Principia Medicinae Digitalis Sotoniensis

Essays on the Evolution of the UHS Clinical Data Estate 1980 -2024

Section 1 Essay 1: A Brief History of the Computerisation of Healthcare

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Publication Plan

The essays which comprise this series will be made available in the first instance on my professional website, https://www.wessexsurgical.co.uk as downloadable PDF documents for review, comment and as a basis for further contributions. They will be amended, updated and supplementary as necessary and as any new material becomes available. All those colleagues with knowledge and experience of the UHS digital programme are welcome to contribute, by communication with me through dr1@soton.ac.uk.

Once the project is as complete as is achievable, final copies of each of the essays will be submitted to the University of Southampton ePrint server for formal publication.

Section 1.

This section is a collection of general essays about the history of clinical computing, with particular reference to the UHS Clinical Digital Estate.

This is the first of nine essays in this section of the collection. It describes a brief history of the transition from paper to digitally based systems across the spectrum of healthcare management and clinical practice from the earliest concepts to the present, and it sets up the story of the Southampton Hospitals digital transformation project.

<u>The History of the University Hospital Southampton Clinical Digital Estate 1980 to 2024</u>

Essay 1:1 A Brief History of the digital transformation of Healthcare in the 20th Century

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The Global Perspective

An Introduction to Computing in Healthcare

In this essay, I review in brief the development of computing as a global mainstream healthcare technology, with particular reference to the history of experimentation and strategy around healthcare computing at national level in the UK from the 1980s onwards. These developments set the conditions in which digital innovation has flourished over three decades.

The history of computing in the second half of the 20th century and the early decades of the 21st century has been the equivalent to an evolutionary explosion, but compressed into months, years and decades rather than millennia. Across this complex landscape of technical and conceptual speciation there have been many extraordinary successes but also many evolutionary blind alleys.

There has been no master plan to this intellectual and technological form of Darwinian evolution, which has created vast wealth and opportunities across all fields of human endeavour. Rules and standards continue to evolve in the wake of technical evolution at breakneck speed, while machine learning, artificial intelligence and quantum computing further challenge the adaptability worldwide of digitally immature healthcare systems.

Within this evolutionary technological cauldron and with a multiplicity of continuously evolving choices, the clinical informatics teams in Southampton have forged a successful ecosystem of software systems to manage the transition from paper and legacy records systems into a modern, adaptable digital environment under continuing change.

The Enduring Importance of Paper and Print Media in Clinical Information Systems

Paper is a remarkable technology. It has been the mainstay of information transmission and storage systems for many centuries, and its replacement with digital systems is far from complete. It has had a profound influence upon mankind's technical and intellectual evolution. It has been the backbone of human communication, information storage and archiving, social and political development for many centuries. It has also inspired much extraordinary architecture across the global portfolio of library buildings (Figure 1).

Figure 1. The Primacy of Paper: The Convento de San Francisco Library, in Lima Peru

The utility of paper has been progressively refined by other technologies, including the pencil, pen, ink and watercolours; by Gutenberg's printing press of the fifteenth century, and by the ink jet and laser printers of the 20th century. Paper has inspired the extraordinary architecture of institutional and national libraries, and it retains widespread utility in the computer age. Paper is easily overlooked as the technology which still underpins the digital revolution.

Paper is uniquely adapted to the functions of human eye, brain and hand as an information transfer system. It retains superiority over computer systems in many applications. These include its convenience and flexibility as an annotation and recording medium for the text, sketches, graphical notes, arrows, margin comments and under-linings which are a common feature of paper based clinical record keeping.

Handwriting also communicates something of the character of the writer. Paper remains the medium by which children are taught to write, sketch and paint, and interaction with paper still suffuses our adult lives. When stored with protection from fire and water, paper based books, journals and medical records files endure for years, decades and centuries, and they are still a key element of the whole of life clinical record of every citizen.

Paper nevertheless has serious practical limitations, in that the information upon it is fixed in space and time, and paper records must be compiled, physically stored, moved and copied to be of wider use. This imposes transportation and duplication costs and obliges the employment of skilled administrative staff and (records) librarians to track documents. Despite these constraints, we still have a complex hybrid system of paper and digital records in widespread use in clinical practice and elsewhere in the third decade of the 21st Century. Critically, paper remains a reliable store of knowledge when digital records have their own vulnerabilities and uncertainties as to their durability.

A Brief History of Computing in General

The origins of digital computing lie in the conceptual work on computable functions of Alan Turing in the 1930s, and his practical work on "universal machines" for the UK Government in the 1940s. The earliest practical computers are generally recognised as those electro-mechanical instruments which were built at Bletchley Park in the UK to defeat German codes and ciphers during the Second World War.

Computerisation has since evolved at an increasing rate across all aspects of our personal, social and professional lives. This epochal transformation in human creativity and intellectual application covers the simultaneous evolution of a huge variety of contributory technologies, incremental innovations and conceptual insights, which include:

Hardware components of Computers: These range from valves to transistors to microprocessors. In 1956, transistor based "second generation" computers were introduced. These were smaller, faster and more energy-efficient than valve-based computers. To a considerable degree, modern computers were developed by the extraordinary minds of entrepreneurial scientists and engineers in and around Silicon Valley in California from the 1950s onwards.

In 1958, John Kilby (1923-2005) of Texas Instruments and Robert Noyce (1927-1990), who founded Fairchild Semiconductor in 1957 and the Intel Corporation in 1968, co-invented the integrated circuit. This was the foundation of all microchip technology. Kilby won the Nobel Prize for Physics for his work in 2000.

Douglas Engelbart (1925-2013) was a pioneer of human-computer interaction. In 1968, he introduced the computer mouse, hypertext, networked computers and the precursors to graphical user interfaces.

David Canfield Smith (1945-) developed the concept of the computer icon for his Stanford PhD Thesis and while working for Xerox Palo Alto Research Center. He subsequently helped commercialise it for the Apple Corporation.

Information storage on Computers: Computer data storage systems have ranged from punched cards and ticker tape to magnetic tape, to floppy disks and to Random Access Memory (RAM), solid state devices and cloud storage, with ongoing experimentation in light, biological and DNA analogue systems.

Computer scale: This ranges from room sized mainframe machines to pocket calculators (1970s) and to the hand held and nano-scale devices of the modern age;

Operating systems and computer languages: Computer hardware has to be designed to operate series of instructions which are presented to it in binary code, above which sit many programming languages and a myriad of software applications which are comprehensible to the specialist and general user. Behind the software lies complex mathematics, materials science, theoretical and applied physics, and sophisticated micro-and nano engineering down to the atomic scale.

Software Applications: These have rapidly evolved from basic coding to many of the staples of modern life, including word processing, spreadsheets, presentation systems, machine controllers, networking systems, human-like intelligence, and the hand held Apps which now govern our lives.

