir and Adleman (at MIT) to develop the first practical public key encryption scheme, RSA.
- Interestingly, PKC, RSA and DH were independently developed in early 1970s by Ellis, Cocks and Williamson at GCHQ here in the UK.

16

16

Merkle, Hellman and Diffie

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Diffie and Hellman

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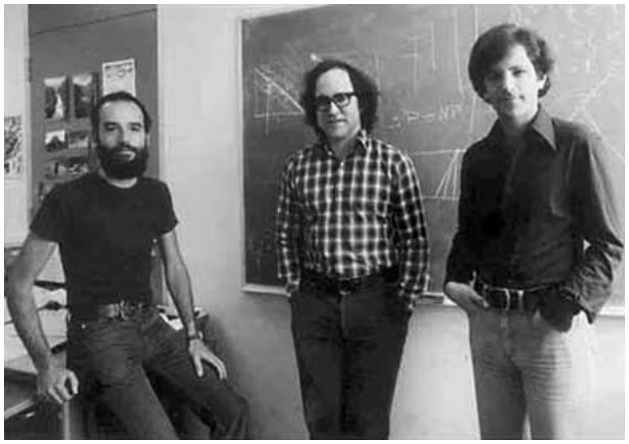
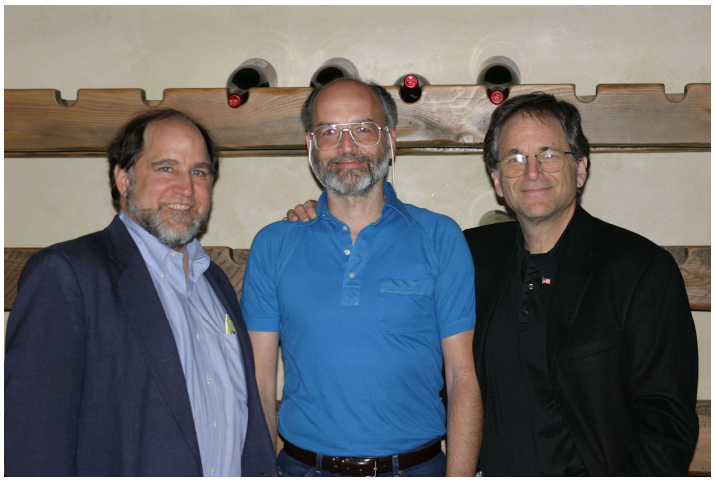
Shamir, Rivest & Adleman – then …



… and more recently (in the right order)



James Ellis, Clifford Cocks and Malcolm Williamson



21

21

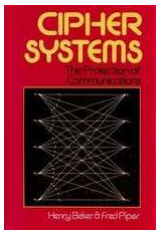
Development of academic subject

- Three books published in the early 1980s played a major role in the development of academic crypto, by:
  - Alan Konheim (*Cryptography: A primer*),
  - Carl Mayer and Stephen Matyas (*Cryptography: A New Dimension in Computer Data Security*), and
  - Henry Beker and Fred Piper (*Cipher Systems*), here in the UK.

22

22

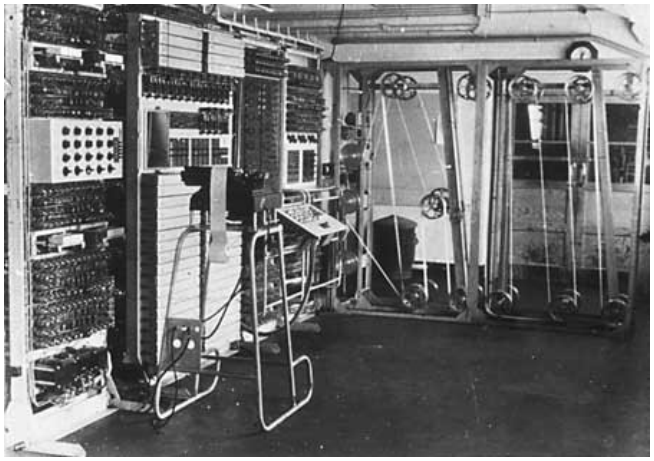
Beker and Piper: Cipher Systems



History of computing

- The development of computing as we know it today was presaged by the development of Colossus in the UK during the 2nd World War.
- Colossus, a fully programmable computer, was developed in 1943 to break the Lorenz SZ40/42 stream cipher.
- Alan Turing and Tommy Flowers played a major role in its development.

