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FULL SCALE ARCHITECTURAL SIMULATION TECHNIQUES FOR SPACE STATIONS

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Architectural Simulation

The Architecture and Planning Research Laboratory (APRL) has carried out a series of research studies that make use of full scale mock-ups of architectural environments. Operational scenarios and empathic training exercises are integrated with mock-up development to provide elaborate simulations of activities in different types of architectural and environmental conditions.

The laboratory uses approximately 5000 sq. ft. of indoor high-bay space, and large outdoor covered areas to build and evaluate mock-up facilities and environments. Ergonomic problems, equipment layout, and comparisons of internal spatial configurations are studied. Realistic operational scenarios are developed and studied in full scale mock-ups to evaluate user and equipment problems and to train potential users of new environments in simulated settings exposed to simulated events. This architectural and environmental simulation laboratory provides an ongoing site for the study of thermal, acoustical, and lighting problems integrated with the layout of work spaces and equipment. APRL has been particularly concerned with the study of new types of architectural environments, critical or dangerous procedures, and frequently repeated work spaces that benefit from studies of this type. Specialized ergonomic studies of individual work stations are studied in this way before design requirements for new facilities are formulated.

Gaming/Operational Simulation

The architectural mock-up of physical and environmental conditions is complemented by and integrated with gaming simulation studies. The simulation of operations and critical events are combined with the architectural mock-up for evaluation and training purposes. Certain common elements can be found in each of the gaming simulations applied. These include:

1. A scenario or simulated set of activities or events that are part of the time-space conditions to be studied.

2. Users playing roles that do or do not correspond to those they assume in real life.

3. An evaluation and monitoring procedure that accounts for what takes place in the simulation and the consequences of matching particular scenarios to particular spatial configurations and environmental conditions. The resulting simulations are recorded and fed-back to participants for reiteration of events, and the modification of the architectural setting for more appropriate ergonomic conditions. Thus the simulation device serves multiple purposes as a conceptual design tool, an evaluation device, and a training environment.

Empathic Modelling

An empathic model is frequently used in simulation studies to approximate sensory changes in the user of the mock-up environment caused by events and conditions of the scenario being used, or by the capabilities and limitations of the population being studied, e.g., age-related sensory loss.

Much of the use of empathic models at APRL has been for the purpose of providing "personal experience" to designers and researchers, in imageable terms, of what it must be like to experience sensory loss or degradation in some environmental conditions. The empathic model is made up of an assortment of appliances that simulate visual, auditory and tactile sensitivity in persons of advancing age. While these simulations are relatively crude, they offer empathic experiences to persons involved in mock-up simulation that can be repeated for various controlled settings of space, light, sound, and so on. Empathic devices can be taken out of the mock-up environment to experience changing conditions in the real world setting, thus developing early appreciation for new problems before a new environment is built.

Computer Aided Simulation

APRL has developed a powerful set of computer aided building design software tools which support all APRL research efforts in software research and development; the Computer Laboratory is a central component of all APRL simulation efforts.

Monitoring And Evaluation

The visual studies component of the laboratory provides specialized equipment and space for the simulation, recording, and analysis of mock-ups. It is equipped to produce live and taped video images, photographic images, and various types of image reproduction. The visual studies area is equipped with two motorized lighting grids, 16 feet by 16 feet with lighting tracks and dimmers, each with individual controls. The ceiling and attached grids may be elevated from 3 to 25 feet.

The Spectrum of Simulation

The combination of architectural mock-ups and gaming scenarios attempt to represent potential real world conditions. The means of simulation can best be visualized as a spectrum from real world to mathematical analysis. The real world contains all the detail and complexity, while the mathematical simulation is the most abstract. For architectural simulation it is possible to use the real world (though this often proves to be costly and impractical, and for many of the environments to be studied that real world does not yet exist). Rather, it is desirable to move tentatively along the spectrum from reality to abstraction (fig.1) settling on a degree of simulation that best suits the problem context at hand.