The distribution of Digital Information: This has evolved in electronic systems from copper wires to fibre optic cables, wireless links and satellite networks, all of which contribute to the Internet in its many forms.

Relentless Creative Destruction in the Computer Industry

All of these technologies have had their own lifespans and trajectories through a maelstrom of creative destruction over eight decades from the 1940s to the 2020s.. This continual turbulence has led to a huge diversity of systems in practical use at personal, commercial, institutional and Governmental levels, and to continual redundancy of equipment, software and hardware systems, and the human skills of coding and of the maintenance of such complex systems.

The consequences of this diversity in circumstances of continuous change in the technologies and capabilities have obliged users, planners and managers to choose from a bewildering array of evolving options to take advantage of the possibilities that are provided by digital systems, and to experiment where new operational needs and opportunities are identified.

It has also had a profound psychological impact on human creativity, and the speed at which ideas evolve and technologies emerge. The expectation of continual changes in digital systems and the ability to adapt to them is now deeply embedded in society.

A Brief History of the Early Computerisation of Healthcare

Practical attempts at the digitisation of healthcare systems can be traced back to the late 1950s. However, early attempts at the transformation of healthcare systems from paper-based to digital systems were handicapped by a range of factors, including:

- Limitations in hardware functionality and data storage capacity;
- Limitations in software and database design
- The lack of adequate communication systems for digital information transfer in the early days of the Internet
- The lack of software engineers, designers and developers with an understanding of the particular challenges and complexities of healthcare information and decision making.
- The lack of understanding of the potential of well designed digital systems among healthcare professionals as information consumers.
- The lack of understanding of the true scale and complexity of the tasks of digital transformation.

The Broad Phases of Development of Clinical Information Systems

Rudi Van de Velde and Patrice Degoulet (2003) proposed that the pattern of evolution of Clinical Information Systems has broadly spanned four overlapping phases, as follows:

1. From 1960-1985, the focus was on Administrative Automation, and the core technology was based upon Mainframe computers.

2. From 1965-2005, the focus on was on Productivity at the Departmental level, for example Laboratories and Clinics, where the core technology was based upon midrange computers

3. From 1975 to the Present, the focus has gradually shifted to Professional Empowerment, as through ease of access and navigation of medical records across Health Networks, with the core technology of Client-server computing

4. From 1990 to the present, the focus has been increasingly on Patient Empowerment in the Community Domain, with the core technology: Internet/Network computing.

Healthcare Computing in the 1960s

In 1959, Robert Ledley and Lee Lusted (Ledley and Lusted 1959) identified computers as a tool for medical diagnostic decision-making, automation and risk reduction. Much early development of systems and standards was driven in the 1960s in the US.

Computers became practical tools of commerce and public administration as semiconductors replaced vacuum tubes, prompting Gordon Moore of Intel to formulate "Moore's Law" from the observation that the number of transistors on integrated circuits was doubling every two years.

Elena Vaganova and colleagues reviewed the early history of clinical and Hospital Information Systems (HIS) (Vaganova et al 2017). They noted that HIMSS (The Healthcare Information and Management Systems Society) was founded at the Georgia Institute of Technology in 1961. It aimed to promote and accredit reform and advancement in the global health information ecosystem through benchmarking and reference standards for healthcare organisations. HIMSS now describes an eight level structure (0-7) of digital operational maturity of healthcare providers which continues to inform the development and implementation of digital healthcare systems.

The first hospital information systems were introduced in the 1960s for managing billing and hospital inventory. In 1965, the Technicon Medical Information System was developed as a collaborative project between Lockheed and El Camino Hospital in California.

In 1967, the “Health Evaluation through Logical Processing (HELP)” system (Warner Homer 1973) was implemented at the Latter-day Saints Hospital in Salt Lake City, Utah. It was the first hospital information system to integrate clinical data accumulation and clinical decision support.

Also in 1967, the International Medical Informatics Association (IMIA) was established as a technical committee of the International Federation for Information Processing (IFIP). It became an independent organization in 1987 and it was established as a legal entity under Swiss law in 1989 (Welcome to the IMIA 2017, Yearbook, 2017.)

In 1968, the COmputer STored Ambulatory Record (COSTAR) (Barnett et al 1979) was developed by the Laboratory of Computer Science at Massachusetts General Hospital.

The concept of the computer based Problem Orientated Medical Information System (PROMIS) was introduced by Dr Lawrence Weed at the University Medical Centre in Burlington Vermont, as a precursor of the Problem Orientated Medical Record (PROM).This helped to clarify the relationship between care inputs, costs and outcomes.

Jan Schultz was associated with the University of Vermont from 1969 until 1981 as a Research Associate in the College of Medicine. He coordinated computer related activities at PROMIS Laboratory during that period and conducted research in programming languages and database systems. In 1981 he founded PROMIS Information Systems, Inc. Schultz subsequently wrote in an essay on A History of the PROMIS Technology: An Effective Human Interface, which was published in “A History of Personal Workstations”, (Goldberg et al 1988) that:

I met Lawrence L. Weed, MD in November 1966. When we began our work, other medical record research groups took the dictated or written words of physicians and other medical personnel and manually entered them into a computer. We decided from the very beginning to interface the information originator directly to the computer and develop techniques and tools to facilitate this direct interface...

It is unusual for a computer technology to grow out of a social movement... A small group of medical and computer people worked together for 15 years developing a computer technology to support a medical philosophy. The grant proposal of 1967 that provided our original funding set forth the goals that were to guide us:
(1) that the medical record, use a "problem oriented" approach, be the instrument whereby the following objectives can be implemented, and
(2) that the technique of record keeping described in previous publications (Weed, 1964, 1968) should be the basis for the realization of these goals, and
(3) that a real-time computer system should be used to overcome the data distribution and time barriers that are insurmountable on a manual basis using conventional hospital and clinical medical records.

Our objectives were to develop a system that would:
1) Facilitate good patient care by making immediately available (in minutes) to the individual physician a complete, updated list of problems on any patient and by providing simultaneously, as a unit, all the data in sequence (narrative, laboratory, etc.) pertinent to any of these problems.
2) Make possible epidemiological studies and other research endeavours in terms of problems, having all the data on any given problem immediately available.
3) Make possible a medical audit whereby the standards of care being provided for a given entity {e.g. hypertension) can be rapidly assessed because of the specific orientation of all the data.
4) Make possible a business audit to assess the physical, financial and time resources that go into the solution and management of a given problem. The need for a more organized, efficient and economical approach to the management of common medical and surgical disorders may then be documented.

