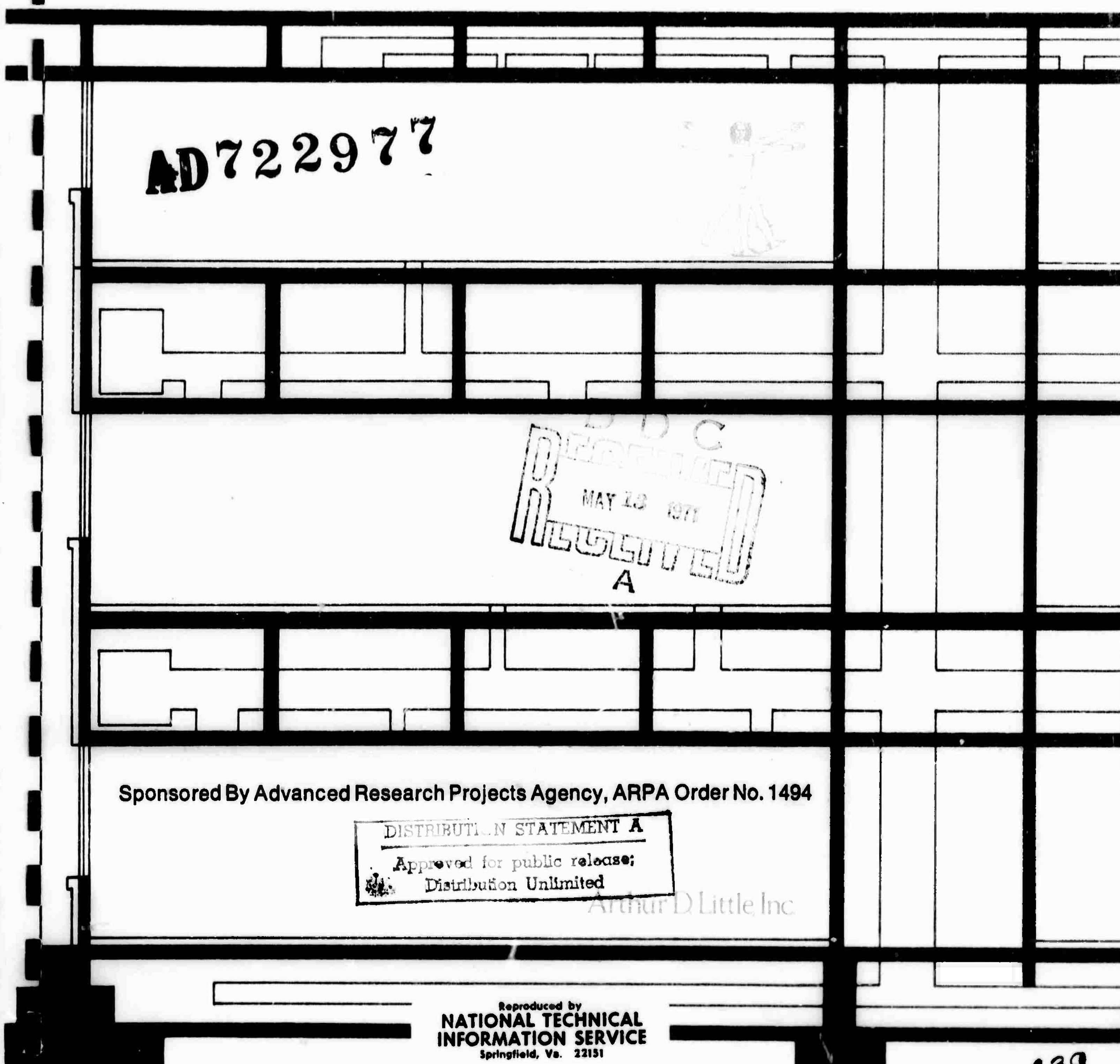
Systems Analysis
For a "New Generation" of Military Hospitals

Volume 7 Appendices: Improvements to Support Services

Final Report



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239

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SYSTEMS ANALYSIS
FOR A "NEW GENERATION" OF MILITARY HOSPITALS

VOLUME 7

APPENDICES: IMPROVEMENTS TO SUPPORT SERVICES

FINAL REPORT
TO THE ADVANCED RESEARCH PROJECTS AGENCY
OF THE DEPARTMENT OF DEFENSE

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Arthur D. Little, Inc.

SYSTEMS ANALYSIS
FOR A "NEW GENERATION" OF MILITARY HOSPITALS

LIST OF VOLUMES

TABLE OF CONTENTS

TABLES OF CONTENTS (Continued)

TABLES OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF FIGURES

7.1. MATERIALS HANDLING

7.1.1. INTRODUCTION

Normal operation of all hospitals requires transfer of large amounts of materials (such as linen, meals, equipment, and trash) and many smaller items (such as drugs, supplies, prescriptions, orders, and other paperwork) from place to place within the hospital. Some planners go so far as to say that hospital design and operation are mainly problems in logistics. In this study we did not itemize materials handling as a functional cost category, because the categories used in Section 1.6. do not lend themselves to this division. Rather, materials handling is a significant fraction of the capital and operating costs in almost all of the functional cost categories. In this part of the report we deal with these costs and possible ways of reducing them.

The standard method of transporting materials, observed in most military hospitals, is to push carts by hand from place to place using elevators for the vertical portion of each trip. Military hospitals sometimes employ pneumatic tube systems as well. In recent years, several other materials handling systems, some designed solely for hospital use, have become available. A few, such as Cyberail, Amscar, Telelift, and ACTS (all described later in this report), are highly automated. These offer the presumable advantage of reducing the number of personnel necessary to make deliveries, and therein lies their major justification. In many respects the novel systems are difficult to compare with one another, because they are designed for different kinds of materials. However, each can be compared with a manual system, and this is what we have done. Even with this approach some problems arise; for example, if people are used to transport linens because that is cheaper, then they might be used to transport supplies as well even though by itself that is a more expensive alternative. Nevertheless the merits of various systems become clear enough in the course of analysis.

Military hospitals are quite different from civilian hospitals in certain respects relevant to materials handling. The amounts of material which must be moved for each military inpatient are generally smaller, because many of them are not so sick as they are in civilian hospitals. The cost of manual labor is not so great in military hospitals for two reasons. One is that military pay scales tend to be somewhat lower (though the small difference conceivably may vanish if anything like a voluntary military service is created). The other is that materials transport is an ideal occupation for many servicemen in convalescent status. This is essentially free labor. We have not tried to estimate the amount of such labor in our evaluations, because it fluctuates and cannot be absolutely relied upon. Nevertheless, the fact that free labor is usually available should be borne in mind when examining the costs of manual systems.

7.1.2. MATERIALS HANDLING REQUIREMENTS AT MILITARY HOSPITALS

In our technical evaluations, our practice has been to imagine that each of the potential improvements is introduced at Fort Dix, Jacksonville NAS, and March AFB and to evaluate its merits in those contexts. In general, we have used the observable requirements placed on the systems under evaluation by present modes of operation; however, we have borne in mind how present operations might be affected by other innovations and by changes in operating load. For example, the amount of trash currently produced in military hospitals is less than what might be expected in the future if disposable ware and convenience foods are used (see Section 7.2.); the amounts of materials per bed in the acute care hospital will also increase if light care facilities are developed, since convalescing patients will be removed from the hospital.

Rather than mix the effects of all innovations into the analysis, we have chosen to examine the impact of alternative materials handling systems by themselves. The three hospitals span a sufficient size range to permit us to determine the merits of each available system and to estimate its impact under other conditions. For instance, if light care facilities are used, Walson Army Hospital would have about 550 acute care beds instead of the current 900. Since Jacksonville Naval Hospital currently has about 520 acute care beds, evaluation in this context furnishes a measure of the situation at Walson if a light care facility were introduced. Similarly, the hospital at March AFB is illustrative of the reduced-size Jacksonville Hospital.

Precise measures of the materials handling load are not necessary to appraise adequately a candidate materials handling system, because the loads are certain to change with time. What is necessary is to use a common basis when comparing different systems. In Table 7.1.1, 7.1.2 and 7.1.3 we have estimated the materials handling loads at each of the three hospitals. These loads are derived from observations (reported in Volume 8), from estimates computed from other studies[1], and from other data concerning likely modifications to present circumstances. In all cases we have assumed that both the hospital and its clinics are being fully utilized, since these are the conditions which a materials handling system must accommodate even though in many observable instances full capacity is not reached.

To eliminate extraneous detail, we used as a basis for layout the schematic diagrams shown in Figures 8.1.1 (Walson Army Hospital), 8.2.1 (March AFB Hospital), and 8.3.1 (Jacksonville Naval Hospital). These diagrams convey the relative size and position of various departments, but they suppress the limitations on actual installation of materials handling systems imposed by the present structures. In this way our estimates are not befogged with detailed problems of installation, which could presumably be resolved if the installation of particular systems were contemplated early in the design phase, as they should be. This approach also keeps analysis on a manageable scale.

The departments enumerated in Tables 7.1.1 - 7.1.3 are those found in the corresponding diagrams in Volume 8. The column called "units" lists the number of planning units (a square of 1200 sq ft) occupied by each department. For the sake of simplicity, corridor space, stair wells, and elevator shafts are generally incorporated in the department which surrounds them, even though they could be regarded as parts of the general circulation area.

7.1.3. MATERIALS HANDLING SYSTEMS AVAILABLE FOR HOSPITALS

Very few truly new systems have been developed within the last thirty years for transporting materials within a hospital environment.

TABLE 7.1.1 [illegible]

WALSON ARMY HOSPITAL
Daily Flow of Clean and Dirty Linen
(pounds)

TO

FROM

[illegible]

TABLE 7.1.1 b

WALSON ARMY HOSPITAL

Daily Flow of Meals and Soiled Food Trays

(All Entries From Dietary are Food Trays; All Entries To Dietary are Soiled Trays)

TO

FROM

[illegible]

TABLE 7.1.1 a

WALSON ARMY HOSPITAL

Daily Flow of Sterile Trays*

[illegible]	[illegible]

TABLE 7.1.1 d

WALSON ARMY HOSPITAL

Daily Flow of Sterile Packages and Bottles

(Number in "Packages" of About 2.0 Cu Ft Each)

TO

FROM

TABLE 7.1.1 e

WALSON ARMY HOSPITAL
Daily Flow of Soiled Utensils Including Trays
(Entries in "Packages" of About 1.0 Cu Ft Each)

FROM \ TO	
[illegible]	[illegible]

TABLE 7.1.11

WALSON ARMY HOSPITAL

Daily Flow of Supplies

(Entries in Cartons of About 2.0 Cu Ft Each)

FROM \ TO	[illegible]
[illegible]	[illegible]

TABLE 7.1.1 g

WALSON ARMY HOSPITAL

Daily Flow of Pharmaceuticals

(Entries in Packages, Each About 2" x 2" x 4")

FROM \ TO	No.	Department	Total	Flow entries
Basement	1	Administration	[illegible]	
	2	Engineering	[illegible]	
	3	[illegible]	[illegible]	
	4	[illegible]	[illegible]	
	5	[illegible]	[illegible]	
	6	[illegible]	[illegible]	
	7	Elevators	[illegible]	
1st Floor	8	[illegible]	[illegible]	
	9	Laboratory	[illegible]	
	10	[illegible]	[illegible]	
	11	Pharmacy	[illegible]	[illegible] (entries in columns of the 2nd through 10th column groups)
	12	Administration	[illegible]	
	13	Records	[illegible]	
	14	[illegible]	[illegible]	
	15	Physical Therapy	[illegible]	
	16	Elevators	[illegible]	
2nd Floor	17	Surgery	[illegible]	
	18	Sterile Supply	[illegible]	
	19	Intensive Care	[illegible]	
	20	Nursing Ward A ([illegible] beds)	[illegible]	
	21	Nursing Ward B ([illegible] beds)	[illegible]	
	22	Auditorium & Library	[illegible]	
	23	Elevators	[illegible]	
3rd Floor	[illegible]	Delivery	[illegible]	
	[illegible]	Nursery ([illegible])	[illegible]	
	[illegible]	Nursing Ward A ([illegible] beds)	[illegible]	
	[illegible]	Nursing Ward B ([illegible] beds)	[illegible]	
	[illegible]	Elevators	[illegible]	
4th Floor	[illegible]	Nursing Ward A ([illegible] beds)	[illegible]	
	[illegible]	Nursing Ward B ([illegible] beds)	[illegible]	
	[illegible]	Elevators	[illegible]	
5th Floor	[illegible]	Nursing Ward A ([illegible] beds)	[illegible]	
	[illegible]	Nursing Ward B ([illegible] beds)	[illegible]	
	[illegible]	[illegible]	[illegible]	
	[illegible]	Elevators	[illegible]	
6th Floor	[illegible]	Nursing Ward A ([illegible] beds)	[illegible]	
	[illegible]	Nursing Ward B ([illegible] beds)	[illegible]	
	[illegible]	[illegible]	[illegible]	
	[illegible]	Elevators	[illegible]	
7th Floor	[illegible]	Nursing Ward A ([illegible] beds)	[illegible]	
	[illegible]	Nursing Ward B ([illegible] beds)	[illegible]	
	[illegible]	Elevators	[illegible]	
8th Floor	[illegible]	Nursing Ward A ([illegible] beds)	[illegible]	
	[illegible]	Nursing Ward B ([illegible] beds)	[illegible]	
	[illegible]	Laboratory	[illegible]	
	[illegible]	Elevators	[illegible]	
9th Floor	[illegible]	Nursing Ward A ([illegible] beds)	[illegible]	
	[illegible]	Intensive Care ([illegible] beds)	[illegible]	
	[illegible]	[illegible]	[illegible]	
	[illegible]	Elevators	[illegible]	
Roof	[illegible]	Elevators	[illegible]	

TABLE 7.1.1 h

WALSON ARMY HOSPITAL
Daily Flow of Trash
(Cubic Feet Uncompacted)

FROM			Units	TO: 1 Administration	2 Support (Engineering)	3 Morgue	4 Stores	5 Dietary	6 Clinics	7 Elevators	8 Clinics	9 Laboratory	10 Radiology	11 Pharmacy	12 Administration	13 Records	14 Emergency	15 Support (Phys. Therapy)	16 Elevators	17 Surgery	18 Sterile Supply	19 Intensive Care	20 Nursing Ward A	21 Nursing Ward B	22 Support (Auditorium & Library)	23 Elevators	24 Delivery	25 Nursery	26 Nursing Ward A	27 Nursing Ward B	28 Elevators	29 Nursing Ward A	30 Nursing Ward B	31 Elevators	32 Nursing Ward A	33 Nursing Ward B	34 Mechanical	35 Elevators	36 Nursing Ward A	37 Nursing Ward B	38 Support (Education)	39 Elevators	40 Nursing Ward A	41 Nursing Ward B	42 Elevators	43 Nursing Ward A	44 Nursing Ward B	45 Laboratory	46 Elevators	47 Nursing Ward A	48 Intensive Care	49 Support	50 Elevators	51 Elevators
			Units	10	6	1	18	30	12	2	46	8	8	4	20	2	5	8	2	14	4	2	10	14	4	2	7	4	10	12	2	10	14	2	10	11	2	2	10	11	3	2	10	14	2	10	11	2	2	12	11	1	2	2
Basement	1	Administration	18				20																																															
	2	Engineering	6				10																																															
	3	Morgue	1				4																																															
	4	Stores	18				150																																															
	5	Dietary	30				260																																															
	6	Clinics	12				60																																															
	7	Elevators	2																																																			
1st Floor	8	Clinics	46				130																																															
	9	Laboratory	8				16																																															
	10	Radiology	8				45																																															
	11	Pharmacy	4				30																																															
	12	Administration	20				30																																															
	13	Records	2				10																																															
	14	Emergency	5				75																																															
	15	Physical Therapy	8				5																																															
	16	Elevators	2																																																			
2nd Floor	17	Surgery	14				150																																															
	18	Sterile Supply	4				50																																															
	19	Intensive Care	2				25																																															
	20	Nursing Ward A (46 beds)	10				30																																															
	21	Nursing Ward B (42 beds)	14				30																																															
	22	Auditorium & Library	4				6																																															
	23	Elevators	2																																																			
3rd Floor	24	Delivery	7				40																																															
	25	Nursery (60 cribs)	4				30																																															
	26	Nursing Ward A (30 beds)	10				30																																															
	27	Nursing Ward B (30 beds)	12				30																																															
	28	Elevators	2																																																			
4th Floor	29	Nursing Ward A (66 beds)	10				40																																															
	30	Nursing Ward B (53 beds)	14				40																																															
	31	Elevators	2																																																			
5th Floor	32	Nursing Ward A (66 beds)	10				40																																															
	33	Nursing Ward B (55 beds)	11				40																																															
	34	Mechanical	2																																																			
	35	Elevators	2																																																			
6th Floor	36	Nursing Ward A (53 beds)	10				30																																															
	37	Nursing Ward B (46 beds)	11				35																																															
	38	Education	3				4																																															
	39	Elevators	2																																																			
7th Floor	40	Nursing Ward A (72 beds)	10				40																																															
	41	Nursing Ward B (64 beds)	14				35																																															
	42	Elevators	2																																																			
8th Floor	43	Nursing Ward A (73 beds)	10				40																																															
	44	Nursing Ward B (66 beds)	11				40																																															
	45	Laboratory	2				6																																															
	46	Elevators	2																																																			
9th Floor	47	Nursing Ward A (66 beds)	12				35																																															
	48	Intensive Care (33 beds)	11				35																																															
	49	Support	1				2																																															
	50	Elevators	2																																																			
Roof	51	Elevators	2																																																			
			431																																																				

TABLE 7.1.1 i

WALSON ARMY HOSPITAL
Matrix of Departments Between Which There is a Significant Flow of Bulk Items

TO (columns, with Units):
- Basement: 1 Administration (10), 2 Support (Engineering) (6), 3 Morgue (1), 4 Stores (16), 5 Dietary (30), 6 Clinics (12), 7 Elevators (2)
- 1st Floor: 8 Clinics (46), 9 Laboratory (6), 10 Radiology (6), 11 Pharmacy (4), 12 Administration (20), 13 Records (2), 14 Emergency (6), 15 Support (Phys. Therapy) (6), 16 Elevators (2)
- 2nd Floor: 17 Surgery (14), 18 Sterile Supply (4), 19 Intensive Care (2), 20 Nursing Ward A (10), 21 Nursing Ward B (14), 22 Support (Auditorium & Library) (4), 23 Elevators (2)
- 3rd Floor: 24 Delivery (7), 25 Nursery (4), 26 Nursing Ward A (10), 27 Nursing Ward B (12), 28 Elevators (2)
- 4th Floor: 29 Nursing Ward A (10), 30 Nursing Ward B (14), 31 Elevators (2)
- 5th Floor: 32 Nursing Ward A (10), 33 Nursing Ward B (11), 34 Mechanical (3), 35 Elevators (2)
- 6th Floor: 36 Nursing Ward A (10), 37 Nursing Ward B (11), 38 Support (Education) (2), 39 Elevators (2)
- 7th Floor: 40 Nursing Ward A (10), 41 Nursing Ward B (14), 42 Elevators (2)
- 8th Floor: 43 Nursing Ward A (10), 44 Nursing Ward B (11), 45 Laboratory (2), 46 Elevators (2)
- 9th Floor: 47 Nursing Ward A (12), 48 Intensive Care (11), 49 Support (1), 50 Elevators (2)
- Roof: 51 Elevators (2)

FROM	No.	Department	Units	1–7	8–16	17–23	24–28	29–31	32–35	36–39	40–42	43–46	47–50	51
Basement	1	Administration	10	✓										
	2	Engineering	6	✓										
	3	Morgue	1	✓		✓								
	4	Stores	16	✓ ✓ ✓ ✓ ✓ ✓	✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓	✓ ✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓	✓ ✓	✓ ✓ ✓	✓ ✓	✓ ✓ ✓	✓ ✓ ✓	
	5	Dietary	30	✓		✓ ✓ ✓	✓ ✓ ✓	✓ ✓	✓ ✓	✓ ✓	✓ ✓	✓ ✓	✓ ✓	
	6	Clinics	12	✓		✓								
	7	Elevators	2											
1st Floor	8	Clinics	46	✓		✓								
	9	Laboratory	6	✓										
	10	Radiology	6	✓		✓								
	11	Pharmacy	4	✓	✓	✓ ✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓	✓ ✓	✓ ✓	✓ ✓	✓ ✓	✓ ✓	
	12	Administration	20	✓										
	13	Records	2	✓										
	14	Emergency	6	✓		✓								
	15	Physical Therapy	6	✓										
	16	Elevators	2											
2nd Floor	17	Surgery	14	✓										
	18	Sterile Supply	4	✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓	✓ ✓	✓ ✓	✓ ✓	✓ ✓	✓ ✓	
	19	Intensive Care	2	✓ ✓ ✓										
	20	Nursing Ward A (46 beds)	10	✓ ✓		✓								
	21	Nursing Ward B (42 beds)	14	✓ ✓		✓								
	22	Auditorium & Library	4	✓										
	23	Elevators	2											
3rd Floor	24	Delivery	7	✓		✓								
	25	Nursery (50 cribs)	4	✓ ✓		✓								
	26	Nursing Ward A (30 beds)	10	✓ ✓		✓								
	27	Nursing Ward B (20 beds)	12	✓ ✓		✓								
	28	Elevators	2			✓								
4th Floor	29	Nursing Ward A (66 beds)	10	✓ ✓		✓								
	30	Nursing Ward B (53 beds)	14	✓ ✓		✓								
	31	Elevators	2											
5th Floor	32	Nursing Ward A (66 beds)	10	✓ ✓		✓								
	33	Nursing Ward B (55 beds)	11	✓ ✓		✓								
	34	Mechanical	2											
	35	Elevators	2											
6th Floor	36	Nursing Ward A (53 beds)	10	✓ ✓		✓								
	37	Nursing Ward B (46 beds)	11	✓ ✓		✓								
	38	Education	3	✓										
	39	Elevators	2											
7th Floor	40	Nursing Ward A (73 beds)	10	✓ ✓		✓								
	41	Nursing Ward B (64 beds)	14	✓ ✓		✓								
	42	Elevators	2											
8th Floor	43	Nursing Ward A (72 beds)	10	✓ ✓		✓								
	44	Nursing Ward B (66 beds)	11	✓ ✓		✓								
	45	Laboratory	3	✓										
	46	Elevators	2											
9th Floor	47	Nursing Ward A (66 beds)	12	✓ ✓		✓								
	48	Intensive Care (33 beds)	11	✓ ✓		✓								
	49	Support	1	✓										
	50	Elevators	2											
Roof	51	Elevators	2											
			431											

TABLE 7.1.2 a

JACKSONVILLE NAS HOSPITAL
Daily Flow of Clean and Dirty Linen
(pounds)

FROM \ TO				1 Administration	2 Records	3 Laboratory	4 Radiology	5 Pharmacy	6 Emergency	7 Dietary	8 Stores	9 Sterile Supply	10 Laundry	11 Clinics	12 Mechanical	13 Administration	14 Clinics	15 Surgery	16 Intensive Care	17 Nursing Wards	18 Nursing Wards	19 Obstetrics	20 Nursery	21 Nursing Wards	22 Nursing Wards	23 Nursing Wards	24 Mechanical
			Units	4	1	4	6	2	1	14	7	3	1	26	4	17	6	9	2	12	14	11	3	14	14	14	6
1st Floor	1	Administration	4																								
	2	Records	1																								
	3	Laboratory	4										20														
	4	Radiology	6										20														
	5	Pharmacy	2										20														
	6	Emergency	1										200														
	7	Dietary	14										140														
	8	Stores	7																								
	9	Sterile Supply	3										50					550	100			100					
	10	Laundry	1			20	20	20	200	140		800		1500			50	300	150	760	610	410	180	610	1000	1000	
	11	Clinics	26										1500														
	12	Mechanical	4																								
2nd	13	Administration	17																								
	14	Clinics	6										50														
3rd	15	Surgery	9										850														
	16	Intensive Care (15 beds)	2										250														
	17	Nursing Wards (76 beds)	12										760														
4th	18	Nursing Wards (61 beds)	14										610														
5th	19	Obstetrics (41 beds)	11										510														
	20	Nursery (36 cribs)	3										180														
6th	21	Nursing Ward (100 beds)	14										610														
7th	22	Nursing Ward (100 beds)	14										1000														
8th	23	Nursing Ward (76 beds)	14										1000														
Roof	24	Mechanical	6																								
			195																								

TABLE 7.1.2 b

JACKSONVILLE NAS HOSPITAL
Daily Flow of Meals and Soiled Food Trays

(All entries from Dietary are food trays; all entries to Dietary are soiled trays)

FROM \ TO			Staff	1 Administration	2 Records	3 Laboratory	4 Radiology	5 Pharmacy	6 Emergency	7 Dietary	8 Stores	9 Sterile Supply	10 Laundry	11 Clinics	12 Mechanical	13 Administration	14 Clinics	15 Surgery	16 Intensive Care	17 Nursing Wards	18 Nursing Wards	19 Obstetrics	20 Nursery	21 Nursing Wards	22 Nursing Wards	23 Nursing Wards	24 Mechanical
			Staff	4	1	4	6	2	1	14	7	3	1	26	4	17	9	9	2	12	14	11	3	14	14	14	6
1st Floor	1	Administration	4																								
	2	Records	1																								
	3	Laboratory	4																								
	4	Radiology	6																								
	5	Pharmacy	2																								
	6	Emergency	1																								
	7	Dietary	14																30	228	183	123	10	300	300	228	
	8	Stores	7																								
	9	Sterile Supply	3																								
	10	Laundry	1																								
	11	Clinics	26																								
	12	Mechanical	4																								
2nd	13	Administration	17																								
	14	Clinics	9																								
3rd	15	Surgery	9																								
	16	Intensive Care (15 beds)	2							30																	
	17	Nursing Wards (76 beds)	12							228																	
4th	18	Nursing Wards (61 beds)	14							183																	
5th	19	Obstetrics (41 beds)	11							123																	
	20	Nursery (36 cribs)	3							10																	
6th	21	Nursing Ward (100 beds)	14							300																	
7th	22	Nursing Ward (100 beds)	14							300																	
8th	23	Nursing Ward (76 beds)	14							228																	
Roof	24	Mechanical	6																								
			198																								

TABLE 7.1.2c

JACKSONVILLE NAS HOSPITAL

Daily Flow of Sterile Trays*

FROM				TO → 1 Administration	2 Records	3 Laboratory	4 Radiology	5 Pharmacy	6 Emergency	7 Dietary	8 Stores	9 Sterile Supply	10 Laundry	11 Clinics	12 Mechanical	13 Administration	14 Clinics	15 Surgery	16 Intensive Care	17 Nursing Wards	18 Nursing Wards	19 Obstetrics	20 Nursery	21 Nursing Wards	22 Nursing Wards	23 Nursing Wards	24 Mechanical
				4	1	4	6	2	1	14	7	3	1	28	4	17	6	9	2	12	14	11	3	14	14	14	6
1st Floor	1	Administration	4																								
	2	Records	1																								
	3	Laboratory	4																								
	4	Radiology	6																								
	5	Pharmacy	2																								
	6	Emergency	1																								
	7	Dietary	14																								
	8	Stores	7																								
	9	Sterile Supply	3				6		4					15			1	100	8	2	2	20	1	3	3	3	
	10	Laundry	1																								
	11	Clinics	28																								
	12	Mechanical	4																								
2nd	13	Administration	17																								
	14	Clinics	6																								
3rd	15	Surgery	9																								
	16	Intensive Care (15 beds)	2																								
	17	Nursing Wards (70 beds)	12																								
4th	18	Nursing Wards (61 beds)	14																								
5th	19	Obstetrics (41 beds)	11																								
	20	Nursery (20 cribs)	3																								
6th	21	Nursing Ward (100 beds)	14																								
7th	22	Nursing Ward (100 beds)	14																								
8th	23	Nursing Ward (70 beds)	14																								
Roof	24	Mechanical	6																								
			163																								

*Each tray is about 20" x 13" x 3".

TABLE 7.1.2 d

JACKSONVILLE NAS HOSPITAL
Daily Flow of Sterile Packages and Bottles
(Entries in "Packages" of About 2.5 Cu Ft Each)

FROM \ TO				1 Administration	2 Records	3 Laboratory	4 Radiology	5 Pharmacy	6 Emergency	7 Dietary	8 Stores	9 Sterile Supply	10 Laundry	11 Clinics	12 Mechanical	13 Administration	14 Clinics	15 Surgery	16 Intensive Care	17 Nursing Wards	18 Nursing Wards	19 Obstetrics	20 Nursery	21 Nursing Wards	22 Nursing Wards	23 Nursing Wards	24 Mechanical
				4	1	4	6	2	1	14	7	3	1	20	4	17	6	9	2	12	14	11	3	14	14	14	6
1st Floor	1	Administration	4																								
	2	Records	1																								
	3	Laboratory	4																								
	4	Radiology	6																								
	5	Pharmacy	2									4															
	6	Emergency	1																								
	7	Dietary	14																								
	8	Stores	7																								
	9	Sterile Supply	3					4	17					20				20	40	16	12	3	1	16	16	16	
	10	Laundry	1																								
	11	Clinics	20																								
	12	Mechanical	4																								
2nd	13	Administration	17																								
	14	Clinics	6																								
3rd	15	Surgery	9																								
	16	Intensive Care (16 beds)	2																								
	17	Nursing Wards (76 beds)	12																								
4th	18	Nursing Wards (81 beds)	14																								
5th	19	Obstetrics (41 beds)	11																								
	20	Nursery (35 cribs)	3																								
6th	21	Nursing Ward (100 beds)	14																								
7th	22	Nursing Ward (100 beds)	14																								
8th	23	Nursing Ward (76 beds)	14																								
Roof	24	Mechanical	6																								
			185																								

TABLE 7.1.2 e

JACKSONVILLE NAS HOSPITAL
Daily Flow of Soiled Utensils Including Trays
(Entries in "Packages" of About 1.0 Cu Ft Each)

FROM			TO →	1 Administration	2 Records	3 Laboratory	4 Radiology	5 Pharmacy	6 Emergency	7 Dietary	8 Stores	9 Sterile Supply	10 Laundry	11 Clinics	12 Mechanical	13 Administration	14 Clinics	15 Surgery	16 Intensive Care	17 Nursing Wards	18 Nursing Wards	19 Obstetrics	20 Nursery	21 Nursing Wards	22 Nursing Wards	23 Nursing Wards	24 Mechanical
			Total	4	1	4	6	2	1	14	7	3	1	20	4	17	9	9	2	12	14	11	3	14	14	14	6
1st Floor	1	Administration	4																								
	2	Records	1																								
	3	Laboratory	4																								
	4	Radiology	6									1															
	5	Pharmacy	2																								
	6	Emergency	1									1															
	7	Dietary	14																								
	8	Stores	7																								
	9	Sterile Supply	3																								
	10	Laundry	1																								
	11	Clinics	20									2															
	12	Mechanical	4																								
2nd	13	Administration	17																								
	14	Clinics	9																								
3rd	15	Surgery	9									60															
	16	Intensive Care (16 beds)	2									6															
	17	Nursing Wards (76 beds)	12									25															
4th	18	Nursing Wards (61 beds)	14									20															
5th	19	Obstetrics (41 beds)	11									12															
	20	Nursery (38 cribs)	3									2															
6th	21	Nursing Ward (100 beds)	14									30															
7th	22	Nursing Ward (100 beds)	14									30															
8th	23	Nursing Ward (76 beds)	14									25															
Roof	24	Mechanical	6																								
			188																								

TABLE 7.1.21

JACKSONVILLE NAS HOSPITAL

Daily Flow of Supplies

(Entries in Packages of about 2.5 Cu Ft Each)

FROM \ TO				1 Administration	2 Records	3 Laboratory	4 Radiology	5 Pharmacy	6 Emergency	7 Dietary	8 Stores	9 Sterile Supply	10 Laundry	11 Clinics	12 Mechanical	13 Administration	14 Clinics	15 Surgery	16 Intensive Care	17 Nursing Wards	18 Nursing Wards	19 Obstetrics	20 Nursery	21 Nursing Wards	22 Nursing Wards	23 Nursing Wards	24 Mechanical
				4	1	4	6	2	1	14	7	3	1	26	4	17	6	9	2	12	14	11	3	14	14	14	6
1st Floor	1	Administration	4																								
	2	Records	1																								
	3	Laboratory	4																								
	4	Radiology	6																								
	5	Pharmacy	2																								
	6	Emergency	1																								
	7	Dietary	14																								
	8	Stores	7	1	1	4	10	3	4	15		25		30		4	10	20	8	10	15	4	8	25	25	20	
	9	Sterile Supply	3																								
	10	Laundry	1																								
	11	Clinics	26																								
	12	Mechanical	4																								
2nd	13	Administration	17																								
	14	Clinics	6																								
3rd	15	Surgery	9																								
	16	Intensive Care (15 beds)	2																								
	17	Nursing Wards (76 beds)	12																								
4th	18	Nursing Wards (81 beds)	14																								
5th	19	Obstetrics (41 beds)	11																								
	20	Nursery (38 cribs)	3																								
6th	21	Nursing Ward (100 beds)	14																								
7th	22	Nursing Ward (100 beds)	14																								
8th	23	Nursing Ward (76 beds)	14																								
Roof	24	Mechanical	6																								
			195																								

TABLE 7.1.2 g

JACKSONVILLE NAS HOSPITAL
Daily Flow of Pharmaceuticals
(Entries in Packages, Each About 1½" x 1½" x 4")

FROM \ TO			Total	1 Administration	2 Records	3 Laboratory	4 Radiology	5 Pharmacy	6 Emergency	7 Dietary	8 Stores	9 Sterile Supply	10 Laundry	11 Clinics	12 Mechanical	13 Administration	14 Clinics	15 Surgery	16 Intensive Care	17 Nursing Wards	18 Nursing Wards	19 Obstetrics	20 Nursery	21 Nursing Wards	22 Nursing Wards	23 Nursing Wards	24 Mechanical
1st Floor	1	Administration	4																								
	2	Records	1																								
	3	Laboratory	4																								
	4	Radiology	6																								
	5	Pharmacy	2						10									40	10	30	24	16	1	40	40	30	
	6	Emergency	1																								
	7	Dietary	14																								
	8	Stores	7																								
	9	Sterile Supply	3																								
	10	Laundry	1																								
	11	Clinics	28																								
	12	Mechanical	4																								
2nd	13	Administration	17																								
	14	Clinics	6																								
3rd	15	Surgery	9																								
	16	Intensive Care (16 beds)	2																								
	17	Nursing Wards (76 beds)	12																								
4th	18	Nursing Wards (61 beds)	14																								
5th	19	Obstetrics (41 beds)	11																								
	20	Nursery (38 cribs)	3																								
6th	21	Nursing Ward (100 beds)	14																								
7th	22	Nursing Ward (100 beds)	14																								
8th	23	Nursing Ward (76 beds)	14																								
Roof	24	Mechanical	0																								
Total			186	4	1	4	6	2	1	14	7	3	1	28	4	17	6	9	2	12	14	11	3	14	14	14	6

