Principia Medicinae Digitalis Sotoniensis

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

Section 2 Essay 2

The Early History of the UHS Lifelines Interface, 2009-2011

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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 with knowledge and participation in 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 with the available contributions, final copies of each of the essays will be submitted to the University of Southampton ePrint server for formal publication.

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Contents of Section 2 of the Essay Collection on the History of UHS Digital

An Introduction to UHS Lifelines and the Visualisation of the Electronic Patient Record

UHS Lifelines (UHSL) is the generic name that we adopted for the transformative software system which we built at University Hospital Southampton from 2009 onwards for the visualisation and interaction with the Electronic Patient Record, according to the principles that I have described in Essay 2.1 of this collection of essays.

This section of the collection is structured as follows:

Essay 2:1: The Principles of Clinical Data Visualisation
Essay 2:2: UHS Lifelines Version 1: 2009-2011
Essay 2:3: UHS Lifelines Version 3: 2014-2016
Essay 2:4: UHS Lifelines Version 3: 2017-2018
Essay 2:5: UHS Lifelines Version 3: 2019-2020
Essay 2:6: UHS Lifelines Version 4: 2020-2024
Essay 2:7: Reflections and the future of UHS Lifelines

In Essay 2.1, I introduced the general principles of computer based data visualisation and the origins of the model of the Lifelines EPR interface in the conceptual work of a productive team at the Human Computer Interaction Laboratory of the University of Maryland under the leadership of Professor Ben Shneiderman in the 1990s.

I discovered the Maryland in the course of my Internet based research into data visualisation systems during the 2000s, and I introduced them to colleagues in the Information Management and Technology Directorate (IMTD) at UHS in 2009.

In this essay (2.2), I describe how we took the raw ideas from the Maryland Lifelines concept work and developed them into a mainstream, enterprise hardened system at the centre of the UHS EPR in a large NHS University Teaching Hospital.

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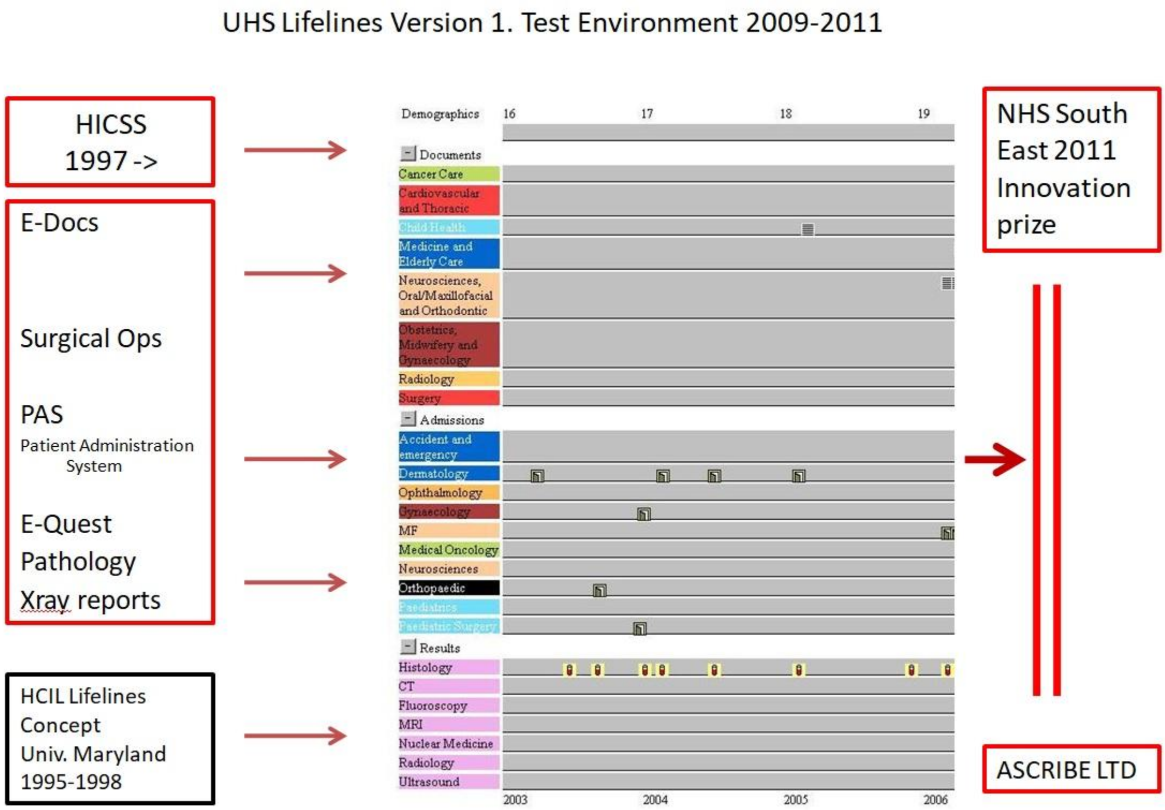

Figure 1: Summary of the history of UHS Lifelines Version 1, 2009-2011

An Outline of the UHS Lifelines Project

UHS Lifelines grew out of a pressing need to build an integrative user-friendly Electronic Patient record (EPR) interface to an increasingly complex array of the rapidly expanding portfolio of digital components of the UHS Clinical Data System (CDE) during the 2000s.

I proposed the concept to colleagues in the UHS IT team in 2009, by whom I was introduced to Alan Hales. Alan worked with me to turn the idea into a workable and highly iterated system which now sits at the heart of the UHS CDE.

The technical history is one of long hours of agile iteration by a small and self-motivated team, from early concept images to a fully formed and enterprise hardened software system with a number of clinical spin-off systems. These have the potential to transform the efficiency, productivity and clinical safety of digital health care systems across the NHS.
It is also a story of perseverance with a compelling innovation in an institutionally challenging environment of apparent indifference at clinical managerial and operational

levels, which will be familiar to many who seek to improve the productivity of the NHS. The UHS Lifelines portfolio of systems is unusual in the history of the National Health Service. It was not funded, commissioned or contracted. It grew from scratch through the voluntary efforts over 15 years to its present state of maturity.

The Lifelines story is non-linear, in that the system was built in phases as the software and operational environments changed around it.. It passed through four principal versions, and it evolved in parallel with the Breast Cancer Data System (Section 3 Essays) when the project looked not to have survived its infancy. The outline history is as follows:

Lifelines version 1, 2009-2010: This system (Figure 1) was our first and experimental version in Microsoft ASP.Net code. It was defined and built to a very satisfactory functional standard and it briefly went live in our test environment September 2010. However, in consequence of the terms of his restrictive separation contract from Ascribe Software Ltd, Alan Hales felt severely constrained from developing this into an operational system at UHS at that time.

Lifelines version 2, 2010-2015: The second version of Lifelines was written in new ASP code as an integral component of the evolving Southampton Breast Cancer Data System. Development in this format was continual through to 2014. The system introduced some powerful and unique features, including an episode structured master cancer timeline (Lifetrak) and a data science module.

Lifelines version 3, 2015-2019: By 2015, it had become apparent that the Lifelines module within SBCDS (version 2) had the potential to become a primary interface for all clinical activity across the Trust. Alan Hales rewrote the old Microsoft ASP code in more modern DotNet code, and the system was launched in a Beta format in the UHS CDE for Trust wide testing and familiarisation in 2016.

Lifeline version 4, 2020 to the present: The success of Lifelines V3 in open use finally persuaded key individuals and fast adopters across the Trust to implement the system as a key element of the UHS EPR, and to invest in enterprise hardening of the software.

Other Key Software Systems that Impacted Upon the Development of UHS Lifelines

Over the period (2009-2023) of development of UHS Lifelines through Versions 1-4, there were a number of major parallel developments and system acquisitions in the UHS CDE which I describe elsewhere in greater detail. These included:

The Hyland OnBase Electronic Document Management System (EDMS), 2014 onwards: OnBase was evaluated in 2014, acquired in 2015 and implemented in 2016. The potential impact of the OnBase EDMS and its reciprocal interactions with Lifelines in its various evolutions, were of particular importance over this period (Section 1 Essay Nine).

The Acquisition of the Somerset Cancer Register (SCR) Software System in 2014: This was the stimulus to our development of the Enhanced SCR system, SCR+ which has transformed the accessibility of clinical cancer records and the efficiency of the multidisciplinary cancer team (MDT) meetings across the Trust.

UHS CHARTS, 2016 onwards: CHARTS was developed in house as a unitary, single sign-on interface for the various components of the UHS CDE. These included eDocs, eQuest and HICSS Surgical Ops. CHARTS was launched alongside the OnBase EDMS.

The Geography of the Project

The project evolved across the hospitals which comprise the estate of the University Hospital Southampton (UHS) NHS Foundation Trust, formerly Southampton University Hospitals Trust (SUHT). These include:

Southampton General Hospital (SGH) is the main site on Tremona Road, Southampton

The Princess Anne Hospital Southampton (PAH) on Coxford Road is adjacent to the SGH site. It houses the Women's Health, Obstetrics, Gynaecology and Breast services.

The Royal South Hants Hospital, RSH sits off Brinton's Terrace, Southampton. It houses a mix of NHS services, along with the Independent Sector Treatment Centre, ISTC.