Dr Mark Anderson, former Royal Naval Officer and Visiting Fellow to the Web And Internet Science (WAIS) Group of Southampton University, contributed the following recollection about PROMIS for me in September 2024:

"An interesting cross link from Medical to Military Service is that the PROMIS system in part inspired Carnegie-Mellon's Record-Based Hypertext System from the mid 1970s, which emerged as ZOG (this is not an acronym and was just meant to be a memorable title). In the early 80's ZOG went to sea in the US Navy aircraft carrier USS CARL VINSON (Akscyn et al 1984)

I recall meeting the VINSON whilst on HMS EURYALUS (c.82–84). At the time we were busy moving engineering docs from paper to microfiche (gasp!) and whilst alongside in the US, Xerox had to get an engineer out of retirement to mend our copier because it was so old. By 1985, I was afloat with AMSTRAD PC running PCW, on which I did my post-action reports and personal records.

Healthcare Computing in the 1970s

The 1970s was the era when the minicomputer and the microcomputer began to replace the huge industrial mainframe systems, thus democratising computing for a much wider range of users, developers, and bespoke applications. The proliferation of systems also mandated the development of means for inter-communication and networking.

Schoolchildren, students and young professionals of that era will recall the early Apple, Commodore, Atari, BBC Micro, TRS-80, ZX81, ZX Spectrum, Commodore 128, and Amstrad Personal computers (PCs); from which the IBM Personal computer with its Microsoft DOS operating system software, and the Apple MacIntosh computer emerged. All of these products spawned dynasties of fantastic wealth, and they stimulated many individuals to become familiar with databases, word processing and graphical systems.

In 1976, **the Systematised Nomenclature of Medicine (SNOMED)** emerged from work in the 1960s by the American College of Pathology on a Systematised Nomenclature of Pathology (SNOP).

Information communication protocols from the 1970s onwards

During the 1970s, a set of international standards were therefore created for the transfer of clinical and administrative data between disparate software applications and computer systems from different healthcare providers.

The Open Systems Interconnection (OSI) model of communications between computing systems exist in seven different abstraction layers". These are the Physical, Data Link, Network, Transport, Session, Presentation, and Application Layers (Wikipedia May 2023).

Health Level Seven (HL7) further describes the Application Layer, which describes the practical applications which sit on top of the infrastructure. The HL7 standards are set by Health Level Seven International, which is a non-profit organisation based in Ann Arbor, Michigan. In recent years, message transmission has been standardized around the HL7 version 3 standards and XML (Extensible Markup Language).

The US Department of Health has also prescribed five standards for the sharing of medical information among federal agencies (Cttee. on Data Standards for Patient Safety 2004), vis:

(1) Messaging standards from Health Level Seven Inc.

(2) Standards for retail pharmacy orders from the National Council for Prescription Drug Programs (NCPDP).

(3) Technical standards for medical devices from the Institute of Electrical and Electronic Engineers (IEEE 1073).

(4) Standard for images from Digital Imaging Communications in Medicine (DICOM).

(5) Standards for the reporting of results from clinical laboratories, that is the Logical Observation Identifier Name codes (LOINC).

Healthcare Computing in the 1980s

The 1980s saw a further acceleration in the democratisation of computing technologies. Edward Ambinder (Ambinder 2005)) notes that:

"During the 1980s, computers improved dramatically. Graphic user interfaces and networking technologies fostered the need for a data interchange protocol for health care, and to standards for the exchange of clinical, financial, and administrative information between health computer systems".

In 1982, Michael Jenkin wrote for the Society for Computer Medicine (Jenkin 1982) that:

The combination of new user-accessible hardware and user-friendly software is stimulating significant new developments in the design of health information systems. The principal change is a major focus by health-care professionals ... manifested by the emergence of the new field known as 'Medical Informatics'.

Crucially, he noted the importance of end user engagement with developers, in that:

Nearly ten years ago, John Jacquez, in his book on computer diagnosis (Jacquez 1982), observed that the major problems in utilizing computers to assist in patient-care management are almost exclusively problems for the provider of that care, particularly physicians. He noted that 'until the physician is willing to investigate his own terminology and his own methodology, all the computer engineer, physical scientist, or mathematician can do is to stand in the wings and help out in very minor ways'.

Eta Berner and colleagues observed in a 2005 review that:

"Networking was introduced on a large scale in the 1980s. This created a need for a data interchange protocol in health care, which stimulated the creation of HL7. This also stimulated the controversy, which continues today, between networked "best of breed" applications and single technology integrated systems....

A (further) major focus of informatics research during the 1980s was on the use of expert system methodologies developed in the 1970s to develop clinical decision support systems to assist with clinical diagnoses... these activities focused on reducing medical errors related to overlooked patient information as well as improved access to medical knowledge".

Healthcare Computing in the 1990s

In 1991 the Institute of Medicine (IOM) in the USA published the *Computer-Based Patient Record: An Essential Technology for Health Care* (Ambinder 2005). It defined 12 requirements for the electronic medical record (EMR) that focused on the patient and the healthcare users, in that it would:

1. Support a problem list
2. Measure health status and functional levels
3. Document clinical reasoning and rationale
4. Provide dynamic links to other patient records
5. Guarantee confidentiality, privacy, and audit trails
6. Offer continuous access for authorized users
7. Support simultaneous multiple user views
8. Support timely access to local and remote information resources
9. Facilitate clinical problem solving
10. Support direct data entry by users
11. Support practitioners in measuring costs and improving quality
12. Support the existing and evolving needs of clinical specialties.

The emergence of the Internet in the 1990s transformed the potential for the sharing of healthcare information and for more evidence based medicine. However, by 2001, there was still serious discontent in the US at the failure adequately to exploit information technology in healthcare. In their 2005 paper, Berner and colleagues highlighted the Quality Chasm Report of the US Institute of Medicine of 2001, in that:

"in the absence of a national commitment and financial support to build a national health information infrastructure, the committee believes that progress on quality improvement will be painfully slow"

The IOM Quality Chasm report laid out the essential elements of 21st Century Healthcare. These included:

- The widespread use of evidence-based medicine (including adaptive evidence-based decision support systems),

- Robust information infrastructure (embodied in a US National Health Information Infrastructure, NHII and EHRs),
- Aligned reimbursement incentives and regulatory requirements,
- and A workforce that was skilled in evidence-based medicine, information technology, and process improvement.

These elements, combined with a focus on assuring a health care system that is safe, patient centred, effective, efficient, equitable, and timely, should make for a compelling formula".

In 2004, President George Bush (Snr) established **the Office of the National Health Information Technology Coordinator**. This in turn led to a **US National Health Information Infrastructure** (NHII), which was to be built upon a standard healthcare vocabulary, with precise definitions for terms to ensure uniformity. **The US National Library of Medicine** (NLM) licensed SNOMED-CT (Systematized Nomenclature of Medicine-Clinical Terms) to standardise clinical communications.

The United Kingdom Perspective

The Evolution of Health Information Systems in the UK from The 1970s

The UK Government began to experiment with national computer systems for health in the late 1960's with Patient Administration Systems. These were followed by Laboratory and Radiology administrative systems in the 1970s.