TABLE 7.1.2 b

JACKSONVILLE NAS HOSPITAL
Daily Flow of Trash
(Cubic Feet, Uncompacted)

FROM		TO	[illegible]	1 Administration	2 Records	3 Laboratory	4 Radiology	5 Pharmacy	6 Emergency	7 Dietary	8 Stores	9 Sterile Supply	10 Laundry	11 Clinics	12 Mechanical	13 Administration	14 Clinics	15 Surgery	16 Intensive Care	17 Nursing Wards	18 Nursing Wards	19 Obstetrics	20 Nursery	21 Nursing Wards	22 Nursing Wards	23 Nursing Wards	24 Mechanical
				4	1	4	6	2	1	14	7	3	1	26	4	17	6	6	2	12	14	11	3	14	14	14	6
1st Floor	1	Administration	4								6																
	2	Records	1								3																
	3	Laboratory	4								12																
	4	Radiology	6								24																
	5	Pharmacy	2								6																
	6	Emergency	1								12																
	7	Dietary	14								115																
	8	Stores	7								100																
	9	Sterile Supply	3								40																
	10	Laundry	1								10																
	11	Clinics	26								80																
	12	Mechanical	4																								
2nd	13	Administration	17								40																
	14	Clinics	6								20																
3rd	15	Surgery	6								90																
	16	Intensive Care (15 beds)	2								30																
	17	Nursing Wards (76 beds)	12								75																
4th	18	Nursing Wards (61 beds)	14								60																
5th	19	Obstetrics (41 beds)	11								40																
	20	Nursery (38 cribs)	3								18																
6th	21	Nursing Ward (100 beds)	14								90																
7th	22	Nursing Ward (100 beds)	14								90																
8th	23	Nursing Ward (76 beds)	14								30																
Roof	24	Mechanical	6																								
			185																								

TABLE 7.1.21

JACKSONVILLE NAS HOSPITAL

Matrix of Departments Between which There is a Significant Flow of Bulk Items

FROM / TO				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
				4	1	4	6	2	1	14	7	3	1	26	4	17	6	6	2	12	14	11	3	14	14	14	6
1st Floor	1	Administration	4								✓																
	2	Records	1								✓																
	3	Laboratory	4								✓																
	4	Radiology	6								✓	✓															
	5	Pharmacy	2							✓	✓	✓						✓	✓	✓	✓	✓	✓	✓	✓	✓	
	6	Emergency	1								✓	✓															
	7	Dietary	14								✓								✓	✓	✓	✓	✓	✓	✓	✓	
	8	Stores	7	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	9	Sterile Supply	3				✓	✓	✓		✓			✓				✓	✓	✓	✓	✓	✓	✓	✓	✓	
	10	Laundry	1								✓	✓		✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	11	Clinics	26								✓	✓	✓														
	12	Mechanical	4																								
2nd	13	Administration	17								✓																
	14	Clinics	6								✓		✓														
3rd	15	Surgery	6								✓	✓	✓														
	16	Intensive Care (16 beds)	2							✓	✓	✓	✓														
	17	Nursing Wards (76 beds)	12							✓	✓	✓	✓														
4th	18	Nursing Wards (61 beds)	14							✓	✓	✓	✓														
5th	19	Obstetrics (41 beds)	11							✓	✓	✓	✓														
	20	Nursery (36 cribs)	3							✓	✓	✓	✓														
6th	21	Nursing Ward (100 beds)	14							✓	✓	✓	✓														
7th	22	Nursing Ward (100 beds)	14							✓	✓	✓	✓														
8th	23	Nursing Ward (76 beds)	14							✓	✓	✓	✓														
Roof	24	Mechanical	6																								
			168																								

TABLE 7.1.3 a

MARCH AFB HOSPITAL
Daily Flow of Clean and Dirty Linen
(pounds)*

Floor	FROM		Units	TO: 1 Administration (13)	2 Records (1)	3 Laboratory (4)	4 Radiology (3)	5 Pharmacy (1)	6 Emergency (1)	7 Dietary (8)	8 Stores (4)	9 Clinics (10)	10 Nursing Ward (7)	11 Nursing Ward (10)	12 Nursing Ward (10)	13 Delivery (3)	14 Nursing Ward (7)	15 Surgery (3)	16 Sterile Supply (2)	17 Intensive Care (5)
1st Floor	1	Administration	13																	
	2	Records	1																	
	3	Laboratory	4								20									
	4	Radiology	3								20									
	5	Pharmacy	1								20									
	6	Emergency	1								200									
	7	Dietary	8								120									
	8	Stores	4			20	20	20	200	120		1600	480	520	520	280	800	280	700	120
	9	Clinics	10								1600									
	10	Nursing Ward (48 beds)	7								480									
2nd	11	Nursing Ward (53 beds)	10								520									
3rd	12	Nursing Ward (53 beds)	10								520									
4th	13	Delivery	3								280									
	14	Nursing Ward (30 beds) (30 cribs)	7								800									
5th	15	Surgery	3								710									
	16	Sterile Supply	2								50					100		480		100
	17	Intensive Care (14 beds)	5								280									
			101																	

*Clean linen weighs about 18 lb/cu ft;
Dirty linen weighs about 16 lb/cu ft.
Each bed on a nursing ward produces a requirement for about 10 lb of linen daily.

TABLE 7.1.3 b

MARCH AFB HOSPITAL
Daily Flow of Meals and Soiled Food Trays
(All entries from Dietary are food trays; all entries to Dietary are soiled trays)

FROM \ TO			Units	13 Administration 1	1 Records 2	4 Laboratory 3	3 Radiology 4	1 Pharmacy 5	1 Emergency 6	8 Dietary 7	4 Stores 8	19 Clinics 9	7 Nursing Ward 10	10 Nursing Ward 11	10 Nursing Ward 12	3 Delivery 13	7 Nursing Ward 14	3 Surgery 15	2 Sterile Supply 16	5 Intensive Care 17
1st Floor	1	Administration	13																	
	2	Records	1																	
	3	Laboratory	4																	
	4	Radiology	3																	
	5	Pharmacy	1																	
	6	Emergency	1																	
	7	Dietary	8										147	156	159		60			30
	8	Stores	4																	
	9	Clinics	19																	
	10	Nursing Ward (49 beds)	7							147										
2nd	11	Nursing Ward (52 beds)	10							156										
3rd	12	Nursing Ward (53 beds)	10							159										
4th	13	Delivery	3																	
	14	Nursing Ward (20 beds) (30 cribs)	7							60										
5th	15	Surgery	3																	
	16	Sterile Supply	2																	
	17	Intensive Care (14 beds)	5							30										
			101																	

TABLE 7.1.3 c

MARCH AFB HOSPITAL

Daily Flow of Sterile Trays*

FROM \ TO			Units	Administration 1	Records 2	Laboratory 3	Radiology 4	Pharmacy 5	Emergency 6	Dietary 7	Stores 8	Clinics 9	Nursing Ward 10	Nursing Ward 11	Nursing Ward 12	Delivery 13	Nursing Ward 14	Surgery 15	Sterile Supply 16	Intensive Care 17
			Units	13	1	4	3	1	1	8	4	19	7	10	10	3	7	3	2	5
1st Floor	1	Administration	13																	
	2	Records	1																	
	3	Laboratory	4																	
	4	Radiology	3																	
	5	Pharmacy	1																	
	6	Emergency	1																	
	7	Dietary	8																	
	8	Stores	4																	
	9	Clinics	19																	
	10	Nursing Ward (49 beds)	7																	
2nd	11	Nursing Ward (52 beds)	10																	
3rd	12	Nursing Ward (53 beds)	10																	
4th	13	Delivery	3																	
	14	Nursing Ward (20 beds) (30 cribs)	7																	
5th	15	Surgery	3				6		3			12	2	2	2	18	2	80		6
	16	Sterile Supply	2																	
	17	Intensive Care (14 beds)	5																	
			101																	

*Each tray is about 20" x 13" x 3"

TABLE 7.1.3 d

MARCH AFB HOSPITAL

Daily Flow of Sterile Packages and Bottles

(Entries in "Packages" of About 2 Cu Ft Each)

FROM \ TO			Units	1 Administration	2 Records	3 Laboratory	4 Radiology	5 Pharmacy	6 Emergency	7 Dietary	8 Stores	9 Clinics	10 Nursing Ward	11 Nursing Ward	12 Nursing Ward	13 Delivery	14 Nursing Ward	15 Surgery	16 Sterile Supply	17 Intensive Care
			Units	13	1	4	3	1	1	8	4	19	7	10	10	3	7	3	2	5
1st Floor	1	Administration	13																	
	2	Records	1																	
	3	Laboratory	4																	
	4	Radiology	3																	
	5	Pharmacy	1																	
	6	Emergency	1																	
	7	Dietary	8																	
	8	Stores	4																	
	9	Clinics	19																	
	10	Nursing Ward (49 beds)	7																	
2nd	11	Nursing Ward (52 beds)	10																	
3rd	12	Nursing Ward (53 beds)	10																	
4th	13	Delivery	3																	
	14	Nursing Ward (20 beds) (30 cribs)	7																	
5th	15	Surgery	3																	
	16	Sterile Supply	2					3	15			30	14	14	14	5	14	30		30
	17	Intensive Care (14 beds)	5																	
			101																	

TABLE 7.1.3 e

MARCH AFB HOSPITAL
Daily Flow of Soiled Utensils Including Trays
(Entries in "Packages" of About 1.0 Cu Ft Each)

FROM			Units	TO: 1 Administration	2 Records	3 Laboratory	4 Radiology	5 Pharmacy	6 Emergency	7 Dietary	8 Stores	9 Clinics	10 Nursing Ward	11 Nursing Ward	12 Nursing Ward	13 Delivery	14 Nursing Ward	15 Surgery	16 Sterile Supply	17 Intensive Care
		Units		13	1	4	3	1	1	8	4	10	7	10	10	3	7	3	2	5
1st Floor	1	Administration	13																	
	2	Records	1																	
	3	Laboratory	4																	
	4	Radiology	3																	
	5	Pharmacy	1																1	
	6	Emergency	1																	
	7	Dietary	8																5	
	8	Stores	4																	
	9	Clinics	10																10	
	10	Nursing Ward (40 beds)	7																15	
2nd	11	Nursing Ward (52 beds)	10																15	
3rd	12	Nursing Ward (53 beds)	10																15	
4th	13	Delivery	3																6	
	14	Nursing Ward (20 beds) (30 cribs)	7																12	
5th	15	Surgery	3																60	
	16	Sterile Supply	2																	
	17	Intensive Care (14 beds)	5																6	
			101																	

TABLE 7.1.31

MARCH AFB HOSPITAL
Daily Flow of Supplies
(Entries in Cartons of About 2.5 Cu Ft Each)

FROM			Units	TO: 1 Administration (13)	2 Records (1)	3 Laboratory (4)	4 Radiology (3)	5 Pharmacy (1)	6 Emergency (1)	7 Dietary (8)	8 Stores (4)	9 Clinics (10)	10 Nursing Ward (7)	11 Nursing Ward (10)	12 Nursing Ward (10)	13 Delivery (3)	14 Nursing Ward (7)	15 Surgery (3)	16 Sterile Supply (2)	17 Intensive Care (6)
1st Floor	1	Administration	13																	
	2	Records	1																	
	3	Laboratory	4																	
	4	Radiology	3																	
	5	Pharmacy	1																	
	6	Emergency	1																	
	7	Dietary	8																	
	8	Stores	4	2	1	3	8	3	4	12		30	16	15	15	4	12	15	20	6
	9	Clinics	10																	
	10	Nursing Ward (40 beds)	7																	
2nd	11	Nursing Ward (52 beds)	10																	
3rd	12	Nursing Ward (53 beds)	10																	
4th	13	Delivery	3																	
	14	Nursing Ward (20 beds) (30 cribs)	7																	
5th	15	Surgery	3																	
	16	Sterile Supply	2																	
	17	Intensive Care (14 beds)	6																	
			101																	

TABLE 7.1.3 g

MARCH AFB HOSPITAL

Daily Flow of Pharmaceuticals

(Entries in "Packages", Each 2" x 2" x 4")

Floor	FROM		Units	TO 1 Administration (13)	2 Records (1)	3 Laboratory (4)	4 Radiology (3)	5 Pharmacy (1)	6 Emergency (1)	7 Dietary (8)	8 Stores (4)	9 Clinics (10)	10 Nursing Ward (7)	11 Nursing Ward (10)	12 Nursing Ward (10)	13 Delivery (3)	14 Nursing Ward (7)	15 Surgery (3)	16 Sterile Supply (2)	17 Intensive Care (5)
1st Floor	1	Administration	13																	
	2	Records	1																	
	3	Laboratory	4																	
	4	Radiology	3																	
	5	Pharmacy	1						6				20	20	20	12	20	40		10
	6	Emergency	1																	
	7	Dietary	8																	
	8	Stores	4																	
	9	Clinics	10																	
	10	Nursing Ward (40 beds)	7																	
2nd	11	Nursing Ward (52 beds)	10																	
3rd	12	Nursing Ward (53 beds)	10																	
4th	13	Delivery	3																	
	14	Nursing Ward (20 beds) (30 cribs)	7																	
5th	15	Surgery	3																	
	16	Sterile Supply	2																	
	17	Intensive Care (14 beds)	5																	
			101																	

TABLE 7.1.3 h

MARCH AFB HOSPITAL
Daily Flow of Trash
(Cubic Feet, Uncompacted*)

Floor	No.	FROM \ TO	Units	1 Administration (13)	2 Records (1)	3 Laboratory (4)	4 Radiology (3)	5 Pharmacy (1)	6 Emergency (1)	7 Dietary (8)	8 Stores (4)	9 Clinics (10)	10 Nursing Ward (7)	11 Nursing Ward (10)	12 Nursing Ward (10)	13 Delivery (3)	14 Nursing Ward (7)	15 Surgery (3)	16 Sterile Supply (2)	17 Intensive Care (6)
1st Floor	1	Administration	13								20									
	2	Records	1								4									
	3	Laboratory	4								8									
	4	Radiology	3								20									
	5	Pharmacy	1								8									
	6	Emergency	1								10									
	7	Dietary	8								50									
	8	Stores	4								50									
	9	Clinics	10								80									
	10	Nursing Ward (40 beds)	7								50									
2nd	11	Nursing Ward (52 beds)	10								50									
3rd	12	Nursing Ward (53 beds)	10								50									
4th	13	Delivery	3								25									
	14	Nursing Ward (20 beds) (30 cribs)	7								40									
5th	15	Surgery	3								80									
	16	Sterile Supply	2								30									
	17	Intensive Care (14 beds)	6								30									
			101																	

*Rule of thumb: About 2.5 cu ft of trash per bed per day
Uncompacted trash weighs about 4 lb/cu ft.

TABLE 7.1.31

MARCH AFB HOSPITAL

Matrix of Departments Between Which There is a Significant Flow of Bulk Items

FROM \ TO			Units	1 Administration	2 Records	3 Laboratory	4 Radiology	5 Pharmacy	6 Emergency	7 Dietary	8 Stores	9 Clinics	10 Nursing Ward	11 Nursing Ward	12 Nursing Ward	13 Delivery	14 Nursing Ward	15 Surgery	16 Sterile Supply	17 Intensive Care
			Units	13	1	4	3	1	1	8	4	10	7	10	10	3	7	3	2	5
1st Floor	1	Administration	13								✓									
	2	Records	1								✓									
	3	Laboratory	4								✓								✓	
	4	Radiology	3								✓									
	5	Pharmacy	1						✓		✓		✓	✓	✓	✓	✓	✓	✓	✓
	6	Emergency	1								✓								✓	
	7	Dietary	8								✓		✓	✓	✓		✓			✓
	8	Stores	4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	9	Clinics	10								✓								✓	
	10	Nursing Ward (40 beds)	7							✓	✓								✓	
2nd	11	Nursing Ward (52 beds)	10							✓	✓								✓	
3rd	12	Nursing Ward (53 beds)	10							✓	✓								✓	
4th	13	Delivery	3								✓								✓	
	14	Nursing Ward (20 beds) (30 cribs)	7							✓	✓								✓	
5th	15	Surgery	3								✓								✓	
	16	Sterile Supply	2			✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓
	17	Intensive Care (14 beds)	5							✓	✓								✓	
			101																	

Many of the older processes have been made more flexible and become more widely used, but until recently there have been few significant advances either in technology or concept.

To evaluate the systems presently available, we classified them into six categories, based primarily on the manner in which materials are transported from one point to another. A general description of these generic categories follows.

7.1.3.1. Messenger (Manual) Transport Systems

Manual transport systems employ people to carry material or push and pull various types of conveyances from one section of a hospital to another. Hospitals that use this form of material transport, which includes most military hospitals, characteristically have low initial capital costs (for purchase and installation) but high operating costs. Factors which tend to increase the operating costs of manual systems include the following:

- A hospital's needs require 24-hour service;
- People get sick or tired, they may be uninterested in their work, or they may become involved in tasks which preclude their performing functions necessary to the proper operation of the hospital;
- Manual systems are more subject to problems of labor turnover;
- People make mistakes, and the more people involved in a particular function, the greater the frequency of those mistakes.

On the other hand, manual systems have one major advantage: they are extremely flexible. There is little difficulty in re-instructing an employee who has just completed a meal delivery, say, to pick up soiled laundry, take a message from one point to another, or deliver medication.

Systems that employ people as the prime material handling agents also typically utilize bins, tables with casters, meal carts, and other portable devices so that the items of supply need not be carried but can be wheeled from one location to another.

There are no suppliers of manual systems as such, though there are many suppliers for the equipment. Normally the equipment (castered tables, food containers, etc.) are bought on an as-needed basis and are completely maintained by the hospital maintenance crew. Repair of this equipment is relatively simple. In most instances the variety of conveyances is larger than necessary, and there is little attempt to reduce the number or type of conveyances used.

7.1.3.2. Automatic Module Transport

This category of equipment has by far the highest purchase and installation costs. The only characteristic which is common to all of the systems in this category is that they employ a modular container of sufficient size to service the needs of a series of wards, labs, clinics, or other using departments. The containers are designed to carry from 20 to 60 meals or linen changes, completely supply a nursing ward with its medication requirements, or perhaps an entire floor with its housekeeping requirements. It is essential that the size of the container be very carefully fitted to the hospital's needs.

Automatic module transport systems employ electronic, magnetic, or manual address controls so that the containers can be automatically transported from one area of a floor to a different area of a different floor. The method of transport varies with the type of system under discussion but includes such methods as: electrically powered, self-propelled transporters to which containers can be automatically attached; overhead monorails; endless-chain conveyors; and battery-powered, guidewire-controlled trucks.

The automatically controlled module provides a moderate speed of transport, can move both vertically and horizontally, and can act as a secondary storage-dispensing unit within its point-of-use area.

Due to their size and power requirements, these systems are best used for bulk and scheduled deliveries of large boxes or many items. They are not an efficient form of transportation for one-at-a-time and small, unscheduled items.

The suppliers of some automatic module systems are listed below.

Amsco System	Amsco Systems Company Division of American Sterilizer Company
Cyberail System	Castle Automated Systems
ACTS System	Columbus McKinnon Corporation Conveyor Division Hospital and Institutional Sales
Guide-O-Matic System	Barrett Electronics Corporation
Von Roll System	Rondezworks (Switzerland)
Cable-Way & chainless con., engineered mat. hndlg. sys., & guidance control vehicles	Americon Monorail & Industrial Truck Divisions of Eaton, Yale & Towne

A few systems cannot be characterized as automatic module transport, because the vehicles must be moved manually in the horizontal direction. Vertical transport, however, is accomplished automatically, in that the container can be injected and ejected from special elevators by simply presetting the controls on the container. Systems of this type are:

Cargomaster	Guilbert, Inc.
Cart-Matic	Security Fire Door Company
(Unnamed)	Amsco Systems Company Division of American Sterilizer Company

7.1.3.3. Tote Box Systems

This type of system employs a container with a capacity of between one and two cubic feet. For the purpose of this discussion, tote box systems are those which move in both the vertical and horizontal planes; systems which can travel only vertically are included with dumbwaiters under the Trayveyor category.

The containers in tote box systems are commonly fabricated from plastic or fiberglass resins and will not sustain rough handling. The addressing mechanism is either on the lids of these boxes or imbedded in the plastic and is the same as that used in automatic module systems -- namely, electronic, magnetic, or mechanical address tabs.

Most of the tote box conveyor systems must change the method of address coding when going from a horizontal transport mode to a vertical one or vice versa.

Usually, the drive mechanisms for vertical and horizontal transport are independent and quite different. Larger systems employing tote box conveyors with many interchanges between the vertical and horizontal transport sections tend to be expensive in both initial and operating costs. The largest portion of the operating cost is system maintenance.

The speed of this type of transport system is considered moderate, and its capacity is considerably less than that of automatic module systems. Tote boxes are primarily used to transport specimens, mail, records, and small supplies. They are not suitable for delivering food, linen, or trash, which form a large percentage of the material requiring transport.

One system falls within the tote box category but is not typical of the normal tote box conveyor design. This is the Telelift System by Airmatic Systems Division of Mosler, Inc. It employes a self-propelled electric car on which is mounted a container the size of an attache case. The car moves on a track network in both the vertical and horizontal modes. This system arrangement avoids the interface problems that occur in other tote box conveyors at vertical-to-horizontal transfer points, and it also reduces the damage that can be done to containers by a unique design which limits the number of points at which a transporter or container can be removed from the track network.

Systems and suppliers included in this category are:

Recordlift	Standard Conveyor
General supply systems soiled material systems selective vertical conveyors	Lamson Corporation
Selective vertical conveyors	Olson Division
Subveyor vertical conveyors	American Chain & Cable Company
Cargomaster Container System (This system bears the same name as one that this company supplies in the automatic module category -- i.e., Cargomaster -- but it is a container system similar to those supplied by the other tote box system manufacturers.)	Guilbert, Inc.

Telelift	Mosler Airmatic Division A subsidiary of American Standard Corporation
SEL 35 SEL 75 SEL 100	Standard Elektrick Lorenz, A.G. SEL (German)
Bin conveyors box conveyor systems	Siemens Aktiengesellschaft (German)

7.1.3.4. Pneumatic Tube Systems

These systems are in wide hospital use, including many military hospitals, and are used for servicing pharmacy, mail, and record transport requirements. They are occasionally used for small instruments, specimens, and small supplies, but as they cannot transport bulk items, they must be regarded as ancillary to the major forms of transport.

The container is usually cylindrical or oval, and ranges in size from 2 1/2 inches in diameter by 8 inches long up to 4 inches in diameter and 16 inches long. (A few systems carry box-shaped containers big enough for records.) It is pushed by pressurized air or pulled by a vacuum through enclosed tubes from one station to another. Most systems use a centralized transfer point, which diminishes the point-to-point speed of transport. Modern systems use coding on the cylinder to determine routing automatically. These systems are the most rapid of all of the mechanical systems under discussion and operate at speeds of up to 33 feet per second.

Users have mixed feelings concerning pneumatic tube systems. We have found that hospitals with good maintenance programs use the systems heavily and are satisfied with their operation, while institutions with mediocre or poor maintenance procedures have allowed the systems to deteriorate to the point where they are of little service. The latter condition prevailed at every military hospital we visited. Maintenance appears to be the most important single factor in the use of pneumatic tubes; discipline to insure correct use and to prevent vandalism is also important in obtaining satisfactory results. Systems and suppliers included in this category are:

Air tube systems	Lamson Corporation
Pneumatic tube systems	Standard Conveyor Company
Pneumatic tube systems	Mosler Airmatic Division American Standard Corporation
Light pneumatic tube systems (Type LR 100 and LR 124)	Standard Elektrik Lorenz, A.G. SEL (a subsidiary of ITT)
Full-intercommunication pneumatic tube conveyor sys. Small-size pneumatic tube conveyor sys. Pneumatic tube conveyor sys.	Siemens and Halske Aktiengesellschaft (German)
Nuflyte Air Chute System Air Chute Systems	Cutler Mail Chute Company

7.1.3.5. Vacuum Collection Systems

This category of systems is an outgrowth of the gravity-fed vertical chutes used for the collection of laundry and garbage. The older system simply collected the laundry and garbage at the lowest level in some type of bin, which then had to be pushed to a central collection point; vacuum collection systems not only transport laundry or waste from the various patient care areas to a low level in the hospital facility but also move it on that low level to a central collection point, so that no personnel need to involved except in the patient care areas. Systems such as this are particularly desirable where more than one vertical line is required, or where the centralized collection point is remote from the vertical lines.

The chief advantage of these systems within hospitals is that they minimize the transport of soiled linen and waste by personnel from remote areas of the hospital to the central collection points. They also minimize the transport of soiled materials and waste through areas of medical or patient activity.

When vacuum collection systems are used, all materials should be bagged; this reduces the dirtying and resultant corrosion of the tubes and permits more efficient operation of the system.

Systems representative of this category are:

Air Flyte Systems	Eastern Cyclone Industries, Inc.
A.V.A.C. Systems	Aerojet General Corporation

Vacuum-sealed suction conveyance systems	A.B. Centralsug (Sweden)

7.1.3.6. Trayveyor Conveying Systems

In this category we include not only systems which are designed specifically for food service, but also tote box and dumbwaiter systems which provide only vertical transport. Trayveyor systems are used to move trays from the dietary preparation area to either cafeterias or patient care areas, and they return the soiled trays from these areas to the washing facilities. The dumbwaiter and vertical tote box systems are used only where their outlets are in point-of-use areas, such as nursing stations or clinical laboratories.

Trayveyor conveying systems have two significant limitations:

- While these systems generally handle many small increments of material and are capable of handling large total volumes, they do so one at a time. As a result, personnel must be available at both the input and output ends.
- For maximum efficiency, the supplying department and the receiving departments should be located directly above one another, because these systems operate in a vertical mode only. Unfortunately, modern hospitals are not often designed with the point-of-use area directly over the storage and supply areas, so these systems have limited application.

Systems and suppliers included in this category are:

Food service conveyors	Lamson Corporation
Traylifts and Traybelts	Lamson Corporation
Subveyor Systems	Olson Division American Chain & Cable Company
Recordlift	Standard Conveyor Company
Cargomaster Container Systems	Guilbert, Inc.
Dumbwaiter systems	Energy Corporation

In addition to investigating the specific systems mentioned above, we talked to a large number of industrial material-handling suppliers for information on the applicability of their systems to a hospital environment. Some of these companies, whose systems were judged to be too industrially oriented to be useful at present, include the following:

Powerflex	A powered and free overhead conveyor system by Columbus McKinnon Corporation, Conveyor Division
Monorail conveyor systems	IKM Industries Division of Republic Corporation
Material handling equipment	Riverside Division FMC Corp.
Conveyor equipment	Javis B. Webb Company
Vertical and overhead transfer systems	H. G. Web & Company
Dashaveyor	Dashaveyor Company
Cartrack Systems	Borgs Fabriks (Sweden)

7.1.3.7. System Efficiencies

To illustrate how the various categories of systems are used within a hospital, we have prepared Figure 7.1.1, which compares the six generic types of systems with respect to their efficiency in performing various material handling needs of hospitals. It can be seen that for regular deliveries of food, linen, normally scheduled pharmacy items, etc., automatic modular systems are quite efficient, whereas for items of small bulk of unscheduled deliveries an automatic modular system would not be particularly efficient. Vacuum collection and trayveyor systems, which are designed to accomplish specific, limited tasks, do in fact perform those tasks efficiently but are not very useful for other applications. The most significant points brought out by this chart are that no one system fulfills all of a hospital's needs and that several combinations of systems could be designed to fully service a hospital situation. Each type of hospital has different materials handling requirements and calls for a different combination of systems to meet these requirements most efficiently.

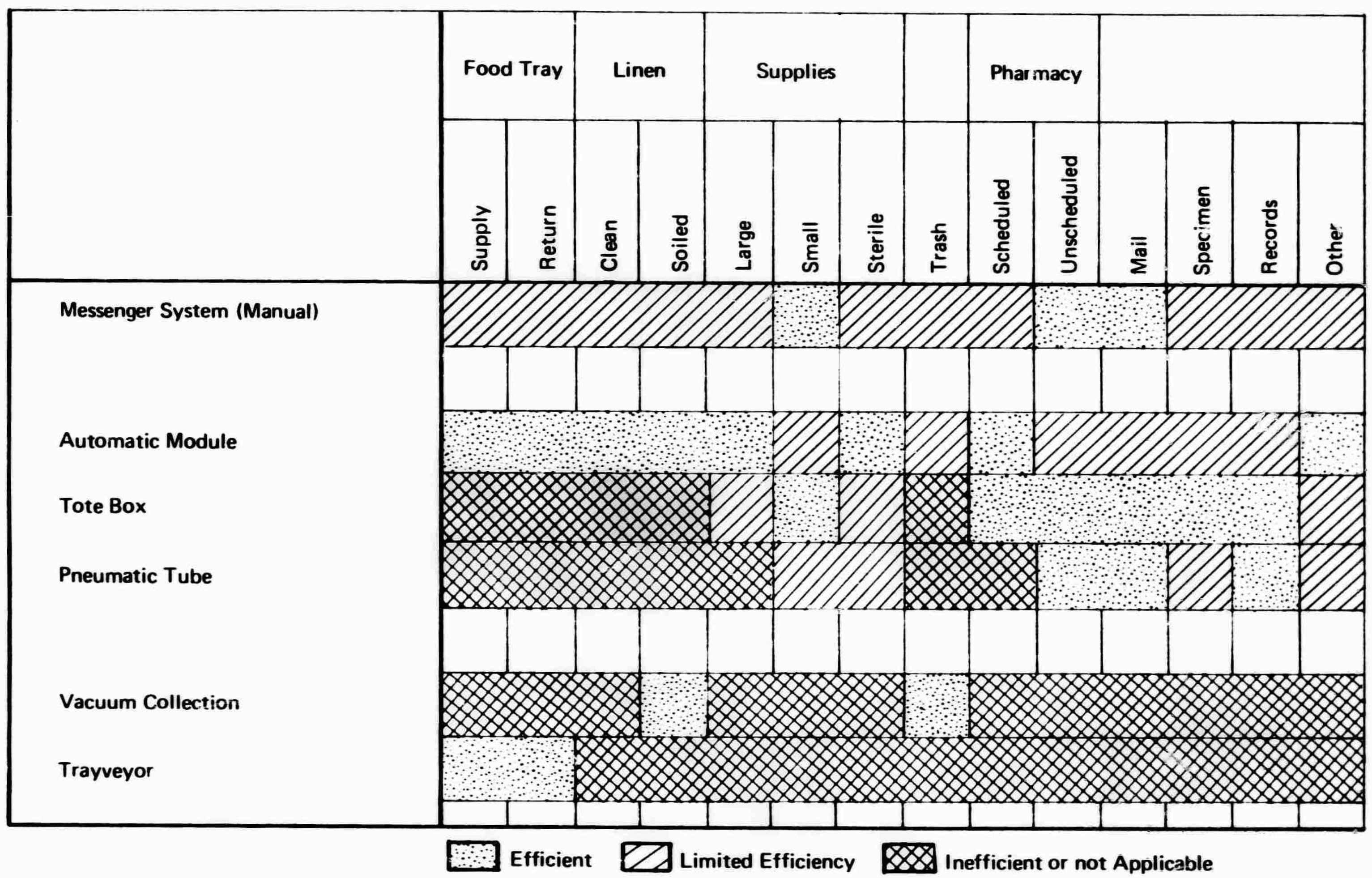

FIGURE 7.1.1 EFFICIENCIES OF MATERIALS HANDLING SYSTEMS FOR HOSPITAL USE

7.1.3.8. Future Developments in Materials Handling

Not long ago, industry was much more advanced than hospitals with regard to materials handling. That statement is no longer true, as the preceding discussion illustrates. Materials handling systems designed particularly for hospitals are fully as sophisticated as their industrial counterparts. Interestingly, most of the novel systems now being marketed in the United States were developed in Europe, and we have investigated European innovations in the course of this study.

Most European materials handling systems now have models adapted for the American market. One exception so far is the Cartrack System manufactured by Borgs Fabriks in Sweden (listed in Section 7.1.3.6.). The carts run on tracks horizontally and are transported vertically in automatic elevators like those described for tote box or trayveyor systems. The novel feature is the horizontal drive mechanism, which is a smooth, round tube parallel to the tracks and lying between them. The tube is continuously rotated by electric motors. The cart is driven forward by a rubber wheel which rests on the tube and whose axis is canted at an angle to the axis of the tube. The wheel is castered and held in place by a spring, which yields when the angle produces excessive accelerations. In this way accelerations and decelerations are kept very smooth, and, since the inertia of the tube is considerable, high power is not needed for starting.

We mention this system not to recommend it but to point out that novel methods are continually coming along and that any conclusions about applicable materials handling systems should be reviewed periodically.

Another novel drive mechanism, currently under development for baggage handling in airports, is the linear induction motor. Here the armature of the motor is secured to the cart, and the stator is rolled out flat along the length of the track. The magnetic field "travels" along the track in the same manner the field in a conventional motor can be said to "rotate" around the stator, inducing currents in the armature and moving the armature forward. The absence of moving parts in the drive mechanism is an attractive feature, though it remains to be seen whether linear induction motors can stand up to abuse in working environments.

Beyond new drive mechanisms, it is difficult to foresee what developments might occur. Computer-controlled dispatch is one possibility, but the practical problems of loading and coding items for dispatch are significant obstacles. There are concepts for materials handling which imagine automatic delivery of items on a patient-by-patient basis, designating items for delivery to particular patients, and avoiding intermediate distribution points such as the nurses' station. Such systems are conceivable, but they would entail formidable complication in trackage, switching, and entering original orders. Complication is manifested in cost and in unreliability, and neither of these drawbacks is likely to be brought within acceptable limits for systems featuring automatic dispatch directly to patients at any time in the near future. Even the automatic module systems presently available cannot be justified in military hospitals.

New alternatives for materials handling will doubtless become available, and existing systems will probably become more reliable and cheaper (with respect to labor costs), but dramatic changes are not likely. We believe that when present alternatives have been evaluated (as they will be in the next section), the range of realistic possibilities for the next five or ten years will have been adequately explored.