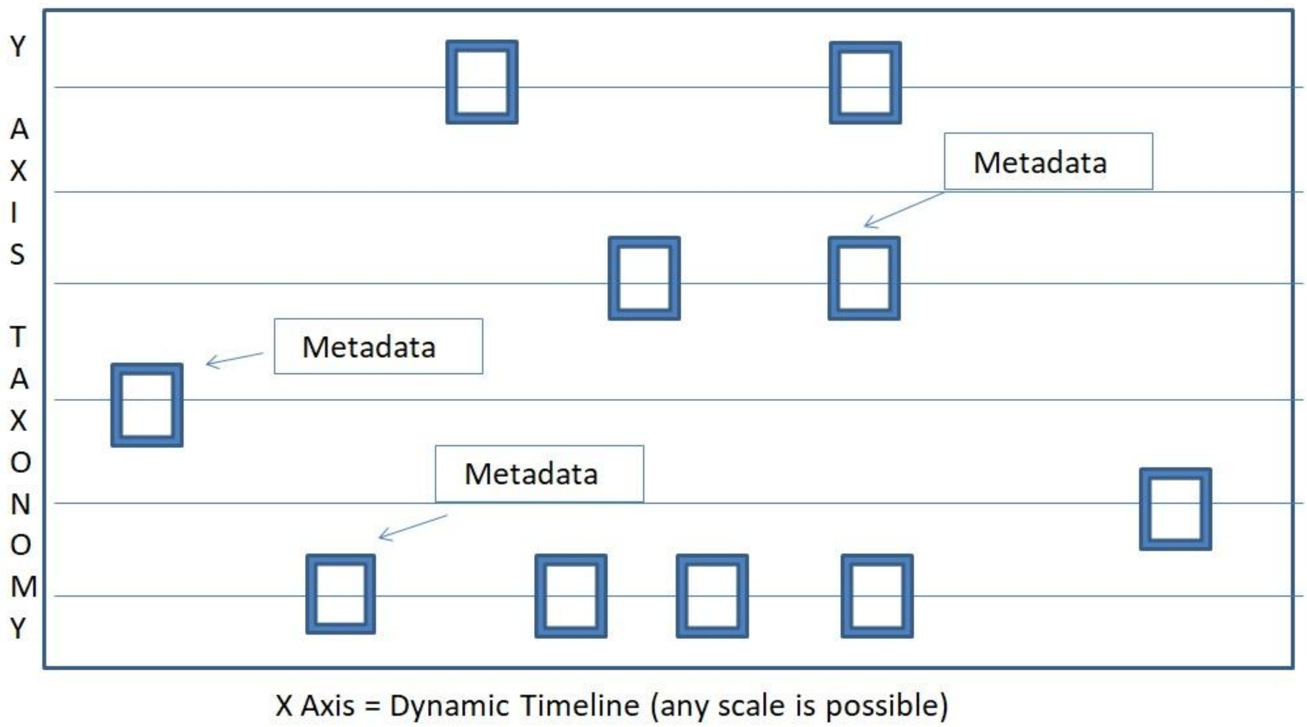

Figure 2. The principal design elements of Lifelines. Each "dynamic icon" is placed on the relevant timeline, according to its specific metadata. The centre point of the icon is the precise time. A "hover-over" balloon for each icon displays the metadata. On our own model, each icon occupied 12x12 pixels of screen space

An Introduction to the Design of UHS Lifelines

The family of systems and versions which comprise the UHS Lifelines project represent a new approach to the visualisation and interaction with the electronic patient record. UHS Lifelines itself is an interactive, continuously accruing, two dimensional matrix of subject specific timelines (Y axis = the subject taxonomy, X axis = time) on which dynamic icons are located according to their subject and timestamp metadata.

UHS Lifelines is a software system that builds an intuitive interface to the UHS Electronic Patient Record whenever it is accessed. It saves the user a substantial amount of screen time and effort on each occasion by doing "the hard work" through excellence in design. I have coined the somewhat clunky phrase Stacked, Synchronised Timelines with Dynamic Iconography to describe this framework. Suggestions for an alternative name would be welcome!

Agility and Iterative Public Sector Software Development

Thereafter, we worked voluntarily in a wholly agile and iterative way to the broadest of design templates with minimal funding within the rapidly evolving UHS Clinical Data Estate (CDE) and with its huge resource of curated clinical data. The products of our trials and tribulations ultimately proved compelling to a wider audience. All grew through curiosity driven research and development from broad concepts rather than to a formal design template. We used an agile, exploratory and iterative methodology and design philosophy without detailed prior specification.

The systems were therefore built and implemented at minimal marginal cost, technical or operational risk to the Trust, and all were ultimately adopted into the mainstream EPR on the strength of their compelling functionality.

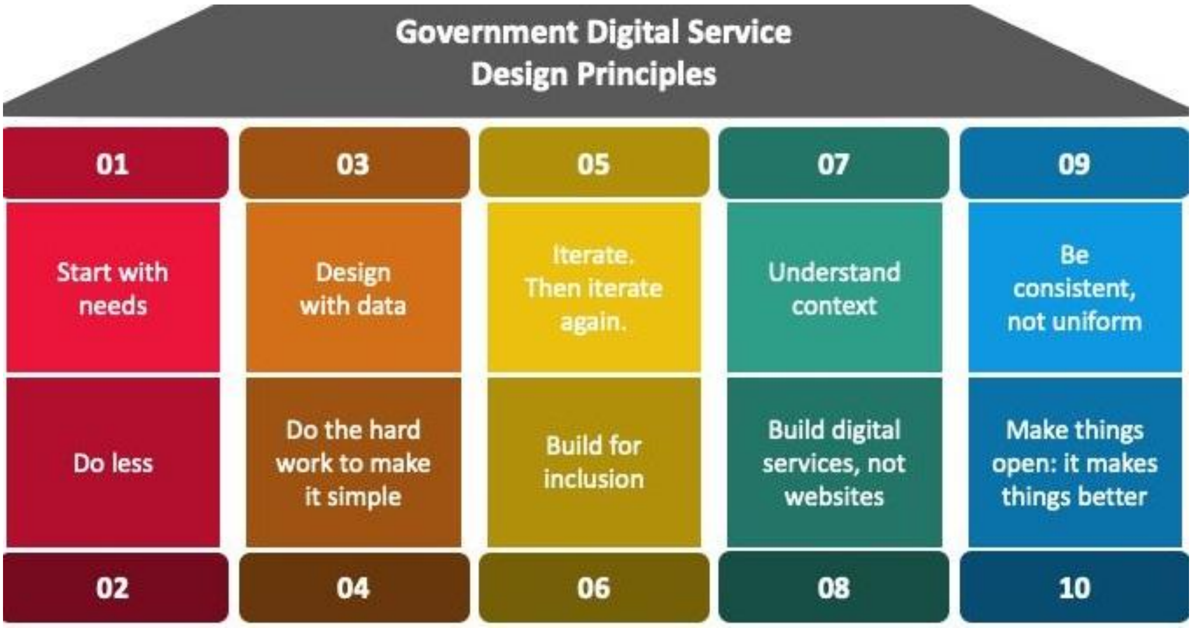

Figure 3; UK Government Digital Service Design Principles for User-Facing Software Systems

For this reason, the effectiveness of our work is also significant in the national context of the need for high quality public facing digital systems at reasonable cost, as expounded by the UK Government Digital Service (GDS) from 2010 onwards.

The GDS agile software development playbook had not been written when we started in 2009, and nor indeed had the GDS even been created, but our subsequent project work had remarkable resonances with the work of the GDS.

Waterfall Methodology in Software Development

The Agile approach to complex software development is radically different from the conventional top down (waterfall) methodology, wherein the entire software specification is written in detail in advance, and where subsequent modifications can be very costly and disruptive. Waterfall methodology has been the basis of the large commercial contracts which have so frequently failed in healthcare software development.