By 1970, serious consideration was being given to the benefits of computerisation of medical records in the UK NHS. Michael Alderson (1976) reported a review of the NHS Computing *Policy in an article in the British Journal of Preventive and Social Medicine. He concluded that "The present knowledge of the optimum approach to health information systems is deficient, despite the lip-service paid to identifying need, monitoring functioning of the health service, and optimizing allocation of resources."*

Early experimentation with the electronic patient record was undertaken in the UK in the late 1970s by the Exeter Community Health Service Computer Project team at the Princess Elizabeth Orthopaedic Hospital, the Royal Devon and Exeter Wonford Hospital, and local GP surgeries , It was funded by the then South-Western Regional Health Authority, and used an ICL 1904 with 100+ Video Display Units. The project was wound up after five years on technical and cost grounds, but valuable lessons were reportedly learned to inform future iterations of the EPR. (MacDonald, British Computer Society 2018).

Hospital Information Support Systems (HISS) followed in the 1980s, along with the Resource Management Programme. Formal consideration of an NHS IT strategy followed in the early 1990s, later to be followed by the Information for Health strategy, and consideration of Electronic Patient Record systems.

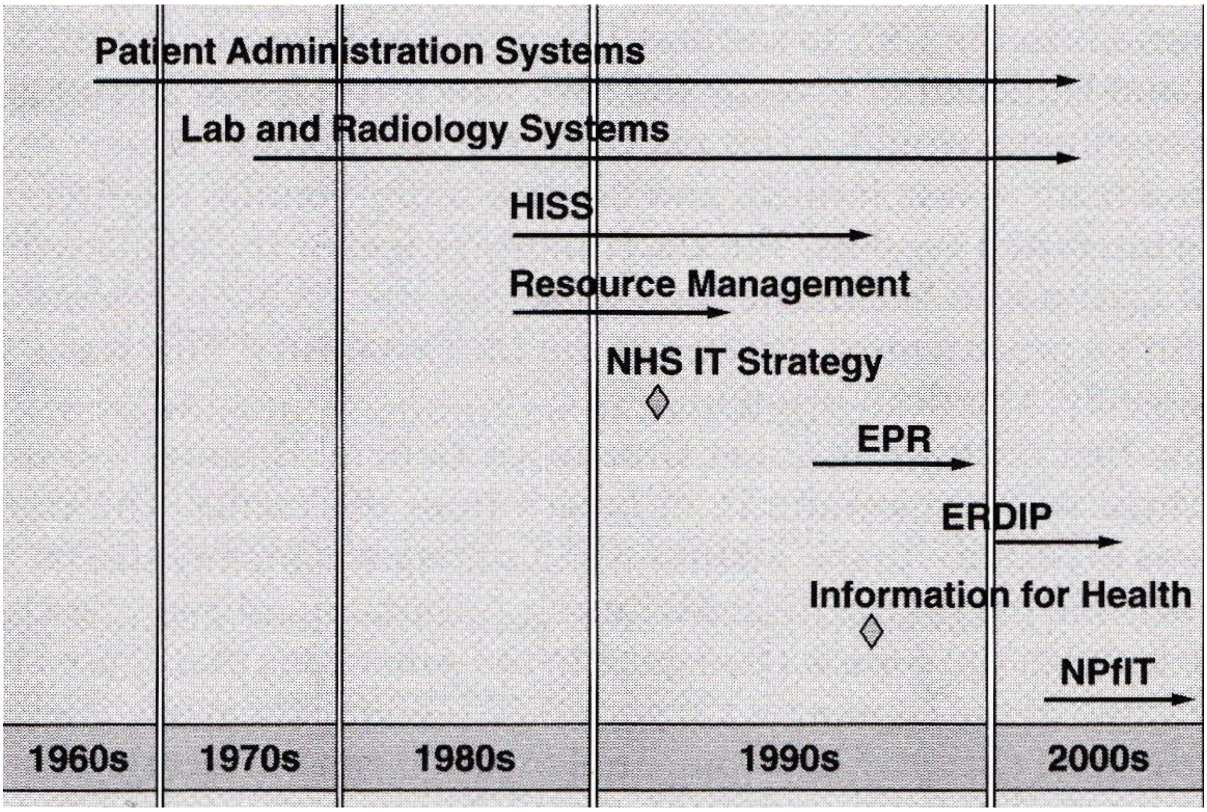

Figure 1: timeline of major NHS IT projects, 1960s-2000s (from Brennan, 2005, p.49, Figure 6.1)

Developments in UK Public Healthcare Computer Systems in the 1980s.

Brian MacMillan records (2018) that “Computers in general practice can be traced back to the early 1970s, with a pilot study by the Department of Health in Exeter in 1972.

In the early 1980s, the UK government-sponsored “Micros for GPs” involved 150 Practices. In 1987, private companies began offering free computer systems to general practices in exchange for anonymised data for pharmaceutical companies. These schemes resulted in an exponential growth in the number of GP practices using computerized systems in the 1980s. By 1996, 96% of general practices used computerised record systems" (MacMillan 2018).

The 1980s were characterised by a series of ambitious but ultimately unsuccessful attempts to computerise various elements of healthcare delivery in the UK with a number of high profile failures to deliver effective systems and at substantial cost to the taxpayer.

The Wessex Regional Health Authority Regional Information Systems Plan (1980s)

Clinician-facing computer systems were virtually unknown in the UK in the early 1980s, when the Wessex Regional Information Systems Plan (RISP) for digital transformation was conceived by members of the then Wessex Regional Health Authority.

The Clinical Data Estate at Southampton General Hospital evolved from observations made and lessons learned from the then Regional Health Authority in the attempted computerisation of local healthcare systems, in partnership with IBM. It used the Royal Hampshire County Hospital in Winchester as the system guinea pig, given its proximity to the Regional Headquarters.

The Wessex RISP plan envisaged the development of five core computer systems to achieve integration across the health region. RISP aimed: "to use modern (1980s era) technology to optimise the use of information in the continuous improvement of the effectiveness and efficiency of clinical and other health services".

The plan was adopted in May, 1984, but flaws in the technology and the concept soon became apparent. Auditor reports were critical of the management of the project from as early as February 1987, but it was not officially abandoned until April 1990. Even as late as January 1989 the emphasis on the Wessex Health Authority management executive had been to bring the project under control and to be clear about its delivery and costs, with a view to ensuring that it succeeded in its vision.

At its eventual abandonment, at least £43 million had been spent and at least £20 million of this, by the management executive's own admission, was wasted due to their determination not to abort the project sooner." (see the 63rd Report of the Committee of Public Accounts of the Hoe of Commons, Paper No HC658)

An Overview of the Outcomes of the Wessex RHA Digitisation Project

John Denham, then MP for Southampton Itchen, set out his concerns about the RISP programme in a long speech to Parliament (Hansard 1993). He *alleged that it amounted to a* major scandal which involved companies, individuals at the heart of the NHS and senior members of the then Government. He stated that:

"In September 1986, Arthur Andersen and Co. and IBM received the main RISP contract... In May 1986 the tendering process had been reopened to enable the IBM-Andersen bid to move from fourth place to become the prime contractor through aggressive inside lobbying...