Colossus



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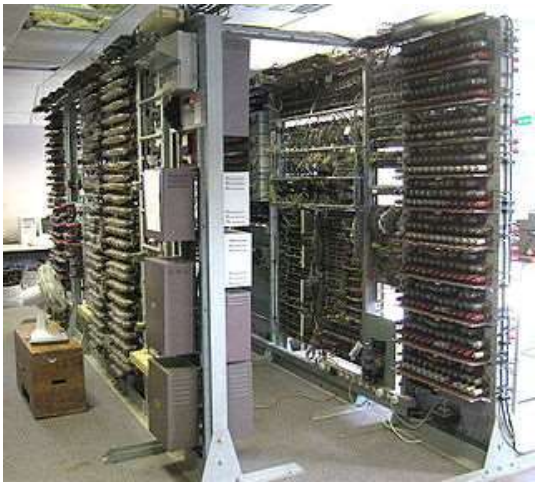
Colossus rebuilt (at Bletchley)



26

Computer security

- In parallel with development of cryptography, modern day computer security emerged in the 1960s and 70s, including:
  - access control models (including fundamental work by Lampson)
  - notion of process isolation (key to modern models of computer security);
  - virtualisation (notable work by Paul Karger at DEC, ideas resuscitated more recently)
  - multilevel security (to meet government requirements);
  - Orange Book certification (US DoD).

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Butler Lampson

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Paul Karger

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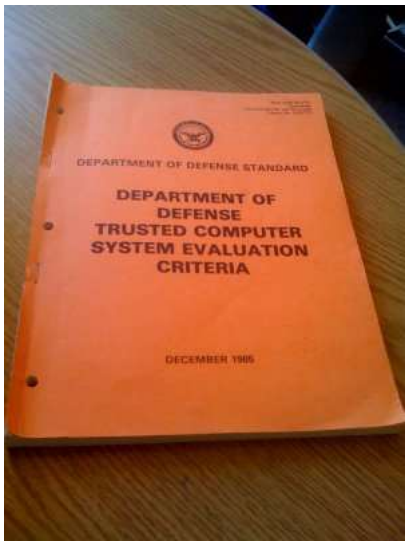
Orange Book



30

Software verification

- Techniques to enable mathematical proofs to be formulated regarding properties of software have been developed in parallel with other security technologies.
- University of Oxford has played a leading role in this area over several decades – I'm sure there are many here today infinitely better qualified than me to explain this history.
- These techniques are likely to prove invaluable in helping to developing everyday 'utility' user software provably free of vulnerabilities.

31

31

Applications of cryptography

- A further strand has been the development of ways of using cryptography in computers and networks.
- The UK's Roger Needham played a key role in two of these:
  - using one-way functions to protect stored passwords (1966);
  - the Needham-Schroeder authentication protocols (1978).

32

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Roger Needham

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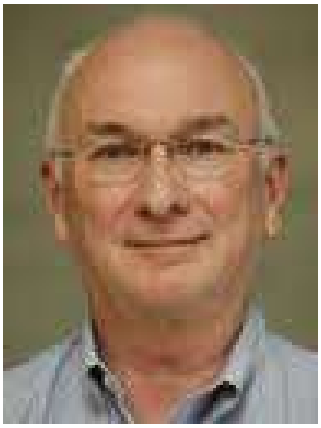
Michael Schroeder

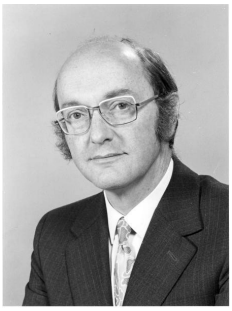


34

Another key book

- A key book for the development of the applications of cryptography was published in the early 1980s.
- Donald Davies and Wyn Price (at the UK's NPL) published *Security for computer networks* in 1984.

Donald Davies (and Wyn Price)



Some links

- Donald Davies (who played a major role in developing packet switched networks) worked with Alan Turing at NPL in the late 1940s, helping to develop the ACE computer.
- Donald Davies also played a key role in setting up the standards committee which evolved into ISO/IEC JTC 1/SC 27 (more on this later).

Interesting observations

- There has been a very strong UK influence on the development of all aspects of cyber security.
- The key technological ideas date back at least 30-40 years.
- We are still struggling to properly deploy some of the well-established technologies developed many years ago.

Education

- Before 1992 (when RHUL launched its MSc in Info Sec) security barely had an impact on university taught courses
- A handful of PhDs in cryptography and computer security were being produced.
- Now, nearly 30 years later, there are plethora of masters-level taught courses in the area, and many PhD students are graduating in security topics every year.

39

39

Royal Holloway

40

40

In the real world – crypto

- 'Early adopters' of cryptography were:
  - the banks (DES rapidly became a de facto international standard),
  - mobile telecommunications (GSM).
- For example, crypto has been widely deployed to protect PINs transferred between ATMs and banks for decades.
- Similarly, from the beginning GSM SIMs incorporated secret keys and crypto-based authentication.