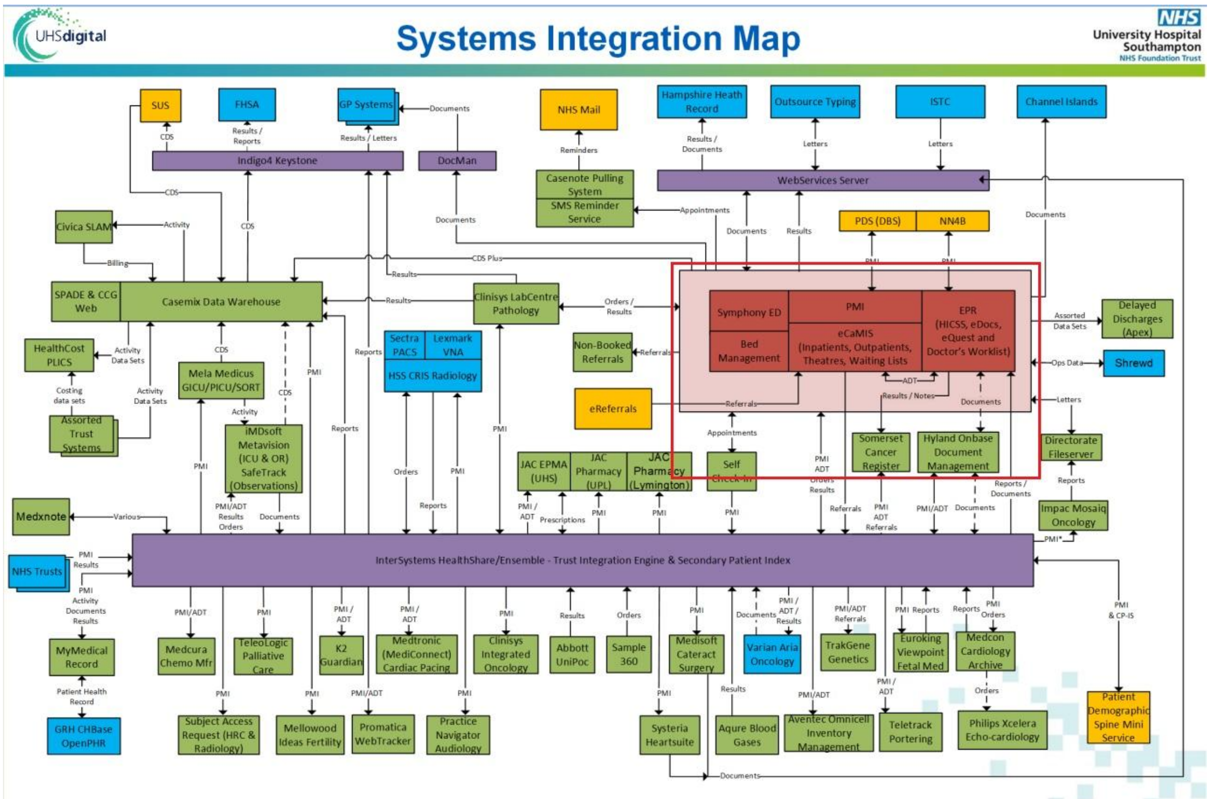

Figure 4: Diagram of the component software systems and their interconnections which comprised the UHS Clinical Data Estate in the decade 2009 to 2019, with the CHARTS EPR components outlined in red. The UHS Lifelines Application sits within this highlighted perimeter. Figure courtesy of Mr Ian Brewer of the UHS Information Technology Team

The UHS Clinical Digital Estate in 2009

By 2009, the UHS Clinical Data Estate (UHS CDE) had evolved into a complex intersection of multiple software elements from a variety of commercial providers and in house developments. It was built around the Intersystems Healthshare Ensemble Trust Integration Engine (Figure 1) and a secondary Patient Index. Every patient of the Trust had a unique seven digit identification number, which links all of the relevant systems.

Also by 2009, the hospital had amassed a large quantity of clinical documents and reports with standardised metadata on more than two million patients. However, the clinical user experience of the IT system had not kept pace. Digital documents were primarily accessed through legacy computer interfaces.

In order to review a Patient Record, the user had to retrieve the documents and reports separately from eDocs, eQuest, Results, HICSS and a range of other specialist systems, and assemble them into a coherent narrative at every clinical consultation. This made for a slow and taxing user experience in clinical service, when large volumes of time-structured information from multiple subject fields need to be assimilated and acted upon in a short time frame in clinics and elsewhere.

The General Design Concepts in our Time-Structured Clinical Record Interface

By early 2010, following a range of exploratory discussions, we had a general sense of direction in what we wanted to build with the UHS Lifelines project. We progressed on a "crawl-walk-run" basis of stepwise experimentation. Using the HCIL Maryland Lifelines concept (Figure   and Essay 2:1) as our general template, we set out to design a unifying clinical interface for a wide range of data inputs (documents, results, reports, imagery).

We intended to develop a system through which any health professional can readily visualise and interact with the complete medical record of any patient or group of patients, and from which clinical management and clinical research can be advanced.

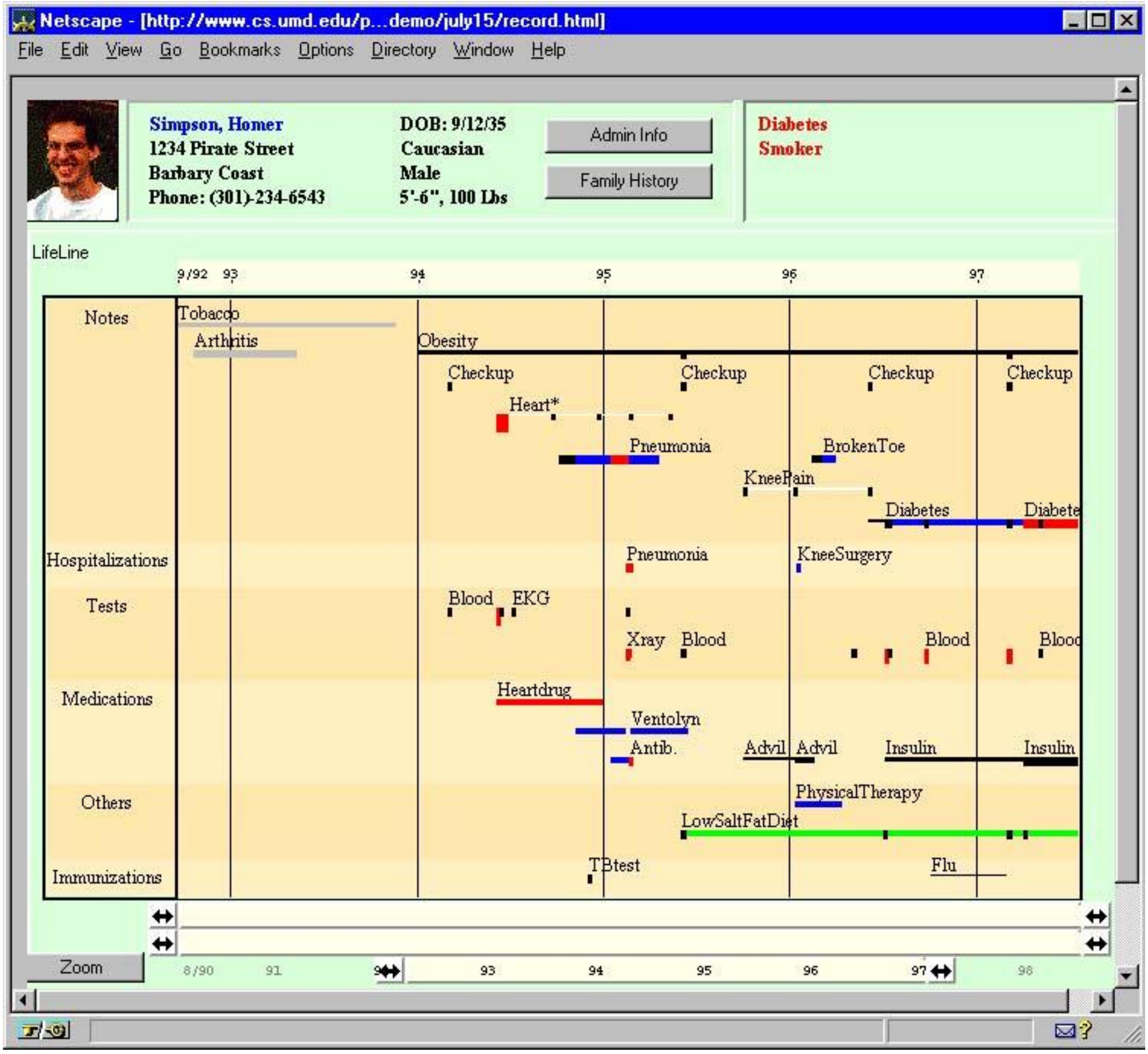

Figure 5: Concept design for Lifelines from the University of Maryland

The lives and welfare of human beings present complex and difficult challenges to informaticians, in terms of longevity (up to 100+ years); complex biology and genomic constitution; multiple organ systems; multiple disease processes; and multiple interventions, including immunisation, medication, surgery and chemotherapy.

The new electronic patient record interface would therefore need to be universal in its application and adaptable to any patient record of any length, and to address a wide range of disease states and populations.

The key design principles which we followed were that:

- The solution should have **a simple and automatically populated interface**, with maximum intuitiveness and attractiveness for any user, and with minimal training requirements

- It should be possible to build the system **with minimal resources and expenditure** and adaptable to the continually evolving information environment of the UHS CDE.

- It should be **evolutionary and economical to develop**, making maximum use of existing IT investments and legacy computer systems.

- It should facilitate **document accrual and display in real time**.

- It should be **designed with analytical capabilities**, allowing the records for individual patients to be linked together to produce **practical cohort analyses**.

- It should provide **speed and convenience of access to digitised records** in a variety of display formats, thus enhancing the efficiency of use of professional time

- it should **display the relationships over time between the various treatment inputs**, which are readily evident in paper documents

- it should highlight **the pattern of disease within the context of the patient's whole life** and disease history.

- it should aid **multidisciplinary clinical team working**

- it should allow the observer **to navigate easily** between documents, results and reports.

- it should also be of relevance and **useful to management and administration teams** in optimising the use of clinical resources for each patient

- it should be **adaptable to address unforeseen uses and applications**.

The Specific Design Parameters of the UHS Lifelines Interface

These would be founded in the Shneiderman principles of the visualisation of electronic data sets, starting with an Overview of the data set to orientate the user, and incorporating the navigational abilities to zoom in on features of interest and to filter out extraneous data.

1. **The X axis timeline would be the anchor for our design**. The starting point of the timeline could be the patient's date of birth; the date of registration of the health episode; the date of diagnosis of the condition under study; any other user defined starting point. The final time point on the record would be the present date, if the patient was still alive, or the known date of death of the patient. Interim endpoints could also be generated to study the time-course of any defined disease or episode.
Later, in Version 4, we also added "look forwards" functionality to display future clinic bookings, at the request of our admin colleagues.

2. **Automaticity and iconography**: The system would be automatically populated in real time with demographic data and with icons representing each point of contact between the patient and the hospital. Each icon would provide a direct link to documents, investigations, histopathology records, or any other relevant data source or event. These might be generated in other systems within the UHS CDE, for example EDocs, eQuest or eCAMIS.