We can see no justification for the Department of Defense to undertake development of new materials handling methods. The needs of military hospitals are not appreciably different from those of civilian hospitals, and both markets are being actively pursued by manufacturers of materials handling equipment.

7.1.4. EVALUATION OF GENERIC CATEGORIES OF MATERIALS HANDLING SYSTEMS

7.1.4.1. Criteria for Evaluation

Costs for initial purchase and for operation, including manpower, maintenance, and replacement, are the most important points of comparison among materials handling systems. However, additional factors affect the choice. Therefore, while our discussion will be based mainly on costs, the following other factors will be regarded as tempering influences on choice:

- Flexibility - The ease with which the system can be modified in response to altered needs or to altered resouces which occur in cases of personnel shortages or breakdown; automated and semi-automated systems are relatively inflexible.
- Reliability - The frequency with which breakdowns occur, their effect on system operation, and ease with which they can be repaired.
- Adaptability to building spaces - The degree to which the systems lend themselves to installation in interstitial space or other areas.
- Suitability as retrofits - Since many military hospitals are expanded instead of being rebuilt, materials handling systems should be adaptable to existing structures.
- Consonance with hospital environment. Cleanliness, silence in operation, aesthetic appearance, and safety.

Two other factors not included in the list above are capacity and speed. These are not so much tempering influences as they are basic limitations on the applicability of a materials handling system. The capacity limits the materials which can be moved: low capacity systems like pneumatic tubes cannot be used for bulk items like linens; high capacity systems like Cyberail are not well adapted to small items like paperwork. Speed also affects applicability: high speed systems like pneumatic tubes are not suitable for some specimens; low speed (comparable to walking speed) is generally entirely acceptable but delays beyond this may be troublesome. We take account of these factors in our subsequent analysis by distinguishing the fraction of the materials handling load which can be handled by each system.

7.1.4.2. Baseline System

Because it is the usual way of handling materials in military hospitals and because it is flexible enough to accommodate all varieties of materials, we choose the manual delivery system as the baseline. In Table 7.1.5 we summarize the operating parameters of a manual system in the context of the hospitals at Fort Dix, Jacksonville NAS, and March AFB. The entries shown in the columns headed "amount" are derived from Tables 7.1.1, 7.1.2, and 7.1.3, combining in some cases the amounts from several physically different sources. For example, the amount listed for nursing wards combines the requirements for all nursing wards, which were itemized separately in the earlier tables.

In the case of linen, we have provided under one heading the flow of clean linen from the laundry pick-up point to the various parts of the hospital and the flow of soiled linen from the various parts of the hospital to the laundry pick-up point; obviously these two flows must be equal. In Table 7.1.5 we have not concerned ourselves with the fact, made clear in the earlier tables, that some linen delivered to sterile supply finds its way back to the laundry pick-up point via the operating rooms, delivery suite, or other routes. In estimating trips per day we have assumed that a cart can hold 100 pounds of linen (about 5 cu ft)* and that dirty linen is picked up on the same trip as a delivery. Linen includes not only bed linen but also hospital gowns, uniforms, towels, washcloths, and other launderable items.

For meals, we have assumed that the hospital is filled to capacity with patients who cannot eat in the cafeteria. While this is not a typical situation, it represents the maximum load which could be placed

*One exception to this rule is made in the case of the nursing wards, where we have assumed that the wards are broken down by nursing stations: 31 at Fort Dix, 17 at Jacksonville, and 9 at March, each of which requires two carts containing a bit over 100 pounds of linen each day.

TABLE 7.1.5

WORKLOAD FOR MANUAL MATERIALS HANDLING

Item	Origin and Destination*		Amount			Trips Per Day			Round Trip Delivery Time (min)		
	From/To	To/From	Fort Dix	Jacksonville	March	Fort Dix	Jacksonville	March	Fort Dix	Jacksonville	March
				Pounds of Linen (approx 18 lb/cu ft)							
Clean and Soiled Linen	Stores or Laundry Area	Laboratory	30	20	20	1	1	1	10	7	7
		Radiology	30	20	20	1	1	1	10	7	7
		Pharmacy	30	20	20	1	1	1	10	7	7
		Emergency	300	200	200	3	2	2	30	14	14
		Dietary	240	140	120	3	2	2	30	14	14
		Clinics	2,500	1,550	1,500	25	16	15	250	112	105
		Nursing Wards	8,970	3,980	2,060	62	34	18	620	340	180
		Sterile Supply	1,000	800	700	10	8	7	100	60	70
		Surgery	400	300	280	4	3	3	40	30	30
		Intensive Care	330	150	150	4	2	2	40	20	20
		Obstetrics	500	410	280	5	4	3	50	40	30
		Nursery	250	180	120	3	2	2	30	20	20
		Other	90	30	20	2	1	1	20	10	10
						124	77	58	1,240	701	514
				Meal Trays							
Meals and Soiled Trays	Dietary	Nursing Wards	2,582	1,402	552	186	102	54	1,860	1,020	540
				Packages or Drawers (approx 4" x 4" x 8")							
Drugs	Pharmacy	Emergency	18	10	6	2	2	1	14	14	7
		Surgery	80	40	40	3	2	2	30	20	20
		Intensive Care	40	10	10	2	2	2	20	20	20
		Nursing Wards	305	165	80	31	17	9	310	170	90
		Obstetrics	20	16	12	2	2	2	20	20	20
						40	25	16	394	244	167
				Packages (approx. 2 cu ft)							
General Supplies	Stores	Administration	8	5	2	3	2	1	30	14	7
		Records	2	1	1	1	1	1	10	7	7
		Laboratory	8	4	3	3	2	1	30	14	7
		Radiology	16	10	8	5	4	3	50	28	21
		Pharmacy	6	3	3	2	2	2	20	14	14
		Emergency	8	4	4	3	2	2	30	14	14
		Dietary	20	15	12	7	5	4	70	35	28
		Clinics	70	40	30	23	13	10	230	91	70
		Surgery	30	20	15	10	7	5	100	70	50
		Sterile Supply	40	25	20	13	8	7	130	56	70
		Nursing Wards	180	103	53	60	34	18	600	340	180
		Intensive Care	20	8	5	6	3	2	60	30	20
		Obstetrics	4	4	4	2	2	2	20	20	20
		Nursery	10	8	4	3	3	2	30	30	20
		Other	10	7	3	3	2	1	30	20	10
						144	90	61	1,440	783	538

TABLE 7.1.5 (Continued)

Item	Origin and Destination*		Amount			Trips Per Day			Round Trip Delivery Time (min)		
	From/To	To/From	Fort Dix	Jacksonville	March	Fort Dix	Jacksonville	March	Fort Dix	Jacksonville	March
			Packages and Bottles (approx 1 cu ft)								
Medical Supplies	Sterile Supply or Pharmacy	Pharmacy	6	4	3	2	2	1	20	20	10
		Nursing Wards	190	81	56	63	27	19	630	270	190
		Emergency	30	17	15	10	6	5	100	42	50
		Surgery	60	30	30	20	10	7	140	70	49
		Intensive Care	70	40	30	23	13	10	230	130	70
		Obstetrics	10	8	5	3	3	2	30	30	20
		Clinics	60	30	30	20	10	10	200	70	100
						141	71	54	1,350	632	489
			Trays (approx 20" x 13" x 3")								
Sterile Trays and Soiled Utensils	Sterile Supply	Nursing Wards	31	14	8	10	4	2	100	40	20
		Clinics	24	16	12	8	6	4	80	42	40
		Radiology	12	6	6	4	2	2	40	14	20
		Emergency	10	4	3	4	2	2	40	14	20
		Surgery	200	100	80	74	34	26	518	340	182
		Obstetrics	35	30	18	12	10	6	120	100	60
		Intensive Care	14	8	6	4	2	2	28	20	14
						116	60	44	926	570	356
			Trash (cubic feet, uncompacted)								
Trash	Administration	Trash Collection Point	60	49	24	8	6	4	80	42	28
	Clinics		170	100	80	21	12	10	210	84	70
	Stores		150	100	50	19	12	6	153	84	42
	Dietary		250	115	50	31	14	6	217	98	42
	Laboratory		24	12	8	3	2	1	30	14	7
	Radiology		45	24	20	6	3	3	60	21	21
	Pharmacy		20	6	8	3	1	1	30	7	7
	Emergency		25	12	10	3	2	1	30	14	7
	Surgery		150	90	80	19	11	10	190	110	100
	Sterile Supply		80	40	30	10	5	4	100	35	40
	Intensive Care		60	30	30	8	4	4	80	40	40
	Obstetrics		40	40	25	5	5	3	50	50	30
	Nursing Wards		545	291	190	69	36	24	690	380	240
	Other		33	10	10	4	1	1	40	10	10
						209	114	78	1,960	988	684
All Material Classes						980	539	365	7,170	4,919	3,288

*To shorten this table, certain classes of material have been combined. For example, clean linen that originates at the laundry pick-up point and is distributed to wards, clinics, etc., is listed together with dirty linen that originates at the wards, clinics, etc. and is returned to the laundry pick-up point. The columns headed "Origin and Destination" are therefore designated "From/To" and "To/From," the applicable designator depending upon which material class is considered. Further amplification of the assumptions for each class is given in the text.

on the materials handling system. To estimate the number of trips, we assumed that six trips (one delivery of food trays and one pick-up of soiled trays for three meals) were required for each nursing station.

In the case of drugs, we assumed that there would be one delivery to each nursing station each day. For other delivery points the number of trips was predicated partially on the amounts which must be delivered and partially on unforeseen demands.

For general supplies, we imagined packages of about 2 cubic feet, up to three of which could be carried in a cart. These include housekeeping supplies, therapy equipment, patient supplies, paper towels and napkins, etc. Some of these items eventually become trash, but others are returned to stores. We have assumed that returned items are picked up on return trips following delivery. Similar considerations apply to medical supplies, except that we have doubled the number of trips required (by using 3 cu ft. as the capacity of a cart) to reflect the lower predictability of such demands. Requirements to move sterile trays were based upon the assumption that six trays could be moved at once and that a separate pick-up trip for used items would be required.

The estimates for trash are somewhat lower than in civilian hospitals (presumably because military patients are not as sick and because there are fewer visitors, fewer flowers, and the like), but their totals coincide with the amount of trash actually removed from the three hospitals, extrapolated to 100% occupancy.

To estimate the round-trip delivery time, we used an average of 7 minutes per trip if the originating department was on the same floor as the destination, and 10 minutes if it was not. These intervals, which are based upon observation, exclude loading and unloading the cart but include normal delays (waiting for elevators, avoiding people in the halls, and time-wasting). Thus the time included in these estimates represents the manhours which are potentially replaceable by using automated equipment.

We have not included in Table 7.1.5 the flow of paperwork, which will be considered in Section 7.5., Hospital Communication Systems, nor have we included the flow of specimens. With regard to the latter, it is preferable to allow laboratory personnel to retain possession of the specimen and the order after the specimen has been taken, although if an automatic system can be justified on other grounds, it could carry specimens as well. Other possibilities with regard to specimens are discussed in Section 7.6.

To establish the cost of the baseline system, we took the manhours computed in Table 7.1.5 as the requirement for each class of materials. These are repeated (in hours instead of minutes) in Table 7.1.6. The number of men necessary to make these deliveries was computed by dividing the manhours by eight (for an eight-hour day), replacing fractions of men by a man, and adding one to fill in for leaves, illness, and turnover. For example, if the number of manhours were 18, dividing by eight yields 2.25 men, which is rounded upward to three, to which one is added, giving four men as the requirement for providing 18 manhours of labor daily. The cost of these men is taken to be $5000 annually. We have not reduced the totals to allow for shared duties, because sharing is not feasible: with the exception of general and medical supplies. all the material classes are under different departments of the hospital. While these estimates are realistic, they are, if anything, on the high side, so we are probably overstating the cost. This remark is reinforced by the fact that convalescent patients and patients waiting for orders can sometimes be used for materials handling duties.

To compute the number of carts, we used various formulas, depending on the material class. In the case of linens, we used the number of daily trips required, imagining a cart replacement system in which a full cart of clean linen is delivered on each trip and a cart of soiled linen is picked up. For meals we imagined a similar replacement system, except that delivery and pick-up occur three times a day. For drugs, we also imagined a cart exchange system occurring once a day and used the total number of trips as the number of carts. For general and medical supplies, we used twice the number of delivery personnel on duty (one less than the number of men required), imagining that each man could be making a delivery with one cart while the other was being

TABLE 7.1.6

COSTS ASSOCIATED WITH MANUAL MATERIALS HANDLING

Material class	Fort Dix			Jacksonville			March		
	Manhours	Men	Carts	Manhours	Men	Carts	Manhours	Men	Carts
Clean and soiled linen	21	4	124	12	3	77	9	3	58
Meals and soiled trays	31	5	62	17	4	34	9	3	18
Drugs	7	2	40	4	2	25	3	2	16
General supplies	24	4	6	13	3	4	9	3	4
Medical Supplies	22	4	6	11	3	4	8	2	2
Sterile trays and soiled utensils	15	3	29	10	3	15	6	2	11
Trash	33	6	10	16	3	4	11	3	4
Totals	153	28	277	83	21	163	55	18	113
Annual salary costs	$140,000			$105,000			$90,000		
Annual amortization	13,000			7,700			5,300		
Total annual cost	$153,000			$112,700			$95,300		

NOTE: The cost of carts was computed at $500 per cart for linen, meals, general and medical supplies, and sterile or soiled trays; at $400 per cart for drugs; and $50 per cart for trash. The cost for personnel was computed at $5000 per man, and the annual cost includes annual salary plus amortization of the carts, assumed to have a ten-year lifetime.

filled in the supply room. For sterile trays, we used one quarter of the trips required daily. Finally, for trash we used the same formula as for supplies. The cost of carts was computed as shown in Table 7.1.6, and the annual cost of manual materials handling was estimated by adding one-tenth of the cost of carts to the salary costs, implying ten-year amortization of the carts.

We have not introduced costs for service elevators, since at least one is necessary for moving beds, stretchers, and other equipment, regardless of what materials handling system is adopted, and one is sufficient. We also have not considered storage space, because it is about the same regardless of what system is adopted, provided they all use the cart exchange pattern.

7.1.4.3. Cost Estimates for Other Systems

To provide reasonable estimates for the capital cost and operating expenses of other materials handling systems, we sought quotations from suppliers. We sent requests to about two dozen manufacturers, including the schematic diagrams of three hospitals (as in Volume 8) and the materials handling loads given in Tables 7.1.1 - 7.1.3. Each was asked to lay out the way he would recommend installing his system, the cost if he were quoting as of May 1970, and the maintenance and power requirements. We purposely supplied schematic diagrams to avoid the problems of detail; the supplier was to imagine that he was involved in design right from the beginning of the concept plans so that any necessary accommodations for his system could be made.

The manufacturers' replies formed the basis for amortization and operating costs. We used the costs for service contracts rather than maintenance by military personnel in estimating operating costs. It is fair to expect that manufacturers have not overstated costs, and the estimates used should probably be regarded as low.

7.1.4.4. Comparison of Generic Categories

The results are tabulated in Tables 7.1.7 through 7.1.13. Besides the five generic categories described in Section 7.1.3, two more have been added: semi-automated systems and Mosler's Telelift. The former is typified by a reduced version of Cyberail and the Guilbert Cargomaster. These systems use a special elevator that automatically picks up and discharges wheeled containers with a destination code dialed in. Such systems are automatic for vertical travel but hand-operated otherwise. They would use special carts (the same number as the manual system), but they would require slightly fewer personnel since travel times would be diminished; to estimate the number of personnel we proceeded as for the manual system, but assumed a 7-minute delivery time regardless of whether the origin and delivery were on the same floor or not.

The automatic module systems are considerably more expensive than any other alternative. Little data on their reliability exist, but operating costs are high, reflecting in part the cost of maintenance. Similarly, semi-automated systems are more costly than manual systems.

Mosler's Telelift is more like a tote-box system than anything else, but it is considerably more elegant and much more flexible with regard to the number and location of stations. Therefore, it was evaluated separately. For the classes of material itemized, it lends itself only to transport of drugs and some supplies; it could be used for other items, such as odd pieces of linen, but it is too small to be seriously considered for anything else. However, it is useful for paperwork, as discussed in Section 7.5. It is more expensive than the manual system for the items considered here.

Pneumatic tube systems are not generally useful for any of the items considered, except possibly for an occasional odd delivery. We have shown system costs, however, for the sake of completeness. Their value for paperwork is undeniable, but their reliability in military hospitals is poor. (Of all the pneumatic tube systems we saw, only one was working, and it was infrequently used because the hospital staff had had too many experiences with lost papers.)

Vacuum collection systems do appear attractive, though not by any wide margin. However, their convenience and reliability are factors in their favor, and the presumable increase in the amount of trash to be handled makes them still more attractive.

Finally, trayveyor-type systems for distribution of meals appear to offer significant savings. If the pantries on the nursing wards are arranged directly above the food assembly area, such systems can be used to advantage. They are not especially elegant, but they are relatively inexpensive.

The conclusion is that a manual cart-exchange system is preferable for bulk material handling in military hospitals, except for vacuum trash and linen collection and for a trayveyor-type food distribution system. Pneumatic tube systems and Telelift remain to be considered in connection with paperwork in Section 7.5.

TABLE 7.1.7

ANNUAL COST FOR AUTOMATED MODULE SYSTEMS

Material Class	Fort Dix		Jacksonville		March	
	Men	Carts	Men	Carts	Men	Carts
Clean and soiled linen	1	0	1	0	1	0
Meals and soiled trays	1	0	1	0	1	0
Drugs	1	0	1	0	1	0
General supplies	1	0	1	0	1	0
Medical supplies	1	0	1	0	0	0
Sterile trays and soiled utensils	1	0	1	0	1	0
Trash	1	0	1	0	1	0
Totals	7	0	7	0	6	0
Annual salary for manual portion	$ 35,000		$ 35,000		$ 30,000	
Annual amortization for carts	---		---		---	
Annual amortization for automatic module system*	117,000		77,500		48,600	
Annual operating costs	58,000		42,700		23,400	
Total annual cost	$210,000		$155,200		$102,000	

*Amortization period: 15 years.

TABLE 7.1.8

ANNUAL COST FOR SEMI-AUTOMATED MODULE SYSTEMS

Material Class	Fort Dix		Jacksonville		March	
	Men	Carts	Men	Carts	Men	Carts
Clean and soiled linen	3	0	3	0	2	0
Meals and soiled trays	4	0	3	0	2	0
Drugs	2	0	2	0	2	0
General supplies	4	0	3	0	2	0
Medical supplies	3	0	2	0	2	0
Sterile trays and soiled utensils	3	0	2	0	2	0
Trash	4	0	3	0	3	0
Totals	23	0	18	0	15	0
Annual salary for manual portion	$115,000		$ 90,000		$75,000	
Annual amortization for carts	-----		-----		-----	
Annual amortization for semi-automatic system*	26,600		22,200		15,500	
Annual operating costs	21,800		9,350		5,800	
Total annual cost	$163,400		$121,550		$96,300	

*Amortization period: 15 years.

TABLE 7.1.9

ANNUAL COST FOR TOTE-BOX SYSTEMS

Material Class	Fort Dix		Jacksonville		March	
	Men	Carts	Men	Carts	Men	Carts
Clean and soiled linen	4	124	3	77	3	58
Meals and soiled trays	5	62	4	34	3	18
Drugs	0	40	0	25	0	16
General supplies	3	4	2	2	2	2
Medical supplies	3	4	2	2	2	2
Sterile trays and soiled utensils	2	29	2	15	2	11
Trash	6	10	3	4	3	4
Totals	23	273	16	159	15	111
Annual salary for manual portion	$115,000		$ 80,000		$ 75,000	
Annual amortization for carts	12,800		7,500		3,100	
Annual amortization for tote-box system*	43,300		26,400		24,400	
Annual operating costs	13,900		8,400		7,800	
Total annual cost	$185,000		$122,300		$110,300	

*Amortization period: 15 years.

TABLE 7.1.10

ANNUAL COST FOR TELELIFT SYSTEM

Material Class	Fort Dix		Jacksonville		March	
	Men	Carts	Men	Carts	Men	Carts
Clean and soiled linen	4	124	3	77	3	58
Meals and soiled trays	5	62	4	34	3	18
Drugs	0	40	0	25	0	16
General supplies	3	4	2	2	2	2
Medical supplies	3	4	2	2	2	2
Sterile trays and soiled utensils	2	29	2	15	2	11
Trash	6	10	3	4	3	4
Totals	23	273	16	159	15	111
Annual salary for manual portion	$115,000		$ 80,000		$ 75,000	
Annual amortization for carts	13,000		7,700		5,300	
Annual amortization for Telelift system*	34,100		22,000		18,100	
Annual operating costs	12,600		8,300		6,300	
Total annual cost	$174,700		$118,000		$104,700	

*Amortization period: 15 years.

TABLE 7.1.11

ANNUAL COST FOR PNEUMATIC TUBE SYSTEMS

Material Class	Fort Dix Men	Fort Dix Carts	Jacksonville Men	Jacksonville Carts	March Men	March Carts
Clean and soiled linen	4	124	3	77	3	58
Meals and soiled trays	5	62	4	34	3	18
Drugs	2	40	2	25	2	16
General supplies	4	6	3	4	3	4
Medical supplies	4	6	3	4	2	2
Sterile trays and soiled utensils	3	29	3	15 .	2	11
Trash	6	10	3	4	3	4
Totals	28	277	21	163	18	113
Annual salary for manual portion	$140,000		$105,000		$ 90,000	
Annual amortization for carts	13,000		7,700		5,300	
Annual amortization for pneumatic tube system*	18,100		13,200		11,100	
Annual operating costs	9,300		6,100		5,800	
Total annual cost	$180,400		$132,000		$112,200	

*Amortization period: 15 years.

TABLE 7.1.12

ANNUAL COST FOR VACUUM COLLECTION SYSTEMS

Material Class	Fort Dix		Jacksonville		March	
	Men	Carts	Men	Carts	Men	Carts
Clean and soiled linen	3	124	2	77	2	58
Meals and soiled trays	5	62	4	34	3	18
Drugs	2	40	2	25	2	16
General supplies	4	6	3	4	3	4
Medical supplies	4	6	3	4	2	2
Sterile trays and soiled utensils	3	29	3	15	2	11
Trash	0	31	0	17	0	9
Totals	21	298	17	176	14	118
Annual salary for manual portion	$105,000		$ 85,000		$70,000	
Annual amortization for carts	13,000		7,800		5,400	
Annual amortization for vacuum collection*	23,800		12,200		12,600	
Annual operating costs	9,000		5,700		5,700	
Total annual cost	$150,800		$110,700		$93,700	

*Amortization period: 15 years.

TABLE 7.1.13

ANNUAL COST FOR TRAYVEYOR-TYPE SYSTEMS

Material Class	Fort Dix		Jacksonville		March	
	Men	Carts	Men	Carts	Men	Carts
Clean and soiled linen	4	124	3	77	3	58
Meals and soiled trays	0	31	0	17	0	9
Drugs	2	40	2	25	2	16
General supplies	4	6	3	4	3	4
Medical supplies	4	6	3	4	2	2
Sterile trays and soiled utensils	3	29	3	15	2	11
Trash	6	10	3	4	3	4
Totals	23	246	17	146	15	104
Annual salary for manual portion	$115,000		$ 85,000		$75,000	
Annual amortization for carts	12,400		6,900		4,900	
Annual amortization for trayveyor-type system*	16,000		6,700		4,700	
Annual operating costs	1,850		2,450		3,000	
Total annual cost	$145,250		$101,050		$87,600	

*Amortization period: 15 years.

7.2. CONVENIENCE FOODS

7.2.1. INTRODUCTION

The food service department in military hospitals represents one of the largest single categories of expense in both capital outlays and operation, as is shown in Table 7.2.1. In addition, the quality of food service operations plays a significant role in the sense of well-being of patients and in their therapy. In military hospitals about half the rations served are eaten by staff, ambulatory patients, and visitors, and the quality of the meals is important to morale. For these reasons it is worthwhile to seek ways for improving quality and reducing costs.

It will be seen that convenience foods--that is, frozen foods prepared outside the hospital and heated in microwave ovens at the time they are served--offer an avenue to achieving both goals. The concept has proved itself in many civilian hospitals, notably the Kaiser hospitals in northern California, where complete conversion to convenience foods came seven or eight years ago. It is not a new idea to the military services, and a few ships have been designed without complete galleys, to make use of convenience foods. The Department of Defense has been moving gradually in the direction of using more preprepared foods, though there is no expectation of a wholesale conversion in the immediate future.

Military hospitals have the opportunity to adopt convenience foods, even though the commissary suppliers may not have converted. Under present practices, the hospital dietician exercises considerably more discretion in her sources of supply than mess officers of other military facilities, as she must in order to meet the special demands of hospital feeding. For this reason, she is well equipped by experience to oversee procurement of convenience foods from local suppliers or local outlets of national suppliers, both of whom can supply prepared foods to hospital standards. Thus, there is no obvious reason not to consider convenience foods as an alternative to conventional food service operation.

TABLE 7.2.1

EXPENSES OF FOOD SERVICE DEPARTMENT

	Fort Dix	Jacksonville	March
Personnel salaries	$1,179,742	$408,228	$283,596
Provisions	536,653	154,394	137,000
Other operating expenses	114,544	95,559	13,715
Total annual operating expenses	$1,830,939	$658,181	$434,311
Percent of annual operating budget	12.27	9.75	7.32
Estimated capital cost for space and equipment	$1,551,000	$811,000	$453,000
Percent of total capital cost	8.81	7.44	6.49

7.2.2. DESCRIPTION OF ALTERNATIVES

The sequence of activities which comprise a dietary system and which are the responsibility of chief of the food service department are these:

- Menu planning and quality control
- Purchasing provisions
- Preparing
- Cooking
- Proportioning
- Assembling trays
- Serving
- Collecting soiled utensils
- Washing and cleaning

Not every menu item is treated at every step (for example, most salads are not cooked), and certain alternatives eliminate some steps (for example, if disposable ware is used, some washing and cleaning is eliminated). It is also possible to interrupt the sequence by preserving and storing the food following cooking and proportioning, in which case an additional step of reconstituting the food is necessary. One can also consider hybrid systems, using one sequence for patients on wards and a different one for staff, visitors, and patients in a cafeteria or dining room.

The basic choices to be made concern whether given activities are to be performed in the hospital or outside, whether they are to be under direct supervision of the chief of food service or supervised by a caterer or supplier, whether they are to be served directly or frozen for later reconstitution and serving, and, in the latter case, whether they are to be reconstituted in a central kitchen or in decentralized areas such as pantries in the wards.

A discussion of all conceivable alternatives for all possible menu items would be hopelessly complex; therefore, we shall consider first the major element of a meal, the entree (meat, potatoes, and vegetables), and then see for each feasible alternative if a compatible method can be conceived for other elements (such as coffee, tea, milk, juices, cereal, eggs, bread, toast, salads, fruits, ice cream, soups, and sandwiches).

A study of dietary systems for the Stanford Hospital[1] described nine feasible alternatives for entrees. These are shown schematically in Figure 7.2.1. Each branching represents a choice in the design of the dietary system, and each path through the tree represents a particular dietary system. In Alternative 1 all steps are performed in the hospital; this is the conventional system, used in all military hospitals and most civilian hospitals.

Alternative 2 is essentially the same except that the sequence is interrupted by preserving and storing the food to be reconstituted at a later time. Under the conventional system, this is done from time to time for particular items--for example, pies might be baked, frozen, and served later. Alternative 3 is the same as Alternative 2 except that food is reconstituted near the wards. This system is used at the Southwest Methodist Hospital in San Antonio, Texas; its advantage over the conventional method is that the kitchen is not concerned with serving, and therefore the problems of getting everything ready to serve at once, keeping hot things hot and cold things cold, are eliminated. Eliminating these problems is the basic advantage of introducing preservation and storage; it also permits the kitchen, (whether in the hospital or not) to function more like an assembly line which "tools up" to make chicken dinners, say, on one day and roast beef dinners on another, taking advantage of the economies offered by making a long run of any one entree.

Alternatives 4, 5, and 6 all comprise preparation outside and cooking inside. Alternative 4 is the pattern used by some catering services, which take responsibility for running the hospital kitchens. Alternatives 5 and 6 differ only in the location where food is reconstituted. To some extent, elements of these alternatives are used in the earlier three alternatives--for example, meats are often bought already cut up for serving. The only advantage offered by these alternatives is transfer of some of the kitchen operations to another location. There is no reason to assert that a caterer can do the job better or more cheaply, unless he is serving several hospitals (or other institutions) at once. This does occur in large cities, which are the only places one finds this practice, but it would not be feasible for most military hospitals. Therefore we shall not consider Alternatives 4, 5, and 6 further.

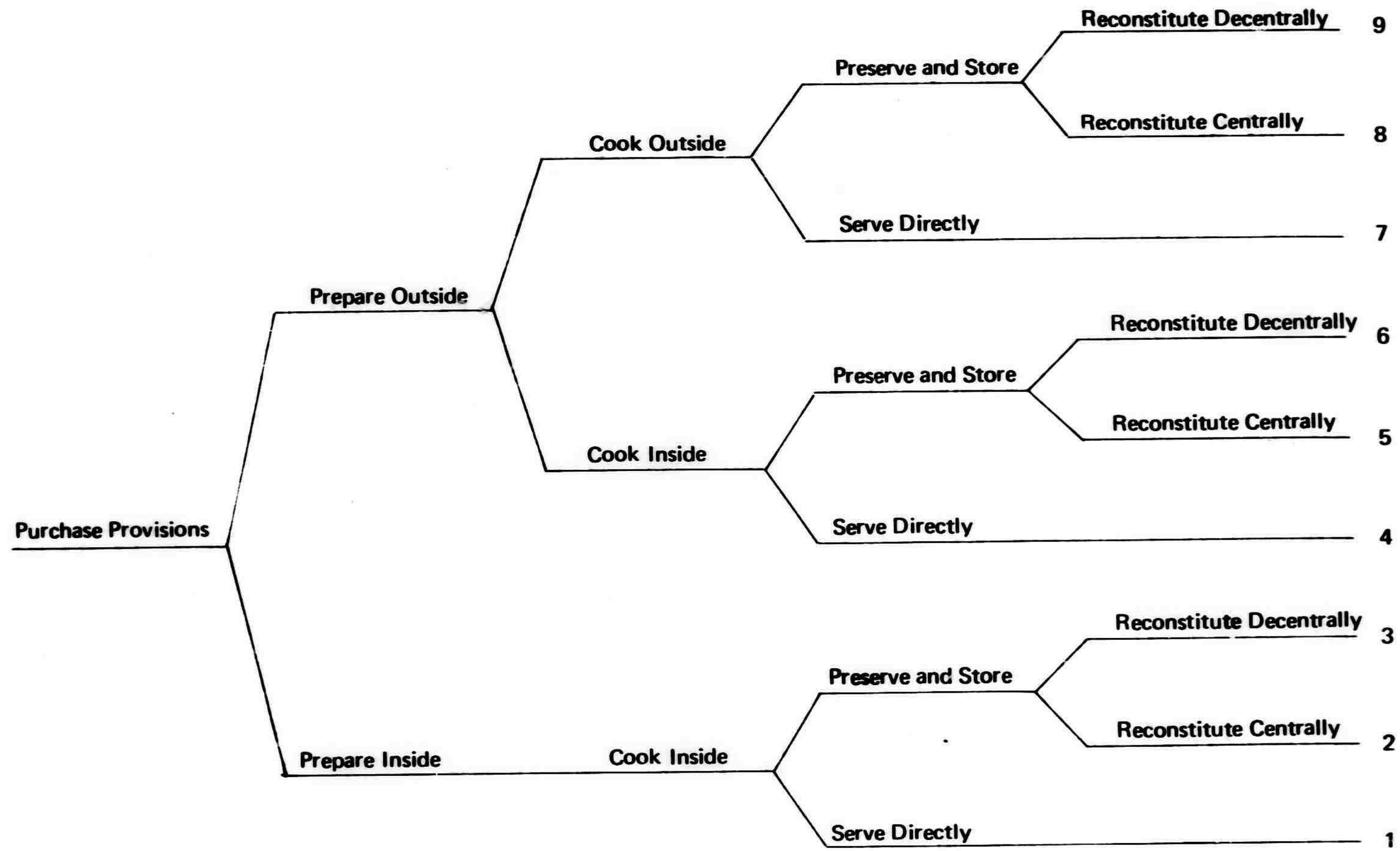

FIGURE 7.2.1 ALTERNATIVE CONFIGURATIONS FOR DIETARY SYSTEM
(From Reference 1)

Alternative 7 is the pattern used by most airlines. The food is prepared and cooked in a central kitchen and put aboard the plane, where it is kept hot until served. Meals that have been heated for several hours are definitely less palatable than those served immediately. On aircraft there is little choice, but this alternative is unnecessary in a hospital. Whatever advantages it may have are also possessed by Alternatives 8 and 9, and therefore Alternative 7 will not be considered further.

Alternatives 8 and 9 take full advantage of whatever merits "assembly line" production of meals may have. In Alternative 8 the food is reconstituted centrally, and in Alternative 9 it is reheated near the wards. The latter method is used at some of the Kaiser Hospitals and elsewhere.

Conceivable ways of preserving foods include canning or plastic packaging, freeze drying, and freezing. Of these, freezing is the only acceptable method for entrees in a hospital; the other methods would be cumbersome in practice, and the reconstituted products are certainly less palatable. Even when freezing is used, foods should be proportioned before hand, as they cannot be frozen easily in bulk form.

The Stanford study referred to earlier concluded that in every case decentralized reconstitution is preferable to centralized reconstitution. The basic reason is that, once one has gone to the trouble of freezing individually proportioned meals, he discards one of the advantages he has gained, namely, the chance to serve the meal hot from the oven, by reconstituting the meal in a central kitchen. This disadvantage is aggravated by the fact that many frozen foods, especially starchy ones, deteriorate rapidly after the first reheating and become less palatable if they are not eaten immediately. On the strength of these remarks we shall also eliminate from further consideration Alternatives 2 and 8.

This leaves three alternatives for further consideration: Alternative 1, the conventional pattern; Alternative 3, in which foods are prepared, cooked, frozen, and stored in the hospital to be reconstituted and served on the wards at a later time; and Alternative 9, in which all operations including freezing are done outside the hospital and the food is delivered frozen. It can be seen that Alternatives 3 and 9 are identical in the manner in which they function but that they differ in personnel and location. Presumably in the former the hospital staff would prepare, cook, proportion, and freeze the food; in the latter these operations would be done by the supplier. In the former, these activities are performed in the hospital under the direct supervision of the chief of food service; in the latter, at some other location under the supervision of the supplier.