Range of mock-up simulation

Real World	Observations of Real World	One to One Mock-up	Gaming Simulation	Computer Assisted Simulation	Mathematical Simulation

Figure 1. Spectrum of Simulation

Generating User Requirements

The simulation environment provides the research site for a three level approach to determining user requirements and matching them with supportive architectural environments. This approach combines the study of activity systems with their major systems support (such as life support and communications) and with key environmental conditions in the mock-up, e.g., acoustical, luminous, thermal factors.

Activity systems: The analysis consists of identifying activities to be carried out in the architectural system and deriving user requirements to achieve system objectives.

Associated support systems: This analysis takes as its focus the various systems of artifacts required in the activity processes. Included are monitoring, life support, and communication systems. Since redundancy is inherent in this approach, greater stress is placed on requirements not easily accessible through the activity based approach, e.g., back-up system of monitoring and control.

	Capab.	Limit.	Capab.	Limit.	Capab.	Limit.	Capab.	Limit.	Capab.	Limit.	Capab.	Limit.	Capab.	Limit.	Implications Adaptive Range
Vision															
Hearing															
Touch															
Smell															
Psychomotor															
Kinesthetic															
Reaction Time															
Memory Short Term Long Term															
Task Performance															
Habits															
Preferences/Attitudes															
Activities	Sleeping		Personal Hygiene		Cooking & Food Prep.		Eating & Drinking		Housework		Leisure & Socializing		Movement & Communication		
Allocation of Function	User	Env.	User	Env.	User	Env.	User	Env.	User	Env.	User	Env.	User	Env.	

Figure 2. Interactive User Considerations

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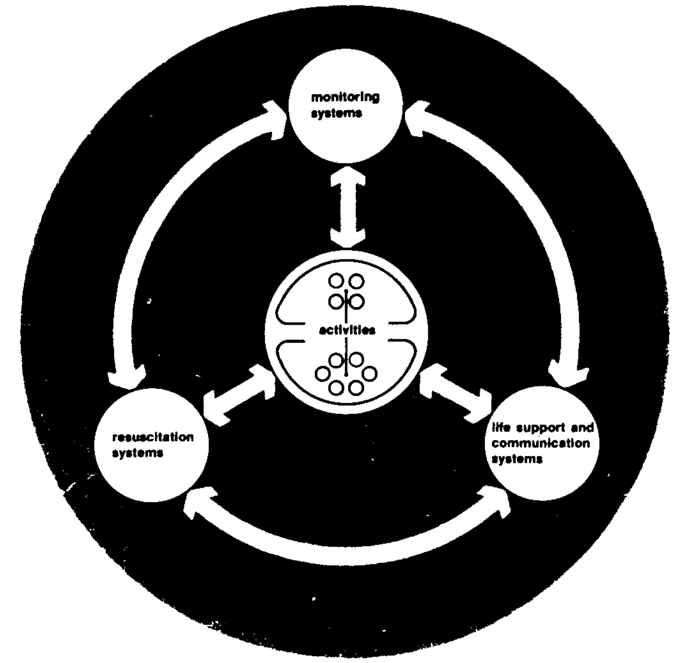

Figure 3. Model for User Requirement Development

Environmental systems: This analysis provides a third approach towards understanding the user needs of the system, as the three major human sensory aspects of the environment are investigated to yield suitable requirements to support and supplement those previously generated.

Simulating Routine and Emergency Events in a Mock-Up Unit

The following section briefly describes a set of simulation studies carried out by Clipson and Wehrer as part of a comprehensive study of health care facilities. The simulations combined full scale mock-ups, elaborate scenarios for everyday and emergency events, role playing by experienced users, and analogue computer simulations (of normal and abnormal physiological conditions of patients) that drove the scenarios. Remote controlled video and motorized photography were used to monitor and evaluate the simulations.

