Human-Machines Systems Engineering

The Emergency Cesarean Delivery Facilitator
The Human-Machine Systems Engineering Process

Needs, Problems, Opportunities

Operate, Test & Evaluate

Analyze

Design

Implement

Manage

Requirements

Human-Machine System

Material
Energy
Information

Processes & Tasks

Humans
Machines

Products
Services

Mockup
Prototype
Final Product

Build
Mock-up
Fabricate
Manufacture

Conceptualization
Preliminary Design (PDR)
Final Design (CDR)

Requirements Verification
Heuristic Evaluation
Usability Testing
Role-Playing
Simulation
Operational Testing

Background Research
Concept Development
Task Analysis
Detailed Task Analysis
Requirements Engineering
Development of an Emergency C-Section Facilitator Using a Human-Machine Systems Engineering Approach

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Note On Terminology

Emergency Cesarean Section (ECS) = Emergency Cesarean Delivery (ECD)
Background, Statement of Need

• Background
  – Cesarean Section: surgical delivery of baby
  – System vulnerabilities, especially in small, rural hospitals
    • Inherent risk of procedure
    • Difficulty in assembling on-call team for unscheduled, emergency procedure
    • Urgent, chaotic conditions
  – Human Fallibilities (sensory, cognitive, motor)
  – System vulnerabilities + human fallibilities = delays, errors, potential for catastrophe

• Need
  – Reduce
    • “decision-incision” time
    • errors
  – Improve
    • Team communication
    • Team awareness of system, processes
    • Coordination of people, processes, procedures

• Cesarean Section Facilitator: Information & communication system to facilitate
  – Notification, assembly, preparation of team
  – Preparation of mother (and baby)
  – Preparation of operating room
Analysis
(Requirements Development)

- **Subject Matter Experts/Potential Users**
  - James Bauer, MD, OB/GYN, PeaceHarbor Hospital (“Client”)
  - David Telasha, MD, OB/GYN
  - David Blatt, MD, Anesthesiologist
  - Other Northwest physicians and nurses

- **Process modeling using IDEF0**
  - User-centered perspective
  - Systematic, top-down knowledge elicitation
  - Knowledge representation for communication, documentation
  - Development of common language and understanding among engineers and SMEs

- **Requirements development from**
  - Elicited knowledge of
    - System
    - Processes
    - Potential errors, interventions
    - User needs
  - Human factors principles and guidelines
To perform a Process, Mechanisms transform Inputs to Outputs, subject to Controls.
Process Hierarchy/IDEF0 Node Tree

A0: Perform Cesarean Section

- A1: Communicate, assess, plan, execute
  - A11: Maintain situation awareness
  - A12: Share situation information
  - A13: Assess situation
  - A14: Plan processes
  - A15: Manage, direct, and execute processes

- A2: Decide to do CS

- A3: Prepare for CS
  - A31: Prepare team
  - A32: Prepare mother & fetus
  - A33: Prepare OR
  - A34: Prepare for maternal recovery care
  - A35: Prepare for neonatal care
  - A36: Mobilize hospital & regional resources

- A4: Perform CS
  - A41: Manage maternal physiology (anesthesia)
  - A42: Manage fetal physiology
  - A43: Position mother appropriately for CS
  - A44: Perform CS surgical procedure
  - A45: Support CS surgical procedure (OR logistics)

- A5: Recover from CS
  - A411: Monitor mother’s physiology
  - A412: Induce anesthesia
  - A413: Maintain anesthesia
  - A414: Reverse anesthesia
  - A421: Monitor neonate’s physiology (other processes TBD)
IDEF0 Prepare for CS (A3)
IDEF0  Prepare for CS (A3)
IDEF0  Prepare for CS (A3 detail)
Requirements From Analysis and Modeling

- The Facilitator shall allow one person to simultaneously summon the entire first call CS Team within 3 minutes of the decision to do a CS.
- The facilitator shall remind team members about tests to be undertaken to assess maternal state.
- The Facilitator shall remind surgical Team members what actions must be performed to Prepare OR.
- The Facilitator shall display the status of OR equipment.
- Facilitator display formats and user interaction protocols shall be consistent across all subsystems.
Design and Prototype Implementation

- **Design**
  - Specifications to meet 65 of 99 requirements
- **Implementation**
  - **Prototype 1 (IE 546, Spring 2006)**
    - Electronic “storyboard”
      - HTML, PowerPoint
      - Screenshots from scripted scenario
  - **Prototype 2 (Summer/Fall 2006)**
    - **Hardware**
      - Laptop server
      - Wireless router
      - Tablet PC
      - PDA
    - **Software**
      - Microsoft Access database
      - ASP.NET
      - CSS
Cesarean Section Facilitator Architecture

- Team PDAs/Smart Phones
- Labor & Delivery Monitor
- Team/Room Tablet PCs
- OR Monitors
- (Redundant) Server
- Ward Clerk Workstation
C-Section Decision and Call

• Delivery fails to progress.
• Baby at risk.
• Obstetrician decides to do C-Section.
• Ward Clerk initiates summons.
Summons via PDAs/Smart Phones

- Summons broadcast to all team members.
- Members respond.
- If unavailable, next on list summoned.
# Team Status