There is no essential reason, of course, why the kitchen must be in the hospital under Alternative 3; it could as well be separate from the hospital but on the base and run by the hospital's food service personnel. If Alternatives 3 and 9 turn out to be acceptable when compared with Alternative 1, then this variant (3) offers a conceivably attractive way of expanding an existing hospital: a new kitchen could be built as a separate facility, and the space thus freed could be used for other purposes. As we have discussed in Volume 3, this is not likely to be done, because kitchens are "hard" areas - that is, expensive to modify - but it might be desirable under some circumstances. Moving the kitchen out of the hospital offers some attractions, because kitchens are hard to keep clean, may be noisy, and may create unpleasant odors.

It is debatable whether, under Alternative 3 or its variant, the hospital food service staff can produce food that is better or cheaper than that prepared by a supplier. Since the same work is performed under either Alternative 3 or 9, any differences must be sought elsewhere. There is no fundamental reason to expect differences in quality: suppliers in the business produce food to hospital standards, and the problems of maintaining quality are the same whether the personnel be military or civilian. Similarly, there is no fundamental reason to expect differences in cost: wage scales are comparable, and, although they have been increasing rapidly in recent years and probably will continue to do so, military and civilian wages tend to stay in step. The supplier has the potential advantage of serving more than one customer, and he does not have the distractions which military duty may impose on the hospital's staff (such as guard duty). On the other hand, he may have more problems with unions. Food supplied through military procurement channels might be better quality-controlled or cheaper, but this is certainly arguable since the ultimate sources of provisions are the same.

Therefore, the choice is not clear-cut. In succeeding sections we shall compare Alternatives 1 and 9. When all the points of comparison have been made, we shall return to the question of how Alternative 3 compares with 9. We shall also explore later the concept of a hybrid system (for instance, Alternative 1 for staff, visitors, and patients eating in the cafeteria, and Alternative 9 for inpatients).

7.2.3. DESCRIPTION OF CONVENIENCE FOOD SYSTEMS

Alternative 9 represents a system of food service operation described as a "convenience food" system.* The best-known example of such a food service system in hospitals, though by no means the only one,** is that used by the Kaiser hospitals in California. To avoid vagueness, we shall base our description on the Kaiser system; it should be obvious, however, that many variations are possible, and we shall point out some of them in passing.

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*The term "convenience foods" has many meanings besides the one which we are describing.[2] The Directorate for Subsistence Management Policy in the Pentagon uses the term for such items as non-carcass meats and dehydrated potatoes. Other people have in mind frozen foods on throw-away utensils, like TV Dinners.

**At least 100 hospitals in the United States and abroad use convenience foods. These include besides the Kaiser hospitals and the Southwest Methodist Hospital, the Mount Sinai Hospital in New York, the Rahway Hospital in New Jersey, the Tuscon Medical Center in Arizona, St. Mary of Nazareth Hospital in Chicago, the Grant Hospital in Chicago, and the Metropolitan State Hospital in Massachusetts.[3,4] All the hospitals in New York City operated under the aegis of the Health Care and Mental Hygiene Facilities Corporation will shortly convert to convenience foods.

Each of the Kaiser hospitals in northern California uses several suppliers for different categories of food, just as any hospital does now. There is one supplier for the frozen entrees, another for fresh fruits and salads, a third for dairy products, and others for other items. Suppliers produce foods to Kaiser's specifications, and an important part of the system is writing good specifications and maintaining vendor quality standards (both of which are done by Kaiser Regional Headquarters rather than by the individual hospitals).

The entree items (meat, potatoes, and cooked vegetables) are prepared, cooked, and frozen by the supplier in accordance with required hospital dietary practice. Various items are supplied according to special standards, including calculated calories, pediatrics, diabetic, ulcer diets, bland diets, low protein, T&A (tonsillectomy and adenoidectomy), puree, low fat, etc. Deliveries are made on a convenient schedule in a freezer van, and a ten-day supply is kept in zero-degree freezers at the hospital.

The frozen foods are served both to inpatients in the wards and to outpatients, staff, and visitors in the cafeteria. On the basis of anticipated demand, which can be fairly reliably predicted, the frozen items are removed from the freezers one day ahead of time and allowed to thaw in a 40-degree refrigerator. Thawing a slightly excessive amount assures no shortage and results in no waste, since unused but thawed items can be used the next day. Inpatients order their meals from one of 16 color-coded menus, corresponding to the variety of special diets. That for the regular diet is shown in Figure 7.2.2. It can be split apart into segments, one for each meal.

Since no food is prepared in the hospital, other items are delivered daily, and all are individually proportioned. These include fresh fruit, salads, salad dressings, milk, bread and rolls, butter, ice cream, and sandwiches. The ingredients for all these items, if not the items themselves, are usually provided daily, even in conventional food service systems.

At each meal an inpatient has a choice from all the items on the menu, not just from three or four as in the case with conventional food service. Trays are made up in a central food assembly area, Regular Diet

EARLY BREAKFAST

Room ______ Name ______________________

Please CIRCLE Your Selection

JUICES

Orange	Prune
Apple	Grapefruit

BREADS

Breakfast Roll	Muffin
Doughnut	Margarine
Toast	

CEREALS

Cornflakes	Sugar Smacks
Rice Krispies	Special K
Oatmeal	Cream of Wheat
Oatmeal with Maple and Brown Sugar	

BEVERAGES

Coffee	Caffein-free Coffee
Tea	Non-fat Milk
Milk	Sugar

Regular Diet

BRUNCH

Served at Approximately 11:30 a.m.

Room ______ Name ______________________

Please CIRCLE Your Selection

JUICES

Orange	Grape
Apple	Grapefruit

FRUITS

Stewed Prunes	Citrus Segments
Applesauce	Jello

SOUP

Vegetable	Cream of Chicken
Broth	Crackers

ENTREES

Waffle, syrup	Creamed Chicken
Egg Omelette	Crepe filled with Apples
Crepe filled with Scrambled Eggs	Pancakes, syrup
Canadian Bacon	
Link Sausage	Fruit and Cottage Cheese
Sliced Bacon	

White Toast   Wheat Toast   English Muffin

Margarine   Jelly

SANDWICH

Cheeseburger, catsup	Corn Chips
Club Sandwich	Potato Chips

BEVERAGES

Coffee	Caffein-free Coffee
Tea	Non-fat Milk
Milk	Cocoa
Instant Creme	Fruitade

Regular Diet

DINNER

Served at Approximately 5:00 p.m.

Room ______ Name ______________________

Please CIRCLE Your Selection

APPETIZERS

Tomato Juice	Dinner Salad, Dressing
Relish Plate	Broth
	Crackers

ENTREES

Hot Entrees served with Selected Potato and Vegetable

- Macaroni and Cheese
- Meat Loaf, Brown Sauce
- Enchilada, Rice
- Braised Beef with Vegetables
- Baked Ham, Fruit Glaze
- Roast Turkey, Dressing
- Breast of Chicken, Supreme
- Crab Newburg
- Club Roast of Beef
- Filet of Sole, Saute
- Spaghetti, Meat Sauce
- Roast Veal, Brown Sauce
- Fried Chicken
- Sirloin Steak

BREADS

Dinner Roll	Margarine
Wheat Bread	
White Bread	

DESSERTS

Ice Cream	Cookies
Sherbet	Pudding
Bavarian Creme	Fresh Fruit
Canned Fruit	Cheese Wedge
Jello	Crackers
Apple Strudel	Cake

BEVERAGES

Coffee	Caffein-Free Coffee
Tea	Non-fat Milk
Milk	Fruitade
Instant Creme	

Regular Diet

EVENING SNACK

Served at Approximately 8:00 p.m.

Room ______ Name ______________________

A selection of fruit juice, or other beverage, cookies or crackers will be served at 8:00 p.m.

Coffee, Tea, and Caffein-Free Coffee are available throughout the day on request.

FIGURE 7.2.2 REGULAR DIET MENU USED IN THE KAISER FOUNDATION HOSPITALS omitting certain items (such as coffee or tea, bread toast, or boiled eggs), which are prepared individually in the ward, and other items which need special storage (such as ice cream and frozen desserts), which are added when the tray is ready for the patients. The trays with the original menus are loaded in carts and delivered to the wards.

Ordinary household refrigerators are used for storage on the wards. (The New York hospitals will use refrigerators large enough to hold entire carts, because this eliminates one step of handling the trays; we are inclined to favor the Kaiser system, since some items such as ice cream requires separate handling anyway, and, although work on the ward would be cut down slightly, it is not sufficient to reduce staff.)

Because food assembly is not an extensive operation (for example, a single aide can prepare 200 trays for early breakfast in an hour or so), it is no particular burden to serve four or five meals instead of three. Patients prefer this, since bedridden people have light appetites and often find mealtimes their only pleasure in a hospital. Similarly, there is no particular pressure to serve a meal on time, and a patient can ask for his meal when he feels like it.

To prepare a meal on the ward an aide places the entree in a microwave oven, which heats the food in a minute or so. Timing is crucial, but it can be done automatically. Toast is made, coffee brewed, water heated for tea, and soup heated using ordinary restaurant equipment. The whole pantry occupies only about 15 feet along one wall near the nurses' station.

Persons dining in the cafeteria pick up thawed but not heated entrees and other items in a cafeteria line. Microwave ovens, heaters for soup and coffee and other necessary equipment is provided, and the patron heats his own meal. One possible objection to this arrangement is that variety for staff members who eat in the hospital day after day may be insufficient. Most staff members, however, have no complaint and observe that they have a choice of 14 entrees each day, which is more than conventional cafeterias usually offer. In any event, staff members do r eat every meal in the hospital, and this is equally true for the staff of military hospitals.

The food is served partially on disposable ware, but the cups and saucers, plates for the main dish, and trays are reusable. This is done because Kaiser wishes to maintain reasonable aesthetic standards, and, although disposable ware is available, their present feeling is that disposable utensils of suitable quality are too expensive. However, disposables will presumably become cheaper and better and therefore offer the preferable alternative for the future.*

7.2.4. CRITERIA FOR CHOICE

In subsequent sections we shall deal explicitly with costs for labor, provisions, services (utilities, maintenance, and housekeeping), supplies, and capital equipment. In this section we deal with a number of issues raised by introduction of convenience foods, a few of which are quantifiable but most of which are qualitative.

7.2.4.1. Advantages of Convenience Foods

Because convenience foods are prepared in a "food factory," where schedules are dependent on the needs of preparation rather than the needs of serving, many problems which arise in hospital kitchens are reduced. Quality control, portion control, and avoidance of contamination are all easier to deal with. Large suppliers have found it desirable to automate some processes and to develop continuous cooking instead of batch cooking. These developments are less feasible in single hospitals, because volume is insufficient.

Since a delay before serving is introduced by freezing and storing, the problems introduced by sudden peaks in demand (by URI epidemics, for example) are diminished. The stored supplies furnish a buffer so that peaks are not a problem.

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*Another consideration regarding disposables is the pollution problem they create outside the hospital. We do not address this question, since it deals with matters outside the health care system. However, this is an excellent example of the way a conclusion might be changed if one were to define different boundaries between the system to be studied and its environment, as discussed in Section 1.5.

Food waste is dramatically reduced, primarily because no more meals are prepared than are served. In addition, pilferage is reduced, because control is easier in a smaller assembly area than in a large kitchen. St. Mary's Hospital in Chicago, for example, reports waste reduced from 25% to 2% by introducing convenience foods. In considering costs we shall not take explicit account of this factor, since is is implicit in the cost experience of the Kaiser hospitals, which we shall use as a base.

The smell, noise, and heat of cooking are eliminated from the hospital. As a rule, none of these is objectionable in a well-designed hospital, but a certain amount of expense must be incurred (for hoods, exhaust fans, etc) and a certain amount of discipline must be maintained to assure that this is so. Similarly, garbage disposal is less of a problem.

Because food is reconstituted at the last minute before serving, the problems of keeping hot foods hot and cold foods cold are minimized. Special carts are not necessary, and special devices like metal doughnuts to preserve heat are eliminated.

The fact that convenience foods can be served in many locations without any appreciable complication of the food service system makes them especially attractive for the light care facility. Having a separate cafeteria in the facility introduces no new problems and is wholly consistent with that concept.

If convenience foods are prepared by a supplier instead of the hospital staff, as in Alternative 3, the need to train and keep cooks, butchers, and other trained food service personnel is eliminated. This is a cost to the conventional system, though we have not included it in our analysis, since the case is strong enough without it. One possible concern with eliminating cooks in hospitals is that they are needed in overseas hospitals and must get their training in domestic hospitals. This argument is not very credible: foreign military hospitals are frequently staffed with foreign nationals, convenience foods are likely to be available in places like Europe and Japan, and in any case there still would be ample opportunity to train cooks in nonconverted hospitals or other facilities.

7.2.4.2. Potential Disadvantages of Convenience Foods

Even though convenience foods are used in many civilian hospitals, it may be that military hospitals, often being in out-of-the-way locations, would have trouble finding suppliers. In certain instances this objection may preclude use of convenience foods. Generally speaking, however, this problem is not likely to materialize often. For one thing, the supplier does not have to be very close by - a hundred miles would not be too far to go. For another, national suppliers provide their services to hospitals all over the country, and adding military hospitals seems entirely feasible. National suppliers, not all of whom are yet in the hospital business but who have the facilities and are actively engaged in exploring the hospital market, include:

- MediDiet (National Hospital Foods)
- Stouffers
- Schraffts
- Swift and Company
- Sara Lee (Consolidated Foods Corporation)
- Marriott Corporation

In addition, the number of local suppliers will undoubtedly increase.

It is certainly possible to supply food of sufficient quality to meet all reasonable standards of hospital dietary practice, because it is being done. However, as we have noted, it is necessary to write careful specifications and to maintain rigorous quality control. This, of course, is what military hospital dieticians and veterinary officers are trained for and experienced in, so there should be no undue difficulty in maintaining quality.

Even food of high quality may become unpalatable because of the effects of freezing, lack of freshness, being served improperly heated or cooled, or being served on poor quality utensils. It is probably fair to say that convenience foods are inferior to high-grade institutional food. It is certainly true that the menu must be curtailed somewhat to eliminate foods which are simply unsuited to this concept (for example, fried eggs, souffles, and baked Alaska). Nevertheless, most users report enthusiastic acceptance.

Variety is another issue, which arises in two ways: one, whether the variety of special menus needed in a hospital can be met, and, two, whether there is sufficient variety for the staff who eat there day after day. We have mentioned that staff members in the Kaiser hospitals find the variety quite acceptable, and indeed the variety is greater than in many office cafeterias. The issue of meeting hospital dietary needs does require examination. From 15% to 40% of the meals served to inpatients require special diets. In Table 7.2.2 we have listed the standard hospital diets published by Womack Army Hospital,[5] which are based on Army Technical Manual 8-500-1, Hospital Diets. About 50 diets are defined, and it is clear that maintaining an inventory of this many special diets, each of which itself might have many menu choices, would be exceedingly cumbersome. Fortunately, many of them are seldom used. Also, within groups they differ only in degree and can be made up by varying amounts of particular foods. The Kaiser hospitals manage with 16 distinct menus. Nevertheless, a vestigial kitchen to prepare unusual diets, particularly diabetic diets, would be needed.

There is also the question of changeover. As we have remarked, adoption of convenience foods should be possible on a local scale using commercial suppliers so that the commissary need not make the change in order for the hospital to convert. If and when more convenience foods become available from the commissary, it would present an alternative source. Once a hospital has been built without a kitchen, it would admittedly be difficult and expensive to change back to conventional foods, but there is little reason to consider this eventuality.

Finally, there is concern over vulnerability to strikes, storms, or natural disasters. While any of these is potentially troublesome, a convenience food system is no more vulnerable than a conventional system; in fact, it might be argued that it is less vulnerable, since it normally maintains a ten-day supply of frozen foods. Whatever precautions might have to be taken in the name of civil defense would also have to be taken in a conventional food system.

TABLE 7.2.2
STANDARD HOSPITAL DIETS

MODIFICATIONS IN PROTEIN
- Hospital regular (high protein)
- Protein restricted (10-20 grams)
- Protein restricted (40-50 grams)
- Purine restricted

MODIFICATIONS IN CONSISTENCY
- Fiber restricted
- Bland
- Bland (six meal)
- Soft
- Mechanical soft
- Dental soft
- Minimal fiber-minimal residue
- Full liquid
- Bland (following tonsillectomy)
- Clear Liquid
- Dental Liquid

MODIFICATIONS IN CALORIES
- Calorie restricted (800)
- Calorie restricted (1000)
- Calorie restricted (1200)
- Calorie restricted (1500)
- Calorie restricted (1800)

MODIFICATIONS FOR AGE
- Baby soft (0-12 months)
- Child soft (1-2 years)
- Child junior (2-6 years)
- Child regular (6-9 years)

MODIFICATIONS IN FAT
- Fat restricted (40-50 grams)
- Fat controlled
- Fat controlled-calorie restricted

MODIFICATIONS IN SODIUM
- Sodium restricted
- Sodium restricted-protein restricted
- Sodium restricted-fat restricted
- Sodium restricted-fiber restricted
- Sodium restricted - soft
- Sodium restricted-full liquid
- Sodium restricted-calorie restricted

DIABETIC DIETS
- Set up to meet individual needs

PRE-TEST MEALS
- Fat restricted
- Fatty meal VMA test

7.2.5. COMPARISON OF COSTS

To compare costs, we have used two basic sources; our summary of operating data on the hospitals at Fort Dix, Jacksonville NAS, and March AFB, collected in Volume 8, and the accounts of the Kaiser Foundation Hospitals for the Northern California Region,[6] which they have permitted us to use.

For the region, which includes 12 hospitals, Kaiser reports a net cost of $3.94 per ration* for inpatients. The cost of meals served to staff and visitors in the cafeterias is recovered by charging patrons who eat there. Although the cafeterias are intended to be run on a "break-even" basis, the above figure includes a small loss ($.08 per inpatient-day in the figures we have available) attributable to the cafeteria. The $3.94 includes all operating expenses (personnel salaries and benefits, provisions, supplies, services, equipment rentals, non-capitol equipment, and mileage expenses), but it does not include amortization of capital expenses. Because military pay scales are different, although similar, we have relied on the Kaiser data only for the cost of provisions. For the region, this amounted to $2.29 per ration and varied from a low of $2.03 to a high of $3.14 at individual hospitals. The last figure applied at the Kaiser Foundation Research Center, which has a small number of beds and is in no way comparable to military hospitals. The hospitals with 200 or more beds generally kept costs below the regional average, but we shall use the average as the cost per ration for convenience foods.

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*A ration is the food consumed by one person in a day, comprising all three meals. In the military services the number of rations served is obtained by adding 0.20 times the number of breakfasts, 0.45 times the number of dinners, and 0.35 times the number of suppers.

One might legitimately ask whether the cost of foods in California, especially that of fruits and vegetables, departs appreciably from the U.S. average. We have made no adjustments for such variations, but a comparison of retail prices in several locations suggests that the differences, if any, are not large.

To estimate the total cost of the conventional food service system, we used actual operating costs as derived in Volume 8, and we estimated capital costs as shown in Table 7.2.3, allotting 25% of the dietary area to the kitchen and 75% to the dining room.

To estimate operating costs for convenience foods (Table 7.2.4), we reduced the number of senior personnel (the chief of food service and dieticians), whose salaries were taken at an average of $10,000, from 16 to 10 at Fort Dix, but made no reductions at Jacksonville or March. Nonprofessionals include food tray assemblers, supervisors, cart delivery personnel, mess attendants, dishwashers, and so forth. The staff levels are based on the number of personnel required in the Kaiser system, scaled, of course, for the size of the hospital. We used an average salary of $6200 for these personnel at each of the three bases which is the actual average salary of nonprofessional personnel at Jacksonville and March. At Fort Dix the average is higher ($8500), but there is no outward necessity for this difference.

The cost of provisions was increased to $2.29 per ration as discussed above. The cost of supplies and services was computed as $0.20 per ration for disposable ware, including knives, forks, spoons, napkins, and various containers, and other utilities. We have supposed that nondisposable trays, china plates for the entree, cups and saucers will be used, and these costs are included in the capital costs. Costs for other disposable containers for prepared foods are contained in the cost of provisions. The costs for general services, housekeeping, maintenance, utilities have been reduced to 80% of their present values because the kitchen area is reduced and equipment for food preparation is removed.

TABLE 7.2.3

ANNUAL COSTS OF CONVENTIONAL FOOD SERVICE

	Fort Dix	Jacksonville	March
OPERATING COSTS			
Rations			
Number of inpatient rations served annually	160,000	71,500	52,700
Number of rations served in dining rooms annually	228,000	63,100	46,200
Total rations served annually	388,000	134,600	98,900
Personnel			
Number of professional food service personnel	16	3	3
Number of nonprofessional food service personnel	132	60	41
Total salaries for all food service personnel	$1,179,742	$408,228	$283,596
Expenses			
Provisions	$536,653	$154,394	$137,000
Supplies and minor equipment	63,384	36,363	2,915
Services, utilities, maintenance, housekeeping	51,160	59,196	10,900
Total operating costs	$1,830,939	$658,181	$434,311
ESTIMATED CAPITAL COSTS			
Installed equipment in kitchen	$250,000	$150,000	$100,000
Other equipment in kitchen	50,000	30,000	20,000
Equipment in wards (carts, freezers, etc.)	56,000	32,000	24,000
Equipment in dining room* (steam table, etc.)	5,000	4,000	3,000
Space for kitchen (@$50/sq.ft.)	350,000	175,000	90,000
Space for dining room (@$40/sq. ft.)	840,000	420,000	216,000
TOTAL CAPITAL COSTS	$1,551,000	$811,000	$453,000
AMORTIZED CAPITAL COSTS			
(10 years for equipment; 25 for space)	$ 83,800	$ 45,400	$ 26,900
COMBINED ANNUAL COSTS	$1,915,000	$704,000	$461,000

*Excludes tables and chairs, which would also be needed for convenience foods.

TABLE 7.2.4

ANNUAL COSTS OF CONVENIENCE FOOD SERVICE

	Fort Dix	Jacksonville	March
OPERATING COSTS			
Personnel			
Number of professional food service personnel	10	3	3
Number of nonprofessional food service personnel	54	24	17
Total salaries for all food service personnel	$435,000	$179,000	$135,000
Expenses			
Provisions	$890,000	$308,000	$227,000
Supplies and minor equipment	78,000	27,000	9,000
Services, utilities, maintenance, housekeeping	41,000	47,000	9,000
TOTAL OPERATING COSTS	$1,444,000	$561,000	$380,000
ESTIMATED CAPITAL COSTS			
Installed equipment in food assembly area	$ 83,000	$ 50,000	$ 33,000
Other equipment in food assembly area	14,000	9,000	5,000
Equipment in wards (carts, freezers, ovens, etc.)	56,000	32,000	24,000
Equipment in dining room* (counters, ovens)	12,000	10,000	8,000
Space for kitchen (@$50/sq. ft.)	210,000	105,000	54,000
Space for dining room (@$40/sq. ft.)	840,000	420,000	216,000
TOTAL CAPITAL COSTS	$1,195,000	$626,000	$340,000
AMORTIZED CAPITAL COSTS (10 years for equip't; 25 for space)	$ 58,500	$ 31,100	$ 17,800
COMBINED ANNUAL COSTS	$1,505,000	$604,000	$427,000

*Excludes tables and chairs

Capital costs are considerably different under the convenience food system. Kitchen equipment was reduced by about 60%, since no food preparation or cooking is necessary. Equipment used in the wards was left unchanged; the carts would be cheaper since temperature control is not important, but microwave ovens would be needed on the wards. The cost of equipment in the dining room was increased for the same reason. Hospitals which have introduced convenience foods have found that the food assembly area can be about 60% of a conventional kitchen area, and this factor was used in computing the cost of kitchen space. No change was made in the dining space.

In Table 7.2.5 we summarize the comparative data from the preceding two tables. It is clear that on the basis of both capital and operating costs a convenience food service system is preferable to a conventional one.

7.2.6. VARIANTS OF CONVENIENCE FOOD SYSTEMS

Two matters on which we have postponed discussion are the merits of Alternative 3 (the hospital staff preparing convenience foods either in the hospital or nearby) versus Alternative 9 (the convenience food system we have evaluated), and the merits of a hybrid system.

As we have said, the advantages of Alternative 9 over Alternative 3 are not great. There are, however, some reasons to expect that the former might be cheaper. A commercial supplier has two advantages over a hospital-based supplier: he does not have to cope with the rapid turnover of staff characteristic of military organizations, and he may be able to take advantage of the economies of large-volume runs if he supplies more than one hospital. Thus, it is likely that a commercial supplier can produce convenience foods more cheaply and maintain standards more reliably. The simplicity of Alternative 9 compared with 3 from the point of view of the food service staff is also desirable; the supervisory personnel can devote most of their attention to operations within the hospital.

TABLE 7.2.5

COMPARISON OF COSTS BETWEEN

CONVENTIONAL AND CONVENIENCE FOOD SERVICE SYSTEMS

	Fort Dix	Jacksonville	March
Operating Cost Per Ration			
Conventional	$4.72	$4.90	$4.39
Convenience	3.73	4.17	3.85
Difference	$0.99	$0.73	$0.54
Capital Cost			
Conventional	$1,551,000	$811,000	$453,000
Convenience	1,195,000	626,000	340,000
Difference	$ 366,000	$185,000	$113,000

Hybrid systems are not attractive. Since convenience foods are superior from the standpoint of costs, the only possible merit in a hybrid system which used conventional foods for the cafeteria would be improved quality. All our inqui.-ies lead us to believe that convenience foods provide acceptable quality and variety, so a hybrid operation would simply introduce greater complexity.

We recommend Alternative 9, a complete convenience food system, for the "new generation" of military hospitals.

7.2.7. REFERENCES

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3. J.A. Prestbo, "The Vanishing Chef: Restaurants Serve More Frozen Dishes," Wall Street Journal, 18 Mar 1970, p. 1.

4. G.A. Friesen and W.O. Neibert, "Monorail: Hot Idea for Hot Food Service," The Modern Hospital, June 1967.

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   Nine Months Ended September 30, 1969
   Three Months Ended September 30, 1969

7.3. UNIT PACKAGE MEDICATION

7.3.1. INTRODUCTION

The distribution of costs allocable to the pharmacy in military hospitals is almost unique among the services, because the cost for staff is a small part of the total cost. Instead, the dominant cost is that of the drugs themselves, as shown in Table 7.3.1. The number of people assigned to the pharmacy is small; thus, even if it were possible to increase their efficiency markedly, there are no opportunities for large savings through reducing the staff. However, others besides those employed in the pharmacy are concerned with dispensing drugs. Studies[1,2] have shown that nurses spend about 16 minutes per patient per day preparing and administering drugs to inpatients, which amounts to over ten man-hours of work in a 40-bed ward. If some inroads on this workload can be made, it should be worthwhile.

The other promising point of attack is on the cost of the drugs themselves. The amount paid for drugs is a matter outside the scope of this study, but the additional costs incurred through pilferage, outdating, or mishandling are matters for consideration. One way of reducing such losses is through unit packaging of drugs. Not only does unit packaging hold the promise of reducing pilfering and mishandling but it also reduces errors in dispensing and administering drugs, and it lends itself to automation. This last feature makes unit packaging seem attractive now.

7.3.2. DESCRIPTION OF PHARMACY FUNCTIONS IN PRESENT MILITARY HOSPITALS

7.3.2.1. Pharmacy Service

There are two separate and distinct pharmacy operations on a military base. The larger, more complex activity is in the base hospital, providing services to active-duty, dependent, and retired inpatients and outpatients. The smaller is in the dispensaries, providing services to active-duty personnel and, to a smaller extent, dependents and retirees on an outpatient basis. The hospital pharmacies that we studied dispense an average of

TABLE 7.3.1

ANNUAL COSTS OF PHARMACY SERVICE

	Fort Dix	Jacksonville	March
Number of pharmacy staff	10	11	9
Cost of pharmacy staff	$110,184	$ 94,528	$ 74,133
Cost of drugs	525,037	318,060	310,541
Cost of other supplies and services	7,902	8,554	1,715
Total annual cost	$643,123	$421,142	$386,389
Percent of total hospital operating costs	4.31%	6.24%	6.51%

about 1000 prescriptions per day, or two per minute in an eight-hour day. Depending on the size of the hospital, between 70% and 90% of these are for outpatients.

The average outpatient receives more than one prescription at a time. In certain areas, retired personnel and their dependents create a heavy demand on the pharmacy medications; prescriptions written by civilian physicians are often brought in to be filled. However, we cannot ascertain the extent of this service, since the records do not clearly distinguish inpatients from outpatients. Some ambulatory inpatients obtain their medication on prescription directly from the pharmacy, and others receive prescriptions from clinic visits.

Pharmacy supplies are drawn from hospital supplies. Inventories are taken visually (i.e., without precise count) each day, and requisitions are made up as needed for low stock. No system exists for determining the rate at which drugs are used and should be replaced.

The medicine for inpatients is supplied from stock maintained at the nurses' station or delivered daily. The stock is added to on written requisition to the pharmacy by the nurse (on medical officer orders). In general, the pharmacy serves only a supply function to inpatient needs, rather than providing any professional input.

The medications stocked in dispensary pharmacies meet the needs of patients who can be treated on an outpatient basis. Medical supplies are obtained from the medical supply depot on the base and do not usually depend upon the hospital pharmacy. Dispensary pharmacies carry a one- or two-month inventory of between 500 and 1000 items, depending on the distance to the medical supply depot. Except for draftees in the enlisted ranks who happen to be registered pharmacists, personnel are enlisted men trained as pharmacy technicians without the supervision of a registered pharmacist.

Most dispensaries repackage commonly prescribed tablets and capsules from large stock bottles into labeled vials sufficient for a two- or three-day supply. Cough preparations are similarly repackaged. Some commonly used topical creams and ointments are compounded, and some solutions are made up. Repackaging forms a significant part of the workload.

7.3.2.2. Staffing and Responsibilities

The hospital pharmacy is staffed by commissioned, graduate pharmacists at the rate of one per 200-300 beds. In some instances, civilian pharmacists are also used. The pharmacist, or responsible officer, supervises the outpatient dispensing operation, inpatient medication preparations, stocking at nurses' stations, and requisitions for inventory. He personally handles the narcotics and alcohol stocks, serves on the pharmacy and therapeutics (P&T) committee, and provides information on drugs as requested by the medical staff. Administratively, he assigns responsibilities and trains enlisted personnel in on-the-job training.

Trained enlisted men rather than the pharmacist fill prescriptions under supervision. At the rate prescriptions are filled, close supervision is impossible, particularly during peak load periods. The process of filling a prescription, at best, requires a minimum of three minutes. Preparing a thousand prescriptions per day requires 50 man-hours per eight-hour day or about six men. Additional staff is required for upkeep of the pharmacy, inventory taking, requisitioning new supplies, or additional nonpharmacy military duties required of most enlisted men. In addition, there is a peak in demand in the latter part of the morning and the latter part of the afternoon, so a larger staff is needed if patients are not to be kept waiting unduly long.

Most hospital pharmacies are open to fill outpatient prescriptions for a seven- to eight-hour period during the day but are staffed at all times for inpatient and emergency needs. Where 24-hour coverage is not practical, a night drug cabinet is maintained, or other hospital staff have access to the pharmacy for necessary medications, increasing the chances for errors and pilferage.

Drug information is disseminated to the medical staff through the pharmacy, and therapeutics committee, on demand from the pharmacists (which is infrequent), or by drug exhibits which are set up periodically by pharmaceutical manufacturers and represented by a company salesman.

There is little checking by the pharmacist as to whether the medication dispensed is as specified, whether it is compatible with other medications being simultaneously prescribed, or whether the strength or quantities of medications are consistent with the medication (i.e., side effects, no response, etc.).

7.3.2.3. Preparation and Dispensing of Drugs

As mentioned earlier, the base hospital pharmacy provides the medication for both inpatients and outpatients; the dispensing system and record keeping differ considerably.

When an outpatient receives a prescription from a physician, he carries it to the pharmacy and presents proper identification. The enlisted personnel then process it and provide the specified medication to the patient. The written prescriptions are maintained in the pharmacy files for a period of time (which varies among hospitals) and then are stored. Figure 7.3.1 is a schematic representation of this dispensing process.

For inpatients, the physician writes the necessary daily orders for those who require medication on an order sheet, which is interpreted and transcribed by the nurse on to a patient medication card. The medication may be available on the floor inventory if it is in frequent demand; if not, it is requisitioned from the pharmacy. The pharmacist does not see the physician's original order. The pharmacy prepares the necessary quantity for one dose or for one or two days, as ordered. If the patient is to be on one medication for a prolonged period, the pharmacy will provide an inventory at the nurses' station on the floor. Figure 7.3.2 shows schematically the inpatient medication dispensing system.

If the physician changes medication and a surplus exists on the floor, it is returned to the pharmacy inventory. The necessary handling in the pharmacy, (i.e., pouring surplus into stock bottles) tends to jeopardize the product integrity and represents a possible source of contamination.