Over a period of eight years, Wessex regional health authority spent more than £60 million on the failed regional information systems plan—or RISP—computer project... The Public Accounts Committee will now examine the Wessex saga in detail, but it might not have done so had it not been for inquiries by Computer Weekly, The Independent and myself.

... Ministers have announced new measures to control computer projects in the health service. Control will never be successful, however, until the full lessons of Wessex have been learnt. I have four main concerns, vis:

- the failure of the Department of Health to control Wessex and its active connivance at the cover-up;

- the network of personal, political, commercial and corporate interests that exploited Wessex and their interest in concealing the truth;

- the way in which Wessex sought to divert attention from key aspects of the RISP project, particularly those personally involving Sir Robin Buchanan, the chairman of Wessex and now of the NHS supplies authority;

- the abject failure in nearly every case to recover public funds or to take effective action against companies or individuals".

In a paper in 2001 from the University of Glasgow (published on CiteseerX), Michele Jeffcott examined the failure of implementation of a series of UK healthcare IT systems. He wrote: *"Centrally controlled government Information System (IS) projects are historically provided with continual investment and resources, despite serious and often long-standing contra-indications. This is due to elected management boards attempting to 'save face', rather than admit defeat".*

The technology of computer and software systems was still very immature through the 1980s, and the healthcare workforce was largely unfamiliar with such systems in an era when mainframe computer systems and "dumb terminals" dominated the Healthcare IT landscape; when mobile telephony, personal desktop computers, icon driven software and the Internet were still unknown.

UK Healthcare Information Technology in the 1990s

The 1990s were characterised by progressive experimentation, as individual health professionals used microcomputers to develop data bases of clinical records, and as various public and independent health providers adopted bespoke systems for clinical various administrative functions.

The 1992 NHS Information Management and Technology (IM&T) strategy identified five main principles for the use of information in the NHS, vis:

1. Information should be person-based;
2. IT systems should be integrated;
3. Information should be derived from existing operational systems;
4. Information should be secure and confidential; and
5. Information should be shared across the NHS. Regrettably, the ambitions of organisations and governments to computerise health information systems were not matched either by the technology or by the understanding of the complexity of computerisation of healthcare at that time.

Regrettably, high profile failures in public digital projects continued through the 1990s, prompting Michele Jeffcott (2002) to further observe that:

“IS projects in the NHS are characterised by a number of high-profile and high cost failures, beginning in the 1980’s and continuing to the present day. Most recent NHS failures include the Hospital Information Support Systems Initiative in 1997 and the Clinical Coding Information System in March 1998.

’Failure’ is not a simple concept, ranging as it does from cancellation or termination, through late delivery and cost overruns, through to non-compliance with specifications and/or the demands and expectations of clients and users. Despite many years of work and investment, both of the above systems failed even before implementation, and so resulted in significant losses for an organisation already strapped for cash.

This is a typical experience, which has led to an increasing concern amongst organisations in the UK and elsewhere with the large amounts of money that appear to have been devoted to software projects with little apparent organisational benefit [5].

There is also an increasing realisation that risks in IS projects in the NHS continue to be underestimated and under-managed, despite the fact that the services long experience in the implementation of comprehensive IS has continually proven it to be a high risk and dangerous process ...

The cost of scrapped or over-budget government IT projects has topped £1 billion since 1997 and the public are no longer willing to see their money thrown away, with no visible improvement in service provision and patient care. This paper has used several case studies to reveal that many of these failures involve a neglect of organisational issues within the overarching NHS and government system, which result in the disregard of end user needs.

Taghreed Justinia (2017) records how:
“The UK's National Programme for IT (NPfIT) was an ambitious programme which was launched in 2002 with an initial budget of some £6.2 billion. It attempted to implement a top-down digitisation of healthcare in England's National Health Service (NHS).

The core aim of the NPfIT was to bring the NHS' use of information technology into the 21st century, through the introduction of an integrated electronic patient record systems; reforming the way that the NHS uses information; and hence to improve services and the quality of patient care.

The authors of a report for the Centre for Public Impact (2017) record that:
“The UK government chose a top-down approach to create a nationwide implementation of Electronic Health Records, EHRs, known as the NHS Care Records Service, as the cornerstone of the £12.7 billion National Programme for Information Technology (NPfIT)". Four companies, including the US Computer Sciences Corporation (CSC), began this ambitious health IT project in early 2002. The NPfIT was officially dismantled in September 2011.” (ref)

In 2011, in a report by the House of Commons Public Accounts Committee, chaired by Margaret Hodge, concluded that:
'The Department of Health is not going to achieve its original aim of a fully integrated care records system across the NHS. Trying to create a one-size-fits-all system in the NHS was a massive risk and has proven to be unworkable. The Department has been unable to show what benefits have been delivered from the £12.7 billion spent on the project so far.'

In a review of the programme in 2014, Oliver Campion-Awwad and colleagues identified three main themes in the strategic leadership of the programme:
• *Haste.* In their rush to reap the rewards of the programme, politicians and programme managers rushed headlong into policy-making, procurement and implementation processes that allowed little time for consultation with key stakeholders and failed to deal with confidentiality concerns;
• *Design.* In an effort to reduce costs and to ensure swift uptake at the local levels, the government pursued an overambitious and unwieldy centralised model, without giving consideration to how this would impact user satisfaction and confidentiality issues; and
• *Culture and skills.* NPfIT lacked clear direction, project management and an exit strategy, meaning that the inevitable setbacks of pursuing such an ambitious programme quickly turned into system-wide failures. Furthermore, the culture within the Department of

Health and government in general was not conducive to swift identification and rectification of strategic or technical errors.

"The Husky That Came Back To Bite"

The problems and costs of the NPfIT programme and its leadership were savagely encapsulated by the DHI News Team in an article in the Digital Health and Intelligence Newsletter of 31st July 2014, under the title of The Husky That Came Back To Bite:

"The architects of the NHS National Programme for IT were fond of boasting that they had negotiated eye-wateringly tough contracts with suppliers that would punish failure and reward success. Yet this week it emerged that the Department of Health will have to pay Fujitsu more than £700m in damages at the end of a long legal dispute over the company's departure from NPfIT in 2008... How did we get into such mess?

Famously, Richard Granger, the original Director General of NHS IT, promised he would manage suppliers to the national programme by shooting "huskies" that failed to deliver...

Fujitsu (of subsequent Post Office Horizon system notoriety, Ed.) *was the last of NPfIT's local service providers to be appointed. It was awarded an £896m contract in 2004 to modernise electronic record systems across the South of England. For hospitals, this meant the clinical software that was supplied by the IDX Systems Corporation. However, there was a switch from IDX to Cerner Millennium in 2005, after GE bought IDX and pulled it from the UK. This is believed by many to have been where things started to really seriously go wrong.*

In a hasty change of contract, the suits from NPfIT asked Fujitsu in the South, and BT in London, to deliver the version of "Cerner Millennium" that was running at Homerton Hospital. Unfortunately, Homerton's version of Millennium wasn't transferrable to other NHS trusts without a huge amount of local configuration at each new site. It also lacked a core patient administration system that reflected the basic model of NHS healthcare delivery and the key concept of finished consultant episodes.

