How to plan and construct a digital hospital

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Biographical Sketch: Elliot B. Sloane

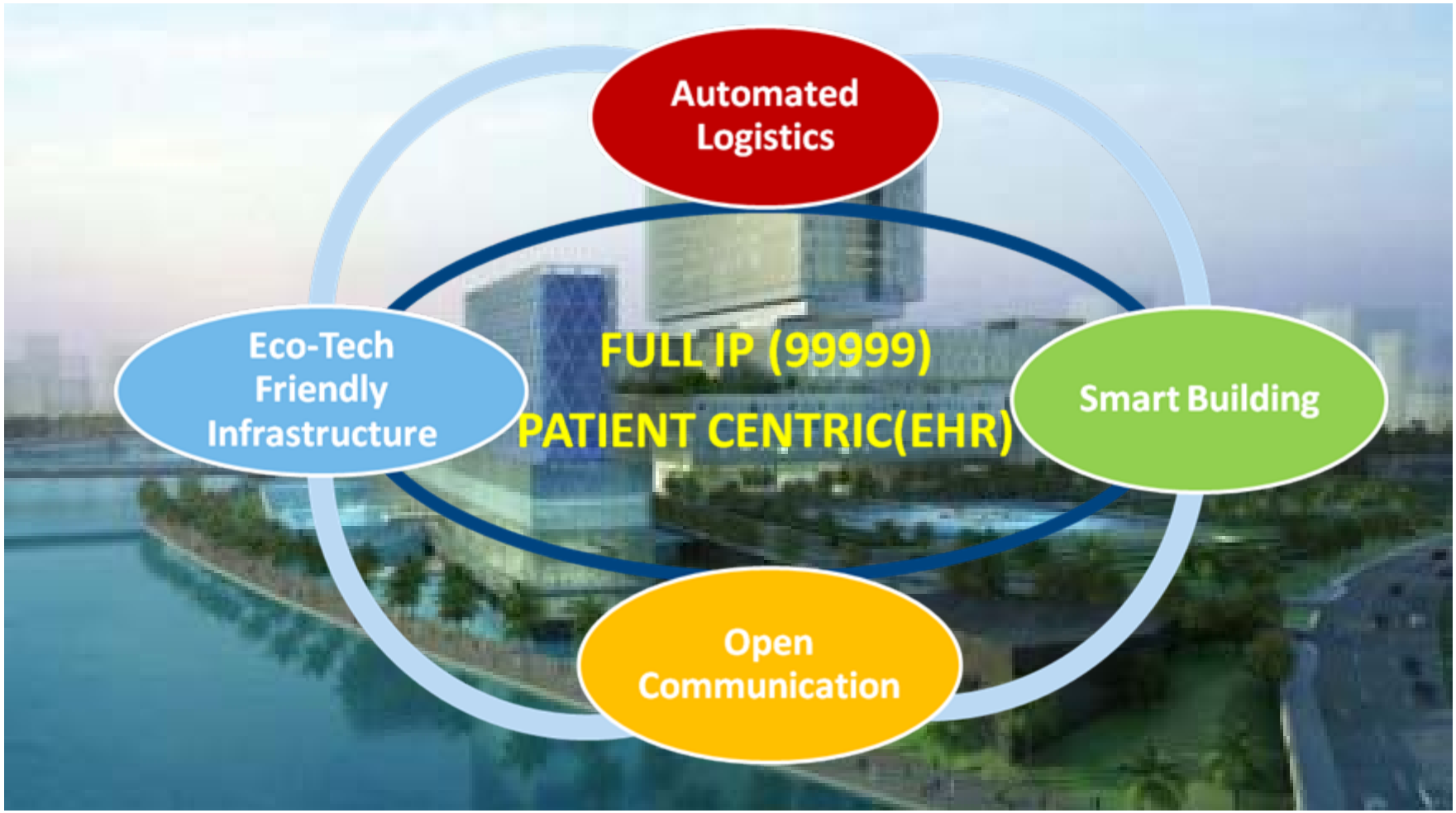
- **Education, Honors** (Cornell and Drexel Universities, USA)
  - BS in Biomedical Engineering
  - MS & PhD in Digital Electronics, Computers, and Informatics
  - Fellow, HIMSS; Certified Clinical Engineer; Past-President, American College of Clinical Engineering; Board of Directors, IEEE/EMBS and ANSI/HITSP
- **Career** (USA, near Philadelphia)
  - 1975-1990 Vice President of ECRI Institute
    - Clinical Engineering and Information Systems
  - 1990-2000 Vice President of MEDIQ, Inc.
    - Medical Device and Drug Manufacturing, Repairs, Rentals, Sales
  - 2000-2009 Faculty of Villanova University
    - Information Systems, Decision Support, Databases, Data Security, Telecommunications, and Medical Informatics
  - Today, Founder and President of the *Center for Healthcare Information Research and Policy*
    - Electronic Health Records, Advanced Clinical Decision Support Systems, Digital and Interoperable Health Systems, Security and Privacy, and Health Systems Engineering

Trusted adviser to the World Health Organization since 1983!