3. **Integration with UHS datasets**: The interface would fit comfortably within the HICSS data environment and subsequently within the CHARTS EPR for ease and speed of access to all relevant data;

4. **Pragmatism**: We would use whatever data and subject categories which were available, relevant and readily linkable into the new interface.

5. **Adaptability**: We recognised that we were designing and building in a very fluid and rapidly evolving digital environment. We needed to be able to run the system in a variety of operating systems, as dictated by the prevailing circumstances.

6. **Intuition and Elegance**: The system would need to be used by staff at all levels and in all professional groups across the hospital. It needed to be both simple and a pleasure to use, as captured in the GDS promoted concept of "Digital by Default!.

7. **Security**: The UHS CDE is heavily protected within a digital firewall, and UHS Lifelines has been designed to work within this firewall. UHS data system managers can trace the users of the system at all times if they need to do so. Users have to record their access to all UHS clinical systems using logins and passwords at a number of levels and frequently as they change computers in daily use.

The Early Promotion of the UHS Lifelines Concept

By 17th October 2009, I was confident in the practical potential of the Lifelines concept as a solution to the display of cancer data, based upon development work on the breast cancer data set (Section 3 essays). I wrote to Professor Catherine Plaisant, Professor Shneiderman's colleague at the University of Maryland, to explain that:

" I have been following the work of your group at a distance with considerable interest for the past decade, and since I wrote to Prof Shneiderman some years ago.

As a consultant surgical oncologist with major academic interests, I have been seeking to define a generic cancer database for use locally, regionally, nationally and internationally which would allow the temporally structured collection of all treatment interventions from diagnosis to final outcome for each and every patient with each and every cancer treated in any health system.

At present, with the exception of clinical trials, which are by their nature highly selective, we have very little idea as to the ground truth, true benefits and disadvantages of each of the therapeutic inputs (surgery, chemotherapy, radiotherapy and medications) and their sequencing in cancer patients, from which to optimise clinical and economic resource allocation.

In essence, if we were to compile and store the medical records as LifeLines for each and every patient, and then to analyse and compare outcomes from large subsets of similar patients, we would be able to advise new patients as to their optimum treatments in the face of all of the "grey" factors (age, comorbidity, obesity, concurrent disease for example) matching them to historic data: and we would be able to compare matched groups of patients undergoing different treatments and in different combinations to identify and select optimum strategies.

The present generation of clinical databases are largely based upon entry registries. They and are not configured to collate, display and analyse temporally structured data, even though this is a fundamental factor in medical treatments.

The potential therapeutic applications of such data management systems are massive. I would be delighted to pursue a conversation with you and your team as to how this work could be developed as a practical project ... to optimise clinical research and outcome analysis. I would be pleased to visit your lab to develop the discussions and a practical research and implementation strategy."

On 19th October 2009, I wrote to Adrian Byrne as the Trust Lead for IT on the topic of the development of a time structured data analysis system, noting that:
"... I have been doing some further research over the w/e on recent progress in such systems, linked to my own academic interest in the work of the Human Computer Interaction Group in the University of Maryland.

Collectively, we could specify and produce a superb state of the art product through some constructive and cooperative working. I would therefore like to set up an academic development group to work on the problem. I think that this could attract very substantial grant and investment funds, and make the best of the diverse energies and skills that we all bring to the table.
Adrian replied directly and very positively to the proposal.

"The development of HICSS as an advanced, clinically informative data system using a time structured graphical framework"

In May 2010, I circulated a paper to senior IT and clinical managers in the Trust, titled:

The key points were as follows:

Observations on the Status of HICSS

"HICSS is a powerful and locally developed multipurpose database system for clinical informatics... It was conceived as a clinically informative system, but it has been used since its introduction primarily for administrative and target related processes. In consequence: its acceptance by clinicians has been patchy. It has not yet realised its full potential as a clinically informative system.

It is evolving towards easier interoperability between these systems. Critically, for many clinical applications, there is yet no facility for integration of histopathology records into HICSS applications. It has nevertheless been used by a number of clinicians for specific applications which have indicated some of its value and potential in clinical informatics.

The Concept of Timeline Structured Clinical Data Visualisation

HICSS has the potential to become an advanced data system of utility to a wide range of clinical specialities, with individual patient records adapted to a timeline structure at minimal cost and with maximum upcycling of existing data in the SUHT data systems.

The concept of graphical Timelines or "LifeLines" is critical to this vision for the development of HICSS.

The Time Element and Structure in Patient Care

The passage of time is central to the evolution and management of many clinical conditions to eventual outcome, as it is from birth to death.

Much of the Trust's activity involves the treatment of children and adults with chronic conditions requiring multiple and multidisciplinary interventions from the point of origin (birth or disease diagnosis) to outcome and/or death.

The graphical representation of the passage of time on a Timeline allows huge quantities of useful information and the intelligence within them to be understood. This insight would otherwise be lost in separate files of paper notes and records, or on card indices.
The linkage of events (hospital visits, treatments) along timelines and their appropriate graphical representation would allow the visualisation of complex inter-related data in individual patients and groups of patients, which would allow:
- a much better understanding of the relationships between disease processes and interventions to ultimate outcomes;
- detection of those interventions and expenditures which are producing better or worse outcomes;
- a major uplift in academic clinical output, and in the process,
- and a potentially world beating clinical informatics system.

I then described the link between the LifeLines Concept and HICSS, such that:
"In LifeLines, the individual patient record is displayed as a graphical timeline along the X axis from the start point, which could be
a. the date of birth
b. the date of registration with SUHT on PAS, or indeed any other health record system
c. the date of diagnosis of the clinical condition under study
The timeline is thus automatically populated with dates at each point of contact between the patient and the hospital, and each date of record entry provides a direct link to documents (e-Docs), investigations (e-Quest), or histopathology records (to be developed).
The final time point on the record will always be the date (and cause) of death of the patient, although interim endpoints of clinical discharge can be used to study particular conditions.

Moreover, different clinical information needs can be plotted as parallel, stacked streams from the Y axis origin. Thus, for example, different diseases, drug and vaccination histories, and any other useful information can be plotted in parallel.

The power of this graphical representation as an administrative and clinical research tool immediately becomes apparent, as the entire clinical record can be absorbed directly, and drilled down to the supporting evidence through our existing data systems.

Graphical Data Mining of Multiple Records

Once the unifying structure of the graphical timeline has been applied to individual clinical records, the opportunity arises to compare and "flick through" multiple records, and to apply data mining, statistical and graphical techniques to the extraction of recognisable patterns in the data.

The Concept as Applied to Cancer Timelines and Multidisciplinary interventions

The treatment of cancer invariably involves multidisciplinary interventions over time, including surgery, radiotherapy and chemotherapy.

Many of these treatments are costly and the true benefits are unknown. They can only be inferred from clinical trials which are based upon highly selected groups of patients under highly controlled conditions, and which do not reflect real world, all comer experiences, and particularly in those with concurrent morbidities, as affect many of our patients. Moreover, the optimal sequencing and temporal structuring of expensive interventions is often unknown, as trials are usually based on single components rather than the totality of treatment.

A data system which allowed data mining of massive data sets on large numbers of patients passing through SUHT with a wide range of conditions; which allowed the presentation of that data in easily assimilated graphical form; and which allowed clinicians and managers to "query at will", would be a profound advance in the clinical, managerial and academic study of disease processes and their clinical and resource costs of intervention."

The immediate challenges are now:

a. To refine HICSS to accept retrospective Surgical Operation data in the most efficient and economical way, such that we can back populate it as far as possible from our manual records. The further back the time period covered by the records, the more detailed the understanding of factors contributing to outcome and death will become. This process of simplification and automation has now largely been achieved for manual surgical records.

b. To create a graphical interface on HICSS for population with further data

c. To test and develop the link between the surgical records and the existing cancer data set, so that the individual patient cancer timeline can be most easily populated.
d. To develop a structured interface for pathology data in the existing computerised pathology system, so that pathology data can be linked and analysed directly within each patient record
e. To refine the data on deaths in the system, so that accurate measures of the time and cause of death can be linked into the patient record.

Further development of the graphical interface concept

The system is still immature in respect of the concepts proposed, and there will be a number of further steps required to realise the full potential. Those steps include the following:

- Simple programming steps which can be conducted "in house" with SUHT and Ascribe team members to optimise the performance of HICSS in data collection.
- Steps which will require decisions and authorisation at Trust Executive level, for example in retrospective mandating data entry by the relevant clinical teams.
- Steps to address the major roadblocks in the system, and particularly in the implementation of structured pathology records which can be imported directly into the HICSS Cancer modules
- "Buy-in" and data upload from all of the key contributors, including medical oncology and radiotherapy teams
- Cooperation at regional and national level in collating critical outcome measures, and particularly causes of death, if the system is to be truly informative.

Future Development Plans

We propose a continued and iterative process to develop the breast cancer data set as a demonstration model as to what can be achieved, with a view to rolling the model out to other cancers within the Trust; to other disease groups within the Trust; to other Trusts within our collaborating network, and to the Department of Health in due course.

In Summary of this paper, I noted that:

"We have spent considerable time in the past two years in critical and constructive discussions and testing of HICSS with the development team. We have posed challenging questions about this potential vis a vis other commercially available systems.