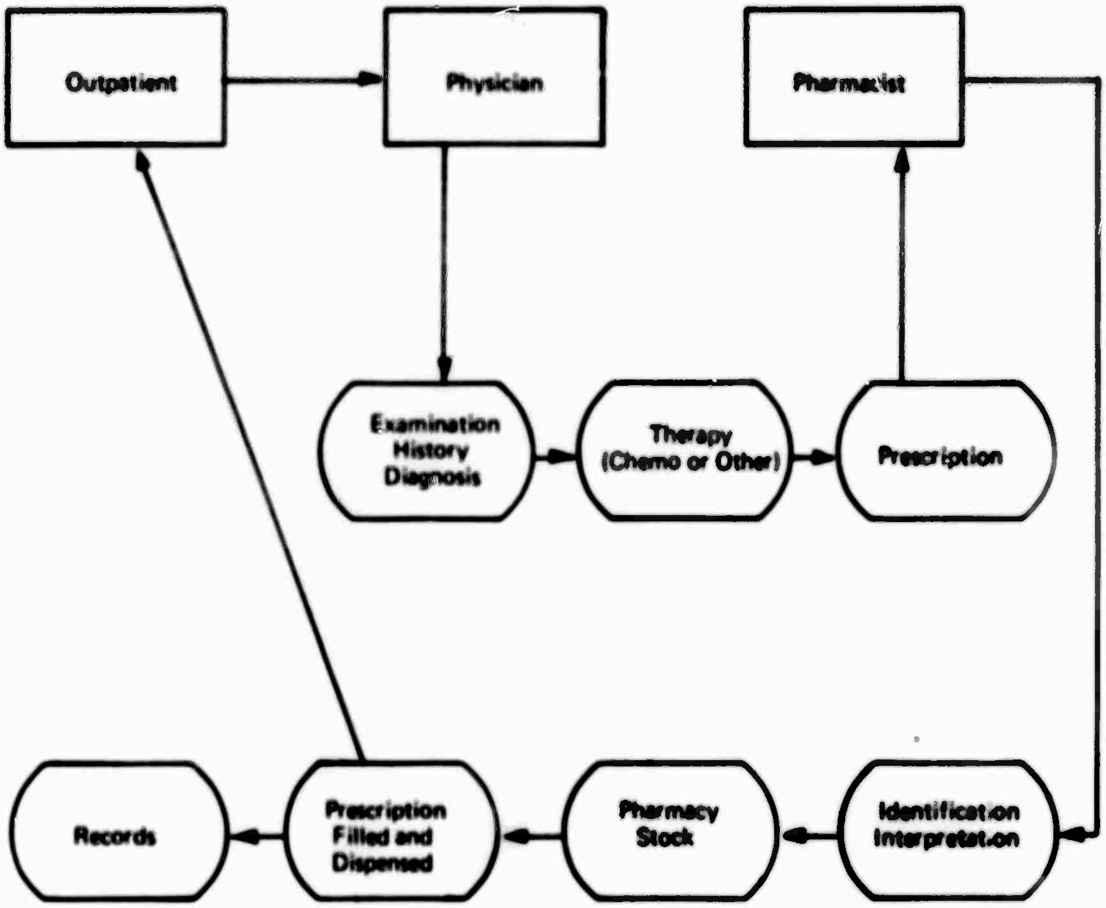

FIGURE 7.3.1 PROCESS FOR FILLING A PRESCRIPTION FOR AN OUTPATIENT

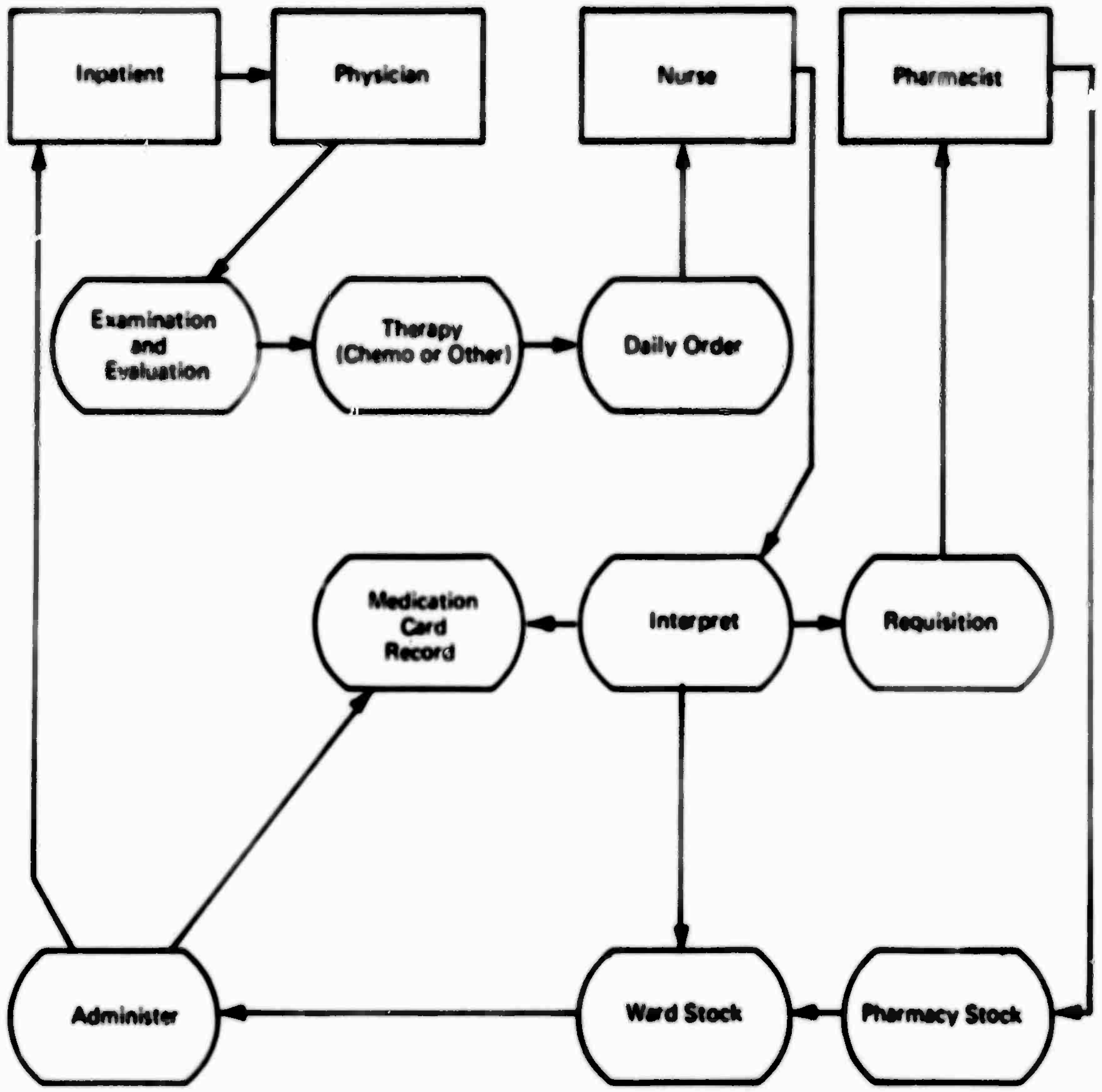

FIGURE 7.3.2 PROCESS FOR FILLING A PRESCRIPTION FOR AN INPATIENT

In two separate studies[1,2] the time required for inventory taking, ordering, preparing for administration, and recording by nurses was found to average approximately 36 minutes per patient per day. This time includes consideration of preparation for regular medications, STAT, PRN, and narcotic orders. In the University of Iowa study, trained observers determined that errors occurred in the preparation and administration of medicine to patients in 5.26% of the orders. Included were errors of omission, errors in medication, errors in route, errors in interval, and errors in amount. The largest single category was errors of omission, which accounted for 2.04%.

7.3.3. UNIT PACKAGING

7.3.3.1. Background

The terms unit dose, unit of use, and unit packaging have each been identified with discussions concerned with increasing efficiency in administering medications to patients. These descriptions specifically refer to the packaging of a medication into a quantity suitable for a patient to take at one time. Since many medications have dosage ranges for different indications or for particular age groups, the unit of medication referred to from this point in the discussion will be the unit package, defined as containing one tablet or capsule for oral solids and the lowest common unit of use for liquids and injectables. For example the active ingredients in liquids is often described as X milligrams per five milliliters. Injectables, somewhat more complicated, describe the active ingredient in milligrams per one, five, or ten milliliters. Therefore, the unit package for oral liquids will be approximately one teaspoon of measure and injectables would represent the most common minimum dose.

The unit package and its delivery system have evolved over many years, in order to maximize the safety and efficiency of drug delivery and utilization in the hospital. The value of such a package and system has been brought into sharp focus in recent years because of the more business-like reappraisal of hospital functions and the costs associated with them.

A study at the University of Arkansas Medical Center several years ago disclosed a range of medication administration errors which further emphasized the need for more appropriate medication identification throughout the delivery system in the hospital. These errors are increased during peak load periods. Although no studies have been reported, it is our opinion that similar errors can easily occur in the preparation of medications for outpatient dispensing from the pharmacy.

The need for a more precise method of product identification has been recognized as important to improved patient care. Faster, more efficient handling because of clearer identification demonstrably reduces errors. The design of the unit package insures product integrity and allows the patient to receive the precise medication prescribed by the physician.

7.3.3.2. Present State of the Art

The use of the unit package is not new. In the injectable form, the morphine syrette was widely used by the military during World War II and the Korean conflict. Rectal suppositories, in many instances, were individually wrapped and identified, and topical sulfa powders were packaged in units for combat medical kits. Physicians have long been supplied with sample packages from many pharmaceutical manufacturers consisting of individual tablets in cellophane, plastic, or foil strips grouped in four or six tablets, commonly in a foldover cover with full product disclosure and identification. During the past few years disposable syringes and needles, either empty or prefilled, have represented a significant move toward the acceptance of unit package medication.

More recently, a wider variety of medications has been made available in unit packages that enhance safety, reduce dosage error, are tamper-proof, reduce waste, and discourage pilferage.

Experiments on unit packages have been conducted in a significant number of hospitals throughout the United States, from which various packages and systems have evolved to meet specific needs.[2-9] Table 7.3.2 summarizes the differences in activities in dispensing medication to in-patients between traditional and unit package systems.

TABLE 7.3.2
DIFFERENCES IN ACTIVITIES IN DISPENSING MEDICATIONS UNDER TRADITIONAL AND UNIT PACKAGE SYSTEMS

	Traditional	Unit Package
1.	Doctor writes order	Doctor writes order
2.	Nurse transcribes order	Nurse transcribes order
	a. in nurse's file	a. in nurse's file
	b. on patient medication record	b. on patient medication record
	c. on pharmacy requisition	- - - - -
3.	Requisition to pharmacy	Original order to pharmacy
4.	Requisition checked by pharmacist	Order interpreted by pharmacist
5.	Medication placed in bottles labeled for patient	Medications placed in patient drawer
6.	Medications delivered to nurse station	Medication delivered to nurse station
	a. orders checked against requisition	a. orders checked against nurse's file
	b. bottles placed on shelf or in cabinet	- - - - -
7.	Medications prepared for administration	- - - - -
	a. patient medication records lined up	- - - - -
	b. souffle cups lined up with records	- - - - -
	c. medication bottles removed from shelf or cabinet	- - - - -
	d. medications placed in cups	- - - - -
	e. medication bottles replaced on shelf or in cabinet	- - - - -
8.	Medication wheeled to patients	Medication wheeled to patients
9.	Medication administered	Medication administered
10.	Administration recorded	Administration recorded

7.3.3.3. Advantages of Unit Package Systems

The advantages claimed for unit packages and systems as they are currently being used are as follows:

- Identification of each medicine up to the time it is consumed by the patient,
- Reduction in preparation time and, in the case of liquid, reduction in time of administration,
- Prevention of possible contamination of medication,
- Reduction in medication errors,
- Provision for more accurate inventory control in the pharmacy and at the nursing station,
- Elimination of waste when unused medications are returned to the pharmacy,
- Better accountability for accurate medication charges,
- Reduction in drug inventories, deterioration, obsolescence, pilferage, and capital investment,
- Easier adaptation to automated dispensing machines.

7.3.3.4. Disadvantages of Unit Package Systems

The disadvantages observed among the many hospitals which have instituted unit packaging and distribution systems include the following:

- Storage space requirements are greater than with traditional packages,
- Cost per unit is greater,
- No standards have been established with respect to size and printed matter on unit packaging,
- Unit packaging is less satisfactory for outpatients, because no automatic dispensing equipment is now available,
- The range of dosage and form requirements is hard to accommodate in unit packaging,
- Not enough products are available in unit packages.

From the point of view of patient care the advantages outweigh the disadvantages. Nevertheless, cost, lack of standardization, staff resistance, and nonavailability of a wide range of products have created enough resistance in hospitals to discourage any broad commitment to unit packaging by any of the pharmaceutical manufacturers.

7.3.4. A SYSTEM FOR AUTOMATIC DISPENSING OF DRUGS

The concept of an automatic dispensing machine for drugs is not new, and several prototype machines have been developed. While some technical problems exist, it is obvious that they can be solved since dispensing pills is not much different from dispensing cigarettes or candy bars. We shall discuss the special requirements for an automated dispensing machine below.

What is equally important is the system by which drugs are ordered, checked, and distributed to inpatients and outpatients. We have already observed that from 70% to 90% of the prescriptions handled by pharmacies in military hospitals are for outpatients. For this reason, outpatient prescriptions assume much greater importance in military hospitals than in civilian hospitals, and the system should be designed with this in mind.

A good system should be convenient for the prescribing physician, for outpatients, for the nursing staff caring for inpatients, and for the pharmacy staff. It should keep transcriptions to a minimum. Ideally, it should allow checking the prescription for authenticity and for appropriateness, given the ailment and the other drugs a patient may be receiving. We have given thought to all these considerations in devising the system to be described.

It is essential that the system simplify the procedures for filling outpatient prescriptions if it is to make much of a dent in the problems of running pharmacies in military hospitals. Accordingly, automated dispensing equipment should be installed in the pharmacy near the outpatient waiting area. Examination of dispensing records shows that, although the formulary includes thousands of drugs, only about 200 are used in 80% of the prescriptions. Therefore the automatic equipment should handle about this number.

For several reasons it is desirable that the drugs be strip-packaged. First of all, strip-packaging vastly simplifies the mechanical design and increases the reliability of a machine which must be capable of dispensing a variable number of tablets at one time. Second, it provides foolproof identification of the drug. Third, it eliminates deterioration due to humidity or contamination due to breakage of a capsule. Finally, it eliminates the need for vials.

Fifty or a hundred strip-packaged pills are, of course, somewhat more bulky than the same number in a vial, but this should not be objectionable, since even 100 strip-packaged pills will fit in a pocket or purse. It is also true that the requirement for storage space would be somewhat increased, though not be an intolerable amount, especially since strip-packaged tablets can be stored in boxes instead of jars, so that storage space is more efficiently utilized.

What we visualize, then, is a machine located inside the pharmacy and capable of dispensing 200 different drugs automatically in response to an order for any number entered from a card reader. When an out-patient presents a prescription at the window, a card is punched as shown in Figure 7.3.3. The card is the permanent record of the transaction, to be used as required for checking, for inventory control, and for whatever other purposes may be desirable. The original prescription is also kept on file. The card reader activates the machine, which dispenses the required number of pills and prints a label to be affixed by hand to the strip, giving all required additional information as shown in Figure 7.3.4.

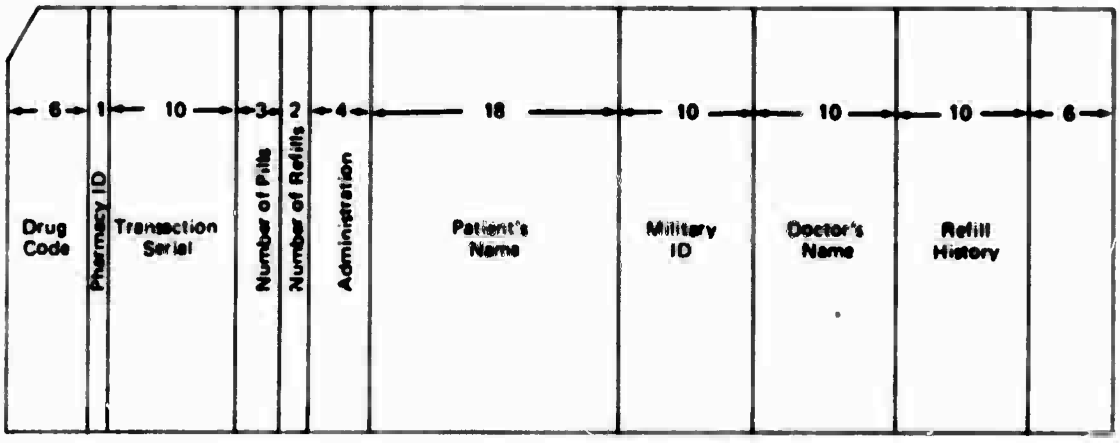

FIGURE 7.3.3 PHARMACY TRANSACTION CARD FOR OUTPATIENT PRESCRIPTIONS

This card is prepared when an outpatient presents a prescription at the pharmacy. It is a standard 80-column card, which can already have the drug code punched in, though this is not necessary. The pharmacy identification is provided in case these cards are to be merged with those from other pharmacies. The transaction serial is read from a counter, which automatically increments by one as each card enters the reader immediately after punching and verification by the card punch operator. The serial number contains by implication the date (e.g., transactions 110471-111516 were entered on 10/21/70). The next six items are entered from the prescription. Administration instructions are encoded in four columns; e.g., the first column is the number of pills to be taken at one time, and the remainder indicate the time and frequency: "at bedtime," "before each meal," etc. The refill history is punched once when the prescription is first entered, and subsequent columns up to ten are punched each time the prescription is refilled. The remaining six columns are reserved for equivalent transactions for inpatients.

10 MG LIBRIUM

SERIAL 110471 10 - 21 - 70

DOE, MRS. JOHN 04033174

DR. SMITH - WALSON ARMY HOSPITAL

TAKE ONE CAPSULE BEFORE EACH

MEAL AND AT BEDTIME

THIS PRESCRIPTION MAY BE REFILLED

4 TIMES

FIGURE 7.3.4 GUMMED LABEL PREPARED BY DISPENSING MACHINE

The serial number provides (by implication) the date. It also establishes the order in which the cards will be filed and thereby furnishes a readable means for resorting the cards if they get mixed up. When a patient presents his old label for refill, the card is taken by hand from the file, the refill history is updated, and the printer prepares a new label.

Obviously, the punching, reading, and printing equipment can be used for all prescriptions, not just those for which automated dispensing is provided. The cards can be used for other purposes, off-line or on-line as desired, as discussed below.

To obtain some of the same advantages for inpatients, hospitals should, we believe, change their present practice of keeping drug supplies at nursing stations. One reason is to relieve the nurses of the work of keeping prescription records and counting out drugs; enlisted personnel in the pharmacy can do this more cheaply, and the pharmacist (or, as we shall suggest, a computer) can review the prescription for conformity to manufacturers' recommended doses, strengths, and absence of contraindicating conditions. Another reason is that the use of light care facilities will lead to smaller hospitals, which can operate efficiently with a single central pharmacy.

When a central pharmacy distribution system is used, the physician writes his order on a form that provides a carbon copy. The copy is filed in a loose-leaf folder at the nurses' station, and the original is sent to the pharmacy. From this order, the pharmacist makes a punched card like that described for outpatients, except that it contains in addition the ward and bed numbers in the last six columns. A single day's supply is counted out (either automatically or manually, depending on the drug) and placed with the label in a drawer, designated for the bed number, in a cart designated for the ward. Drugs not among the 200 which have been strip-packaged would be put in a throw-away plastic container to which the label could be affixed. When the complete drug inventory for the ward for the day (which includes prescriptions from previous days) is complete, the cart is delivered to the ward. When they arrive at the ward, the drugs supplied can be checked against the nurse's copy of the prescriptions, thus providing an independent check on accuracy. The nurse then wheels the cart through the ward, administering drugs as prescribed during three or four scheduled drug administration periods.

Hospitals which have tried this scheme have found that one collection of new prescriptions and cancellations of old prescriptions in the morning following rounds, and one delivery of the loaded drug cart as soon as possible thereafter, is often sufficient. Obviously, if circumstances dictate, these activities can be scheduled more frequently. Emergencies would be handled individually by telephone. Non-prescription drugs would be kept in the cart and resupplied by topping off each day when the cart was returned to the pharmacy. Narcotics would be kept in a locked drawer in the cart and would in any case constitute no more than a one-day supply. There would be no drug supply at the nurses' station except for the cart. Special carts containing an appropriate inventory would be provided for the emergency room and for surgery.

7.3.5. AUTOMATIC DISPENSING MACHINES AND STRIP-PACKAGED DRUGS

As we have remarked, there are no important obstacles (except possibly cost and space) to building an automatic dispensing machine.* The drugs intended for this machine would be packaged on a strip 1-1/2 inches wide, one tablet to a bubble and one bubble per inch. The paper backing would be printed with the name and dose of the drug and other necessary information such as the manufacturer's name and the expiration date. The strip would be punched with holes along the edges for a sprocket drive in the dispensing machine. Strips would be supplied in boxes with the strips inside folded in accordion pleats so that they would feed easily out of the box. A box 18 in. by 18 in. by 1-3/4 in. would contain 1000 tablets. A tear-off opening would expose the end of the strip, which would be fed by hand into the drive mechanism; the box would remain as the holder for the strip in the machine.

The dispensing module containing the box and drive mechanism for each drug would be 2 in. by 24 in. by 19 in. high. (See Figure 7.3.5.) Thus, a machine with 200 modules would be 24 in. deep, 80 in. high (four tiers plus a base), and 100 in. long. Its back would be open for replacement of the disposable supply boxes.

*Automatic dispensing machines are commercially available, but they do not embody the features contemplated here.

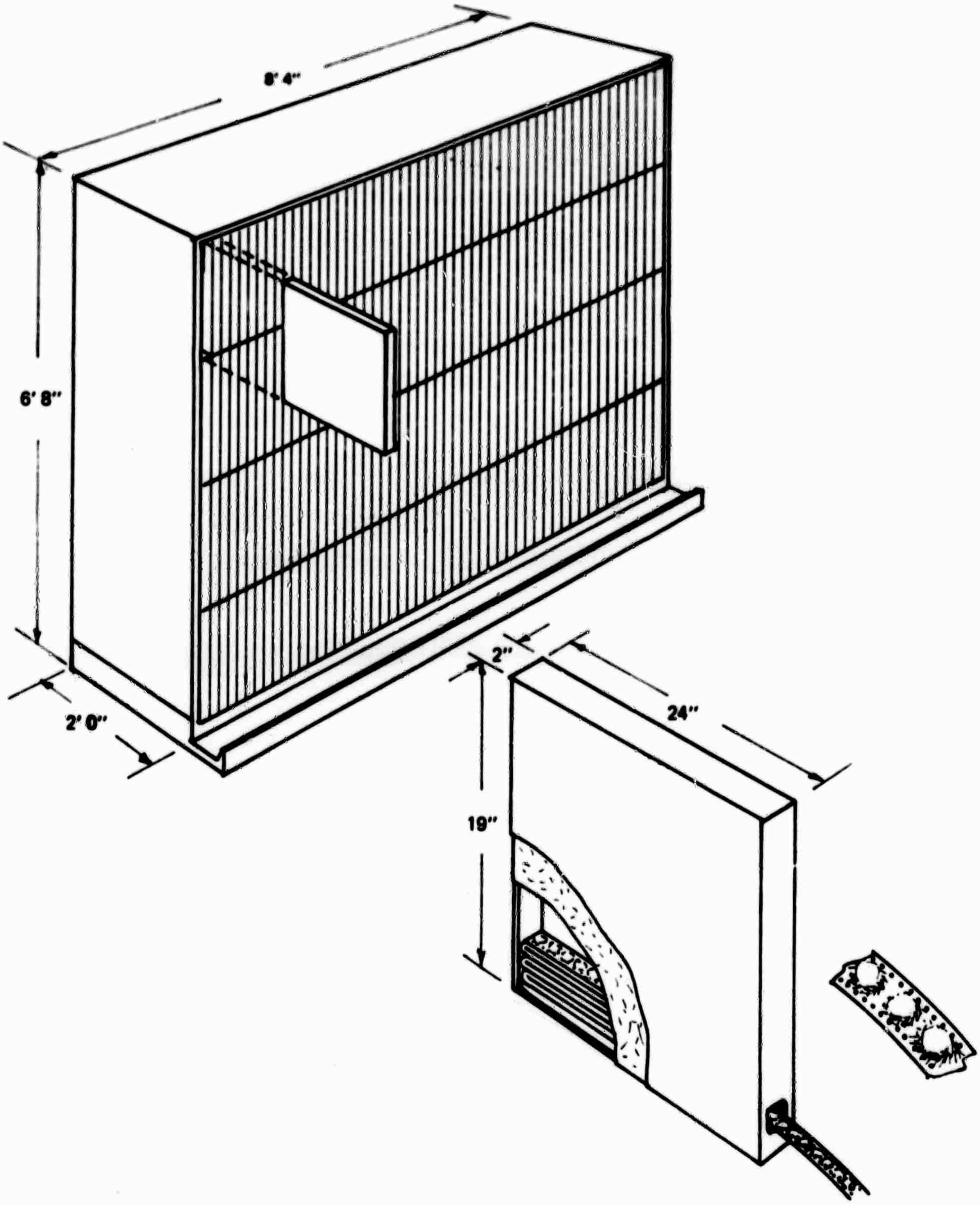

FIGURE 7.3.5 SKETCH OF AUTOMATIC DISPENSING MACHINE FOR 200 DRUGS

The drive mechanism would have to count sprocket revolutions to dispense the correct number of tablets, and this same counter could be used to signal when the end of the strip was near, say, by lighting a light on the rear of the machine, so that a clerk could refill the bin. Each strip could have a gummed tail to which the new strip could be attached.

One of the major reasons that such machines are not in widespread use today is that there has been no strong impetus for drug suppliers to standardize strip packaging; indeed, competition has tended to proliferate various strip configurations. The Department of Defense is a big enough customer to enforce standards, however, and several avenues are open:

- The hospital itself could undertake strip packaging with a specially designed machine. We are not inclined to favor this alternative, because it will be hard to train operators and to assure standards of operation which maintain product integrity.
- DOD could write specifications requiring that drugs in the formulary of 200 be supplied by the manufacturers on strips as described. We believe this would be feasible but not as practical as the third alternative below.
- DOD could buy through one of the commercial repackaging houses. Since the packaging machinery would initially be of special design, it would not have to be designed and installed in many different pharmaceutical houses but only in one (or a few) repackaging houses, thus confining initial problems to only one (or a few) places. Repackaging firms can be required to maintain the same standards as those of the original manufacturers.

In time, DOD specifications are likely to become standard, and normal competitive mechanisms will keep the price for strip packaging about the same whether drugs are bought from the original manufacturer or from a repackager.

Currently, the additional cost of strip packaging amounts to about one cent per tablet, or about 15% of the cost of drugs, but it could be less.

The dispensing equipment we have described would cost about $150,000 to develop, and we expect that the machine could be made to sell for about $30,000 ($150 per module). The modules would be of molded plastic, and each would contain its own stepping motor. Since prescriptions can be entered only as fast as they can be punched (say, one every 20 seconds, if there were three punch machines), only one module would need to be energized at a time. Thus, a single power amplifier could drive 200 modules with its output switched among them.

7.3.6. COMPUTER SYSTEMS

Largely as a means for reducing the manual transcription process, we have introduced a card punch, a card reader, and a label printer in the pharmacy. However, once the prescription data have been encoded, a variety of other possibilities for a computer system are opened. A small computer is obviously necessary to allow the expansion of data on the card into the label format. Fairly large files (about 5000 bytes) will be required for the instructions for administration, so one is quickly led to considering disk memories. With a disk memory available, more elaborate computer operations than those described so far are possible. With regard to pharmacy functions alone, the following operations are eligible for consideration:

(1) Drug inventory
- Control information - storage figures
- Usage rates
- Replenishment of stock and purchasing information
- Vendor or source information for each drug (manufacturers, wholesalers, etc.)
- Expiration dates for stored medications
- Storage requirements (refrigerated, frozen items, etc.)

(2) Retrieval of drug data
- Doses and forms
- Usage (symptoms of diagnosis: as for diuretics, antibiotics, etc.)
- Interactions with other drugs or with foods

- Antidotes
- Duplications of generic medications
- Effect of drugs on laboratory tests
- Routes of administration

(3) Printing (in any language or symbol)

- Hospital formulary
- Prescription and prepack labels
- Auxiliary and cautionary labeling

(4) Charging, accounting or statistical information

- Medication scheduling
- Personnel scheduling by workload
- Work apportionment
- Budgetary information

(5) Formulas for pharmaceutical preparations

- Ingredients with quantities
- Costs of manufacturing

(6) Reagents with diagnostic tests (also, drugs affecting results)

(7) Patient medication histories

(8) Index of manufacturers' identification numbers (Parcode, Identicode, etc.)

It is easy to conceive computer systems which perform not only these functions but which combine other interactive functions such as ordering from the nurses' station or making the prescription part of a computer-based patient record. (We deal with these possibilities in Section 7.) We believe, however, that it is unwise to be too ambitious at this time. Instead, a dedicated computer system (that is, in the case of the pharmacy, a computer system dedicated to pharmacy functions and not interactive with other functions except through buffers like the card records we have described) should be developed first. The problems lie not in hardware but in software. Once workable subsystems have evolved in pharmacy and in other parts of the hospital, the problems of interfacing them and providing executive control can be attacked. Naturally, the ultimate problems of interfacing should be borne in mind in developing hardware and software for subsystems, the main ones at this time being modular construction of routines and consistent construction of data files.

While all of the functions listed above are possible in a dedicated computer system, we believe that the most useful are in items (1) and (2), inventory data and drug data. The functions itemized under inventory data are valuable because these data are dynamic and difficult to keep track of without a systematized approach. The functions itemized under drug data are valuable because they help to avoid serious mistakes. The formulary is already so large that most physicians have difficult keeping up with incompatibilities, contraindications, and other essential data.*

The inventory control system is relatively straightforward, in the sense that numerous analogous systems exist and designing the software is a matter of adaptation rather than creation. The system utilizes the prescription data for stock depletion information. To the system we have already described, it would be necessary to add files containing the complete formulary, formulas for computation of usage, stock levels, and reorder points. It would also be necessary to prepare cards for receipt

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*In this connection we have given careful thought to the role of the pharmacist in prescribing drugs in a hospital. Pharmacists receive a great deal of training in the available forms of drugs, their utility, their side effects, and so forth. They argue with considerable justification that they are better equipped than many physicians to make judgments about the efficacy of a pharmaceutical regimen, given the diagnosis and other pertinent facts about the patient. Therefore, they believe they have a professional role advising the physician about the drugs he prescribes. The argument is perfectly sound, and in many hospitals the pharmacists play exactly that role. Nevertheless, we have concluded that it makes little sense to recommend that pharmacists in military hospitals should perform this function to any greater extent than they do now. This is not a reflection on the competence of military pharmacists, but a reflection on the conditions under which military pharmacists and military physicians operate. In the instances where pharmacists have developed this role effectively, it has been necessary for them to achieve a personal rapport with and to obtain the confidence of the medical staff. While this is obviously not impossible in military hospitals, the relatively short tours of duty make it difficult. If and when this confidence does of stock. No additional hardware for these functions would be necessary, and software, as we have said, could be adapted without great effort.

A system for utilizing drug data in assessing the acceptability of a new prescription presents more problems. Although such a system might be contemplated for outpatients, it would not appear to be greatly needed, because outpatients are seldom so ill that they are taking numerous drugs. In addition, the problems of learning what other drugs an outpatient is taking and entering these data in the computer are formidable. What could be done, however, is to include on the label warnings about other common drugs (such as alcohol) which react badly with the prescribed drug.

For inpatients a system of cross-checking compatibilities has more obvious merit. It is not uncommon for inpatients to be receiving six or eight different medications by various routes. A computer program which checked each medication against all of the others for contraindications is certainly feasibile. Expanding this program to check against all diagnoses and all foods which imply contraindication is also possible. We recognize that the pharmacy is not ordinarily made aware of diagnoses or diet for patients whose prescriptions they handle; thus, in a development program it might be worthwhile requiring the prescribing physician to include this information with a prescription. This approach comes close to the problem-oriented record discussed in Section 7. Because acceptance of the problem-oriented record is probably some time away, we suggest that the dedicated computer in the pharmacy be capable of being modified to

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develop, as it well may through the pharmacists' activities on the Pharmacy and Therapeutics Committee, it obviously cannot help but be beneficial. However, if this confidence does rot develop or is not deserved, the medical staff will regard the pharmacist's advice as unwarranted interference. For this reason, we have concluded that a more reasonable way to attack the problem of providing a physician more detailed information on the merit of a contemplated drug therapy is through computerized review of a prescription.

accept and check against diagnoses, but that it be designed at first only to print out lists of contraindications with the label, just as we have suggested for outpatient prescriptions.

The data necessary to do this are compiled already in places like the Physicians' Desk Reference to Pharmaceutical Specialties and Biologicals. About 10,000 items are listed, of which about half are carried in the formularies of military hospitals. The lists of contra-indications for each drug are often very long, running to over 100 specifications. A complete listing of all contraindications would be perhaps 500,000 items, each of which would require about 100 bytes in memory; such a formidable requirement cannot be justified. However, an examination of the listings shows a large amount of grouping, and the memory requirements could be substantially reduced by referring to groups. Coding the items (using numbers instead of English words in the memory) could bring memory requirements down to a manageable size. Establishing the feasibility of this approach is a matter for further R&D.

For the immediate future -- that is, installation in the prototype hospital -- we recommend development of automated dispensing equipment, a card system for prescriptions as described, and a pharmacy inventory control system, all operating under a dedicated computer in the pharmacy.

7.3.7. IMPACT OF THE RECOMMENDED SYSTEM

The recommended system can be expected to eliminate some of the errors in administration of drugs, though this benefit is not one to which a cost can be attached. It should also reduce losses due to contamination, spillage, and pilferage, though we have no basis for quantifying this gain. However, since drugs are the largest element in the cost of pharmacy services, even a small reduction in such losses can lead to a large dollar saving.

Two studies[1,2] indicate that 7-10 minutes out of the 16 minutes required, per patient per day can be saved from the nurses' time in the medication process by transferring to the pharmacy the tasks of entering the prescription and counting out the tablets. On a 40-bed ward this amounts to between five and seven hours of nurses' time per day, which presents the problem of getting rid of a fraction of a nurse. If the wards were larger, or the staffing were flexible, this saving could be realized. Since both these possibilities exist, we shall count this saving, though we acknowledge that in some situations the saving may not be realizable. The saving in nurses is partly offset by the additional staff required in the pharmacy to prepare the carts. The increase in man-hours should be exactly that saved the nurses, that is, 7-10 minutes per inpatient per day, the delivery time for the carts can be regarded as a cost, but it replaces the replenishment of the drug supply presently kept at nurses' stations and therefore represents no increase. Each cart entails a capital expense of about $400, or $80 per year when amortized over five years.

Currently it takes about three minutes to fill an outpatient prescription. With the automatic system we have described, this time can be halved (one minute to punch the card and 30 seconds to affix the label and hand out the prescription). Dispensing about 1000 prescriptions per day requires 50 man-hours now, and this can be reduced to 25, thus eliminating three pharmacy technicians. Additional recordkeeping and inventory activities performed by the computer may save staff time, though experience indicates that this is seldom true.

We shall not include development costs for the dispensing equipment (previously estimated at $150,000) or for the computer software (about $70,000 for the dispensing and inventory functions), since these are legitimately spread over all military hospitals.

There are additional capital costs for the dispensing equipment ($30,000), for three keypunches ($12,000), one card reader ($10,000), one printer ($20,000), and a medium-sized computer with a disk memory ($80,000). If these costs are amortized over ten years, the annual cost is $15,200. Additional space in the pharmacy for this equipment is estimated to be 120 square feet, which at $50 per square foot, amortized over 25 years, amounts to $240 annually. Unit packaging increases the cost of drugs packaged in strips by 15% and applies to 80% of the drugs. The aggregate of costs and savings is summarized in Table 7.3.3.