The main purpose of developing the mock-up unit was to provide a realistic, operational environment for the simulation of routine and emergency care procedures, and to provide a physical environment which would be easily modified to provide a wide range of physical configurations and make possible the collection of data critically needed for making decisions on the delivery of intensive cardiac care.

After some initial pilot observation projects in existing Cardiac Care Units (CCU's), the following problems became apparent, which could only be overcome by developing a simulated environment: 1) Setting up observations and equipment in the close confines of the CCU is very obtrusive and could be detrimental to the patient and to the operation of the unit. 2) Witnessing cardiac emergencies in real situations and resuscitative procedures is unpredictable and very time consuming. 3) The use of closed circuit TV installed in patient rooms is considered to be an intrusion on the privacy of the patient and staff at so critical a time. 4) It is often impractical and undesirable to experiment with changes in operational routines, staff roles, and space use in the day-to-day operation of the cardiac care unit.

The Mock-Up Structure: The structure is made up of a set of easily erected, easily changed wall panels constructed from 1" x 4" pine frame, with 4' x 8' homosote face panels painted in typical hospital colors. Using simple drilling jigs and assembly jigs, 17 wall panels were constructed, along with life support service panels for electrical supply, oxygen, air, and suction. Five of the 17 wall panels were built with removable window areas which could easily be interchanged for viewing in and out of the mock-up. The wall panel frames were pre-drilled to permit edge-to-edge bolting in three places. Shelving track attached to 1" x 4" strips was sandwiched between each panel frame to permit adjustable shelving and storage units wherever required.

The structure is stabilized overhead with 2" x 6" beams running from wall to wall at each 4' module, with external diagonal bracing. The overhead beams are used for hanging lighting, video cameras and microphones, and curtains. The initial structure was completely erected and furnished by a 4-man team in two hours. Adjustments and re-arrangements of the apparatus take only a few minutes.

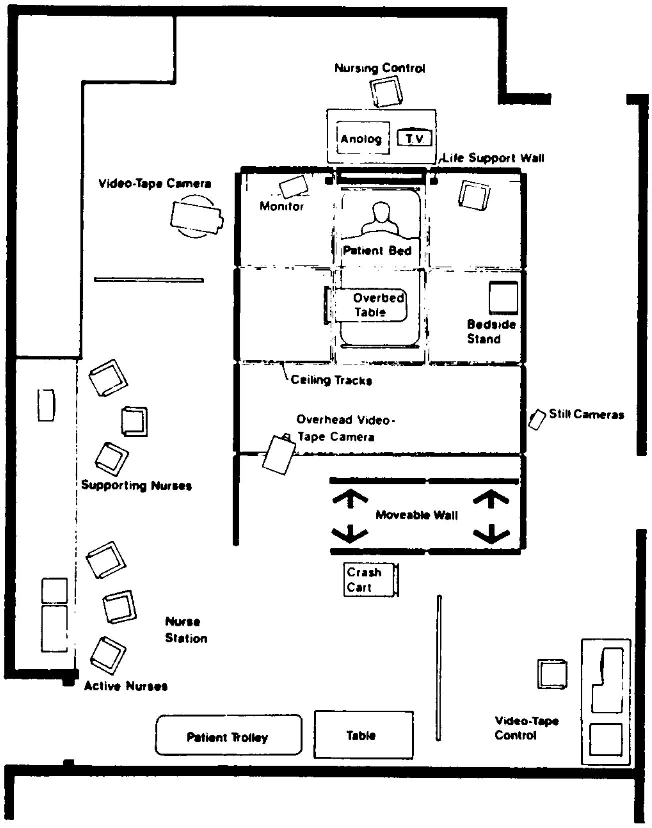

Figure 4. Plan of Mock-Up Facility

Equipment: A key piece of equipment in the simulation activity is Resusci Anne, a lifelike "manikin" which can be electronically programmed to develop a range of arrhythmias and life threatening states, for example, ventricular tachycardia, ventricular fibrillation, and cardiac arrest. The manikin patient's EKG output is displayed on cardiac monitoring equipment at the bedside and at a mock-up training station adjacent to the patient bed area. Resusci Anne is also equipped with a special thorax skin so that cardiopulmonary resuscitation can be performed. In addition, nursing personnel can actually defibrillate or countershock arrhythmias by proper use of DC defibrillator electrodes on the manikin's bare chest.