We believe that HICSS has the potential to meet the requirements for a nationally significant, temporally structured informative data system which can be developed locally and credited to the SUHT- Ascribe development team;

The beauty of the integrated data system of the HICSS/e-docs-eQuest-PAS environment is that all patient contacts with the local health system can be readily identified by date and time, collated and displayed into graphical timelines. Developments in hand will allow seamless movement between these systems in the study of individual patients.

The introduction of a simple, graphical interface to the HICSS front page for each and every patient, to be populated with existing data which is collected in the course of routine hospital activity on existing systems, will provide an information environment which will be much more user friendly to all users within the Trust.

This will lead to a much more sophisticated and universal understanding of inputs and outcomes in all cancer pathways and many other chronic diseases.

These gains can be secured in a highly economic and cost effective way, using simple conceptual adaptations to the existing SUHT data systems.
Early implementation of this system in a test model (the breast cancer test data set) is recommended, so as to identify and iron out problems prior to a general roll out."

On 17th May 2010, Alan Hales stated that:
"I am persuaded by the arguments you have made and I am also confident that we can re-kindle some of the original aims of setting up HICSS back in 1997/1998....
- We must be very careful in reference to other systems or IT solutions which may have elements of copyright or other forms of intellectual property... I don't think we need to copy

ideas from anywhere, but it is useful to refer to other systems where it emphasises that our ideas have support elsewhere.

- In terms of your immediate challenges, I agree that we may need to make further tweaks for other specialties.

- We have two existing proven methods of graphing, vis

(i) embedded graphing as used in the eQuest Results Graphs and the Renal End-Stage-Renal-Failure prediction,

(ii) automated invocation of Excel Pivot Charts as used in Endoscopy GRS reporting and Cardiac Surgery VLAD and other analyses.

- The concepts used in the Ascribe Clinical Viewer provide good examples of how we might construct timeline presentation of clinical event data.

- I agree that integration of surgical and HICSS cancer data is important. it now needs a changed emphasis from being driven by Dept of Health cancer target analysis to outcome analysis. We have the data to achieve this goal, it is now a matter of working with clinicians to ensure we link the data in the most appropriate way.

- In the matter of Histopathology reports, we have long recognised the need for structured (i.e. categorised) result reporting.

- We need to discuss how cause of death data is efficiently acquired by the HICSS database. A key factor, as always, is to have the data entered once only and stored centrally.

- I would be delighted to see your proposals for future developments supported. At last we could see some of the enormous latent capabilities of the system released and I would feel that my personal efforts had not been in vain."

Acceleration of the Development Of Early Renditions of The UHS Lifelines Architecture

By mid-May 2010, I had manually back-loaded into HICSS the surgical operations records from the Breast and Endocrine Surgical Unit for the previous 12 years from our theatre logs and printed lists. Alan and David Cable agreed to meet to explore the wider project concept of a Breast cancer Data System with me, so as to establish whether:

(A) We could obtain basic cancer status data (e.g. NHS Numbers and Cancer Diagnoses) from the Wessex Regional Cancer Intelligence Unit.

(B) We could import PAS admissions/discharges from 1996 to 2003 into HICSS.

(C) We could import Histology reports into HICSS.

(D) We could generate some short-term prototype time-line screens for wider review.

(E) Whether we could tweak HICSS to allow for fast entry of additional data beyond current scope of the Surgical Ops module.

(F) And how the further development work could be resourced and funded

On 20th May 2010, Alan reported that:

... We have successfully loaded all the PAS admissions (into HICSS) back to 1996.... We will have all of the discharge dates for all of the surgical procedures that you have backloaded into HICSS, so this will enable us to generate a length of stay for each case. I'll see what progress I can make on the timeline display and continuing to look at how we can make the most of the data we currently have.

Work continued through the summer of 2010 in populating the Breast Cancer Data System, to which the UHS Lifelines was intended to be a subsidiary component at this point. Informal discussions and experimentation with minimalist formats for the Lifelines interface continued.

On 5th August 2010, Alan, David Cable, Ashley Beecham and I held the first of a series of strategy meetings around UHS Lifelines. The minutes of those meetings are very helpful in reconstructing the rapid development of a usable “Alpha” form of Lifelines within HICSS.

1. The Accurate Recording of Deaths

The accuracy of the recording of the date and cause of death is a critical element in clinical research for many diseases. Early on, we were able early on to build an accurate date of death into the system for every patient who had died, if the death had occurred in the UK. This was because the PAS pulled the date of death from nationally sourced Office of Population Statistics, which mandated that every death that occurred in the UK was reported centrally. The records of dead patients were clearly flagged in the PAS and HICSS.

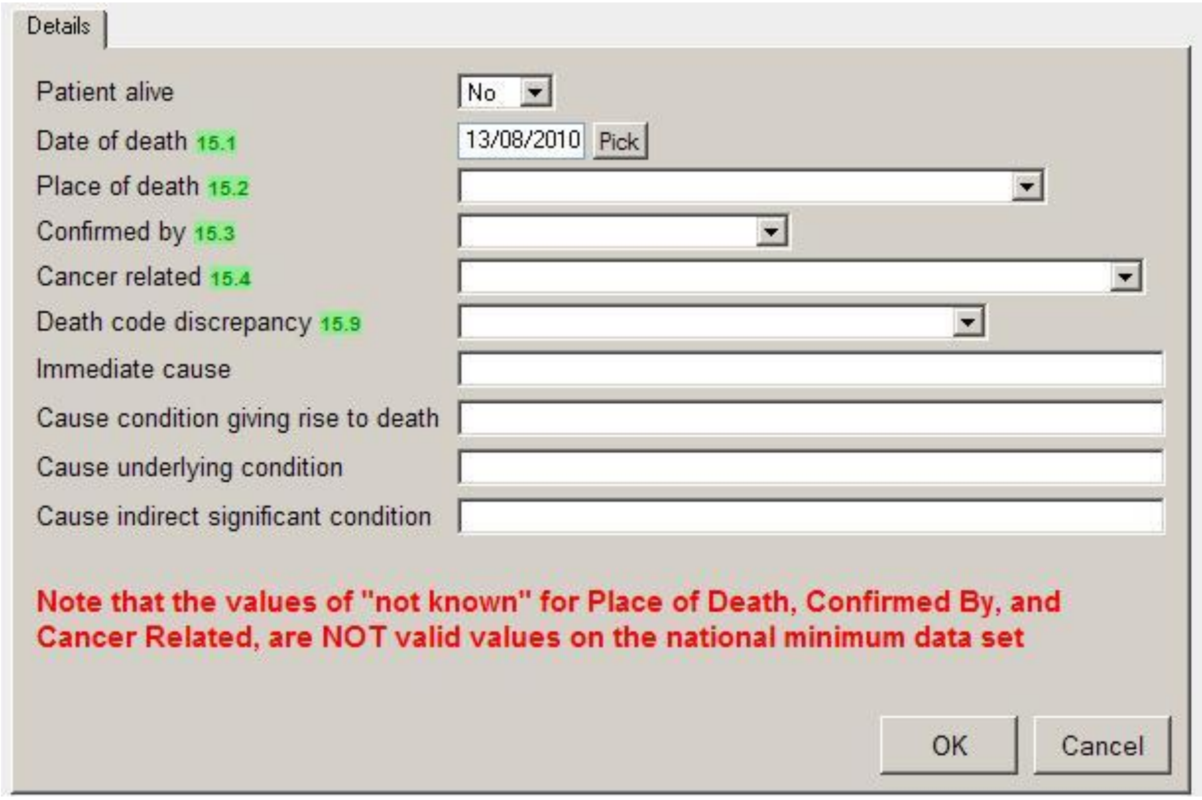

Figure 6: The “Cause of Death” data entry module in the HICSS system, May 2010

Ashley had uncovered a Death notification module within HICSS, which suited our immediate purpose (Figure 6). We therefore agreed to seek to transfer the death recording system which we found in the cancer data set to "front end" of the hospital records system to improve and standardise the recording of death with Ashley’s help.

I also raised the question of developing a means by which a numerical value would be assigned to the probability that death was caused by the cancer, rather than by some other cause, so that long term cancer outcome data would be more accurate.

2. The digital pathology record

We noted the aspiration to develop a universally structured pathology reporting system that we could interrogate along any required parameters.

3. Early iterations of the Timeline structured record.

Alan presented the first demonstration version of the timeline structured record concept, with the use of standard icons to represent documents, surgical events, OPD attendances.

- We needed a suitable terminology or shorthand to describe each taxonomy timeline in the model (eg Surgery, Cancer Care, Child Health).

4. Naming the interface

- We considered names to describe the time structured interfaced. I suggested "LifeLine" or "TimeFrame", noting that "Lifeline" acknowledged the source of the original concept.

5. Agreeing the Subject Taxonomy and its Representation

-We considered how best to integrate information from the various source systems in the UHS Clinical Data Estate, including Clinical Viewer and e-Docs.

We agreed that it would be straightforward to take the established taxonomy of subject headings in e-Docs which had been inherited from UHS paper records, , eg Surgery, Cancer Care, and the date ordered lists of documents within them, and to reorder the documents from the familiar List Mode in eDocs to the horizontal linear timeline (Speciality Timeline) mode for the next test model.

- We discussed the porting of the speciality-based colour coding of the standard trust clinical records in paper notes folders to the LifeLines interface. Thus surgical docs might have a red icon, medical docs a blue icon, cancer docs a green icon and so on.

- We considered the pros and cons of producing a global "LifeLine" record of all patient contact with the hospital. We noted that this might produce a large number of Speciality Timelines for some of the more complex medical records.