Agenda
Objectives

- **Defining Digital Hospitals**
- The Design and Procurement Phases
- The Construction Planning Phase
- The Installation Phase
- The Testing and Commissioning Phase
- Questions /Challenges

The Modern Digital Hospital



21st Century Digital Hospital Characteristics

- **Full IP (Internet Protocol) design**
  - Wired, wireless, and optical networks
- **Comprehensive patient- and staff-centric EMR**
  - Easy for staff or patient to use
  - Well matched to workflow and record-keeping needs
- **Smart building**
  - Lets the "building" do much of the background work
- **Automated logistics**
  - Ensures that supplies do not run out
- **Eco-friendly infrastructure**
  - Low carbon- and water-footprints

The Digital Hospital "Deliverables" – Part 1

Full IP (Internet Protocol) design

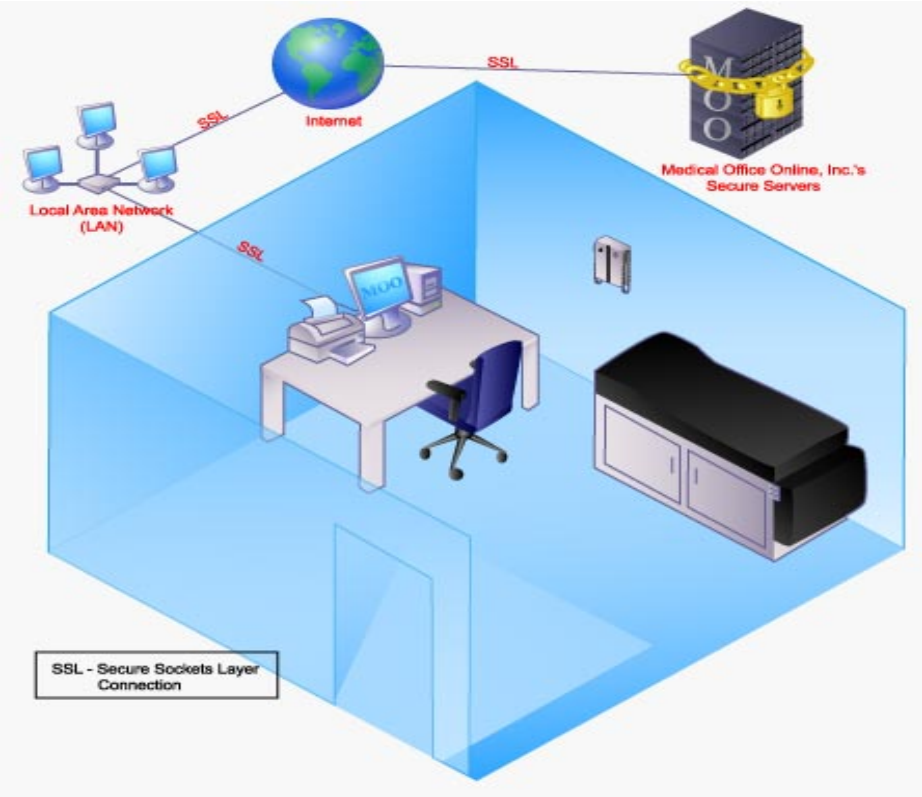
- Network- and internet-ready, for business and clinical applications
- Open (and secure) communication from/to ALL places and things
- Adequate "quality of service" for Voice and Patient Alarm applications
  - Patient monitoring requires very reliable network; alarm and waveforms must not be delayed by simultaneous large image files, entertainment data-streams, personal computing, or other network demands
  - Wireless network support is needed reliably everywhere in hospital

Comprehensive patient- and staff-centric EMR

- Patient-centric, integrated, interoperable technologies that automatically update central EMR (Electronic Medical Record) system
  - Allows timely and optimal, point-of-care clinical data collection, clinical decision support, and patient safety
  - Supports state-, regional-, national-, and international-Electronic Health Record data exchange

Electronic Medical Records improve patient care!