In a sequence of each training session on patient delivery and admitting, the manikin is replaced by a live patient, a volunteer adult subject prebriefed in a patient role, and delivered to the unit on a standard hospital cart. Patient handling, movement to the bed, and preparation for care can be more realistically simulated this way than by the use of the manikin, which has none of the handling characteristics of the actual patient.

Patient surveillance equipment consists of a bedside EKG monitor and, at the nurses' station, an EKG monitor with rate meter, alarms, and printout capability. The unit is equipped with an emergency crash cart which carries a defibrillator and other life support equipment and medications.

In addition, the entire activity in the mock-up is recorded on video tape from video camera equipment situated over the unit for vertical scanning, and around the floor of the unit for eye level viewing. Both cameras have 300mm close-up capability for close details of care techniques, and the cameras are synchronized and controlled from a video control center adjacent to the mock-up. Simultaneously, the visual output is displayed on TV screens for the benefit of instructors, observers, and other groups outside the mock-up area. "Instant replay" can be used for discussion and critique seminars after the training seminar is completed. From this video record, the design team has been able to extract data on specific care routines for ergonomic analysis and design development.

A 35 minute video tape of edited excerpts of the simulations has been prepared for teaching purposes in nurse training programs. In addition, 35mm cameras have been used to record selected sequences of the space use and details of equipment location at the beginning and conclusion of each training session.

Procedures: The simulation activity consists of a limited number of coronary events enacted in different physical settings. Nurses from the University Hospital training programs are divided into work teams, six nurses to a team. Prior to work in the mock-up, the trainee nurses have undergone either classroom training and demonstration in cardiac intensive care or, in the case of advanced training, nurses have actually worked in CCU's.

After briefing on the purpose of the mock-up, during which nurses familiarize themselves with the mock-up unit and its equipment, each team of nurses is exposed to 40 minutes working in the mock-up, where they must deal with routine care procedures and cardiac emergencies pre-programmed into Resusci Anne. At the beginning of a training session, the six-nurse team is divided into two groups. Three nurses play an "active role" for 40 minutes, working directly with the patient and making decisions on courses of action. The other three nurses play a "supportive role," observing the events on a closed circuit TV and helping only when specifically called on by the three active nurses. Whenever it is necessary, the nurse attending the patient makes his or her own decision about pressing the alarm button, calling for assistance from other nurses in the team, asking for additional equipment not in the room, and taking any other course of action that is necessary. At the end of 40 minutes, there is a five minute break while the active and supportive nurses switch roles.

At the beginning of the training period, the nurses are provided with the patient's case notes so that, as each simulation period starts, the nurses can familiarize themselves with the patient's condition much like at a change of shift in a hospital. The active nurses then begin to watch the patient's progress on the monitor at the nursing station and patient bedside. Throughout the training period, the instructors record trainee progress on a series of checklists.

In a second series of simulations, teams comprised of a cardiologist, anesthesiologist, inhalation therapist, and CCU nurses and technicians ran through a series of cardiac emergencies utilizing both fixed and portable emergency equipment. As in the simulations using nursing teams, the room configurations were adjusted to provide a range of room dimensions and equipment locations.