We also wished to give the observer (clinician, manager or researcher) the option to include or edit out any superfluous Speciality Timelines to simplify examination of the LifeLine record. We therefore agreed that individual speciality timelines should only appear on the interface if they were populated by information held in the SUHT system. This would eliminate the appearance of blank lines and minimise the amount of blank space on the LifeLine interface.

The next review meeting took place on 2nd September 2010. Alan presented a revised model, incorporating the various changes that we had discussed in August, with which we could test further developments using real data. We considered how and where "Lifelines" would link to HICSS. At this point, we were not considering the development of an independent application. We agreed that it would be accessed by a link within the HICSS menu list for the evolving Breast Cancer System.

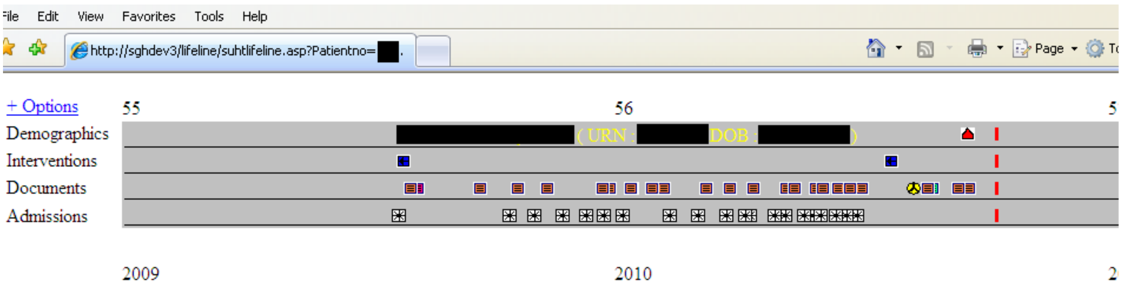

Figure 7: The UHS Lifelines prototype of September 2010. Data is drawn directly from PAS (demographics and admissions), HICSS (interventions) and e-Docs (documents). The icons each flag up the source of the document or type of event (eg endoscopy, radiology) when clicked upon, but do not yet link directly to the original source documents.

The timelines were not yet colour coded by speciality and subspeciality, according to SUHT conventions. They include icons for admissions [+], documents, radiology, interventions (blue squares), and death (red triangle).

The blue options button (top left of screen) allows the user to reset and rescale the timeline to the patient's date of birth.

It was already clear how the crude graphical timeline representation of this patient's data might provide considerable insights to her pattern of interaction with the Trust, treatments and "resource use".

Figure 8: UHS Lifelines prototype of September 2010. The screenshots are of real patient records. This patient died of advanced colorectal cancer and liver metastases at the end of August 2010, following a series of chemotherapy treatments (admissions), with discharge summaries (documents) and other investigations (interventions).

Further developments of the model as discussed on 16th September 2010

At the third meeting of the IT group on Thursday 16th September 2010, Alan demonstrated the revised timeline model, incorporating the key elements that we had previously discussed, using real patient data.

We agreed that the next steps were to increase the number of Speciality Timelines and their functionality, by allowing them to expand or contract ([+]/[-]) to free up vertical screen space. This was akin to the function in MS Outlook to expand of collapse lists of emails. The interventions listing would be expanded to display Endoscopy, General, Orthopaedic, ENT surgery and so on.

Imaging data would be sourced from CRIS, so that radiology episodes could be visualised and displayed according to type, eg MRI scan, CT scan, nuclear medicine.

Pathology records would be included as another Speciality Timeline, with a “document” link to each (free text) pathology report.

We discussed how e-Quest records of blood tests, microbiology and so on could best be displayed, whether by subject (haematology, biochemistry) or preferably by user preference, such as of the serum [Ca] and [PTH] for primary hyperparathyroidism, and of the T4, TSH and T3 for hyperthyroidism.

Alan agreed to adopt the existing SUHT speciality colour coding conventions wherever possible, eg red-General Surgery; pale green-oncology; black-orthopaedics; blue-medicine in general; yellow-ENT; dark green-dermatology, for ease of use by system naïve users.

We discussed how best to interact with the graphical interface, including tools such as a slider to rescale the X axis timeline, and consultant and speciality specific, user defined options and formats.

We also discussed a timescale for completing development and roll out of the LifeLine model into the SUHT work environment. We considered that the individual patient record model could be broadly complete by the end of 2010 within the real data environment, while recognising that this might merely be a starting point for user defined requests as the utility became apparent to clinicians in general.

We also discussed the benefits of expanding the proposed test environment from breast cancer to thyrotoxicosis and primary hyperparathyroidism, as a device for also demonstrating to physicians the benefits of the UHS LifeLines model.

We began to consider how multiple patient records could be grouped, classified and analysed for clinically informative outputs, once the Individual Patient Lifeline Record (IPLR) was up and running.

We agreed to give the "death record module" much higher profile in the system to ensure that as much relevant detail as possible was captured on notification of death. This was important in the proposed back-loading of the records of large numbers of patients who had died of their breast cancer.

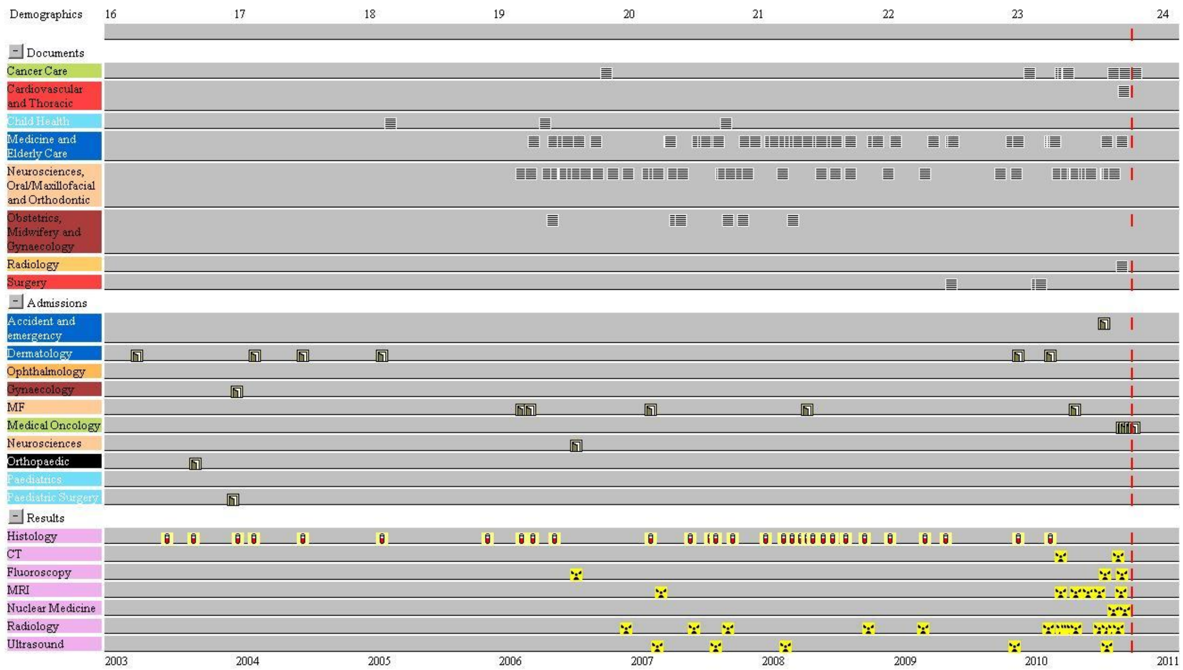

Figure 9. A live screenshot of a live individual patient record in UHS Lifelines (Version 1) of 29th September 2010. This case is a young woman with multiple co-morbidities who died in 2010.

The completed first version of UHS Lifelines of 29th September 2010

Alan's progress with the project over the next two weeks was extraordinary. He completed the first live version of the interface in advance of the ISSG Meeting on 29th September. That morning, he wrote to the team to state that

"I have completed some of the changes agreed at the previous meeting. These include:

- Rows (timelines) are now split by event types and care-groups. More work will be needed to abbreviate names and to harmonise specialties, care-groups and HICSS specialties).

- Each event type can be collapsed or expanded.

- Care-groups and specialties are colour coded.

- To zoom in the X-axis, simply click on a year to make it the starting date.

- Some visual improvements to the overall solution.

- The demographic row so that the DOD icon displays where relevant.

We had been invited to present the work to the Trust's Information Systems Steering Group (ISSG) Board meeting that afternoon. I wrote in advance to Derek Waller, Chair of the Group, and to various clinical managers, to notify him that:

"As a result of work with Alan Hales and David Cable in the past two months, we have made dramatic progress in producing a unifying medical records structure for the SUHT software suite, based upon the concept of a time structured, graphically rich and interactive individual EPR. This pulls all of the source material from HICSS, PAS/CAMIS, e-Docs, e-Quest, CRIS, Clinisys etc into a single, simple to use, colour coded, user-definable and iconic single page format with total oversight of the individual patient's medical record.

Alan Hales is presently refining the model to the general specifications that we have agreed to make it as simple to use and informative as possible, and with a view to going live (in the Trust's CDE) shortly."