<table>
<thead>
<tr>
<th>Role</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obstetrician</td>
<td>![X]</td>
</tr>
<tr>
<td>Dey, Jane</td>
<td>![Play]</td>
</tr>
<tr>
<td>Surgical Assistant/CNM-Midwife</td>
<td>![X]</td>
</tr>
<tr>
<td>Short, Bill</td>
<td></td>
</tr>
<tr>
<td>Anesthetist</td>
<td>![X]</td>
</tr>
<tr>
<td>Long, Mary</td>
<td></td>
</tr>
<tr>
<td>OB Nurse</td>
<td>![X]</td>
</tr>
<tr>
<td>Cole, Jack</td>
<td></td>
</tr>
<tr>
<td>Scrub Nurse</td>
<td>![X]</td>
</tr>
<tr>
<td>Kim, Linda</td>
<td></td>
</tr>
<tr>
<td>Circulating Nurse</td>
<td>![X]</td>
</tr>
<tr>
<td>Lee, Ken</td>
<td></td>
</tr>
<tr>
<td>Family Practice Physician</td>
<td>![X]</td>
</tr>
<tr>
<td>Jones, Gary</td>
<td></td>
</tr>
<tr>
<td>Respiratory Therapist</td>
<td>![X]</td>
</tr>
<tr>
<td>Gage, Cindy</td>
<td></td>
</tr>
</tbody>
</table>

*Available on all platforms to all team members.*

![Diagram of labor and delivery system]

- Labor & Delivery Monitor
- Team/Room Tablet PCs
- (Redundant) Server
- Ward Clerk Workstation
Patient Preparation With Tablet PCs Or PDAS

- Nurses prepare patient (checklist).
- Enter patient data (entry form).

<table>
<thead>
<tr>
<th>Patient State Assessed</th>
<th></th>
<th></th>
<th>✅</th>
</tr>
</thead>
<tbody>
<tr>
<td>Informed Consent Signed</td>
<td></td>
<td></td>
<td>✅</td>
</tr>
<tr>
<td>ID &amp; Allergy Band Verified</td>
<td></td>
<td></td>
<td>✅</td>
</tr>
<tr>
<td>IV and Oxygen Started</td>
<td></td>
<td></td>
<td>✅</td>
</tr>
<tr>
<td>Prophylactics &amp; Antibiotics</td>
<td></td>
<td></td>
<td>✅</td>
</tr>
<tr>
<td>Bicitra Administred</td>
<td></td>
<td></td>
<td>✅</td>
</tr>
<tr>
<td>Blood Drawn for CBC</td>
<td></td>
<td></td>
<td>✅</td>
</tr>
<tr>
<td>Foley Catheter Inserted</td>
<td></td>
<td></td>
<td>✅</td>
</tr>
<tr>
<td>Clipper Prep Performed</td>
<td></td>
<td></td>
<td>✅</td>
</tr>
<tr>
<td>Transported to OR</td>
<td></td>
<td></td>
<td>✅</td>
</tr>
<tr>
<td>Prepared for Anesthesia</td>
<td></td>
<td></td>
<td>✅</td>
</tr>
</tbody>
</table>
OR Preparation

• Nurses & physicians prepare OR (checklist).
• Check (√) completed items.
• Mark (►) items in progress.
• Mark (X) problem items.
# Labor & Delivery, OR Status Displays

## Labor & Delivery Details

**Patient:** Field, Susan  
**Gestation Age:** 37 Weeks  
**Reason for CS:** Failure to Progress

**Current Medications:** None  
**Allergies:** NKDA  
**Health During Pregnancy:** No Major Problems  
**Past Major Illnesses:** None

**Membrane Rupture:**  
**Time / Color / Amount:** 12:13 / Clear / 4 fl. oz.

**Cervix Position:** Anterior  
**Uterus Size:** 3 inch  
**Uterus Lie:** Longitudinal  
**Presentation:** Breech (Butt)  
**Dilation:** 1 cm

**Contraction Interval:** 11 min  
**Contraction Duration:** 11 sec  
**Contraction Intensity:** Medium

## OR Status

- **Obstetrician:** Dey, Jane  
- **Surgical Assistant/CNM-Midwife:** Short, Bill  
- **Anesthetist:** Anesthesia Machine  
- **Suture Supplies:** Prepared Baby Warmer

## Equipment

- **Anesthesia Cart**  
- **Oxygen & Airway Supplies**  
- **Surgical Equipment**  
- **Table & Lighting**  
- **Mayo Stand & Instruments**  
- **Neonatal Crash Cart**

Status displays also available on:  
- Tablets  
- PDAs  
- Desktops
Operation and Evaluation of Prototype 2

- Demonstration scenario at PeaceHarbor Hospital
  - Emergency C-Section
  - Problems
    - First-call pediatrician fails to respond
    - Baby warmer prep assigned to RNA, miscommunicated
    - Problem with equipment in the OR (forceps and Kiwi).

- Usability assessment
  - Learnability
    - Intuitive
  - Efficiency
    - Easy entry of patient data
    - Simple
    - Good interface design
  - User satisfaction
    - Great
    - Better communication
    - No rigid enforcement of procedural order
    - No major problems
  - Recommendations (implemented in previous screenshots)
    - Less intense colors
    - Different icons
    - Reduced display clutter
Prototype 3

http://flightdeck.ie.orst.edu/ECD/
Summary, Discussion, Plans

- Requirements development through IDEF0 process modeling
  - Systematic, top-down knowledge elicitation
  - Shared vocabulary, understanding among engineers, users
- Rapid prototyping with off-the-shelf components
- Prototype:
  - Mobile, wireless information/communication system to facilitate
    - Surgical team assembly and preparation
    - Patient preparation
    - Preparation of operating room
    - Situation awareness: patient, OR, team
  - Well-received by users
  - Believed that it would significantly reduce decision-incision time
- Future plans for
  - Refined requirements
  - Revised prototype
  - Evaluation in simulation trials