Space use: The patient bed and the configuration of equipment and room furniture are re-arranged to simulate typical and novel patient bed spaces to be studied by the facility design team. These configurations represent changes in room size, bed position, room entrance position, relationship of entrance to the bed, storage location and volume, location of equipment and services, partitions and curtains between beds, and transportable equipment. The efforts of the simulation team are directed toward presenting a variety of layouts which range from the minimum bed area and clearances for patient delivery, up to more spacious units, where more flexible arrangements of the support equipment and bed can be observed. Because of the provision of flexible wall modules, shelving and service modules (which house electrical outlets, nurse paging system, clock, and inhalation equipment), it is possible to make many changes in the unit in a matter of minutes, thus observing, in the next sequence, any effects due to changes made.

The range of room shapes and room arrangements were chosen to explore the use of a) typical hospital room layouts, and b) recent innovations in the design and position of the life support service walls.

Experiences in the mock-up: Even with limited use, it has been convincingly demonstrated to the project research team that simulating cardiac events in the mock-up

Schedule of CCU Simulation Project

Training Session for 18 Nurses

Coronary Events: a = ventricular fibrillation
b = cardiac arrest
c = patient transfer

Training Groups	Coronary Event	Space Configuration	Event Time	Total Time
First Day 6 Nurses: 3 active 3 supportive	Team 1: active Team 2: supportive a b c	1	40 min.	1 1/2 hr
		Room Change	10 min.	
	Team 2: active Team 1: supportive a b c	2	40 min.	
Second Day 6 Nurses: 3 active 3 supportive	Team 1: active Team 2: supportive a b c	3	40 min.	1 1/2 hr
		Room Change	10 min.	
	Team 2: active Team 1: supportive a b c	4	40 min.	
Third Day 6 Nurses: 3 active 3 supportive	Team 1: active Team 2: supportive a b c	5	40 min.	1 1/2 hr
		Room Change	10 min.	
	Team 2: active Team 1: supportive a b c	6	40 min.	

Figure 5. Space-Activity Interaction

CCU Simulation: Sequence A — Ventricular Fibrillation

1. Normal Sinus Rhythm — 2 Minutes

Nurses Station -
3 nurses at scope reading chart
3 support nurses watching T.V. monitor

2. 4 Premature Ventricular Contractions per minute (Repeat Once) — 2 Minutes

Nurse	1	2	3	4	5	6
Obtain write out tracing (30 sec.)						
Prepare Lidocaine bolus (1 min.)						
Administer Lidocaine bolus into I.V. tubing (1.5 min.)						
Add Lidocaine to I.V. bottle (2 min.)						
Reassures patient (1 min.)						
Returns to nursing station (1 min.)						

3. Ventricular Fibrillation — 3 Minutes

Checks scope at alarm (30 sec.)						
Identifies arrhythmia (30 sec.)						
Enter room and check patient (30 sec.)						
CPR						
Clears Airway						
Inserts airway						
Bags Patient						
Initiates chest compressions						
Calls supportive nurses						
Calls a code						
Brings crash cart						
Defibrillator						
Plugs in						
Turns on power						
Sets watts seconds						
Applies paddles						
Safety check and gives warning						
Discharges defibrillator						
Prepares sodium bicarbonate and gives I.V.						
Checks patient (responsive)						

4. Sinus Bradycardia (Rate 40) — 2 Minutes

Recognizes sinus bradycardia						
Draws up Atropine						
Administers Atropine I.V.						

5. Normal Sinus Rhythm — 2 Minutes

Checks Scope						
Recognizes EKG pattern						
Observes patient						
Reassures patient						

Sequence Completed

Figure 6. Operational Simulation Routines

does provide a reasonable facsimile of actual events. By preparing and carrying through a carefully prepared scenario for each cardiac activity, a high degree of realism is achieved in the delivery of care to the stricken patient, as well as in the appearance of the environment in which the activities take place.

Experienced CCU nurses receiving advanced training procedures reported in post-simulation discussions how quickly their awareness of the simulation features of the activity faded and that they were completely engrossed in the problems of nursing procedures.