Fujitsu duly took the Homerton version of Millennium and there followed a series of fraught implementations, plunging several trusts into crisis. First out in 2005, was small, specialist trust the Nuffield Orthopaedic Centre. A further five trusts received the system before it was

installed, in February 2007, at Milton Keynes General Hospital, where the Trust board subsequently said the implementation "resulted in near melt down." Against this backdrop, Fujitsu's contract was terminated.
Richard Granger stepped down later that year It's never been clear how much this was deliberate or by accident. The termination notice to Fujitsu was issued by Granger's long-term deputy Gordon Hextall, who took up the reins at NPfIT.
At this point, Fujitsu had nine sites live with Cerner Millennium software. One of these users, Worthing and Southlands Hospitals NHS Trust announced that it was going to switch off the system and move back to its Sema-Helix software in January 2009.

BT was brought in to support the remaining 'live' sites, so as to get them onto the version of Millennium that it had developed for London, and to put this version of the system into three 'greenfield' sites at Bath, North Bristol and Oxford.

Even so, in the seven years since Fujitsu left, much of the NHS in the South of England has failed to get much needed clinical IT systems, setting many hospitals back a decade. In addition, the taxpayer must now pay damages to the supplier for reasons that remain unclear. Just why was Fujitsu 'exited' from the programme? Details have never been released – but given the consequences they should be.

The judgement on the case has not been published, either. Indeed, the progress of the dispute has only surfaced occasionally. In 2013, the Commons health select committee, heard that it had just gone to arbitration, having run up £31.5m of legal charges on the DH side alone. .. Mistakes were clearly made that should not repeated... "

The 2000s and the UK National Programme for IT (NPfIT)

By 2000, the health records of UK citizens still lacked a coordinated system of information standardisation, management or exchangeability. Unfortunately, the problems of the 1990s were once again revisited, but at a grander scale.

The ERDIP (Electronic Record Development and Implementation Programme) project

This was a series of IT pilot projects at 19 NHS demonstrator sites between 2000 and 2003. It tested the technical and ethical boundaries of creating community-scale electronic health records. Michael Cross, writing about NHS computerisation: lessons from what the bosses never learned" in the Guardian on the 12th August 2009, noted that:

"ERDIP was airbrushed from history. A subsequent independent review into NPfIT found it "extraordinary that the ERDIP recommendations were largely ignored". The reason, of course, was that the ERDIP findings were inconvenient. The evaluations stressed the need for closely involving system users – and patients – in the design of electronic records, and for introducing IT as part of improvements to patient care, not as an end in itself. This implied that the subsequent NPFIT national programme's massive scale and gung-ho timetable were unrealistic".

"There IT goes again"

Michael Cross wrote an article titled "There IT goes again" in the British Medical Jounal in 2011 that:

"The perception of NHS failure is only part of a wider narrative of waste and incompetence in public sector computing. While anecdotes date back at least to the 1970s, the issue became a political cause célèbre in the early 1990s.

It was triggered by revelations of three separate sets of events in the NHS: revelations of waste, conflict of interest, and alleged criminal behaviour associated with large scale computerisation at Wessex Regional Health Authority (Committee of Public Accounts: Sixty-third Report 1992-93); mismanagement at a services company set up by West Midlands Regional Health Authority; and the failed implementation of a computer aided dispatch system at London Ambulance Service (Dalcher 1999).

In a pattern that would be repeated, only one of the "IT fiascos"—that at London Ambulance—could truly be blamed on IT problems, and then only in part. Indeed, the hospital systems which were installed under the Wessex programme at two sites performed well. However the narrative of disaster became firmly established in the political and media agenda, with news of cost over-runs and failed or delayed implementations at public bodies ..."

The Unheralded Benefits of the NHS NPfIT programme

Despite the foregoing negative assessments, the National Audit Office published a paper in June 2013 which aimed to quantity the return on expenditure for the NPfIT programme. The report noted that The overarching National Programme comprised a number of component programmes, vis:

- National infrastructure, including a broadband network and foundation applications;
- National applications, including appointment booking and prescription services; and
- Local services, including care records systems and electronic X-ray and scanning systems.

In the case of the local care records systems, BT was now providing systems in London and the South, while Computer Sciences Corporation CSC was providing systems in the North, Midlands and East. However, different care records systems were being delivered in different parts of the country and in different care settings.

The National Programme was managed at national level by NHS Connecting for Health, part of the Informatics Directorate of the Department of Health (the Department). The Department was responsible for procuring and managing the National Programme's central contracts, including those with the local service providers.

Within the NHS, responsibility for delivery was split between the local service providers and trusts. Trusts were generally responsible for business change, delivery plans and staff training, and for signing off acceptance of systems as meeting their requirements.

Specifically, the NPfIT programme successfully delivered the following systems:

National infrastructure: A fibre-optic and broadband network connecting all NHS sites.

NHS Mail: A secure email, text and fax service, transferring patient data.

NHS Spine: A group of eight applications which underpin the NHS Care Records Service.

National applications:

Choose and Book: An electronic referral and booking service giving patients a choice of time and place for their first outpatient appointment.

Electronic Prescription Service: Enables primary care prescribers to send prescriptions electronically to a dispenser of the patient's choice.
Summary Care Record: Part of the NHS Care Records Service, containing key medical information from a patient's record to support urgent or unscheduled care.
GP record transfer: Enables patient records to be transferred electronically between GP practices, replacing the existing manual transfer process.

Local services:
Detailed care records systems: Part of the NHS Care Records Service, containing full details of a patient's medical history and treatment, accessible to a patient's GP and local community and hospital settings.
Picture Archiving and Communications System Enables X-rays and other medical scans to be stored electronically and viewed on screens.

In 2019, Colin Price and colleagues published a review of Twenty-five years of National Health IT, in which they explored the strategy, structure, and systems in the NHS in England. They noted that:
"There is global interest in implementing national information systems to support healthcare, and the National Health Service in England (NHS) has a troubled 25-year history in this sphere. The NHS has a complex and hierarchical multi-organization form in which restructuring may impact a range of intra- and inter-organizational factors...

We reviewed the strategic plans, legislation, and health policy documents, and found that against a background of frequent NHS reorganisations from 1973 to 2017, there has been a logical and emergent NHS IT strategy focusing progressively on technical and data standards, connectivity, applications, and consolidation.

Following the criticisms of the NPfIT programme, the UK Government therefore reverted to a distributed, Darwinian approach to digital implementation, wherein individual healthcare providers were freed to contract to a range of different healthcare software providers (for example EPIC, Allscripts, Cerner) for their systems, from which optimum solutions were expected to evolve over time.