Electronic medical records



Efficiency of Care Processes

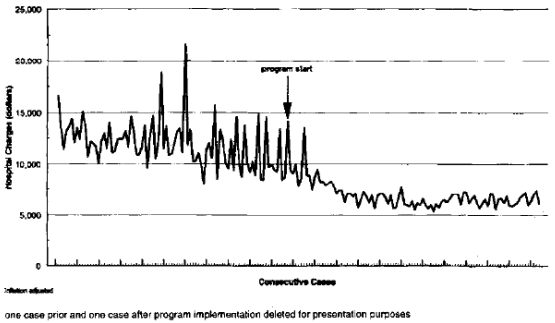


FIGURE 2. *Total hospital charges on consecutive radical retropubic prostatectomy patients before and after implementation of the collaborative care/critical pathway program.*

Part 2 Digital Hospital "Deliverables" Towards the *"Sentient Hospital™"*

Smart, "thinking" buildings

- Internal computer systems automate comfort & safety
- All alarms, elevators, heating/cooling/circulation, water, medical fluids/gases, and security systems are fully integrated and automated
- Building Management Systems (BMS) ease workload, reduce mistakes, minimize maintenance and system failures

Automated logistics

- Optimal material and human resource flows
- Use of robotic delivery is coming to hospitals!
  - Moving drugs, supplies, and food automatically where/when needed.
  - Not only to reduce labor; like factories, designed for speed, reliability!

Eco-friendly infrastructure

- Optimal environmental impact, minimum waste production, lowest use of electricity & water, lowest operating cost

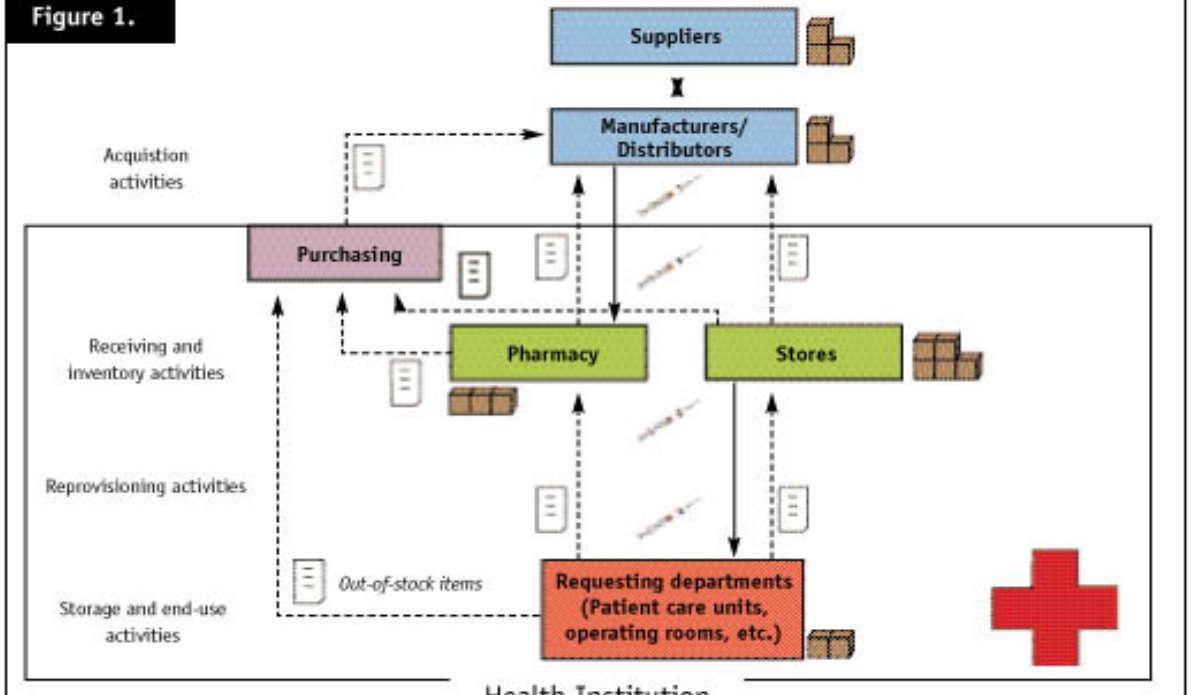
Robotics for the Healthcare Factory!