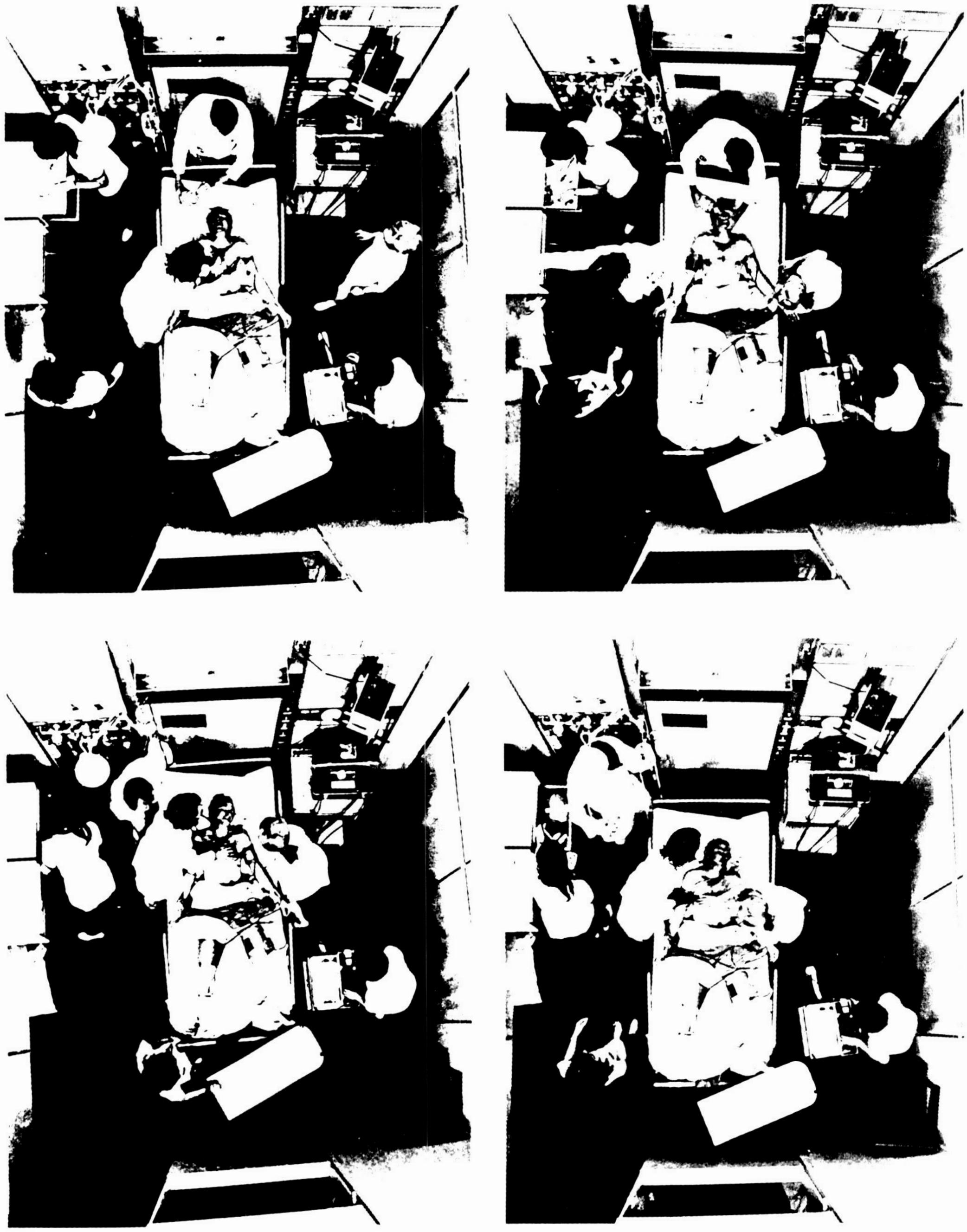

Figure 7. Emergency Simulation in the Mock-Up

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