TABLE 7.3.3
ANNUAL COSTS AND SAVINGS ATTRIBUTABLE
TO A UNIT-PACKAGED MEDICATION SYSTEM

	Ft. Dix	Jacksonville	March
Number of beds in acute hospital*	546	295	180
Number of nurses saved	10	5	3
Number of additional technicians required to prepare carts	10	5	3
Number of carts required	19	13	10
Number of dispensing technicians saved	3	3	3
Annual cost of all drugs	$525,037	$318,060	$310,541
Salaries of nurses saved (@ $9000)	$(90,000)	$(45,000)	$(27,000)
Salaries of technicians required (@ $6000)	42,000	12,000	---
Amortized cost of equipment	16,700	16,200	16,000
Amortized cost of additional space	240	240	240
Additional cost of drugs	63,000	38,000	37,000
Total additional costs	$31,940	$21,440	$26,240

*Excluding beds in light care facility.

As this analysis makes clear, the basis on which unit packaging and automated dispensing must be justified is in terms of patient benefit (due to reduced errors) and in terms of reduced loss (due to the unquantified reduction of contamination, spillage, and pilferage). If the latter benefit amounts to even 9% of the annual cost of drugs, then these innovations are clearly justified. As it is, justification is not clear-cut. However, if unit packaging were more common, the cost might be less than the one cent per tablet, which is the current cost. Also, we have been generous in our estimate for the cost of computer equipment, since we want to use the equipment for other purposes as well. The cost of computers and bulk storage has been decreasing and is likely to decrease still further. Accordingly, we believe that the potential benefits of unit packaging and automated dispensing hold enough promise to warrant further R&D.

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7.4. LINEN SERVICES

The procedures and costs for providing linen service have been investigated at each of the military hospitals that we have visited. In this chapter we review the practices observed, draw comparisons, and point out the shortcomings of the available data. For more reliable and realistic estimates of costs we draw on data developed in the civilian market. We also present cost figures for typical disposable items and discuss their advantages and disadvantages. Finally, we draw conclusions and develop recommendations for linen service in a new generation hospital.

7.4.1. WALSON ARMY HOSPITAL, FORT DIX, NEW JERSEY

General linen service at WAH is handled through the Supply and Services Division. The staff assigned to this function consists of 12 civil servants. In addition, ambulatory inpatients from the Medical Holding Company provide the equivalent of two full-time workers. This staff collects, sorts, and distributes linens throughout the hospital and arranges transport to and from the base laundry, which is run by the Quartermaster. Truck transport is provided by the base motor pool.

White clothing worn by the medical staff, such as doctors' coats, nurses' uniforms, and corpsmen's shirts and trousers, is handled separately by the Medical Holding Company and is not the responsibility of the Supply Division staff mentioned above. However, the Supply Division does take care of the uniforms worn by food service attendants.

One room in the hospital, about 1000 square feet in size, is used for storage of clean linens, and another room about half as large is used for sorting and temporary storage of soiled linens. Twelve pushcarts are used to move linens about the hospital; six for clean linens and six for soiled linens. Ward personnel notify the Supply Office daily as to their linen requirements and these linens are delivered as requested. A one- or two-day buffer stock is maintained in the wards in their linen closets.

No precise counts are maintained by the hospital staff of linen use, but it was estimated to average about 13,000 pieces per day of all types. Moreover, no running inventory of linen stock is kept. Total value on hand was estimated to be about $300,000. Most of the new stock is kept in a separate warehouse about 2 1/2 miles from the hospital.

Because of the lack of detail in the accounting system, the true cost of linen service at Walson Hospital is impossible to determine. Certain gross items can be identified and priced, but others are hidden in various aggregates. The known figures are as follows:

	FY 1968	FY 1969
Supplies purchased	$173,000	$120,000
Civilian labor	75,000	61,000
Laundering cost	-	176,000

It should be noted that the laundering cost given above is an estimate supplied by the Quartermaster of the proportionate share of the total base laundry operating costs that he would assign to the hospital. It is not actually a line item in the hospital budget, and there is no transfer of funds. In other words, the hospital gets its laundry done free, so far as its operating budget is concerned. The hospital pays only for the linens it buys and for the civilian labor it assigns to linen handling. Moreover, the hospital does not pay for any trucking and transportation, and neither does the laundry. That is all included in the motor pool expense. Also, no military labor is charged to the hospital budget, nor are any utilities.

Under these circumstances there has been no reason for the laundry to try to develop a price list, item by item, for its services to the hospital, nor has the hospital felt any need to allocate linen service costs to separate functional or organizational groups. Two effects can be noted. One is that no meaningful comparisons with the costs of alternatives can be carried out. The other is that there is no direct incentive to economize on linen service. So far as the hospital administration is concerned, it is enjoying a bargain and any change, either to another laundry service or to increased use of disposables, would only increase its visible costs. So far as a consuming unit is concerned, linens are free and no one has to account for linen use, so it does not make sense to be frugal.

It might be mentioned that despite the "free" laundry service, Walson has switched largely to disposable diapers because of their convenience.

Apparently the added expense has not been large enough to be a deterrent. Also, disposable patient bibs are used in the dental clinics, and some disposable washcloths in the hospital. Walson does not use disposable surgical packs or drapes; these are all launderable items processed through the central sterile service.

No specific checks are made on pilferage of linens at Walson, but there seemed to be a confident feeling on the part of the Supply staff that this is quite low. Nevertheless, some sort of routine inventory count and comparison with purchase and salvage records would seem to be prudent. Apparently, this is not being done now.

7.4.2. MARCH AIR FORCE BASE HOSPITAL, RIVERSIDE, CALIFORNIA

General linen service at March AFB Hospital is handled through the Materiel Service. The staff assigned to this function consists of three enlisted men and one civilian seamstress who does sewing and repair work. Separate hampers are kept in the wards for soiled sheets, pillowcases, gowns, etc., and are wheeled down to the loading dock daily by ward corpsmen. Replacement linens as needed are then picked up and carted back to the wards. All personal clothing, such as doctors' coats, nurses' uniforms, corpsmen's shirts and trousers, is carried to the loading dock by individuals and dropped off on the way in or out. Fresh clothing is stored in racks alphabetically according to sewn-in name tags, and people pick up their own uniforms as needed. Thus, the Materiel Service only deals with linens at the loading dock and the main storage room, and does not do any in-house pickup or delivery.

Transportation between the hospital and the base laundry, which is run by Base Supply with mostly civil service employees, is provided by the base motor pool at no cost to the hospital. The laundry does charge the hospital for its services, according to the following price list:

General laundry	.10 per piece
Doctor coats	.40 each
Nurse uniforms	.40 each
Shirts (except fatigues)	.25 each

Trousers (except fatigues)	.35 each
Fatigue shirts and trousers	.30 each
Coveralls	.35 each
Flight suits	.25 each
Rags	.05 per pound

Final sorting and counting are done at the laundry and total charges are rendered monthly. The hospital does not allocate charges to separate cost centers within the hospital because it makes no count of how much ea 'ı ward or clinic uses. They do get a bimonthly count of how many items of each type are laundered. During August and September of 1969, for example, this totaled about 71,000 pieces. The largest single usage was sheets, about 15,000.

Note that the artificiality of the laundry pricing schedule, under which every general item costs 10 cents, whether it is a sheet or a washcloth, renders direct comparison with alternatives difficult unless one takes a specific distribution of usage among types of items. It also leads to efforts to discourage use of small items. For example, the hospital is pushing disposable washcloths, which cost just over a penny each, in place of woven washcloths which cost 10 cents to launder. However, the ward staffs are not taking too kindly to the switch and prefer to keep using the standard cotton terry cloth variety.

From the available accounting statements we find that the laundry bill for FY 1968 was $69,000, for FY 1969 it was $78,000, and for the first quarter of FY 1970 it was $22,000. The total cost of linen service in FY 1969 was listed as $99,000, which purportedly included materials and the salary of one civilian but no military pay. From these figures we can derive an estimate of about $12,000 as the annual expenditure for linens, which seems extremely low but is in line with linen expenditures of just over $3,000 shown on the books for the first quarter of FY 1970. On the other hand, the linen inventory on hand was valued at about $25,000, which would mean about a two years' supply, yet we were told that linen inventories were kept low because of lack of storage and that they reordered fairly frequently. The discrepancies here could not be resolved without a detailed audit of requisitions, and since this specific inventory problem was not directly connected with evaluating laundry service, it was not pursued.

There is no specific check made of inventory and salvage records, so there is no way to estimate the total useful life of launderable items or pilferage rates. The opinion was expressed that pilferage is not a serious problem, but there is no proof available.

Disposable items are not used to any great extent. They do use disposable diapers in the nursery but not in the pediatric ward, and there is some usage of disposable washcloths, as mentioned earlier. There is no usage currently of disposable surgical packs or drapes.

7.4.3. JACKSONVILLE NAVAL AIR STATION HOSPITAL, JACKSONVILLE, FLORIDA

Laundry service for linens at the Jacksonville NAS Hospital is now provided by its own separate laundry, located a block away from the hospital. Laundry chutes in the hospital building carry soiled linens to the ground floor, where they are sorted into large hampers and transferred by truck to the laundry building. Fresh linens are returned by truck to the linen distribution room in the hospital. Carts are used to distribute clean linens to the wards. These carts have shelves and are loaded with the designated allowance for each ward. They are then wheeled to the wards and substituted for the previous day's carts, which are returned to the issue room with their remaining linens. The carts serve as part of the linen storage in each ward. Four men from the laundry staff are involved part time in this distribution operation. Unscheduled supplementary deliveries can be made if a ward runs short.

At present, no counts are kept of the amount of linen used by each ward, but a periodic inventory is made of the total linen supply. They are now considering a program of color coding by wards to trace and identify linen losses. This will increase handling costs and inventory costs considerably; there are mixed feelings about whether it would be worthwhile. The hospital administration favors the idea but the laundry manager is opposed. The net value of such a change cannot be quantified because no one knows the present loss rate or what the future loss rate would be nor how much increase in inventory would be required. The present linen inventory is worth about $63,000, with annual replacement costs of $18,000 to $20,000.

The laundry is operated by eleven civil service employees under the management of a Navy NCO, supplemented by the services of seven full-time equivalents from the rehabilitation and holding wards. The annual civilian payroll is $68,000, including fringe benefits, and supply costs are $6,375 per year. The initial cost of the laundry equipment was over $94,000. Utilities are charged to the laundry at the rate of about $11,000 per year, but maintenance and transportation are furnished by the base at no cost to the laundry. The laundry operates on a single shift, five days per week.

The average daily load of the laundry is 4950 pounds, or an estimated 13,500 pieces of various types. Including only direct operating expenses (no amortization or free labor and services), the cost per pound of laundry works out to be 6.86 cents, or 2.5 cents per piece. Recently a price quotation was obtained from a commercial laundry in Jacksonville for laundry service to the hospital. Their proposed price is 7.5 cents per pound averaged over all types of items as listed on the estimated breakdown, including pickup and delivery and one-day service. Although this is slightly higher than the present direct cost on the hospital's budget, it actually would be cheaper than the total real cost to the Navy if one includes amortization and all the costs now hidden in other budgets. The basic reason the commercial laundry can operate so cheaply is that their wage scale is much lower than the civil service scale. On a purely economic basis it would appear sensible to convert to commercial laundry service in this situation. However, there is some feeling that the hospital laundry provides useful occupational therapy for ambulatory patients, so the issue is not exclusively economic. Flexibility and control are also of concern. The decision is still under active consideration at Jacksonville. If they do choose the commerical option, this will have to be approved by BUMED, and there is considerable uncertainty as to whether BUMED will approve.

Only limited use is made of disposable substitutes for launderable linens at the Jacksonville NAS Hospital. They do use some disposable gowns for isolation patients and some wrappers for instruments in the operating rooms, and these are considered satisfactory. They have tried disposable washcloths but found their quality unacceptable. Altogether, their use of disposables is a minute fraction of the total linen requirements.

They recently studied a number of other disposable items but concluded that there would be no monetary savings and the quality did not match that of the corresponding launderables. Consequently, there is no present intention to convert to greater use of disposables.

7.4.4. DEWITT ARMY HOSPITAL, FORT BELVOIR, VIRGINIA

Very limited information on linen service costs was obtainable at DeWitt Hospital. Their laundering is done at the base laundry, which is operated by the Quartermaster. The hospital pays nothing at all for this service out of its budget and keeps no records on poundage or piece counts. The Quartermaster estimated that the portion of laundry operating costs allocable to the hospital would run about $220,000 per year. This does not include transportation, which is provided by the base motor pool.

Linen distribution within DeWitt Hospital is provided by the Supply and Services Section. All linens, soiled and clean, are transported on carts throughout the hospital. There are no separate data maintained on the amount of labor involved in this service, partly because all military labor is free so far as the hospital budget is concerned.

Linen purchases in FY 1968 amounted to $88,000 and in FY 1969 they bought $82,000 worth. No inventory records are maintained; they simply buy new items when the supply runs low. They have no way of estimating losses through pilferage, but the Supply Officer expressed an opinion that such losses are probably appreciable. No significant use is made of disposables. Moreover, there was virtually no interest at DeWitt in linen service costs or in finding ways to economize in this service area.

7.4.5. COMPARISONS

From the available information on laundry costs in military hospitals, such as those presented in the preceding sections, it is clear that a reliable general price structure cannot be derived. The costs for a few specific items of clothing that prevail at March AFB may be fairly realistic, but the flat price of ten cents per item for all other linens is of little help. Even the gross totals appear to be quite arbitrary and highly suspect. For example, at DeWitt Army Hospital, where the average daily inpatient census is just over 200, the estimated annual laundry cost is $220,000, whereas at Walson Army Hospital, with a daily average inpatient census of about 600, the estimated annual laundry cost is only $176,000. Such a large discrepancy renders both estimates rather useless. Moreover, in all cases, some of the cost elements representing non-budgeted services are omitted.

Consequently, there is no satisfactory way to measure the efficiency of the military laundry services. Only at Jacksonville was any comparison with commercial laundry costs even partially feasible, and there it appeared that the commercial costs would be slightly lower if all the hidden costs in the military system were to be included.

The absence of a genuinely representative price list for laundering military hospital linens, and the lack of information on the life of laundered items at the institutions visited, make it impossible to develop direct economic comparisons of launderables versus disposable substitutes at those sites. However, rather than leaving this issue unresolved, it seems reasonable to draw on information developed at civilian hospitals where detailed studies have been carried out. Even if the military laundry costs are not exactly equivalent, the order of magnitude should not be so different as to vitiate the general conclusions that can be drawn from the civilian sector.

Fortunately, we were able to obtain the results of some studies made recently of hospital laundry costs in New York. These figures were checked with an independent laundry consultant who stated that they were reasonably consistent with his experience with large laundries in metropolitan areas. For comparison, price lists of a variety of disposable linens for hospital use were obtained from several reputable manufacturers. Table 7.4.1 presents a summary of the per-use costs of the principal items for which data were obtainable. Although costs will vary somewhat from one locality to another, those given here are believed to be sufficiently representative to serve as a basis for comparison.

Comparing the last two columns, we observe that in most cases the per-use cost of the reusable item is lower than the total cost of the disposable substitute by a rather wide margin, often a factor of two or more. The per-use cost of the cotton-dacron blend apparel which can be pressed automatically is substantially below that of either disposables or standard cotton

TABLE 7.4.1
PER-USE COSTS OF LAUNDERABLES AND DISPOSABLES

Item	Linen Replacement Cost per Use (cents)	Linen Laundering Cost per Use (cents)	Linen Total Cost per Use (cents)	Disposable Cost per Use (cents)
Bedsheet cotton	2.2	10.4	12.6	27-62
Bedsheet cotton-dacron	2.9	8.7	11.6	
Pillowcase	0.9	2.2	3.1	9-16
Washcloth	0.9	0.2	1.1	1.3-3
Patient gown	3.2	6.3	9.5	21-65
Examining gown	4.1	6.9	11	21-47
Lab coat cotton	16.1	9.5 + 23.4[a] = 32.9	49	46-104
Lab coat cotton-dacron	10.5	7.5 + 3.0[a] = 10.5	21	
Service dress cotton	13	6.9 + 23.4[a] = 33.3	46.3	54-59
Service dress cotton-dacron	9.5	3.8 + 3.0[a] = 6.8	16.3	
Operating Room pack	36.1	32.5 + 103.1[b] = 135.6	171.7	411
Surgeon gown	12.3	10 + 30[b] = 40	52.3	103-173
Scrub shirt	3.9	4.7	8.6	43-63
Scrub pants	4.9	5	9.9	49-67
Diapers	2.1	0.9	3	2.5-5.8

[a] pressing cost

[b] sterilization and assembly cost

that requires much more ironing. In most cases the laundering cost is the dominant part of the per-use cost of reusables. Hence, much higher loss rates than those normally experienced would be needed in order to make the cost of reusables as high as that of disposables.

In view of the apparent cost disadvantages of disposables, one might wonder why their use has been increasing in the civilian market. Actually, this growth rate has been fairly slow to date and there is no anticipation of a sudden boom. Where disposables have been adopted, the reasons cited include the following:

- to save time for nurses and other personnel;
- to compensate for limited laundry capacity;
- to relieve limited sterilization capacity;
- to improve contamination control;
- to improve patient care; and
- to add convenience in supply, storage, handling, and cost accounting.

Projections that have been made do not indicate any substantial changes in the per-use cost of durable linens in the foreseeable future. Higher laundry operating costs, due partly to higher capital investment for automated equipment and partly to escalation in wage rates, should be offset by reduction in manhours per unit of laundry processed through the use of automated equipment. The cost of laundering and pressing articles of apparel will decrease through the use of automated ironing devices. Increased life of various pieces of linen due to the use of cotton-synthetic mixtures will also tend to stabilize the per-use costs.

An analysis of the costs of disposables has also been carried out to determine whether there is any likelihood of major reductions due to improved manufacturing processes. In most cases the raw materials, such as wood pulp, acrylic binders, and synthetic fibers, represent over 60% of the total cost of the roll stock, and there is little chance of reducing these costs. The processing and fabrication are already fairly well automated and no major breakthroughs are visible in these steps. Volume is sufficiently high, so that economies of scale will not have a major effect. Finally, the marketing and distribution functions add a significant contribution to the total cost of disposable articles, and no major reductions are foreseen here either.

All in all, we do not expect the cost relationships between durables and disposables in the hospital market to change appreciably within the next five years or more. Hence, with the exception of diapers and a few other small items, disposables can compete with durables on a cost basis only in those applications where unusual conditions of damage or pilferage reduce the times used of durables to a point where the total per-use cost is greatly increased. Disposal costs have not been factored in, but these have been estimated to be only about one cent per pound, which is not large enough to affect the comparison.

The appeal of disposables is largely that of convenience and the saving of staff time. On a quality basis they are generally inferior to launderable linens. Future development of disposables is expected to concentrate heavily on improving their quality rather than on lowering their cost. Since linen costs are only a small fraction of the total operating costs of a hospital, it is not unreasonable to give heavy weight to the convenience factor in deciding whether to convert to disposables, especially if this can be done on item by item basis as quality becomes comparable. However, a major commitment to convert to disposables across the board does not seem warranted at this time.

7.4.6. SUMMARY AND CONCLUSIONS

If one takes an extremely parochial point of view and limits his concern with operating costs strictly to the elements that are visible in his own budget, it appears that Army hospitals enjoy the greatest bargain in linen service, because their laundering is done for them by the Quartermaster at no charge. The Navy and Air Force hospitals, on the other hand, bear at least part of their laundry costs. In fact, in some instances it is possible that these costs may even be inflated beyond their true value by use of an unrealistic price list as a basis for transfer of funds between on-base accounts. The various artifacts of military accounting are such that the total real costs of in-house linen service cannot be determined from available records. The actual cost to DOD is fully visible only where outside commercial laundry service is purchased, as at Andrews AFB. Even here the per-use cost is not known for specific items because the records do not reveal average lifetimes.

From a broader viewpoint concerned with estimating realistic and inclusive costs to the military of specific service activities, and with developing comparative costs of possible alternatives, it is not unreasonable to draw on civilian experience with similar functions, where more detailed data are available. This has been done for linen service, and typical per-use costs of various items of hospital linens were presented in Table 7.4.1. Standard catalog prices for currently marketed disposable items for the same uses have also been tabulated. Item-by-item comparisons reveal that launderables are substantially cheaper to use than their disposable counterparts.

It should be noted that this item-by-item cost comparison does not include handling costs within the hospital and there may be some differences here. In effect, the prices given may be thought of as prices at the hospital loading dock. Delivery costs to the wards should be about the same for either launderables or disposables. Getting rid of disposable trash is probably somewhat cheaper than sorting and returning soiled linens, particularly if shredding and flushing systems for disposables can be used in the wards. However, it is not evident that identifiable reductions in staff could be anticipated as a direct result of conversion to disposables, because of the part-time nature of most delivery activities. Moreover, where soiled linen chutes are in use, the difference in effort would be slight. In any event, the differential costs of handling are undoubtedly small enough that they would not significantly alter the noted cost margins.

At the present time the only disposable substitutes for linens that seems to be widely used in military hospitals are diapers, but even in this case they have not been universally adopted. The quality of dispoable diapers seems to be generally acceptable, and greater convenience is acknowledged. In cost they are reasonably competitive, Disposable washcloths are in limited use because of their very low price, but their quality is regarded as distinctly inferior to launderable washcloths. Disposable isolation gowns are also used to some extent because of their benefits relative to limiting the spread of infection, and their quality is apparently acceptable. There is occasional use of some disposable sterile wrappers for surgical instruments, but no significant move is apparent in military hospitals toward general adoption of complete disposable surgical packs. Launderable packs still seem to have the edge in both quality and price, but it is believed that disposable packs are being improved and that they may eventually become competitive. Further testing and development in civilian markets are needed before one could recommend their general adoption by the military.

Items of disposable clothing for general duty use by the staff, such as doctors' coats, nurses' dresses, and corpsmen's uniforms, as well as bed linens, towels, and patient gowns and robes for normal usage, all seem to be unlikely candidates for early adoption because of disadvantages in both cost and quality. Considerable development is needed before they acquire the feel, drape, strength, porosity, absorbency, and other characteristics that they need in order to compare with launderables. Whether such improvements in disposables can be achieved along with lower costs is problematic. At the present time the use of disposables of the above types can be justified economically only in applications where damage and loss rates are exceptionally high or where they are vital for control of contamination.

What do these observations and comparisons imply with regard to a new generation hopsital? Broadly, it seems evident that despite some of the enthusiastic hopes for disposables, it would be premature to plan on large scale elimination of launderables in the near future. Therefore, it will be necessary to have access to a source of laundry service. However, the interest in disposables is great enough throughout the whole medical market so that improvements in quality and cutting of costs may eventually be such as to make them increasingly competitive. Moreover, where staffs are overburdened and labor is tight, convenience and time saving may be given increased weight. Hence, it seems advisable to plan for as much flexibility as possible in this area.

There are basically four ways of obtaining laundry service. One is to equip the hospital with its own laundry; the second is to use the base laundry; the third is to send linens out to a commercial laundry; and the fourth is to rent clean linens from a linen supply service. The advantages cited for a hospital having its own laundry are a greater degree of control, some use of free patient labor, and occupational therapy for rehabilitation patients. However, there seems to be no demonstrable economic advantage, despite the access to free labor. The disadvantages are that a sizable capital investment is required and once the laundry operation is established there is a built-in commitment to continue using launderables. Thus, freedom of choice tends to be restricted.

On balance, we would recommend against building a special laundry into a new hospital unless there is no other alternative available. Use of either the base laundry or a commercial service, whichever is more attractive in a given instance, appears to be a better means of obtaining the necessary service while preserving the freedom of choice regarding changeover to disposables on an item-by-item basis as quality, price, and convenience warrant.

Because of the possibility of future expansion of the use of disposables, it is important to incorporate in a new hospital building the appropriate mechanisms for handling disposable materials via drains or chutes. Specific recommendations cannot be developed here, but there are shredding and masticating devices on the market that allow bulky disposable materials to be flushed away or otherwise conveniently eliminated. Initial provisions of this sort during construction can save costly modifications later on. With regard to disposal systems one also needs to bear in mind that the field of disposables encompasses more than just linens. For example, there are disposable syringes, bedpans, urinals, emesis basins, and a variety of food service items made of paper or plastic. A comprehensive, all-devouring waste disposal system adequately distributed through the hospital appears to be a worthwhile feature to consider for future construction.

7.5. HOSPITAL COMMUNICATIONS

7.5.1. INTRODUCTION

The alternatives available for communications in clinical activities abound and proliferate. They include direct conversation, telephone, written messages hand-carried or transported by pneumatic tube or other conveyance, television, radio, and a wide variety of computer-related communication devices such as teletypewriters, cathode ray tubes, card readers and printers, and many others. The newer developments, especially television and computer-related devices, not only offer alternative methods for communicating but also offer new patterns for operation. In fact, it is precisely because these devices allow changes, and in some cases demand changes, that their acceptance is uneven and their reputations spotty.

In this section we shall begin by examining the major paper flows presently set in motion by an inpatient admission or an outpatient visit at the three hospitals under study - Walson Army Hospital, Jacksonville Naval Hospital, and March AFB Hospital. The mechanical alternatives for moving these records, orders, and results are a manual delivery system, pneumatic tubes, or perhaps a tote box system such as Telelift.

Then we shall turn our attention to computerized communications systems, which not only replace much of the paper flow but actually alter the means by which information formerly recorded on paper is captured, stored, formatted, and recovered. This field is currently in a state of rapid change, so it is impossible to be definitive about its costs and benefits. There are no completely successful computerized communications systems today which embrace the totality of information flow in a hospital (these are referred to as hospital information systems or medical information systems); nevertheless, while the problems encountered are greater than most developers anticipated, none of them seems insuperable. The primary obstacle is cost, which currently amounts to $10-$20 per patient-day in civilian hospitals. Most administrators consider this excessive, particularly for systems which only marginally satisfy original expectations.

The problems do not lie in the hardware (except as it contributes to costs) but in the system concept and software. For reasons which we shall point out, military hospitals are sufficiently different from civilian hospitals so that they cannot rely upon civilian developments to solve their problems, and the Department of Defense will have to undertake its own development if it wishes to capitalize on computerized hospital information systems. Military hospitals should have greater chance of success than their civilian counterparts, because the problems arising from fragmentation of responsibility and authority are less severe in military hospitals. Nevertheless, these applications must be regarded as development efforts whose eventual contribution to cost savings and improved care are some years away.

Finally, in this section we shall consider television links for consultations between stations such as dispensaries and the main hospital. Here again, the problem is not technological but procedural; whether such methods of communication will work efficiently cannot be determined without actually trying them.

We have omitted from consideration in this section many other uses of computers for administrative matters (such as inventory control, supply requisitioning, and scheduling) and for business matters. Collectively, a hospital information system plus administrative data plus business data form a total management information system, which sounds attractive in that it holds the promise of providing up to date information to anyone who needs it about any aspect of hospital operation. Doubtless such information could be useful in running the hospital or any of its departments, but its utility is problematical, as we have discussed in Volume 4. This, however, is not the main reason for being less ambitious at this time. We believe strongly that any new developments in computerized information systems in military hospitals should be built up gradually from smaller elements;

a complete management information system represents a synthesis of numerous smaller information systems, which should be tackled one at a time. It is premature to contemplate a full-scale management information system.

Despite this belief, it is entirely appropriate to consider various computer applications individually in military hospitals. Some of these are discussed in Section 7.3 (Unit Package Medication), Section 7.6 (Automation in the Clinical Laboratory), and Section 7.7 (Other Computer Systems).

7.5.2. PAPER FLOW IN DOD HOSPITALS

As necessary background to deciding whether or not it would be advantageous to replace some of the paper flow in military hospitals by other types of communication links, we have defined the major (in terms of quantity) paper flows in three hospitals. While we have not attempted to account for all pieces of paper, the following description covers most of the paper flow generated by inpatient and outpatient visits to the hospitals.

7.5.2.1. March AFB Outpatient Department (Figure 7.5.1)

An outpatient appointment at March is made by phoning the central appointments office. The appointment is noted in an appointment book for the clinic. Each afternoon, a master clinic schedule for the next day is typed and taken to the outpatient record room. There the records are pulled and an "out" card is inserted in the file. The records and master schedule are carried by the record room personnel to the appropriate clinic. About 900 records are pulled for appointments each day.

During the clinical transaction, the physician inserts his notes directly into the outpatient record. The record is collected by someone from the record room the same day and is usually refiled by the night crew within 10 hours. It is always refiled within one day.

All basic tests are ordered on BOB forms, which is standard procedure for all the hospitals. Orders for x-rays, lab tests, cytology, or blood transfusions are two-part forms, because the lab keeps one copy for its files and one is put in the patient's record. Other tests like EKG's

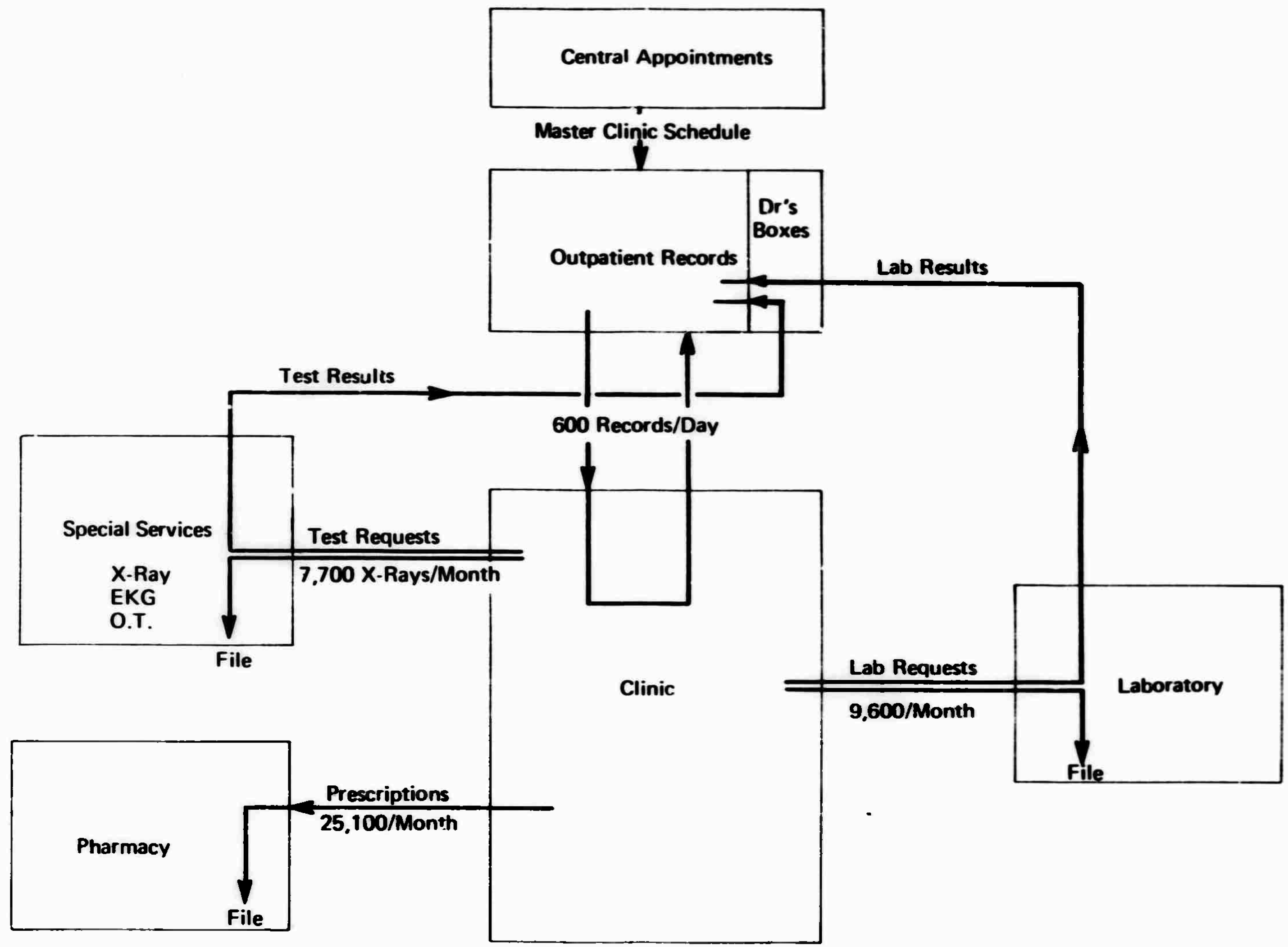

FIGURE 7.5.1 PAPER FLOW FOR AN OUTPATIENT VISIT AT MARCH AFB HOSPITAL

or EEG's are ordered on single-copy forms, which go into the patient's record. In the outpatient department, the doctor fills out his test order on the appropriate form, and it is carried by the patient to the lab. After the test is performed, the results are noted on the same form, and the record copy is put in a pile to be picked up by the record room personnel. About 9600 lab orders, 7700 X-ray films, and 400 EKG evaluations are processed for outpatients each month.

Each physician has a mailbox in the record room, and the results of tests he has ordered are filed in these boxes. When he has reviewed the results of a test, the physician gives the form to the personnel in the record room, who file it in the patient's record.

At March AFB a very small percentage of outpatient tests are ordered "stat," and the patient waits for the results to be generated. In these cases, the results are immediately reported to the doctor by telephone, but the paper flow remains the same. Outpatient prescriptions are carried by the patient to the pharmacy, where they are filled and then filed in the pharmacy. About 25,000 outpatient prescriptions are filled per month.

7.5.2.2. Walson Army Hospital - Outpatient Department (Figure 7.5.2)

At Fort Dix, the outpatient records for active-duty personnel are called health records and are kept at the dispensaries; outpatient records for dependents and retired personnel are kept in the outpatient record room at the hospital.