- **Automated Transport and Logistics Integration Systems – Just in time delivery**

- **Real- time access to inventory information linked to the EHR – IT Controlled**

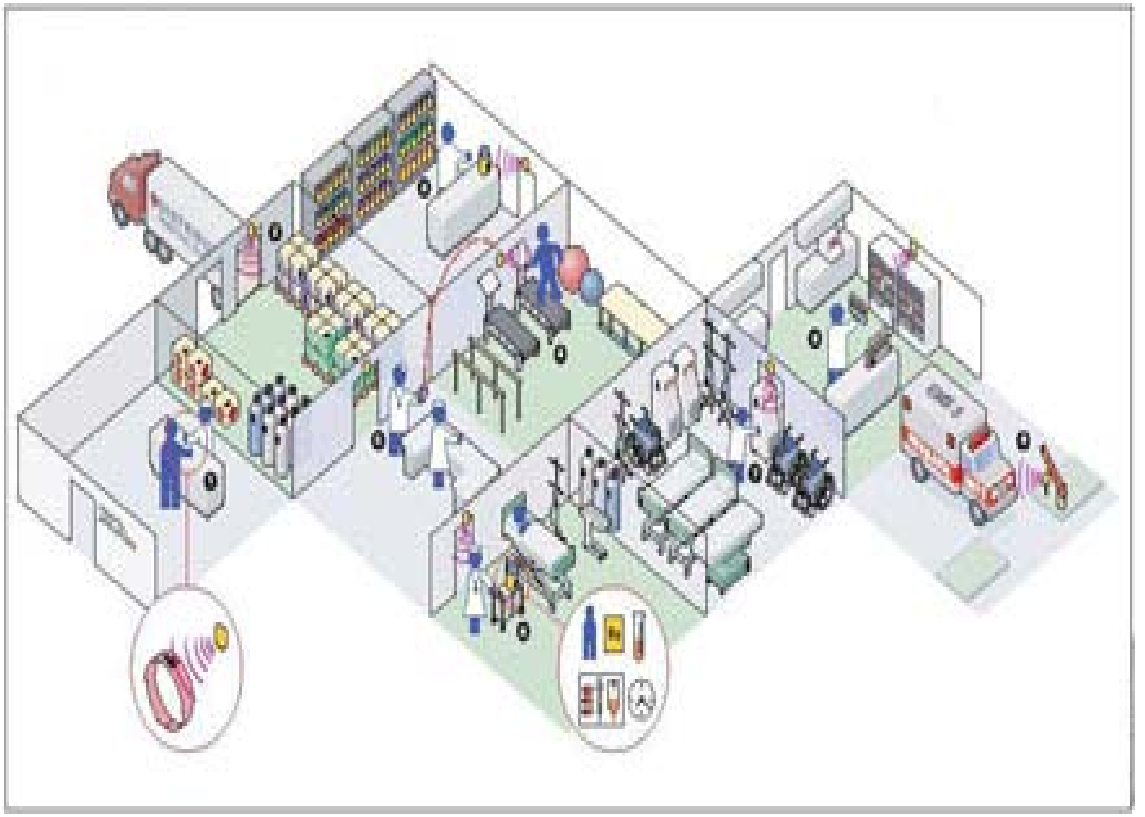
- **Reduce operating costs (space), improved productivity and service levels**

Figure 1.



Radio Frequency Identification (RFID) tags can locate people and supplies, and can prevent process/safety failures like vaccines that get too warm or drug errors!

RFID Tracking



ALL ICT (Information & Communication Technologies) are integrated via IP-based networks

Integrated Technical Architecture

Voice *Video* *Security* *Data* *Storage*

PBX – Phone & Paging System & Nurse Call

TV System & Personal Entertainment

Building Access, Safety Control & Video surveillance

Logistics, Smart Building with Pervasive Sensors

Full IP Data Network

Secure & Resilient

Patient Monitoring & Clinical Departments

How can we classify "Digital Hospitals?"

- HIMSS, the Healthcare Information Management Systems Society, did an extensive survey in 2005/2006
  - Wanted to learn how many US hospitals are really ready to become Digital Hospitals
  - HIMSS created a 8-level scale of sophistication, capability, and readiness, which they labeled Stages 0-7.
    - www.HIMSS.org

7 Stages of Digital Hospital 'Maturity'

© 2005, by HIMSS Analytics, a division of the Healthcare Information Management Systems Society

STAGE	CAPABILITY	% OF USA HOSPITALS
7	Sharing clinical records externally, Data Mining, advanced analytics and Clinical Decision Support	0.0%
6	Physician documentation (Structured templates), full Decision support (variance & compliance), full PACS	0.9%
5	Closed loop medication administration	1.0%
4	CPOE (Computerized Physician Order Entry), Clinical protocols	1.8%
3	Clinical documentation (flow sheets), Order error checking, PACS available outside Radiology	32.0%
2	Result viewing, simple decision support, may have Document Imaging	33.9%
1	Ancillaries – Lab, Rad, Pharmacy (LIS, RIS, PIS)	12.6%
0	The 3 Ancillaries information systems above not installed	17.7%

The HIMSS Analytics maturity ranking scale (1-7) is cumulative

e.g.,

- To achieve level 6, all of the capabilities of levels 1, 2, 3, 4, & 5 must be substantially met!