Alan's solution (UHSL Version 1) demonstrated all of the features which we had discussed , in that:
- The content taxonomy on the Y axis included sections for Documents, Admissions and Results.
- The Specialities for the documents and Admissions were colour coded according to a historic convention at UHS from the paper era, which would be familiar to all clinicians at the hospital
- The collapse/expand (+/-) function for each section allowed for the creation of space to accommodate the entire record in "busy" EPRs
- The individual icons were each actionable to reveal the underlying documents, reports or admission dates
- The entire record could be read on a single screen, and the entire system was consistent with the Shneiderman mantra of "Overview, Zoom, Filer Out and Details on Demand"
- the entire interface was dynamic and continuously incremental with linear progression of the timeline and the addition of all new content as it was generated in the course of daily clinical activity.

We were delighted and enthused by the success of this agile proof of concept exercise which had so quickly yielded a working system at minimal cost but for our individual contributions which were largely made in personal time.

There remained a challenge in the management of document overlap on individual timelines, and it was to take us until 2015 to find the most elegant solution to this conundrum. I also requested modest funding for my professional time to focus on the project, but no such funding was forthcoming.

Immediately following the meeting of 29th September, David Cable wrote to Alan to state that:

"David's presentation and your demo product went down pretty well with ISSG. Importantly, we have agreement to continue with the development. Our thoughts on next steps are:

1. Can a new grouping be added for Results? This will retrieve results on separate lines for Radiology (all modalities) and Cellular Pathology.

2. Can we consider linkage of the lifeline icons to a preview of the full document?

Thanks again for all your hard work into the early hours this morning".

The Naming of UHS Lifelines

We also played around with names for the system to trademark the new system, but many of the obvious names like Timeline, Timeframe, and Lifeline, were already in use. We even considered "Einstime" or [e-in(s)time] as a memorable pun. However, we did not pursue the trade-marking and simply settled for "UHS Lifelines" in honour of our antecedent HCIL Maryland Lifelines concept model, about which I corresponded with that team

Derek Waller had asked during the ISSG meeting whether individual physicians could pull out their own medical interests from within the blue Medicine speciality line. The same question may arise when surgeons from different specialities want to see their own subsets, eg orthopaedics.

In the matter of the display of Test Results, individuals and subspecialties would have different requirements. We agreed to adopt the linear approach which was suggested by David Cable, such that cellular pathology reports from all specialties would be displayed on a single timeline. In the matter of radiology results, we ultimately displayed the results by modality, for example Ultrasound, MRI, CT, Nuclear Medicine Scans, and plain radiology.

This discussion led to the observation that there are two general types of test results; those of investigations which are conducted infrequently, and those which are conducted frequently (usually biochemistry and haematology). Alan immediately proceeded to experiment with a new format which also included the Cellular Pathology and Radiology Timelines (Figure 9).

On 30th September, Alan signed off the work to date with the observations that:
"I don't plan to do any more work on this now until we meet again and discuss the next tranche of ideas unless you find bugs. We also need to think about how exactly this tool might be integrated into the existing EPR applications.

In terms of displaying the detail associated with the markers, much of the functionality for this exists in the EPR applications already. It will really be a matter of deciding on preferred format and mechanism to invoke the reports. If you hover over a marker you will see I've added a unique ID.

This is the key to getting the associated report/detailed record. For pathology you will no doubt recognise it is the specimen ID, for a document the eDocs Document ID and so on, so you can go into eDocs/eQuest and find that report at the moment if you want to check consistency between the lifeline and the EPR apps".

I showed the model to our outpatient clinic nursing staff. They intuitively grasped the concept and the ease of understanding of each patient's case history, from the patterns of icons and the metadata alone. I therefore suggested that we went live with the model in its present state as soon as possible. Even if it was felt premature to go live Trust-wide, I would very much like to have it myself for demo purposes to immediate colleagues and staff, and for use in the Breast Multi-disciplinary Team meetings.

I also wanted to develop an audit mechanism to measure the rate of uptake of the system, and perhaps even a "survey monkey" questionnaire once the system was up and running to assess uptake, acceptance and satisfaction with the system.

On 1st October 2010 Alan Hales wrote to say that:

"In the matter of your specified requests, I will need to coordinate this with the guys from the Hythe Ascribe office as it will mean a change to the operational system and I need David Cable's approval to commence the work as per my agreement with the Trust.

Display Methodology

I agree that clicking rather than hovering is a better mechanism for triggering the display of the associated document, I plan to implement this in the near future with David C's agreement.

Pathology backloading

Very little if any data existed prior to 1996, as this was when the current (IBA Unicare) PAS system was implemented. Also, Pathology and Radiology data do not go back much before the current millennium, though there might be a potential to backload additional pathology and radiology to the late 90s if a very strong case were made and the data quality made this worthwhile. There may be innovative ways of gathering data beyond this time if the case is strong and the costs can be justified and funded, something for a later discussion.

Naming the system

In the matter of a catchy name, http://www.einstime.com/ demonstrates the minefield of trying to come up with original trademarks and copyrightable phrases, which is why I keep well clear of using anything that might generate intellectual property issues.

Originality of the Code

Every line of code in the prototype is from my head, and I have not copied any code from anywhere and no part of the prototype is cloned from anything I've seen; It comes directly from our meetings and collective ideas.

As the prototype becomes more sophisticated we must be very careful to avoid copying anything because if it does become "valuable" you will be surprised how many others will emerge to claim we have stolen their ideas. I recall the experience with Birthrate Plus!"

I replied that I understood that the Intellectual Property (IP) arrangements with Ascribe are somewhat tortuous, but I am increasingly confident that the combined effort of the past few weeks will add substantially to the value of the Ascribe Product suite.

I wondered how best we could develop **an easy to use "dashboard" of analytical tools**, displays and statistical devices which could be used by a wide range of individuals with minimal training over a range of diseases as intuitively and simply as possible.

The final Lifelines development meeting of 2010

On the 18th November 2010, Alan Hales, David Cable, Ashley Beecham and I held the final Lifelines development review meeting of the year. We agreed that while the original driver for the UHS Lifelines project had been a specific question about breast cancer inputs and outputs, the project was now directed at producing a generic interface which can be of use to allcomers using the UHS CDE.

We recognised the strength and effectiveness of the group and the unusually broad resources of the HICSS data set, along with the unique local opportunities for development and experimentation embodied in this team.

We recognised that by taking a stepwise approach to development and to release of the further functionality to a wide user base, we would be able to make further progress (as with the timeline) which might presently be unpredictable but which would undoubtedly be significant.

We would need to take steps both to control and prioritise demands from new users for new functionality, and to audit usage and progress.

We continue to recognise the IP issues vis a vis Ascribe Ltd as they affect the work of the group and the longer term opportunities for the Trust, and the complexities and security considerations which they bring to the Trust.

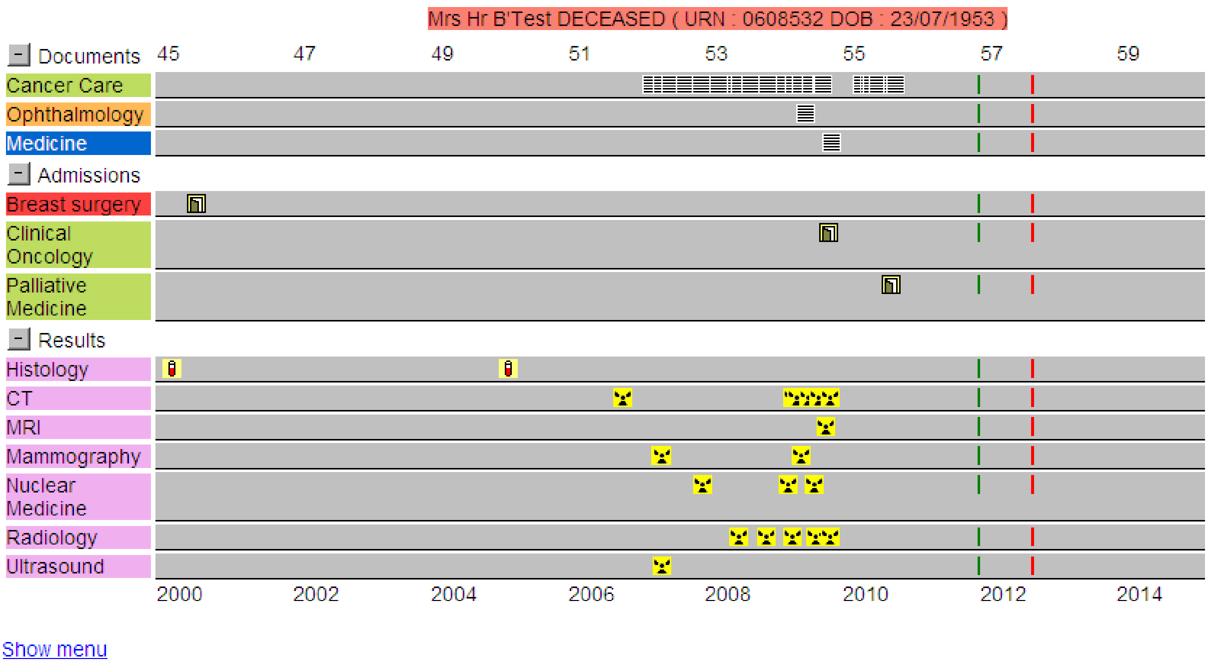

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Figure 10. A screenshot of Lifelines v1 in late 2011 from within the test system, of a lady who died of breast cancer in late 2011. The record has been anonymised. This image highlights the problem of document overload in the “busy” cancer care and CT scan timelines, causing overlap and blocking out of underlying icons.