Appointments for about half the clinic are made through the central appointments office, which is accessible only by phone. (OB-GYN, Well Baby, O.T., P.T., the dental clinic, and several others schedule their own appointments.) When an appointment is made, it is recorded on the schedule for that clinic, and a multicopy 3x5 appointment slip is made. One copy of this slip is filed by clinic, date, and time; one alphabetically by patient name (for reference if someone calls about a forgotten appointment time); and, for active-duty personnel, one copy is sent to the dispensary so that they can pull the health record. (The enlisted men carry their records with them to the clinic.) Central Appointments

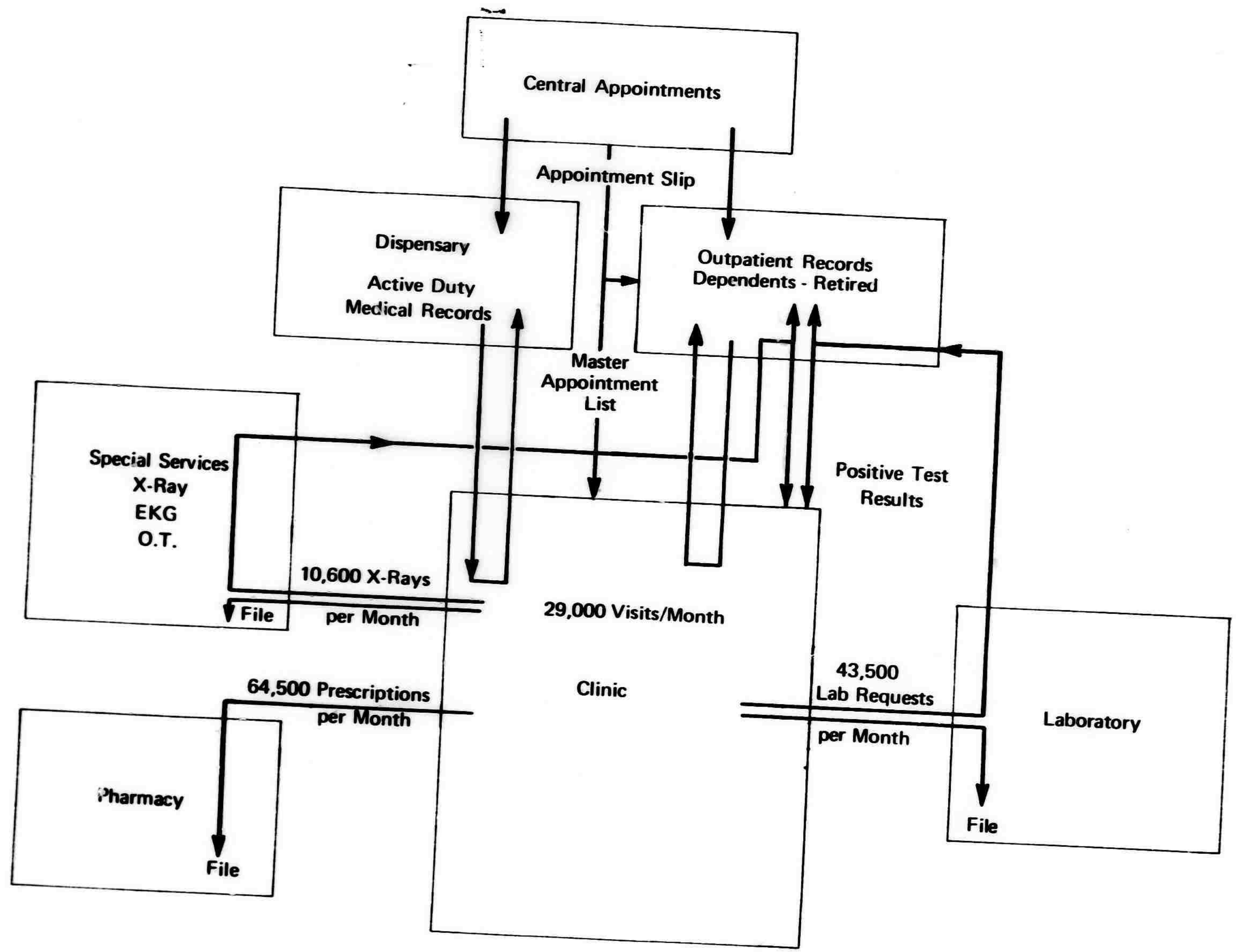

FIGURE 7.5.2 PAPER FLOW FOR AN OUTPATIENT VISIT AT WALSON ARMY HOSPITAL

makes a master schedule of the appointments by clinic and sends one copy to the appropriate clinic. The other copy is taken, with the original appointment slips for the retirees and dependents, to the outpatient records room. There the record is pulled, and the appointment slip is inserted in its place to show where the record has gone. Record room personnel carry the records to the appropriate clinic.

There are approximately 1400 visits to the outpatient clinic per day. The procedure for ordering tests and filling prescriptions is the same as at March AFB except that a much larger portion of the lab tests (approximately 30% on Monday through Thursday and 50% on Friday) are ordered "stat." "Stat" orders are processed immediately -- normally in an hour -- and the results are usually telephoned to the doctor. In round numbers, 42,800 lab orders, 10,600 X-ray films, 500 EKG's and 64,500 prescriptions are processed for outpatients each month.

The results from tests are returned to the outpatient records room, where they are screened by a clerical employee. If the results appear normal, the slips are put in a box to be filed in the records; this may take three months or more. If the results are abnormal, the ordering doctor is notified of the results. The system does not work well, because lab slips are not refiled in the record by the time a patient comes for his next appointment or calls the physician. The physicians cannot be sure that the slips have been scanned properly or that the result has not been lost, so they call the lab to get results. Answering these calls interferes with the laboratory work.

7.5.2.3. Jacksonville - Outpatient Department (Figure 7.5.3)

At Jacksonville, the central appointments desk is in the outpatient records room. Appointments can be made in person, by phone, or by mail. When an appointment is made in person or by mail, one copy of the appointment notice is given to the patient. The other copies are filed by clinic and date. The night before the appointment, these slips are removed from the file by the record room personnel. When a record is pulled, one copy of the appointment slip is inserted into a card which replaces the record; this indicates where the record has gone. The records and a copy of the

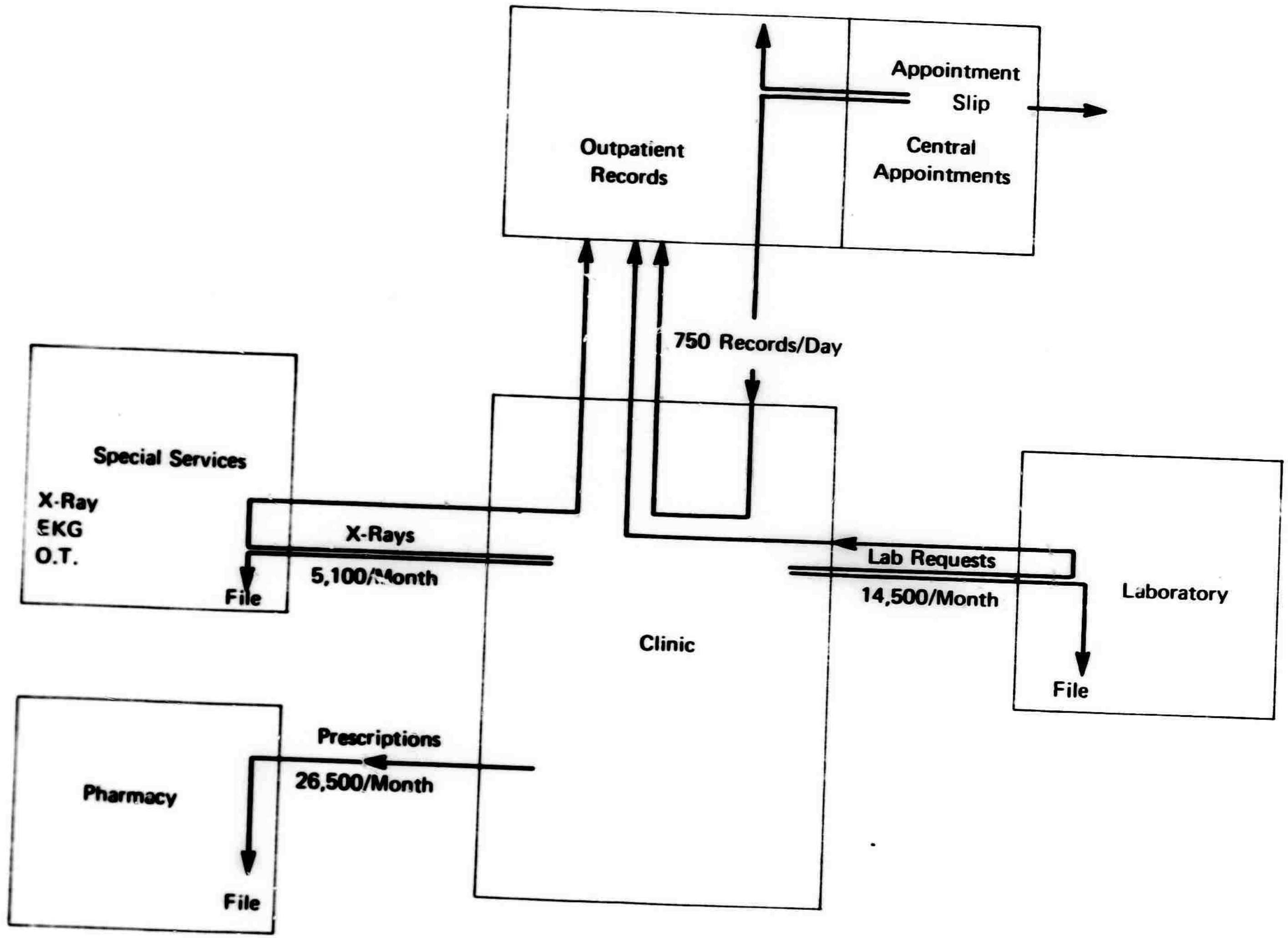

FIGURE 7.5.3 PAPER FLOW FOR AN OUTPATIENT VISIT AT JACKSONVILLE NAVAL HOSPITAL

appointment slip are delivered to the clinic by the night staff in the records room. About 900 visits are made to the outpatient department each day.

Each outpatient has an Addressograph plate, and all tests ordered are imprinted with this plate. After the clinic visit, the outpatient records are put in a pile and are picked up by the record room personnel several times a day. The record copy of each test result is returned to the ordering doctor, who initials it and sends it to the records room to be filed. About 15,000 outpatient lab orders, 5100 X-ray films, 250 EKG's, 26,500 prescriptions are processed for outpatients each month.

7.5.2.4. March AFB - Inpatient (Figure 7.5.4)

A patient who arrives to be admitted at March AFB Hospital must bring an admission slip with him. This is presented at the admissions desk, where an I.D. card, an inpatient record folder, and a clinical record cover sheet are made. The patient carries these with him to the ward. (About 500 direct admissions are made at March each month, and about 50 patients are transferred there.) From the ward, the patient goes to the clinic for a work-up, carrying his record with him. For inpatients, copies of all lab orders, test results, anesthesia reports, operation reports, etc., are included in his record. These are all recorded on the standard BOB forms. Since there is no internal mail distribution, the test results are picked up by the ward staff. About 5200 lab orders, 1800 X-rays, and 290 EKG's are processed each month. The pharmacy processes about 1500 orders from the wards each month; most drugs for inpatients are obtained from the ward stock.

When a patient is discharged, his record goes to a holding area and remains there until the physician has completed his narrative summary and the results of all tests have been returned. Then the record is brought to the medical library for storage. A copy of the doctor's narrative summary of the inpatient admission and a copy of the clinical record cover sheet are filed in the outpatient record room.

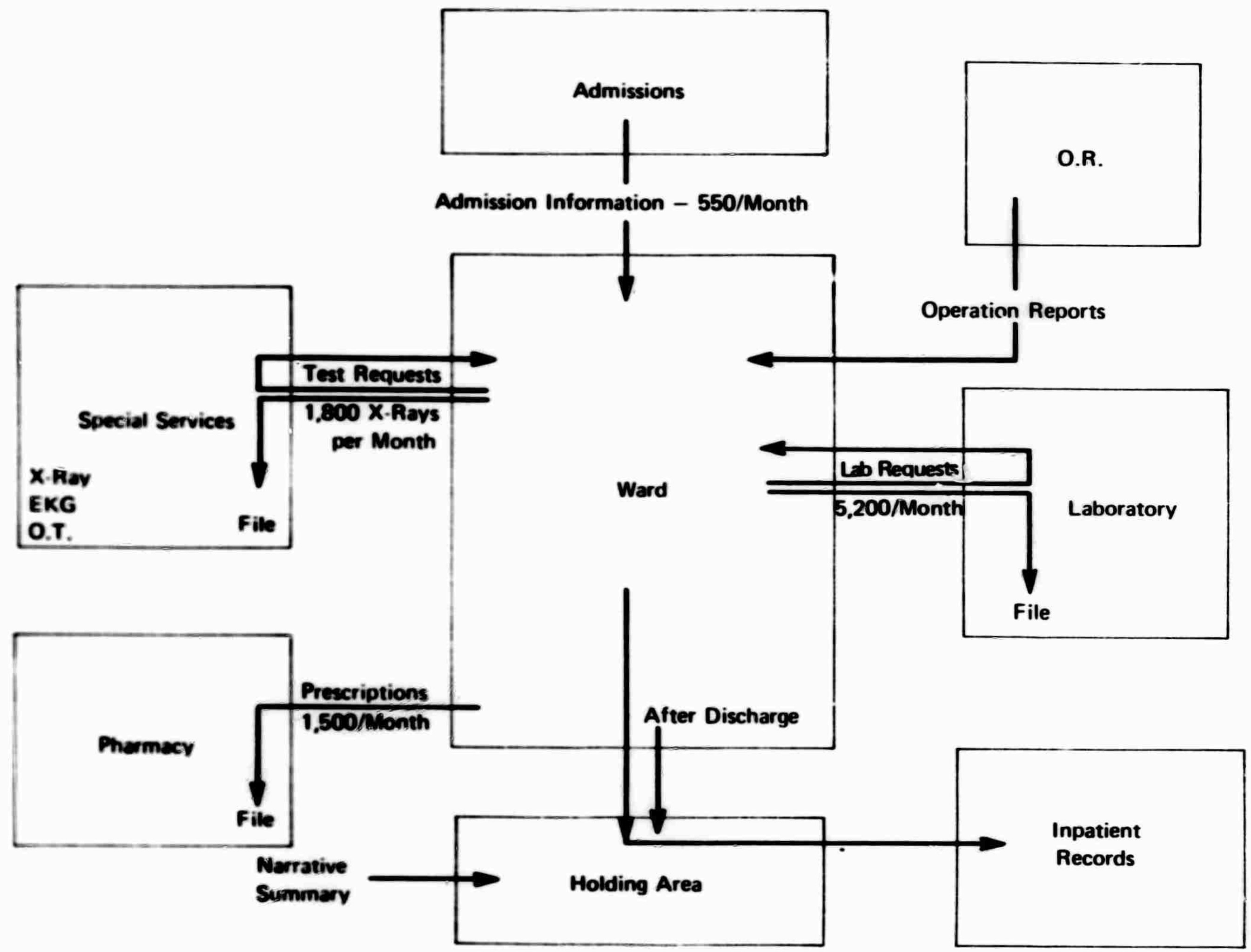

FIGURE 7.5.4 PAPER FLOW FOR AN INPATIENT VISIT AT MARCH AFB HOSPITAL

7.5.2.5. Walson Army Hospital - Inpatient Records (Figure 7.5.5)

Upon admission, a patient at Walson Army Hospital presents his admission slip at the inpatient admissions desk. The personnel at the desk make an Addressograph plate, and with this they imprint several copies of the cover sheet, a nameplate for the bed, an I.D. bracelet, lab and X-ray orders; they also imprint a list of valuables, which the patient takes to the treasurer's office when he deposits his belongings. From there, the patient goes to the ward. About 2500 patients are admitted to the hospital each month.

On admission, a copy of the record cover and the clinical records cover sheet are sent to the inpatient medical records to be stored until the patient is discharged.

For inpatients, all lab reports, X-ray results, etc., are posted along with the doctors' and nurses' notes in a chart on the ward. About 6000 X-rays, 42,800 lab orders, and 10,500 pharmacy orders are processed each month for the wards.

When the patient is discharged, the record is given to the secretary of the admitting department. It is held there until it is complete and then sent to the medical library to be filed; there is a one- or two-month delay between discharge and the time the record arrives to be filed. Copies of the physician's narrative summary and the cover sheet are sent to Outpatient Records to be filed with the outpatient or health records.

7.5.2.6. Jacksonville - Inpatient Records (Figure 7.5.6)

When a patient is admitted to Jacksonville Naval Hospital, several copies of an admission record, an Addressograph card, and an I.D. band are made at the admissions desk. One copy of the admissions record is carried by the patient to the ward, where it is placed in a Kardex file. One copy goes to the medical archives (inpatient records room); other copies go to the chaplain and to the information desk. There are about 800 admissions per month at Jacksonville. For inpatients, all X-ray results are posted in the patient's chart on the ward. About 13,000 lab orders, 2700 X-rays, and 3400 orders to the pharmacy are processed each month.

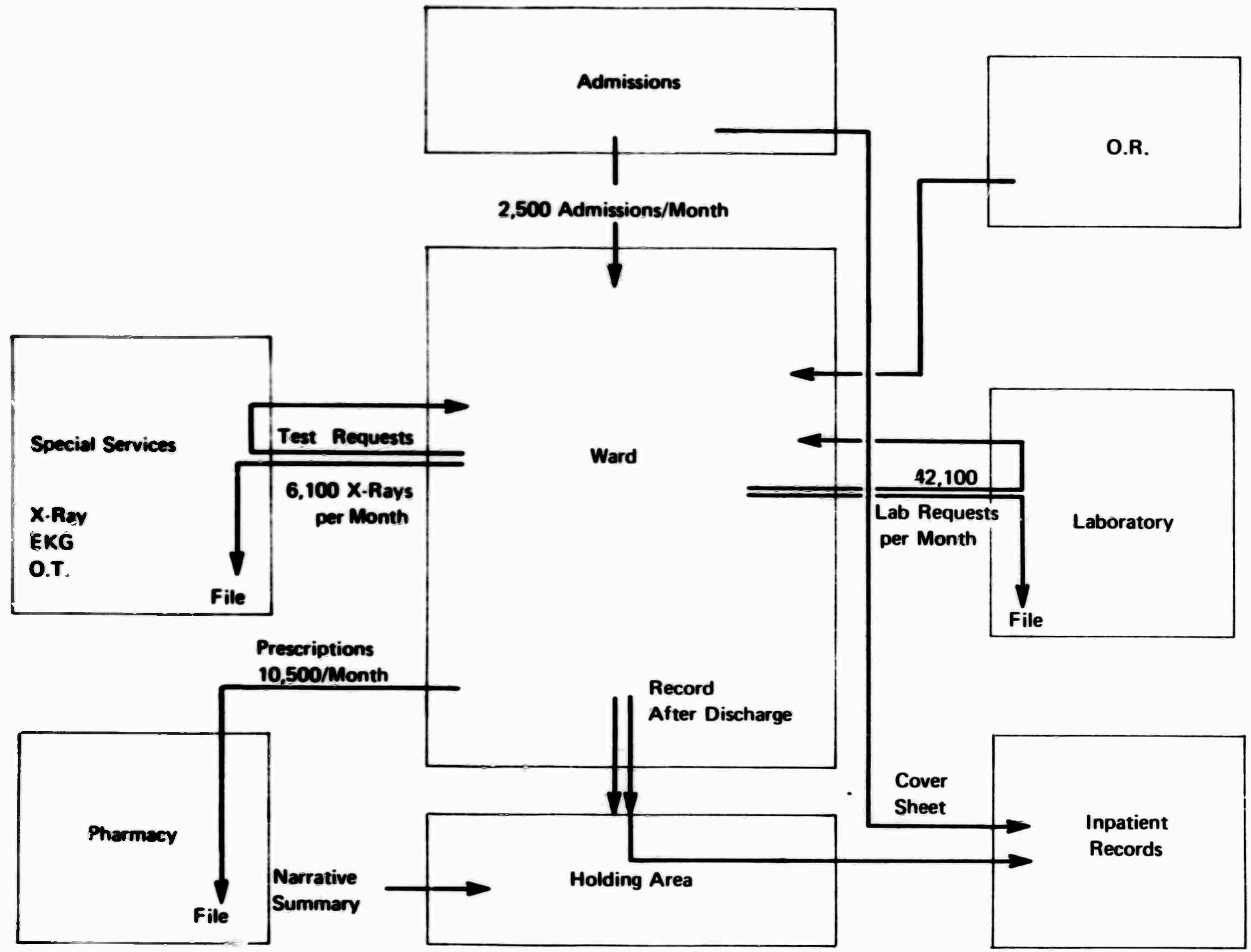

FIGURE 7.5.5 PAPER FLOW FOR AN INPATIENT VISIT AT WALSON ARMY HOSPITAL

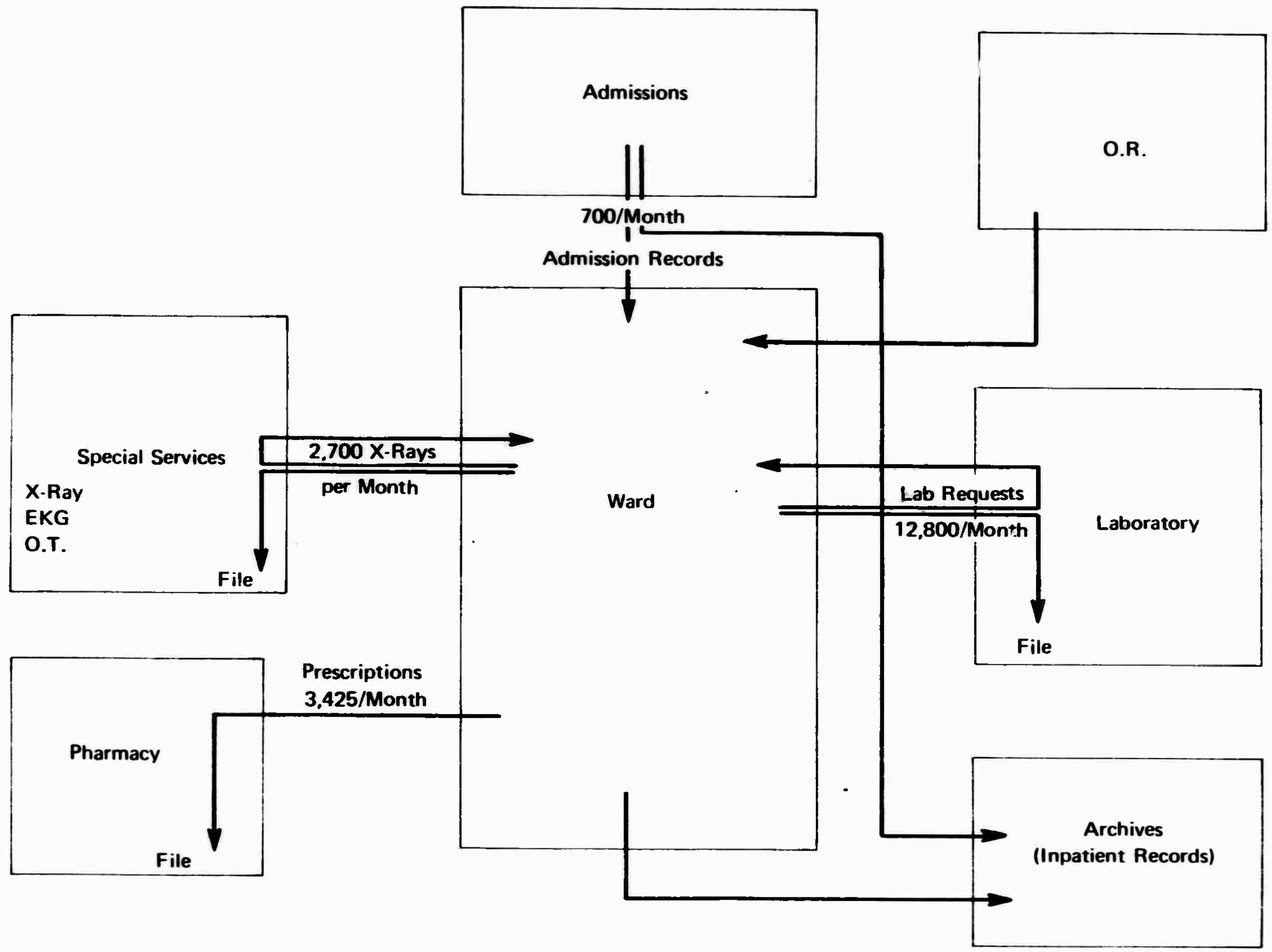

FIGURE 7.5.6 PAPER FLOW FOR AN INPATIENT VISIT AT JACKSONVILLE NAVAL HOSPITAL

Upon discharge, the nurse adds a disposition notice to the chart and sends the record to the attending physician, who adds his narrative summary and sends the record to the medical archives for filing. Copies of the narrative summary and the admission form are included in the patient's outpatient record. If a patient is transferred to another hospital, his inpatient record is sent with him; only a copy of the narrative summary is sent to the medical archives.

7.5.3. MECHANICAL METHODS FOR TRANSPORTING PAPER

Overlooking the problems and delays presently occurring in military hospitals, which were described in the preceding section, we can view paper flow simply as a materials handling problem. As pointed out in Section 7.1., there are only three surviving contenders for moving paper within the hospital; pneumatic tube, Telelift, or a manual delivery system. The amount of paper flow is displayed in Tables 7.5.1 a,b, and c.

To estimate the cost of moving paper manually, we shall isolate the materials handling costs using a messenger system. This does not correspond precisely to the way that it is actually done now -- ward and clinic personnel who have other duties are normally used -- but it is necessary to estimate the cost for a messenger system alone in order to compare it with the mechanized alternatives. We imagine, then, a system in which messengers circulate through the hospital on a schedule, picking up and dropping off paper items as necessary, using carts designed for the purpose and traveling in the elevators and corridors; this is the way interoffice deliveries are customarily made in many hospitals and offices.

Unlike bulk items, frequency of delivery rather than volume is the major determinant of the number of delivery personnel required. At Walson Army Hospital, about 10,000 items are transported daily; at Jacksonville, about 7000; and at March, about 4000. To make four deliveries and pick-ups daily at each station (one every two hours) would require eight messengers at Walson, six at Jacksonville, and three at March. Using, as we have before, an annual cost of $5000

TABLE 7.5.1a

WALSON ARMY HOSPITAL

Daily Flow of Paperwork*

(All entries are numbers of reports or requests, except for those items from Records, which show numbers of records.)

FROM \ TO	No.	Unit	Units	1 Administration	2 Support (Engineering)	3 Morgue	4 Stores	5 Dietary	6 Clinics	7 Elevators	8 Clinics	9 Laboratory	10 Radiology	11 Pharmacy	12 Administration	13 Records	14 Emergency	15 Support (Physical Therapy)	16 Elevators	17 Surgery	18 Sterile Supply	19 Intensive Care	20 Nursing Ward A	21 Nursing Ward B	22 Support (Auditorium & Library)	23 Elevators	24 Delivery	25 Nursery	26 Nursing Ward A	27 Nursing Ward B	28 Elevators	29 Nursing Ward A	30 Nursing Ward B	31 Elevators	32 Nursing Ward A	33 Nursing Ward B	34 Mechanical	35 Elevators	36 Nursing Ward A	37 Nursing Ward B	38 Support (Education)	39 Elevators	40 Nursing Ward A	41 Nursing Ward B	42 Elevators	43 Nursing Ward A	44 Nursing Ward B	45 Laboratory	46 Elevators	47 Nursing Ward A	48 Intensive Care	49 Support	50 Elevators	51 Elevators
			Units	19	6	1	16	30	12	2	46	9	8	4	20	2	5	6	2	14	4	2	10	14	4	2	7	4	10	12	2	10	14	2	10	11	3	2	10	11	3	2	10	14	2	10	11	3	2	12	11	1	2	2
Basement	1	Administration	19																																																			
	2	Engineering	6																																																			
	3	Morgue	1																																																			
	4	Stores	16																																																			
	5	Dietary	30																																																			
	6	Clinics	12									200	150	200		80																																						
	7	Elevators	2																																																			
1st Floor	8	Clinics	46									1000	650	800		420																																						
	9	Laboratory	9						200		1000												60	60				10	60	40		60	60		60	60			60	60			60	60		60	60			60	60			
	10	Radiology	8						150		650												20	20				2	20	5		20	20		20	20			20	20			20	20		20	20			20	20			
	11	Pharmacy	4																																																			
	12	Administration	20																																																			
	13	Records	2						80		420						20						8	8				8	8	8		8	8		8	8			8	8			8	8		8	8			8	8			
	14	Emergency	5									80	50	100		20																																						
	15	Physical Therapy	6																																																			
	16	Elevators	2																																																			
2nd Floor	17	Surgery	14																																																			
	18	Sterile Supply	4																																																			
	19	Intensive Care	2					10																																														
	20	Nursing Ward A (45 beds)	10					45				60	20	20	8	8																																						
	21	Nursing Ward B (42 beds)	14					42				60	20	20	8	8																																						
	22	Auditorium & Library	4																																																			
	23	Elevators	2																																																			
3rd Floor	24	Delivery	7																																																			
	25	Nursery (50 cribs)	4									10	2	20	8	8																																						
	26	Nursing Ward A (30 beds)	10					10				60	20	20	8	8																																						
	27	Nursing Ward B (38 beds)	12					30				40	5	20	8	8																																						
	28	Elevators	2					38																																														
4th Floor	29	Nursing Ward A (69 beds)	10					69				60	20	20	8	8																																						
	30	Nursing Ward B (53 beds)	14					53				60	20	20	8	8																																						
	31	Elevators	2																																																			
5th Floor	32	Nursing Ward A (65 beds)	10					65				60	20	20	8	8																																						
	33	Nursing Ward B (55 beds)	11					55				60	20	20	8	8																																						
	34	Mechanical	3																																																			
	35	Elevators	2																																																			
6th Floor	36	Nursing Ward A (53 beds)	10					53				60	20	20	8	8																																						
	37	Nursing Ward B (46 beds)	11					46				60	20	20	8	8																																						
	38	Education	3																																																			
	39	Elevators	2																																																			
7th Floor	40	Nursing Ward A (73 beds)	10					73				60	20	20	8	8																																						
	41	Nursing Ward B (64 beds)	14					64				60	20	20	8	8																																						
	42	Elevators	2																																																			
8th Floor	43	Nursing Ward A (73 beds)	10					73				60	20	20	8	8																																						
	44	Nursing Ward B (80 beds)	11					80				60	20	20	8	8																																						
	45	Laboratory	3																																																			
	46	Elevators	2																																																			
9th Floor	47	Nursing Ward A (58 beds)	12					58				60	20	20	8	8																																						
	48	Intensive Care (33 beds)	11					33				50	20	20	8	8																																						
	49	Support	1																																																			
	50	Elevators	2																																																			
Roof	51	Elevators	2																																																			
			421																																																				

*Does not include requests for supplies; requests for data, such as census; items of data necessary for the registrar, commander and others; and paper accompanying bulk items.

FIGURE 7.5.1b

JACKSONVILLE NAS HOSPITAL

Daily Flow of Paperwork*
(All entries are numbers of reports or requests, except for those items from Records, which show numbers of records.)

FROM \ TO				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
				Administration	Records	Laboratory	Radiology	Pharmacy	Emergency	Dietary	Stores	Sterile Supply	Laundry	Clinics	Mechanical	Administration	Clinics	Surgery	Intensive Care	Nursing Wards	Nursing Wards	Obstetrics	Nursery	Nursing Wards	Nursing Wards	Nursing Wards	Mechanical
			Units	4	1	4	6	2	1	14	7	3	1	26	4	17	6	9	2	12	14	11	3	14	14	14	6
1st Floor	1	Administration	4																	7	7	5		8	8	7	
	2	Records	1											600						7	7	5		8	8	7	
	3	Laboratory	4											720					40	85	85	70	10	100	100	85	
	4	Radiology	6											250						12	12	9	1	14	14	12	
	5	Pharmacy	2																								
	6	Emergency	1			20	15	40																			
	7	Dietary	14																								
	8	Stores	7																								
	9	Sterile Supply	3																								
	10	Laundry	1																								
	11	Clinics	26		600	720	250	1200																			
	12	Mechanical	4																								
2nd	13	Administration	17																								
	14	Clinics	6					10																			
3rd	15	Surgery	9				4	2																			
	16	Intensive Care (15 beds)	2					2		4																	
	17	Nursing Wards (76 beds)	12	7	7	85	12	20		76																	
4th	18	Nursing Wards (81 beds)	14	7	7	85	12	16		81																	
5th	19	Obstetrics (41 beds)	11	5	5	70	9	12		41																	
	20	Nursery (36 cribs)	3			10	1	5		10																	
6th	21	Nursing Ward (100 beds)	14	8	8	100	14	[illegible]		100																	
7th	22	Nursing Ward (100 beds)	14	8	8	100	14	32		100																	
8th	23	Nursing Ward (76 beds)	14	7	7	85	12	20		[illegible]																	
Roof	24	Mechanical	6																								
			186																								

* Does not include requests for supplies; requests for data, such as census; items of data necessary for the registrar, commander, and others; and paper accompanying bulk items.

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FIGURE 7.5.1c

MARCH AFB HOSPITAL

Daily Flow of Paperwork*

(All entries are numbers of reports or requests, except for those items from Records, which show numbers of records.)

		FROM \ TO	Units	1 Administration	2 Records	3 Laboratory	4 Radiology	5 Pharmacy	6 Emergency	7 Dietary	8 Stores	9 Clinics	10 Nursing Ward	11 Nursing Ward	12 Nursing Ward	13 Delivery	14 Nursing Ward	15 Surgery	16 Sterile Supply	17 Intensive Care
		Units		13	1	4	3	1	1	8	4	10	7	10	10	3	7	3	2	5
1st Floor	1	Administration	13										7	7	7		4			
	2	Records	1						7			600	7	7	7		4			
	3	Laboratory	4									480	50	50	50		40			
	4	Radiology	3																	
	5	Pharmacy	1									380	16	16	16		14			
	6	Emergency	1		7	20	15	40												
	7	Dietary	8																	
	8	Stores	4																	
	9	Clinics	10		600	480	380	100												
	10	Nursing Ward (40 beds)	7	7	7	50	16	14		40										
2nd	11	Nursing Ward (52 beds)	10	7	7	50	16	14		52										
3rd	12	Nursing Ward (53 beds)	10	7	7	50	16	14		53										
4th	13	Delivery	3																	
	14	Nursing Ward (20 beds) (30 cribs)	7	4	4	40	14	12		50										
5th	15	Surgery	3				4	2												
	16	Sterile Supply	2																	
	17	Intensive Care (14 beds)	5					2		4										
			101																	

*Does not include requests for supplies; requests for data, such as census; items of data necessary for the registrar, commander, and others; and paper accompanying bulk items.

per messenger (and neglecting the cost of carts, which cost about $50 each), the annual cost of a messenger system would be $40,000 at Walson, $30,000 at Jacksonville, and $15,000 at March.