AND

- The necessary ICT infrastructure to safely, reliably, and economically sustain all of the levels is ASSUMED!

ICT = Information & Communication Technologies

What does "safe and reliable" imply?

Critical Success Factors:

- From Stage 3 up, direct and timely ***Integration*** and ***Interoperability*** of data and systems become **mandatory**. (i.e., "Interfacing" is not good enough!)
  - Above Stage 3, delay, errors, or missing data defeats reliable automation and ***increase errors, waste, & injuries***
- From Stage 3 up, ICT system **SECURITY** must exist and be robust and resilient
  - Patient safety, clinical efficacy, and operational efficiency become dependent on the ICT system.

SECURITY = Confidentiality + Integrity + Availability (CIA)

By Stage 5 must add **+ Safety** to the list **CIAS**

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How to build a state-of-the-art, 21st Century Digital Hospital

- Begins right from the initial conceptual and architectural discussions and designs!
  - Almost impossible – or impossibly expensive – to retrofit after the steel, concrete, wiring, plumbing, and finishing stages are complete
  - VERY few design or construction firms are ready yet!

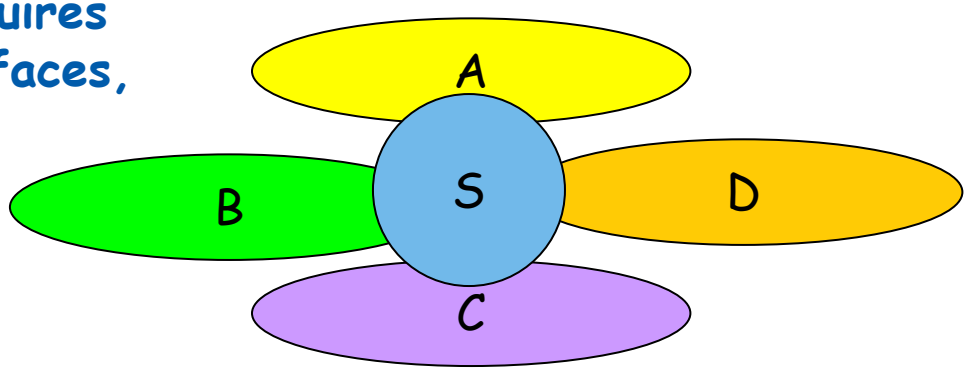
Two key Digital Hospital Essentials

1. All building, business and medical equipment, computers, and software must be carefully specified in advance
   - Compatible interoperability specifications can GREATLY reduce installation and life cycle maintenance costs, reliability, safety, and satisfaction
   - See www.IHE.net, and www.COCIR.net, and www.IHE-Europe.net
2. Advanced internal and external networks and telecommunications
   - All conduit, wiring, antennas, optical fibers, connection rooms, and emergency cooling and power must be designed into the structure just like steel, electricity and plumbing

Important Lessons Learned about: Digital Hospital *procurement!*

- "Interoperability" is essential, and it is VERY different than simple "Interfacing"
  - Interoperable systems A-B-C-D can all be connected with a single interface for each system IF and ONLY IF a common Interface S exists:

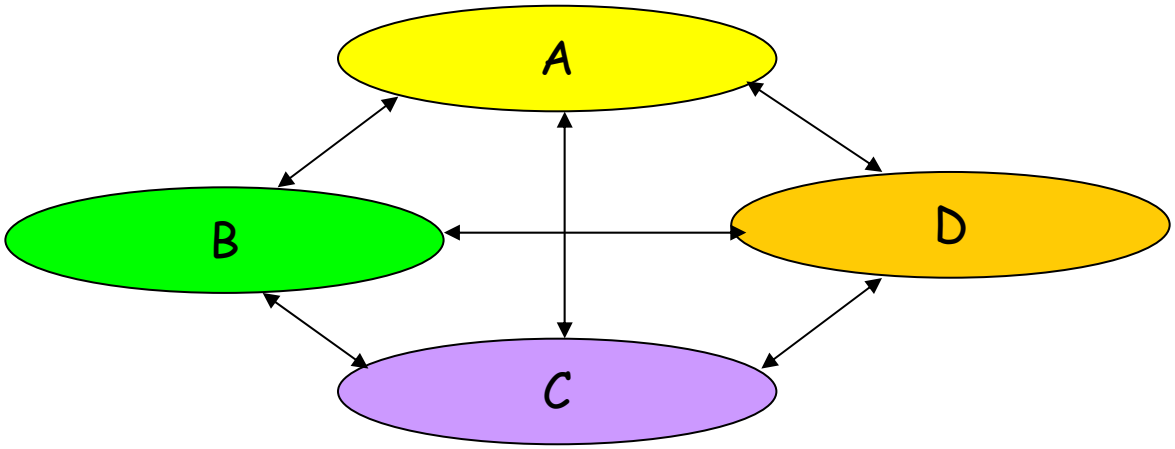
Each system only requires a single pair of interfaces, for a total of 8:
A-S; S-A
B-S; S-B
C-S; S-C
D-S; S-D



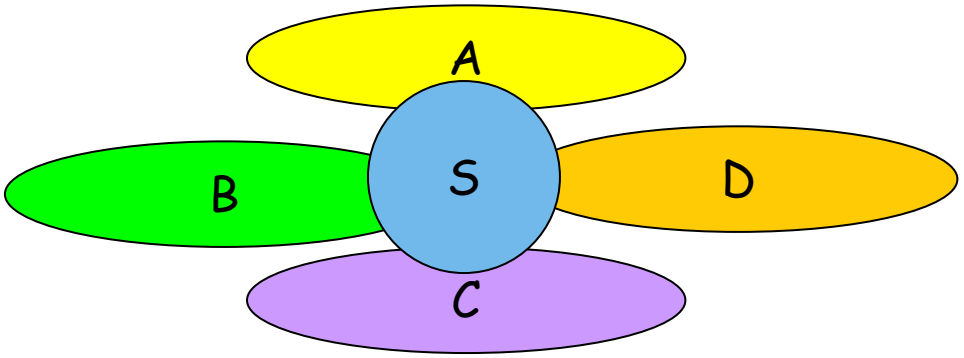
Interfacing alone is NOT good enough

- "Interfacing" requires a huge, and growing number if discrete hardware and software "adapters" between each and every system

Each system needs a separate interface to every other system!
A-B; B-A; A-C; C-A
A-D; D-A; B-C; C-A
B-D; D-B; C-D; D-C



Interfacing's fatal flaw!



8 Interfaces

The "Interoperable Solution"

Each system needs a separate interface to every other system !

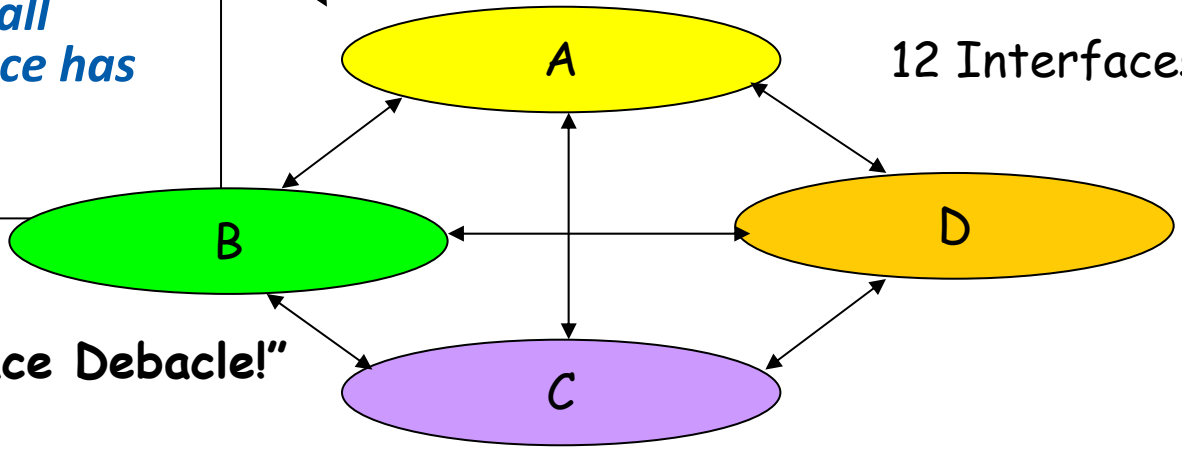
A-B; B-A; A-C; C-A

A-D; D-A; B-C; C-A

B-D; D-B; C-D; D-C

Now, 12 interfaces are needed, not 8, as the Interoperable Solution would require.