Lifelines version 1 remained live in the HICSS test system through 2011, and I continued to use it for illustrative purposes for breast cancer cases (Figure 10) We agreed that this was now ready for formal launch, and that we would continue to seek to back populate the system with as many documents, including in particular historic pathology reports, as far back as possible.

NHS Innovations South East

To conclude with this first episode in the life of UHS Lifelines, I was pleased to receive notice on Wednesday, November 09, 2011 that our work had generously been recognised with the award of **the 2011 UHS Innovation Competition prize by NHS Innovations South East.**

Essay Summary

By the autumn of 2010, we had developed a fully working version of UHS Lifelines from scratch in a year, at no cost to the Trust. It was available for further developmental work in the test environment of the UHS Clinical Data Estate. There were no technical constraints to its live release across the Trust, although we still had some practical issues to resolve around document overlap on the timelines. All was good to go ahead with life implementation.

There were many additional work-streams that we could have included in the visualisation model, and which we discussed in detail on many occasions. These included blood tests, key pharmacology prescriptions and general practice records. We also considered in greater detail the issue of adaptability of the interface to the requirements of individual clinicians. This would increase greater subject granularity within individual timelines, and in particular in general surgery and general medicine, which collectively included a range of subspecialties, for example colorectal surgery and gastro-enterology.

Bureaucratic and Legalistic Obstructions to Further Progress

Alan had left his previous employment with Ascribe Ltd, having preciously sold his own company, Scorpio Ltd, to Ascribe in 2008, with a restrictive separation contract. This reportedly severely limited his freedom to develop software products at UHS using the code with which he had built the key software products.

This constraint clearly distressed him to the point that he so feared legal action against him by the Ascribe management team that he felt compelled to shut down the development of UHS Lifelines Version 1 at the point of our success. Regrettably, Ascribe and its executives will never be held to account for this restriction upon the intellectual practice of a remarkable digital talent, for which no sensible mediation seemed possible at the time.

We therefore had to return to the drawing board and evolve a new strategy of interface development. We nevertheless had gained some very valuable experience and had proved the utility and power of agile teamwork between the very different streams of probabilistic clinical thought and linear software development.

Reflections on the Potential Value of UHS Lifelines to the Trust

Had the system been widely supported by the Trust's IT advisors at that time, we would cumulatively accrued huge savings in costs through improved clinical productivity through the radical reduction in time wasted by clinicians in searching and loading content on computer screens, and we would have measurably mitigated the clinical risk over time in missing important clinical information in other speciality records. We might even speculate that the Trust would have freed up to £100M of public funds for more productive activity over the next decade at no investment cost but for one factor which I had not foreseen.

David Cable and I undertook a "back of the envelope" calculation of the value of this system to the Trust. We noted that there were approximately 750,000 outpatient attendances across the hospital estate per annum, and that each attendance could take up to five minutes of record search and reconstruction time per patient.

Financial Waste: This estimate amounted to more than 60,000 hours of expensive professional time per annum that were spent in the wasteful activity of record reconstruction and mouse driving at every patient interaction. At £50/hour of professional time, this would amount to around £3M per annum, and to much more wasted money if all of the other clinical and administrative case uses were taken into account, for example in anaesthetic pre-assessment, Emergency Room case reviews and so on.

Clinical Risk Mitigation: The presentation of all documentation on every patient in a unitary format using Lifelines would substantially de-risk the chance of missing key themes and clinical events under the pressure of time in a typical consultation.

Reflections on our Agile Methodology and the UHS Clinical Data Environment

As our small concept development team were rapidly to discover, the key to success with this working model was an agile and iterative approach, whereby the direction of the project was broken up into small chunks to "build, test and adjust" the evolving software.

It required considerable mutual trust and understanding as to the direction of travel between me, as the de facto User Experience (UX) lead and evaluator, and Alan Hales as the system designer, software engineer and sole programmer. In this model,

Alan Hales was guided by my requests as the clinician user and de facto User Experience (UX) lead, and by his own intuition and particular experience of developing software systems. This approach involved considerable flexibility of thinking from both or all parties. In general terms, clinicians think in probabilistic terms (it is probably diagnosis A but in could be diagnoses B to n), whereas effective programming requires rigid adherence to linear coding and to the constraints of software and hardware system design. Once the direction of travel was understood, we would each propose elements and features for integration and testing as we matched the Aspirational to the Art of the Possible.

The agile approach was embodied in a continuous feedback loop of positive reinforcement of the working elements, and immediate elimination or reconfiguration of unsatisfactory elements. The cycle of proposal, negotiation and experimentation around ideas and software models created considerable excitement, and would often involve to and fro emails into the early hours as the project gathered pace.

The approach also required trust from the IT department leads, and we were given considerable freedom of experimentation in the digital test environment. Contributors with knowledge of various existing systems and procedures were co-opted into the project, and Ashley Beecham, Steve Kawandami and David Cable all made important contributions to the early progress.

By the nature of the project team, our work was initially optimised for a surgical outpatient service, with a focus on the relevant documents, histopathology reports and imaging reports. However, the wider utility of the system to the clinical service became apparent as we incrementally added more timelines and more content from other data sources.

The philosophical approach was to use a browser based system, which is accessible from any personal computer or other electronic device on the UHS local and wide area network.

This eliminated the need for specific software installation or configuration, and additional licensing costs. Documents and reports could be called upon from elsewhere in the system at will**.** The User Interface was delivered as pages encoded with hypertext mark-up language (HTML). The primary software was Microsoft ASP with data sourced from an Oracle relational database.

The Selection of Content for Display on UHS Lifelines

We were constrained and pragmatic in the use of the available data resources of documents and reports, which were in effect "upcycled" into the new visualisation format. We adopted the following general design objectives for the system, in that:

- it should be optimised for the specific needs of the end user (in this case, an outpatient clinician), with intuitive usability
- it should display all available clinical e-documents and reports in a logical framework
- it should fulfil Sheiderman's mantra for visualisation of the entire data set
- it should be visually rich, dynamic, interactive and accrue new content in real time
- it should work fast and seamlessly within the UHS CDE
- it should be intuitive in daily use, to maximise voluntary uptake by the workforce and to minimise the costs of training and implementation
- it should be economic to iterate and continuously adaptable to future needs and data resources.

The Subject Taxonomy for the UHS Lifelines timelines

Each timeline is specific to a clinical discipline and subject content. Our own standard clinical document taxonomy was established at UHS in the 1950s in the era of paper records. Our pragmatic solutions addressed a wide range of design elements, including:

- Colour,
- visual impact;
- Icon size and display;
- Metadata display;
- Document, Report and Result Display;
- System access;
- Inclusions and exclusions; and Document Overlap

Subsequently we had to work with major changes in the software operating environment, for example with browser evolution from serial releases of versions of internet Explorer, through Microsoft Edge and on to Chrome. This led to a number of versions of Lifelines and an unwontedly complex Version history which imposed substantial delays to full operational status over the next decade.

Lifelines Content: The Exclusions and our Reasoning

There were a number of information feeds which were not included in UHS Lifelines Version 1 but which might have future utility. We debated and concluded that there was little value in posting Equest test results on Lifelines, because EQuest itself had some valuable graphing and display tools for serial data.

This general approach did not preclude experimentation with specific tests for specific user cases, and we later posted timelines for Prostate Specific Antigen (PSA) for Urology colleagues on Lifelines Version 3, and Blood Groups and Transfusion records for anaesthetic use.

We also discussed the posting of pharmacy and prescribing data on separate timelines. We, noted the likely future utility of prescription records in the machine analysis of the EPR. Many pharmacologic agents are disease specific, for example Insulin and Diabetes, Immunochemical ("biological") agents and specific inflammatory conditions.

We were also to become frustrated that a range of "closed access" commercial systems which were in use at the Trust do not easily permit the transfer of data to open systems, as for example the Mosaic and Aria cancer therapy systems. We recognise that there may be other data sources and systems within the UHS CDE which we have yet to explore.

In the next essays in this section, I will describe how we ultimately overcame these challenges to build a fully functional system and derivative systems which now sit at the heart of the UHS Clinical Data Estate.

Acknowledgements

My primary colleagues in this project were Alan Hales, whose enthusiasm for innovation, programming skills, vision and deep knowledge of the UHS Clinical Estate, made these projects possible; and David Cable, whose diplomacy and similarly deep knowledge of the systems from within the IT Department smoothed the paths of progress.

Alan had built the eDocs, eQuest and HICSS systems for the Hospital over the previous decade. Collectively, we formed a very creative partnership and we worked very effectively on a series of projects.

I am also grateful to a number of contributors as friends, colleagues and students, who played important roles at various stages of the project, including Ashley Beecham, Alex Potter and Matthew Warren.

Many others contributed at various stages of the UHSL project, and I am pleased to acknowledge these in the text. Throughout this venture, Adrian Byrne, the Trust's Chief Information Officer, who fully supported our "blue skies" projects in an austerely resourced system and with many competing priorities to sponsor.

In 2020, we appointed Matthew Warren to support the project. Matt was a graduate in Computer Sciences from the Faculty of Electronics and Computer Sciences at the University of Southampton.

His crucial role through the Covid pandemic was to help Alan with a major upgrading of the code base and the functional structure of the software. They jointly created a self-contained Application with far greater developmental flexibility and operational adaptability than the earlier versions.

They also added a range of attractive new features to the interface, including enhanced speed of operation, collapse/expand functionality to increase the display capacity of the primary interface; and look forwards functionality to see future clinical appointments and planned events.