The Need for Interconnectivity between Healthcare Information Systems.

The fundamental challenge around these systems is incoherence. Every health provider keeps its own record sets, including family practices, hospitals, occupational health services, dentists, opticians and special context providers, and progress towards the integration of the core elements of the records of the life of any one citizen or patient into a single common data system.

Therefore, an individual's personal medical record will consist of paper documents in domestic files, along with separately stored electronic records in general practice; community health records; one or more public and independent hospital systems in one or more cities, regions or countries; and in specialist record systems such as those relating to military service, prison occupancy and so on. Ancillary records such as dental records are held in other systems.

In the UK, the 10 digit NHS number has provided a unitary healthcare identifier for every citizen over the past 30 years. Large volumes of health data on primary care and hospital activity statistics (HAS) have been collected centrally for around 20 years. However, moves to practical integration, provision and accessibility of personal health records have only really developed momentum in the UK in the early 2020s with the Covid Pandemic, the NHS App and the Summary Care Record of GP-held records.

Progress in other countries in EHR integration has been more variable, with Estonia reportedly leading the way with unitary citizen information systems.

The Scope of Clinical Information Systems

Computing in healthcare covers a wide range of applications. These include:

Core administrative functions in the delivery of healthcare services, which include finance and accounting, logistics, estate management, personnel administration, human resources, pay, and so on. These functions are common to all businesses and public organisations, and are addressed by a rich ecosystem of software and hardware.

General administration of citizen and patient demographic records: the maintenance by the state and by major healthcare providers and funders of information on citizen identities, residences, contact details and related information in databases and Registries is critical to the efficient administration of health systems.

Patient administration systems (PAS). These are databases which are specific to individual health providers and to the daily management of patients under the providers' care, including appointments. The Patient Master Index (PMI) within a PAS acts as a core information framework for the population under care, and feeds core demographic and location data into the Electronic Patient Record.

The patient-specific Electronic Medical Record (EMR), also variously termed the Electronic Patient Record (EPR) or Electronic Health Record (EHR), has been the most challenging of the computational evolutions of the digital age to date.

The clinical records of individual patients typically comprise a complex mix of information in many different types, legacy formats and ages that pose a substantial integration challenge and a considerable challenge of clinical risk, additional cost and workforce inefficiency.

Much of the intellectual and development work around the EMR has been done in the US and the UK, with the key difference that US EMR work has been integrated with accounting and billing systems to reflect the particular needs of the funding methods of US healthcare.

The global search for effective solutions to the design and implementation challenges of the EMR is also the story of the Southampton Hospitals Digital Programme, which we will develop in later chapters of the project.

Commercial Software Systems and the Electronic Health Record

In order to ensure commonality and consistency of supply of commercially sourced EPR systems, the NHS introduced an accreditation system for suppliers. Eight such suppliers were accredited in the first assessment round in 2019. These were Allscripts, Cerner, DXC, IMS Maxims, Nervecentre, Meditech, TPP and System C.

Concurrently, healthcare providers in England can now be qualified by a **Digital Maturity Assessment** which allows the organisation to measure its progress to a digitally mature organisation. NHS Trusts which achieve a high level of digital maturity in the transition from paper to fully digital organisations are designated **Global Digital Exemplar** organisations, and are paired with less digitally advanced organisations to share expertise.

However, this accreditation does not measure the usability of the software products or their particular state of digital maturity in respect of the health care professional as the end user.. This poverty of utility is common experience and it is evidenced in the academic literature.

For example, in 2019, Benjamin Bloom and colleagues surveyed members and fellows of the Royal College of Emergency Medicine during 2019 about the usability of EHR systems in UK Emergency Departments using a validated assessment tool. The primary outcome was the System Usability Scale Score, which ranges from 0 (worst) to 100 (best). Scores were compared with an internationally recognised measure of acceptable usability of 68. Results were analysed by EHR system, country, healthcare organisation and physician grade.

They received 1663 responses from 8794 members, representing 192 healthcare organisations (mainly UK NHS), and 25 EHR systems. Fifteen EHR systems had at least 20 responses and were included in the analysis. No EHR system achieved a median usability score that met the industry standard of acceptable usability. Individual EHR systems' inter-quartile range scores ranged from 35 to 65. They concluded that in this survey, that no UK ED EHR system met the international standards of usability for information technology.

Chapter Summary

The history of computing since the 1940s is one of extraordinary and epoch-defining intellectual and technical virtuosity by far sighted and talented individuals, teams and technology companies. It describes continuous and rapid change and evolution, with the life cycles of machines and software systems measured in months and years rather than decades, and with a wide and changing range of technology solutions from which to choose.

It is also the story of technology driving change, in which governments, institutions, finance directors and administrators have struggled to keep abreast of the operational opportunities which those technologies have provided. Specifically in the matter of healthcare, it is primarily the history of attempts at the adaptation of technologies from other industries to the complex and diverse needs of healthcare providers, and of the expensive lessons to be learned when national and institutional bureaucracies seek to impose digital systems and solutions on this evolutionary tsunami.

However, the one conspicuous group who have been largely absent from this narrative are the actual end users of the systems, the health care professionals, the front line clinical administrators and secretariats who continually have to struggle with the marked imperfections and immaturities of clinical digital systems.

The founders of the UK Government Digital Service in 2010 coined the phrase “Digital by Default”, in which digital systems are so well designed to the specifications and experience of the end users that these users would choose no other means of completing their tasks. Instead, most healthcare computer systems are designed with only token engagement of the true end users, on whom imperfect systems are imposed through “Digital by Diktat”.

The success of Southampton healthcare informatics has been founded in the uniquely close interaction of users, system and software developers in one institution. This collection of essays is their story.

Chapter References

Anon: Welcome to the International Medical Informatics Association IMIA. Yearbook Med Inform. 2017 Aug; 26(1): 269–71. doi: 10.1055/s-0037-1606513

Akscyn, Robert M. and McCracken, Donald L. 1984 ZOG and the USS Carl Vinson. In *Computer Science Research Review*, Interaction Design Foundation, London, 901–906.): http://repository.cmu.edu/compsci

Alderson Michael: A review of the National Health Service's computing policy in the 1970s Brit. J. prev. soc. Med. (1976), 30, 11-16

Ambinder EP. A history of the shift toward full computerization of medicine. J Oncol Pract. 2005 Jul;1(2):54-6. doi: 10.1200/JOP.2005.1.2.54. PMID: 20871680; PMCID: PMC2793587.