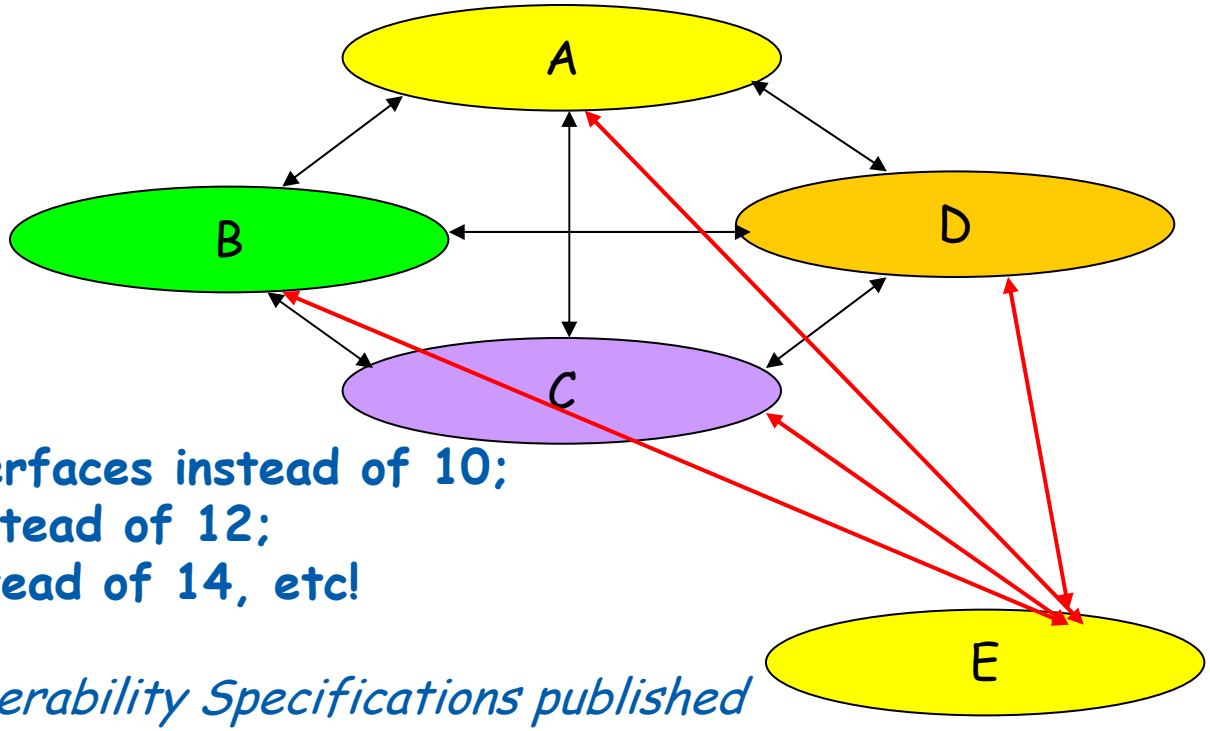
Thus, even in this very small example, using interface has 50% more cost AND complexity!



12 Interfaces!

The ""Interface Debacle!"

Procurement Lesson Learned: Without a SINGLE common interoperable interface, the number of unique interfaces becomes a n^2 (n-squared) geometric problem!



5 systems need 20 interfaces instead of 10;
6 systems need 30, instead of 12;
7 systems need 48 instead of 14, etc!

That is why the Interoperability Specifications published by IHE International are becoming so important!

See www.IHE.net, and www.COCIR.net, and www.IHE-Europe.net examples.

Important Digital Hospital Procurement Lesson:

- Always specify a single (or very, very few), common, interoperable interface for all building, clinical, financial, and clinical applications
  - IHE International specifications are FREE, and should be added to all procurement specifications
  - Vendors will try to stall, BUT, insist on a firm timeline AND COST for IHE compliance or pay the price!