41

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43

In the real world – secure computing

- Multilevel secure computing has remained primarily the realm of government.
- DOS and Windows pre XP had no security model – assumed single user – no internal protection for OS against applications.
- Unix always had a simple security model.
- Both Windows and Unix had major user authentication flaws.

44

Emergence of cyber security

- We have seen an evolution of security:
  - from being a concern only of government and military for their own secrets (**for ever**),
  - to a matter of huge importance for corporations, e.g. banks, telecoms, and owners of IT infrastructure (**from 1970s**),
  - to a matter of concern for domestic users, threats of phishing, ID theft, etc. (**from 1990s**),
  - to being a matter of public policy: cyber security (**from around ,mid 2000s**).

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Managing security

- The compliance approach to security management appears to dominate.
- Most prominent amongst the compliance approaches is specified in the ISO/IEC 27000 series (ISO/IEC 27002 was previously BS 7799 and ISO/IEC 17799).
- Sector-specific compliance documents also exist, e.g. for payments industry (PCI) and for government.
- Compliance standards try to capture and encourage use of current understanding about best practice.
- However, serious danger of reducing security management to a 'box ticking' exercise.

47

47

Designing security

- We have developed heuristics for designing secure systems, building requirements on detailed risk analyses.
- These have been successful to some extent, e.g. in developing 3G mobile security system.
- In most cases they fall some way short of the 'ideal' of provable security.
- In practice many problems remain, e.g. sub-optimal uses of cryptography, incomplete risk analyses, poor implementation, …
- Perhaps most serious problems arise where system designers do not take security sufficiently seriously, e.g. when they do not understand the risks.

48

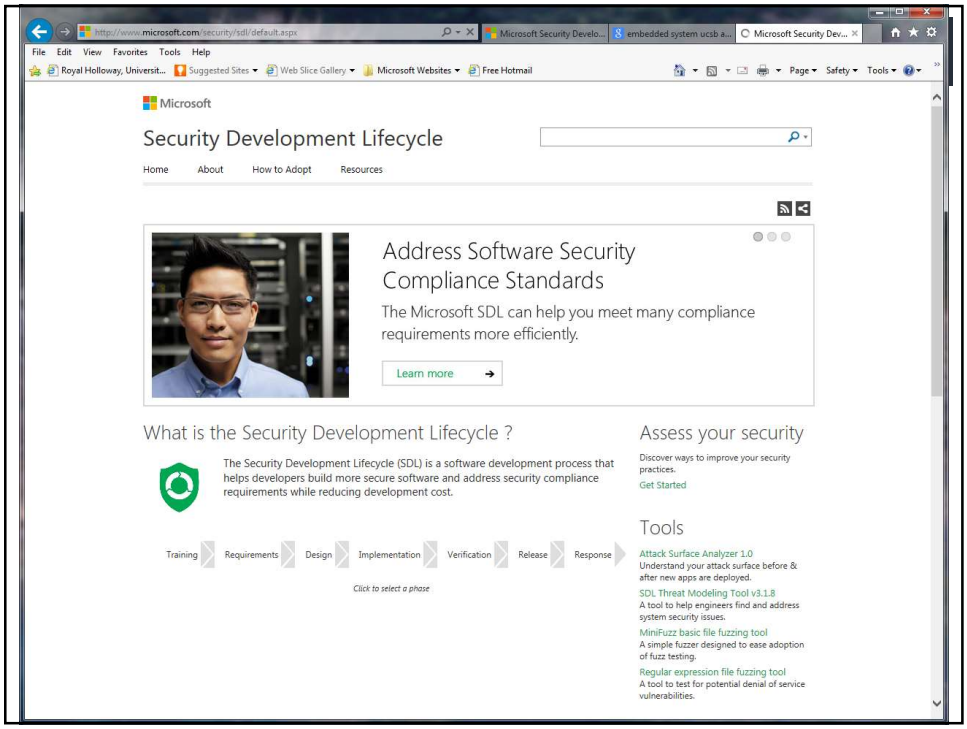
48

Implementing security

- Many problems arise in going from designs to implementations.
- Manufacturers of major pieces of software are constantly issuing patches to fix vulnerabilities arising from flawed design or implementation.
- Recent research has shown that many widely deployed embedded systems are hopelessly insecure
- Even widely deployed protocols like SSL/TLS and IPsec have been shown to have security flaws.

Building secure systems

- Major software manufacturers have developed methodologies to try to improve design and implementation with respect to security.
- Notable example is Microsoft's Security Development Lifecycle (SDL).
- Has been widely adopted across the industry.
- Yes, it is all heuristic in nature (although some of the freely available tools do use formal techniques).