Aspden P, Corrigan JM, Wolcott J, et al., editors. Patient Safety: Achieving a New Standard for Care. (Institute of Medicine (US) Committee on Data Standards for Patient Safety; Washington (DC): National Academies Press (US); 2004. 4, Health Care Data Standards. Available from: https://www.ncbi.nlm.nih.gov/books/NBK216088/:

Barnett G. O. *et al*., "COSTAR—A computer-based medical information system for ambulatory care," in *Proceedings of the IEEE*, vol. 67, no. 9, pp. 1226-1237, Sept. 1979, doi: 10.1109/PROC.1979.11438.

Berner ES, Detmer DE, Simborg D. Will the wave finally break? A brief view of the adoption of electronic medical records in the United States. J Am Med Inform Assoc. 2005 Jan-Feb; 12(1): 3-7. doi: 10.1197/jamia.M1664.

Goldberg Adele A history of personal workstations: Published:01 January 1988
Pages: 537; The Association for Computing Machinery New York United States
ISBN: 978-0-201-11259-7 DOI: https://doi.org/10.1145/61975

Institute of Medicine (US) Committee on Quality of Health Care in America. Crossing the Quality Chasm: A New Health System for the 21st Century. Washington (DC): National Academies Press (US); 2001. Available from:
https://www.ncbi.nlm.nih.gov/books/NBK222274/ doi: 10.17226/10027)

Jacquez JA (1972), *Computer Diagnosis Methods* (Charles C. Thomas, Publisher, Springfield, Illinois, USA).

Jenkin, Michael (1982) Computerised health information systems in the 1980s, Medical Informatics, 7:1, 1-6, DOI: 10.3109/14639238209020637

Ledley Robert S. and Lusted Lee B. Reasoning Foundations of Medical Diagnosis: Symbolic logic, probability, and value theory aid our understanding of how physicians reason
Science 3 Jul 1959 Vol 130, Issue 3366 pp. 9-21 DOI: 10.1126/science.130.3366.

Vaganova E., Ishchuk T., Zemtsov A. and Zhdanov D.
Health Information Systems: Background and Trends of Development Worldwide and in Russia. In Proceedings of the 10th International Joint Conference on Biomedical Engineering Systems and Technologies (BIOSTEC 2017), pages 424-428 ISBN: 978-989-758-213-4
Copyright 2017 by SCITEPRESS DOI: 10.5220/0006244504240428;

Van de Velde Rudi and Degoulet Patrice: Clinical Information Systems: A Component-Based Approach Springer 2003

Warner Homer R: Health Evaluation Through Logical Processing – HELP 1973 KIIS pp197-203 in the Proceedings of Medis '73, International Symposium on Medical Systems, Kansai Institute for Information Systems, Copyright © Kansai Institute of Information System & Industrial Renovation 1973

Weed L. A History of the PROMIS Technology: An Effective Human Interface in ACM's *A History of Personal Workstations*. 47pp. edited by Adele Goldberg, in 1988 by the ACM, the

Association for Computing Machinery (ACM) Press published by Addison-Wesley Publishing Co., Inc., Reading, Massachusetts.

UK Healthcare Computing

Alderson M. A review of the National Health Service's computing policy in the 1970s. Br J Prev Soc Med. 1976 Mar; 30(1): 11-16. doi: 10.1136/jech.30.1.11.

(Anon) Report of the Centre for Public Impact April 3rd 2017 https://www.centreforpublicimpact.org/case-study/electronic-health-records-system-uk

Bloom BM, Pott J, Thomas S, et al. Usability of electronic health record systems in UK Emergency Departments. Emerg Med J 2021;**38**:410–415.

Brennan, S. 2005. The NHS IT project: The biggest computer programme in the world... ever! Oxford, UK: Radcliffe Publishing Ltd.

British Computer Society Blog Post of 16th October 2018: https://www.bcs.org/articles-opinion-and-research/electronic-patient-records-in-the-1970s/

Campion-Awwad. Oliver, Hayton Alexander, Smith Leila and Vuaran
The National Programme for IT in the NHS: A Case History
MPhil Public Policy February 2014, University of Cambridge

Cross M. "NHS computerisation: lessons from what the bosses never learned" in the Guardian on the 12th August 2009

Cross M. There IT goes again. BMJ 2011; 343: d5317

Colin Price, William Green and Olga Suhomlinova: Research and Applications: Twenty-five years of national health IT: exploring strategy, structure, and systems in the English NHS. Journal of the American Medical Informatics Association, 26(3), 2019, 188–197 doi: 10.1093/jamia/ocy162

Committee of Public Accounts: Sixty-third Report:
Wessex Regional Health Authority Regional Information Systems Plan.
House of Commons, London: HMSO, 1992-1993.

Conference Paper: Engineering of Computer-Based Systems, 1999. Proceedings. ECBS '99. IEEE Conference and Workshop IEEE Explore April 1999 DOI:10.1109/ECBS.1999.755860

Dalcher Darren: **Disaster in London; The LAS Case study**
Forensic Systems Research Group, School of computing, South Bank University SE1, UK.

DHI News Team: The Husky That Came Back To Bite; Digital Health and Intelligence Newsletter of 31st July 2014
https://www.digitalhealth.net/2014/07/the-husky-that-came-back-to-bite/

House Of Commons Committee Of Public Accounts June 2013: Review of the final benefits statement for programmes previously managed under the National Programme for IT in the NHS for the Dept of Health: National Audit Office | June 2013

Jeffcott M. A., Technology Alone Will Never Work: Understanding How Organisational Issues Contribute To User Neglect And Information Systems Failure in Healthcare.
Personal Paper (2001), published on Citeseer X from the University of Glasgow, Scotland

Jeffcott, M., Johnson, C. The Use of a Formalised Risk Model in NHS Information System Development. *Cognition Tech Work* **4**, 120–136 (2002).
https://doi.org/10.1007/s101110200011

Justinia T. The UK's National Programme for IT: Why was it dismantled? Health Serv Manage Res. 2017 Feb; 30(1): 2-9. doi: 10.1177/0951484816662492.

Macdonald R, Clarkson M. ECHSCP: BCS Award-winning IT project 40 years on
https://www.bcs.org/articles-opinion-and-research/echscp-bcs-award-winning-it-project-40-years-on/

McMillan B, Eastham R, Brown B, Fitton R, Dickinson D. Primary Care Patient Records in the United Kingdom: Past, Present, and Future Research Priorities. J Med Internet Res. 2018 Dec 19; 20 (12): e11293. doi: 10.2196/11293.

National Audit Office Dept of Health: The National Programme for IT in the NHS Report By The Comptroller And Auditor General | HC 1173 Session 2005-2006 | 16 June 2006

Price, Colin; Green William, Suhomlinova Olga, Twenty-five years of national health IT: exploring strategy, structure, and systems in the English NHS, *Journal of the American Medical Informatics Association*, Volume 26, Issue 3, March 2019, Pages 188–197, https://doi.org/10.1093/jamia/ocy162

Transform: Directgov Strategic Review: Executive Summary 29 September 2010 https://www.gov.uk/government/publications/directgov-2010-and-beyond-revolution-not-evolution-a-report-by-martha-lane-fox