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Important Lessons Learned about: Digital Hospital *Construction*

- Very high bandwidth internet lines should enter the building from two different underground sources for reliability (has to be done before concrete is poured!)
  - Alternate: providing a second very high-bandwidth wireless from the building to a nearby tower
- All in-wall network wiring and fixtures AND all antennas and access points must be installed BEFORE wall/ceiling finish-work is begun
  - Just like electrical and plumbing, though, ALL network services must be tested and corrected room by room, floor by floor, before the walls are finished!
- From HIMSS Stage 3 hospitals and higher, special planning for emergency power and cooling is needed for network equipment and rooms
  - The network will be supporting life-critical care, and cannot afford to fail during common emergencies
- All other low-voltage wiring like nurse call alarms should also be completed then

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Important Lessons Learned: Wireless networks can be critical for Digital Hospitals

- Requires an added step before closing walls and ceilings
  - A room by room, floor-by-floor electromagnetic interference, signal strength, and bandwidth capacity survey needs to be done, and flaws fixed BEFORE finish work is done
    - This has to be done

      a) after all high-power motors and systems are installed and while they are running, including elevators, air-conditioning, etc, and

      b) on- and off-emergency power

The lesson learned?

- The Network is like the Hospital's "Nervous System;"
  - It is a fundamental and critical infrastructure element just like the concrete and steel;
- The nervous system MUST work properly, and therefore must be designed, constructed, and installed properly!

Important Lesson Learned: Clinical (and Business) System *Installation and Commissioning* for the Digital Hospital

- The Stage 3 and higher Digital Hospital is actually a very complex "System of Systems"
  - Each system is dependent on its components AND on other systems it relies on.
    - i.e., the components, sub-systems, and systems are ALL inter-dependent
  - Examples
    - if the network or disk storage system fails, neither the clinical nor the business systems will operate;
    - If the Electronic Medical System fails, the alarm, billing, and any clinical decision support system will probably fail, too!

Verification and Validation (V&V) of a System of Systems (SoS) is different!

- Most Clinical Engineers are trained to do safety and performance tests on every piece of medical equipment before use
- The Digital Hospital (SoS) requires a

  UNIT <> SUB-SYSTEM<>SYSTEM<>ENTERPRISE

  safety and performance testing strategy!
  - V&V each piece of equipment;
  - V&V each sub-system of equipment groups, like each patient room;
  - V&V each combination of sub-systems, like the patient rooms to the central monitoring system;
  - V&V all subsystems to the enterprise system, including the Electronic Medical Record, Life-Critical Alarms, etc

Verification is different than Validation! Both are important…

- **Verification** – the system operates as specified or designed ("works right")
- **Validation** – the system performs the correct and safe activity ("serves the valid/correct real-world function," i.e. Does the right thing!)

Example: If the specification did not address adequate emergency cooling when the electricity fails, and life-critical functions actually fail, the system cannot "do the right thing," so it fails **Validation** testing and must be repaired before acceptance/commissioning!

Digital Hospital Lesson Learned: *Installation, Testing, and Commissioning*

- A System of Systems approach, with unit/sub-system/system/enterprise installation and testing strategies is needed
  - For healthcare, complex systems need to be challenged by Verification and Validation at each step to ensure the system "does the right thing" under all expected operating conditions!
  - This is very important for JCAHO accreditation.

The Conclusions?

- Successful design, building, installation, and testing of the 21st Century Digital Hospital ***requires collaboration*** between the architecture, construction, ICT, and clinical engineering teams ***from the very beginning*** up ***until the final hours*** of commissioning and turn-over of the hospital!
  - Safety and performance must be ***designed into*** the hospital!
  - ***Procurement*** and ***installation*** require ***System of Systems*** thinking!
  - Testing and commissioning require ***Verification and Validation*** strategies at each of the ***Unit<>Sub-System<>System<>Enterprise*** levels!

Good luck in YOUR journeys to the 7th Stage of Digital Hospital Maturity and Success!

STAGE	DIGITAL HOSPITAL CAPABILITY SCALE © 2005 HIMSS Analytics, all rights reserved	
7	Sharing clinical records externally, Data Mining, advanced analytics and Clinical Decision Support	
6	Physician documentation (Structured templates), full Decision support (variance & compliance), full PACS	
5	Closed loop medication administration	
4	CPOE (Computerized Physician Order Entry), Clinical protocols	
3	Clinical documentation (flow sheets), Order error checking, PACS available outside Radiology	
2	Result viewing, simple decision support, may have Document Imaging	
1	Ancillaries – Lab, Rad, Pharmacy (LIS, RIS, PIS)	
0	The 3 Ancillaries information systems above not installed	

谢谢 - xièxiè – Thank you!

You may contact me at:

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or simply Google™ me!

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Your questions and comments are invited now, and they are most WELCOME!