51

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Security standards

- Today we have a very broad-ranging set of international standards for security, covering:
  - security management (27000 series);
  - cryptographic techniques;
  - security evaluation (common criteria);
  - network and system security;
  - privacy and identity management.
- Not always adopted, not least because of lack of awareness.

52

52

Hidden dangers

- Often systems are used in situations, or are subject to interconnectivity, of which the original designers had no idea.
- 'Black box' security components are used, which may not be secure.
- There is a widespread lack of understanding of security, how vulnerabilities can arise, and how pervasive the threats are.
- This applies in particular to products not thought of as needing security, e.g. a wide range of embedded systems.

53

53

Security education today

- Information security has become a widely offered masters degree topic – good supply of specialists.
- Also has become a core part of a Computer Science undergraduate curriculum.
- However, it appears there are still issues with software developers not understanding threats to software
- Security needs to be fully integrated into undergraduate education.

54

54

Rise of privacy concerns

- Over the last decade the need to enforce privacy for IT systems has become a major concern, in parallel with need for security.
- Providing privacy requires security (to prevent leakage and corruption of personal data).
- However, the goals of privacy and security may be very different, e.g. accountability can be seen as 'anti-privacy'.

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Major challenges

- Many huge challenges remain for security:
  - in security management we need to go beyond a rigid compliance approach.
  - need to understand security implications of ever-greater connectivity and pervasiveness of computing;
  - must address threats arising from ever-increasing complexity, and the growing criticality of systems;
  - widespread use of cloud introduces new range of privacy and security concerns.

Managing security

- Managing security in organisations large and small is today a major challenge.
- We need to find ways of addressing the large gap that often exists between:
  - organisational threat analyses, procedures and processes (perhaps developed using ISO/IEC 27000), and
  - the actual practice of (in)security by employees.
- If security rules prevent employee doing his/her job properly, then they will be broken.

Building secure systems

- We need better tools to design everyday systems that will be secure (as opposed to security systems).
- Current methodologies do not prevent all vulnerabilities.
- Moreover, they simply don't work for some types of software, e.g. software for providing cloud services which is constantly being modified.

Proving systems secure

- Ultimately we need ways of developing systems which we can prove have no vulnerabilities.
- This is extremely challenging since systems are so complex, systems often need to be developed quickly, and vulnerabilities can arise in so many ways, e.g. through:
  - imperfect risk analysis, or emergence of new classes of threat, e.g. through deployment of new technology;
  - flawed design;
  - flawed implementation;
  - use of poor security components (e.g. flawed crypto).

Vulnerabilities and disclosure I

- We have a developing crisis relating to vulnerabilities and disclosure.
- Security vulnerabilities in products are being found at a huge rate.
- Despite efforts by manufacturers (including a standard – ISO/IEC 29147) there is a lack of consensus on the morality/best practice of disclosing vulnerabilities.
- Highlighted by the famous Megamos car immobiliser security case, in which three academics were prevented by a UK court from presenting full details of a system they had broken.

61

62

Vulnerabilities and disclosure II

- This is just the tip of the iceberg …
- Established 'best practice' for 'responsible disclosure' were developed piecemeal through practices in finding and revealing crypto and software vulnerabilities.
- Researchers believe they have a right to publish vulnerabilities (perhaps after giving manufacturers a few months to fix things), arguing that manufacturers deserve to be punished for poor security practice.
- However, in many cases it is the poor old users who suffer the most.
- Who is right and what should be done?
- This touches strongly on public policy …

63

63

Public policy

- Some degree of regulation of pervasive/consumer IT probably inevitable.
- Need to get it right.
- In principle, existing regulations might well be sufficient – e.g. covering safety.
- However, new classes of vulnerability caused by interconnectivity and computing everywhere probably elude existing regulatory regimes.

64

64

Future of security education

- The last 20-30 years has seen a growth in masters level cybersecurity education from nothing to a very significant level.
- Security education at the undergraduate level, particularly for Computer Science and Electrical Engineering, is still developing.
- An appreciation of security risks needs to be built into broad range of curricula.

65

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Address growing privacy concerns

- The Snowden and other revelations (e.g. relating to Facebook) have drawn attention to the huge potential for monitoring and processing of personal data.
- This is not going to go away.
- Somehow, we need to reconcile desire for privacy with use of 'free' services depending on targeted advertising, and needs of government security services.

66

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Concluding remarks

- Cybersecurity has emerged as a major academic discipline in its own right, paralleling developments in industry, commerce and government.
- A wide range of major challenges remain.
- With criminal organisations and governments increasingly targeting all aspects of our information infrastructure, which is itself growing more complex daily, **there are no shortages of security issues to be addressed for the foreseeable future**.

67