From the tables in Section 7.1 we find corresponding annual costs for pneumatic tube systems and for Telelift. (These are summarized in Table 7.5.2.) While the convenience and speed of Telelift are attractive features, its extra expense is hard to justify, especially when computer-based alternatives to much of the paper flow should be available within a few years.

Pneumatic tubes are cheaper in the larger hospitals. However, as we have remarked earlier, in all but one of the military hospitals we visited the pneumatic tube systems were out of order; furthermore, the one operable system was used for only a small proportion of the paperwork and was not trusted by the staff. For this reason we believe that pneumatic tube systems are not suitable for use in military hospitals. This conclusion is only strengthened by two arguments we have presented earlier: that messengers in military hospitals are sometimes available free when convalescent patients are used for this duty, and that in the not too distant future much paperwork will be replaced by computer-based communication systems.

Therefore, we conclude that manual methods for moving paperwork are preferable to any mechanized alternative in military hospitals. They are by far the most flexible, and any accommodations to new patterns in the future can be made easily.

TABLE 7.5.2

ANNUAL COST FOR

DIFFERENT METHODS OF PAPER HANDLING

	Fort Dix	Jacksonville	March
Messenger system	$40,000	$30,000	$15,000
Pneumatic tube	27,400	19,300	16,900
Telelift	46,700	30,300	24,400

7.5.4. COMPUTERIZED COMMUNICATIONS FOR CLINICAL DATA

Because computers can store, retrieve, sort, and merge data at multiple terminals where information is put in or taken out, they introduce a new dimension to communications. The lists, schedules, and other documents prepared by a computerized system are seldom the same as those that they replace; the pattern and format are usually changed, partly to meet the inherent need of computers for precise specification and partly to take advantage of the comparative ease with which data can be reordered for different purposes. For example, if a computerized system is used for requesting lab tests, it can not only accept requests and, later, results, but it can also create schedules for collecting specimens, work schedules for the lab, and reminders of work not completed.

Rather than trying to conceive a computerized communication system which deals with all kinds of information flow in a hospital, we shall focus upon clinical data. The latter include information contained in a patient's medical record and all information concerned with the current episode--namely, the working chart which contains physicians' notes and orders, nursing notes, medication orders and actions, lab requests and results, X-ray requests and results, and other observations. To the extent that other data can be incorporated in a system with this orientation, and to the extent that other functions besides patient care can be supported by these data, we shall note them. Nevertheless, clinical data to support patient care comprise the most important class of data, and a computerized communication system is hard to justify unless it does this job well.

Although location of inpatients and appointments for outpatients are not strictly clinical data, this information is essential in a communication system which must route information. Furthermore, scheduling beds and scheduling visits, as well as keeping track of the locations of inpatients and of records, are genuine problems for which computerized systems offer a promising solution. Therefore, we shall regard such information as an integral part of a communication system for clinical data.

A related function is the locating of patients' medical histories, X-rays, and other records which are not storable in computer memories. To simplify recording of receipt or dispatch of a record, it is feasible and entirely consistent with the use of these records outside the hospital to affix to the permanent jackets a machine-readable label, either magnetic or optical. As each record is received or dispatched it would be passed through a reader and a button for the appropriate action code pressed. Combined with a patient-locating system, this concept could largely solve the pervasive problem of misplaced records.

Virtually all existing hospital communication systems use a cathode ray tube (CRT) as the primary means for inputting data and verifying it. Some also use it for recall. As a rule, the CRT is equipped with a keyboard for inputting text or numbers, but to speed up input and to serve as a reminder, it is common to display lists of possible inputs from which the user can select the ones he desires. Some systems have buttons along the side of the console opposite lines in the list, and others use a light pen; the function of the button or pen changes, of course, with the list displayed. The fact that CRT's are silent in operation and that their display formats are flexible make them ideal for hospital use.

Since the amount of data which can be displayed at one time is limited, it is customary to arrange lists in hierarchical form; the user must "page" through a succession of lists which become more and more specific until he reaches the item he wants. This approach may have the advantage of reminding the user of some items he may have overlooked, but it is a waste of time for an experienced physician who knows just what he is looking for. From a computer programming standpoint, it is presently infeasible to avoid this "paging" through lists; only if computer response is practically instantaneous (a design criterion which so far has been only imperfectly met) can this tedious process be avoided.

Orders for specific actions and their results, such as dressing changes, lab tests, X-rays, or drug administration lend themselves to formatting in advance of the action and are the first candidates for an automated communication system. Report composition is more difficult, because the variety of material for inclusion is greater. Also, this matter gets much closer to the practice of medicine, and many physicians quite rightly resist the idea that their practice can be reduced to selection of a predefined set of observations and actions. Nevertheless, medical reports are made up largely of standard phrases, and a persuasive case for attempting to codify their format can be made, not only on the grounds of facilitating communication among physicians but also on the grounds of improving care by requiring the physician to deal with every item entered in the clinical record, even if only by explicitly bypassing it.[1]

In any event, since composition of reports is a time-consuming activity for a physician and delays may be important to a patient, ways of speeding it up deserve serious consideration. There have been two approaches using computers:

- One simply uses the computer display as a convenient remote verification device. The physician dictates his report, which is transcribed directly into the computer memory by a typist at a teletypewriter. The transcript is then displayed to the physician for editing and, finally, approval, after which the report can be made available in hard copy as needed. The main advantage is in convenience to the physician and the time saved in having the report available at many locations as soon as it is approved.

- The other approach involves composing the report by selecting from sets of standard phrases and descriptors displayed for the physician, much as checklists are used. This approach is still under development, but it is promising enough to warrant consideration by the Department of Defense.

In a sense, the patient can be regarded as a "store" of clinical data that include his own description of his illness, his reaction to therapy, and his history, for example. His blood, through laboratory examination, is also a source of clinical data, as is his body when subjected to X-rays. The physicians, nurses, technicians, and others attending a patient can also be regarded as "stores" for data, since they interact with the patient and with other obvious "stores" such as the working chart. Similarly, supporting services such as laboratory, X-ray, pharmacy, EKG, and EEG might all be regarded as "processing stores," since they process data into a form that is useful for diagnosis or therapy. Existing stores and flows are shown in Figure 7.5.7.

The reason for adopting this somewhat abstract point of view is that it clarifies the computer's role as an information processor. It will be seen that computerized systems do not work with any new data, but they do permit new stores and flows, which substantially modify operating practices. Their degree of success must be measured against the philosophies under which they were designed and the problems to which they have been applied. Depending upon who defines the philosophies and the problems, existing systems are considered successes by some and failures by others.

However, one can learn from experience to date. The most important lesson is that the linking of all communications in one grand hospitalwide system is too ambitious a goal. It is preferable to build up the system from a set of "stand-alone" computers whose programming has been proved in particular applications. Through step-wise development, it is possible to capitalize on the achievements to date, to avoid many of the mistakes of the past, and to accommodate new developments which are certain within the next five years.

Figure 7.5.8 is a schematic diagram of the existing communication system with certain computerized stores and flows added to it. These additional functions are those which currently appear feasible and desirable; in any event, they will form the nucleus of an extended system which might be contemplated later on. Other computerizable functions currently under development or in practice are discussed in Section 7.7.

The basic goal of the computerized communication system described here is to maintain an inpatient's working chart in the computer memory. To do this requires terminals at nursing stations, in the laboratory, the X-ray department, the pharmacy, and the admissions office. Orders from the physicians are entered at the nursing station terminals and routed as appropriate to lab, X-ray, and pharmacy, or, in the case of nursing orders, back to the nursing station. As results are obtained, they are stored for recall as needed at the nursing stations.

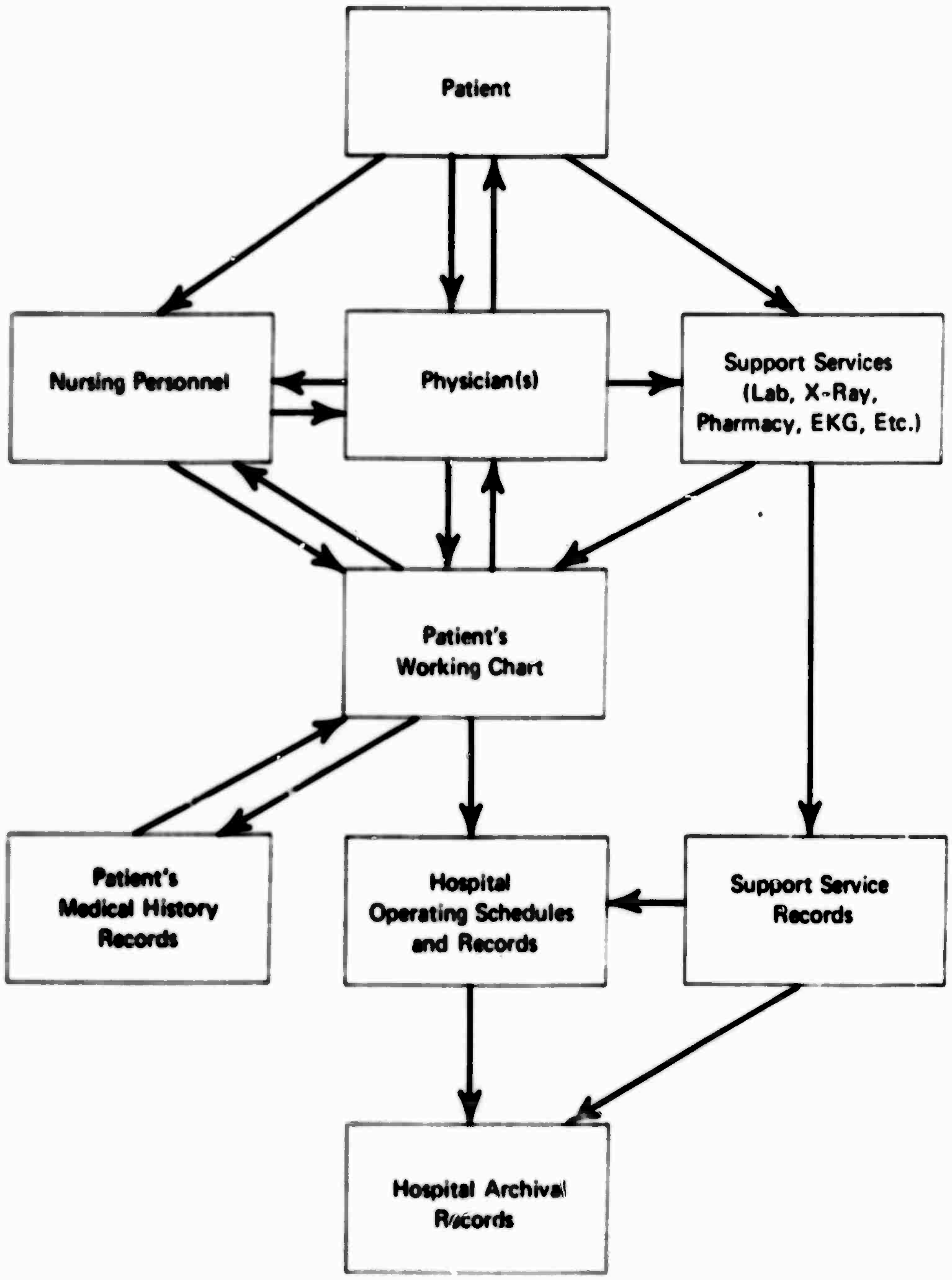

FIGURE 7.5.7 STORES AND FLOWS OF PRIMARY CLINICAL DATA

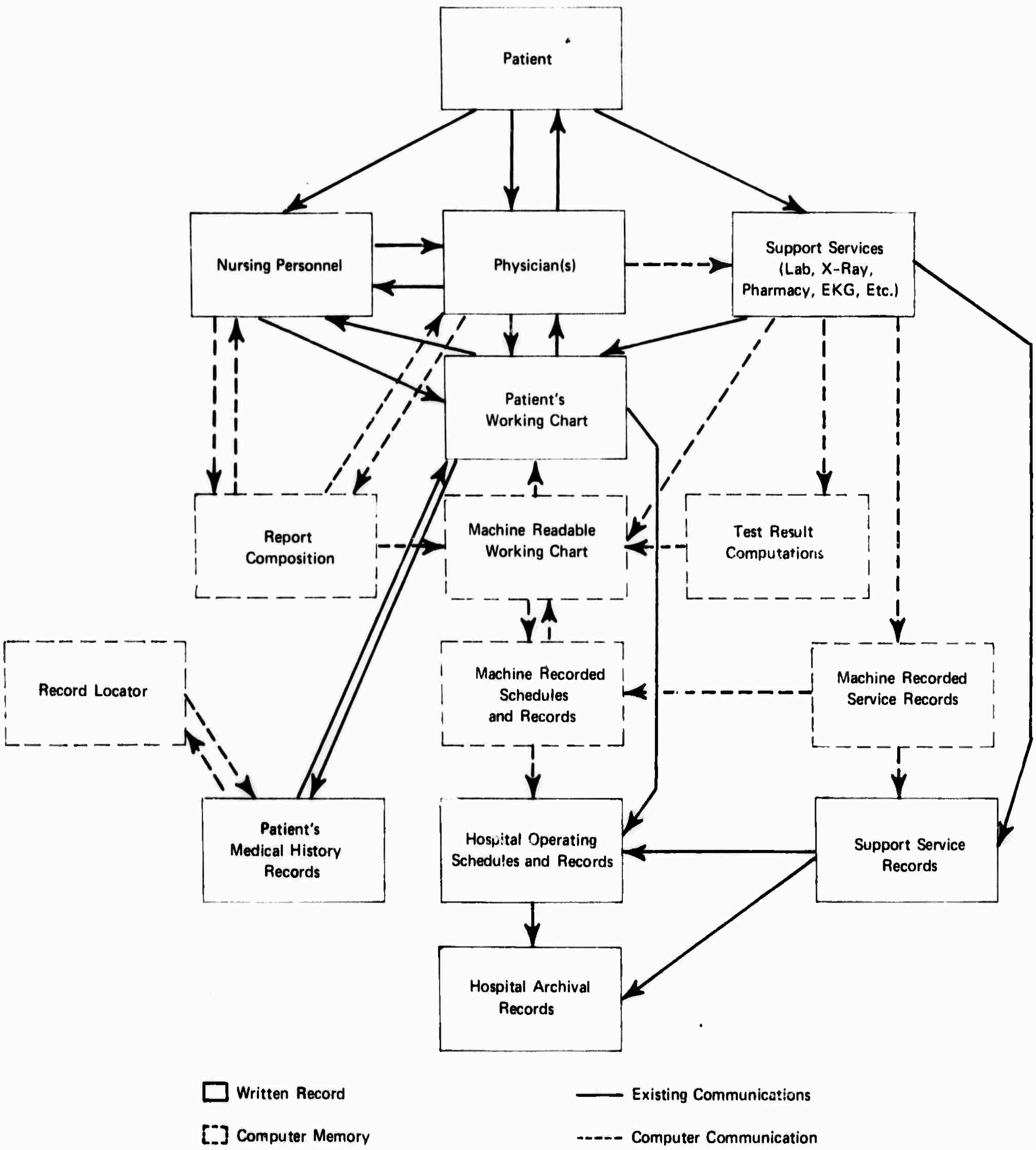

FIGURE 7.5.8 STORES AND FLOWS OF PRIMARY CLINICAL DATA WITH COMPUTERIZED COMMUNICATION SYSTEM

It is possible, of course, to let the computer memory serve as the sole record of these data, but this is unwise for two reasons. One is the problem of reliability: if the computer breaks down, these data become unavailable. While computers in tandem are in theory highly reliable (calculated nonavailability of such systems is said to be as low as 15 minutes per year), there is too much evidence that their actual reliability is too low and the consequences of failure are too severe to avoid written records. The other reason is that, from a physician's point of view, written records are by far the most convenient and quickest way for him to scan the working chart. For the foreseeable future any computerized communication system should provide hard-copy outputs at most of its terminals. The system shown in Figure 7.5.8 interposes the computer in certain communications links, notably ordering and reporting results, but it maintains intact the existing practice of recording these events, both at the origin and destination; in this case the records on paper are produced by the machine. Thus, in the event of failure, no data are lost and it is not difficult to fall back to a manual system.

As we have remarked, it is essential that a computerized communication system keep track of the location of patients in order to route messages concerning them to the correct destination. One of the common causes of lost records and delays is that patients are moved between the time a record or result is requested and the time it is received. A patient location file could be maintained solely from the nursing stations, but it makes more sense to pick up this information at the time of admission, either through the regular admitting office or through the emergency room. It is a small step from this file to maintaining a bed census file and an admissions schedule, which are natural adjuncts to the primary system.

7.5.5. EXISTING COMPUTER-BASED COMMUNICATION OF CLINICAL DATA

In this section we shall examine the state of the art in computer-based communication of clinical data. It should be borne in mind that this field is developing rapidly and information quickly becomes outdated. We shall dwell at greatest length on the REACH system (Real-time Electronic Access Communications for Hospitals), developed by

National Data Communications (NDC) of Dallas, Texas; it is the most fully developed and tested of the existing systems.

Various problems have come to light in the REACH system installed at the Baptist Hospital at Beaumont, Texas, and we shall note these, not as failings of REACH (for most of them are being corrected), but as examples of errors to be watched for in any new developments.

Once we have described REACH, it will be comparatively easy to describe other systems in terms of their differences from REACH and to arrive at certain general specifications for future systems.

7.5.5.1. REACH

The functions of REACH are centered in a specially designed CRT terminal which, in addition to a typewriter keyboard and associated special-function keys, has two unique features. It has 20 buttons along its longer (vertical) dimension that are used for choosing one or more of up to 20 lines of alphanumeric information displayed on the CRT. The terminal is turned on by the insertion of a punched credit card or "badge;" its removal shuts off the CRT. Each terminal also has a modified receive-only teletype which, when a card is in the slot, can be used to log console actions. When the console is not in use, the teletype prints messages from the system originating elsewhere. If a substantial volume of such messages is expected, additional printers can be supplied.

In addition to the twin Honeywell CCD 516's and associated I/O devices in the hospital, the original REACH concept was to transmit over voice-grade lines to a central office for additional data processing on a large central computer. As the system has evolved, however, all computations are performed in the hospital; the only non-accounting function of the central computer is to reduce patients' charts to microfiche size (4" x 6") following their discharge. Each hospital will have microfiche reader-printers.

Eighteen different kinds of personnel have been defined, and a separate type of badge has been designed for each. Many of the functions are shared by different kinds of users, but some (such as coding discharge diagnoses, entering drug orders, and signing reports are limited to the appropriate professionals. Several hundred actions have been developed for the 18 types of personnel. The richest variety exists for the physicians and the nurses. Each of the 18 types has its own characteristic CRT display, which appears whenever a badge is inserted and which provides the first of a series of choices that ultimately define an action and whatever the action is to affect (patients, records, inventory items, etc.). Each decision is reached by choosing one of the displayed alternatives and pushing the associated button along the CRT's left-hand margin. Skilled and practiced operators can go through these "decision trees" with surprising speed.

When all the necessary choices have been made, they are brought together on a final CRT screen. At this point, if there is additional information over and beyond what is normally required, it may be entered through the typewriter keyboard and is displayed on the CRT screen for final editing.

When all the information is in desired format, the action is initiated by depression of the "Enter" special-function key, and the system reverts to the appropriate entry "screen" according to the type of badge that is in the slot.

The system, as it stands, has about 3000 programs and about 1000 CRT images called "screens." Each console is associated with a dedicated buffer into which is moved a short controller program; the latter corresponds to one of the 18 professional groups designated by the various badges.

REACH still incorporates some awkward procedures. For example, the admitting office has sole responsibility for bed assignment, so transfers between or within a floor are entered into the system only by that office. This makes it necessary for the floor charge nurse to telephone the admitting office to record transfers; if she were able to enter the information herself, it would be immediately available to the office. The system disseminates information on all transfers to the chaplain's office and the dietary department via slave printers.

In the MDC system, if a physician writes or telephones an order, it can be entered by an appropriate nurse and become effective immediately. However, such orders must ultimately be acknowledged by the physician, so the system builds a file or orders awaiting "signature" for each patient.

When a patient enters the hospital system, he names a physician. Only this physician (or a nurse acting on his behalf) can set up the consultant relationships that make the patient's record accessible to other physicians. An exception to this rule is the special class of physicians who carry responsibilities for the hospital staff as a whole; these people can access any chart.

For administration of drugs, the system works from a file of generic names and a linked file of trade names for all drugs in the formulary. These files can be accessed by a code number specific for the trade name and dosage form or by name. It is possible to "page" through the list displayed alphabetically on the CRT until the drug appears and then indicate selection of the drug by using the margin button; more efficiently, the first three letters of the trade or generic name can be provided and the system then "opens" the alphabetic file at the last entry that (alphabetically) precedes the three designated letters.

Thus a drug and dosage form is ordered either by trade name or generic name, by item number, and, perhaps, from a small list of drugs with the same action or indication. Dose, frequency, and duration are selected from successive screens, and comments are typed in. When the order is verified and entered, it becomes effective, the pharmacy supply is drawn down, and appropriate charges are recorded.

Laboratory orders are created in the same way as drug orders, except that instead of appearing in and affecting the pharmacy inventory, an order to pick up blood appears on the teletype printer in the clinical lab. The physician cannot initiate a group of orders which can then be modified as desired; each order for a treatment or an investigation must be initiated separately.

In scheduling for facilities, such as X-ray and physical therapy, which have limited capacity and require reasonably long patient stays, REACH provides a choice of several appointment times; however, the staff physicians have recommended that this procedure be dropped and the first open appointment selected. For each order that will take the patient off his floor, the physician or nurse is required to specify whether the patient is ambulatory or bedfast, requires a wheelchair, or whatever. The system is responsible for giving notice to the floor and to the X-ray or other department so that the patient can be transported in time for the study.

A novel feature of the system is its use by stenographers in transcribing dictated physician reports, be they history, initial physical examination, progress notes, or reports of special studies such as X-rays, EKG's, and pathologic examinations. Like unsigned orders, these draft reports are included in the file associated with each patient. The physician may redictate it, make corrections if the report is not acceptable, or accept ("sign") it while viewing it on the CRT. Nurses and physical therapists are provided similar "note" facilities.

Since the system is designed to be used directly by physicians, nurses, and others, users must often wait until a console is available. Physicians customarily make their rounds at about the same time early in the morning, and this is the time that the longest queues are likely to build up.

To avoid excessive delays, multiple consoles at each nursing station will probably be required, one console for every ten or so beds. On this basis, the cost in larger hospitals would be between $7 and $8 per patient-day, of which roughly $1.10 could be accounted for by console rental; additional consoles can be added (within the designed limits of the system) for $331 a month. So far, NDC has configured three systems (Models I, II, and III) ranging from 32 to 120 consoles. Table 7.5.3 shows the equipment specifications. Rental costs for the systems range from $66,000 per month to perhaps twice that.

NDC's cost and feasibility studies in a Florida hospital suggested that for a $1.2 million annual rental, REACH would provide savings amounting to $1.8 million. Other calculations showed that a

TABLE 7.5.3

EQUIPMENT SPECIFICATIONS FOR

REACH MODELS

	I	II	III
Consoles and Printers			
Minimum	32*	40	60
Maximum	40	60*	120
Honeywell CCD-516			
32K	2		
48K		2	
64K			2*
Honeywell Disk Drives			
259 (capacity = 9.2 million characters)	8	8*	8*
Honeywell Tape Drives	2	2	2*
Additional Printers	11	15*	17*

* ADL estimate, not confirmed with NDC

12-hospital group in Louisiana would realize much greater savings, $3 million, as a result of paying $1.2 million to NDC.

The sources of savings computed by NDC include some items irrelevant to military hospitals, notably losses from failing to post charges (through oversight or delay), losses from charges computed at too low a rate, and opportunity losses on amounts billable but not yet invoiced to third party payers. Presumably, some savings should accrue from displacement of clerical personnel or professional personnel, such as nurses, who perform clerical duties; however, experience with the introduction of computers in other applications suggests that this is not likely.

The most convincing source of savings is shortened patient stays. Delays of a day or more arising from misplaced requests or results of lab tests and X-rays, or problems with scheduling, are common. A system like REACH can ameliorate such problems. Better control of inventories should also lead to some savings. At this time, however, no savings can be clearly substantiated in military hospitals; until more experience with systems like REACH has developed, their contribution to reduced costs must remain problematical.

Since REACH is one of the first full-scale hospital information systems, it has brought to light a number of problems, many of which can be overcome. Along these are the following:

- After entry of a piece of information, such as a note by a nurse of medication administered to a patient, the machine automatically reverts to the original display at all the nursing stations. Even if the next drug has been administered to the same patient, the nurse has to repeat the same selections--nursing station, patient name, "chart patient data," "medication administration"--before she can select the second drug. This difficulty can be eased by better programming. For example, at the end of each series of choices and depression of the "Enter" button, a screen could be displayed which allows a choice of how far to go back up the decision tree for the next task (instead of always going back to the original "badge-in" routine). Another improvement would be to provide ways of jumping down the decision tree to high-frequency actions, particularly the charting of drug administrations. Nursing practice tends to group high-frequency actions; a nurse will sit down to chart medications for a number of patients, for example. It makes little sense to have the nurse's first decision at the CRT the choice of patient rather than the choice of action, as she is much more likely to do the same action for a number of patients than to make entries on a variety of actions for the same patient.

- The system also lacks a way of fully replacing the Kardex. "Screens" could be provided by the system that display in compact form the salient features of a patient and his nursing care. This fast review process should be set up to be "paged" through quickly at change of shift. It would not be portable, but nurses rarely take the Kardex to the patient anyway.

- If physicians do not use the terminals themselves, the nurses enter physicians' orders. Such orders are operative without physician confirmation, although a list of "unsigned" orders accumulates for each patient and presumably is acknowledged by the physician as part of the chart completion process many days later. It would be better to facilitate immediate physician review of these orders (as transcribed by the nurse from the written order sheet) by making it easier for him to find (via the CRT) unsigned orders for his review and "signature." Following the "rubberstamp rule," the REACH system treats the physician's badge and affirmative action on the CRT as the "signature." Thus, when a physician inserted his badge, he would be offered a choice of functions before or at the same time he offered his patient list. In this way he could get announcements and phone messages, and could review his unsigned orders and unsigned reports without checking those files for each of his patients.

- Similarly, the physician could be presented with all new laboratory and special study reports. Alternatively, he could get just the subset of new data that showed abnormalities--parameters either beyond the range of the hospital norms, significantly changed from previous findings, or outside limits set at the time the work was ordered. CRT ordering of lab work lends itself very well (either through a nurse or directly by the physician) to the introduction of expected ranges. When results fall outside of expected limits or break trends, they probably belong in a final narrative summary and should be flagged on consolidated lab sheets.

- While it would be folly to encourage physician use of the system in its present form (because of its inefficiences in shifting from job to job), some physicians might find selective presentation of important new data useful. To the extent that this encourages physicians to "treat the chart," to fail to integrate the new data with the old, to fail to be fully aware of changes in the patient's signs and symptoms, these facilities will be resisted by thoughtful physicians. However, an easy, direct jump from new out-of-range lab results to that same patient's full lab reports, history, physical, and progress notes would help the physician to integrate the new data with the old and meet part of these objections.

7.5.5.2. Lockheed Medical Information System

Lockheed Information Systems has developed and installed in El Camino Hospital, Mountain View, California, an information system comparable in function to the REACH System. It differs from REACH in that computing is done remotely at a regional center which is operated by Lockheed and connected to the hospital over wide-band phone lines. In the existing installation, only two nursing stations are connected, so the equipment has not yet stood the test of full-scale operation.

Like REACH, the Lockheed system uses CRT displays. However, items are selected with a light pen; this increases considerably the amount of information which can be displayed at one time, because format constraints are minimal. CRT displays are augmented with an electrostatic ink printer, which provides hard-copy outputs and is silent in operation. Lockheed software permits entering the branching hierarchy at various levels, thus avoiding one of the annoying (though correctible) shortcomings of REACH.

Lockheed has proposed a full-scale system for El Camino Hospital which will rent for $75,000 per month, or about $7 per patient-day.

7.5.5.3 Spectra Medical Systems

Spectra Medical Systems of Palo Alto, California, recently announced an information system for hospitals that is generally comparable to MDC's REACH or Lockheed's MIS. It is scheduled to become operational in mid-1971, although a demonstration model is expected sooner.

Like REACH (but not MIS), the system uses a dedicated computer in the hospital. Spectra has elected to concentrate on clinical and scheduling data, omitting business functions except for providing inputs to a business system, either on magnetic tape or conceivably core-to-core. A novel feature of the Spectra system is use of color on the CRT screen. Printing different messages in different colors provides an additional set of descriptors for messages, which may reduce reading time or human error in interpretation.

Spectra believes that it can sell or lease its system for about two-thirds of Lockheed's price, that is, for $4 - $5 per patient-day in medium or large hospitals. Whether this goal can be achieved when the system is fully developed remains to be seen. Nonetheless, this new entry into the field illustrates the increase in competition and supports the view that the cost of computer-based hospital information systems will decrease.

7.5.5.4. The Medelco Communication System

The Medelco system differs from full-scale information systems in that it deals exclusively with communications and is simpler in concept, though remarkably effective. It aims at a modest goal--elimination of transcription in ordering--and thereby provides a much cheaper system.

The Medelco system provides "store-and-forward" communication. Instead of setting up circuits to the desired destination and then transmitting the message to it directly, store-and-forward systems receive and store the message in a central computer until a circuit between the computer and the desired destination is available.

Such systems are particularly well adapted to applications in which the message (order) is to be broken up or duplicated and then sent to several destinations. Medelco has exploited this characteristic to "peel off" and send the patient charge to accounting as each order is transmitted to, say, a clinical lab. Unfortunately, orders which are cancelled, or simply not done, are likely to be charged for under the present Medelco system.

For each order the Medelco system requires that two perforated cards be placed manually in a card reader. One card identifies the patient and the second identifies the order. The cards are selected manually by reading the printing on them which corresponds to the punched codes. If the full array of laboratory work and X-ray studies are to be transmitted by this device, a substantial variety of cards are needed and must be placed in a rack or bin next to the card reader. To add new messages or to change the messages (for example, the price of a test or its destination) merely requires the perforation of a new card, and the use of a typewriter driven by the perforations to print the message and duplicate the perforations on a card for each ordering point.

Using this framework, the Medelco system has added to the basic store-and-forward function. A file is maintained in its central computer listing all of the hospital's beds and their occupants. Whenever a patient occupies or leaves a bed, the admission office and the nursing stations send messages to this file through the system to keep it updated. If the Medelco system distributed lab results, it could use this information to return the results to the patient's current location, regardless of whether the patient had been moved since the test was ordered.

Typical costs range from $1.00 to $1.50 per patient-day. The Medelco system has been running successfully for a year or two, and it therefore embodies none of the risks presently associated with more ambitious systems.

7.5.5.5. Meditech

Meditech of Cambridge, Massachusetts, offers a system which computerizes certain functions concerning clinical data. Though it is not integrated like REACH, it does have some unique features. Services are provided at terminals in the hospital, using a time-shared computer at a remote location. Programming is done with a special version of MUMPS (MGH Utility Multi-Programming Systems), which was originally developed at Massachusetts General Hospital. This language was devised to make programming and reprogramming of interactive routines (as are needed for automated history-taking or report composition) simple for users. Because of this, Meditech can offer programs tailored to each user's special requirements; in fact, a user can rewrite his program from his own terminal.

Meditech developed and is now using the following programs:

- Automated medical history-taking and summary,
- Patient examination report,
- Hospital census operations,
- Patient admissions and transfers,
- Appointment scheduling,
- Medication ordering, and
- Lab test ordering and result reporting, including an interface with automated analyzers.

7.5.5.6. Other Communications Systems

There are numerous other entries in the field which are at least partially competitive with the systems described. Among these are the following:

- Compucare, Chicago, Illinois
  Systems for the Health Care Field

- Control Data Corporation, La Jolla Systems Division, Calif.
  Integrated Medical Systems

- General Electric Company, Syracuse, New York
  Medinet

- International Business Machines, New York, New York
  Medical Information Systems Program (MISP)

- McDonnell Automation, St. Louis, Missouri
  Hospital Shared Computer Systems

- Medi-Data, Charlotte, North Carolina
  Medi-Data Systems

- Sanders Associates, Nashua, New Hampshire
  Hospital Data Management System

This list illustrates the intense competition developing in the field of hospital information systems.

7.5.5.7. Comment on Existing Systems for Military Hospitals

Certain applications of computers for communication of clinical data in hospitals are definitely established as successful and reasonable in cost. These include clinical laboratory systems, pharmacy systems, and the Medelco forwarding system. The more complex systems, typified by REACH, are still experimental; they are expensive, and users cannot depend on realizing the benefits they promise. Despite the difficulties and uncertainties currently evident in the larger systems, however, there do not seem to be any insurmountable obstacles to their ultimate success. Costs will be high for the next several years, to compensate for continuing development expenditures. However, costs for computing and terminal hardware are gradually decreasing, and the competition in developing applications programs is intense enough to cause an eventual decline in costs.

Under these circumstances a tenable plan of action for the Department of Defense would be simply to stay out of development of large-scale systems and wait for the dust to settle. This would be the best policy for most DOD hospitals. However, there are enough differences between military hospitals and their civilian counterparts so that any system developed for the civilian market would require adaptation for military hospitals. In addition, hospital staffs have much to learn before they can use such systems effectively. For these reasons, the Department of Defense should begin the adaptation and learning processes by including a full-scale hospital information system in the prototype hospital. One of the existing systems would form a natural starting place for DOD.

In the next section we comment on the differences between military and civilian hospitals that are significant for computerized information systems, and in the following section we outline a plan for developing such a system for a military hospital.

7.5.6. DIFFERENCES BETWEEN MILITARY AND CIVILIAN HOSPITALS AFFECTING COMPUTERIZED COMMUNICATIONS SYSTEMS

In most respects, the activities and communications in military hospitals are no different from those in civilian hospitals. However, there are several important differences, which modify substantially the value of various automated procedures. Because of these differences, the Department of Defense cannot justify its developments on the same basis, nor can it rely upon civilian developments to meet all of its needs. The salient differences are these:

- Civilian hospitals expend much effort in accumulating billing charges for each patient, and a major justification for computerized communications systems is simply to insure that charges will be properly billed. A few hospitals (the first was West Valley Hospital in Encino, California) have tried flat-rate charges based upon diagnosis or length of stay, and the simplification provided by this innovation appears well justified and acceptable to insurers. This practice will probably spread, but as of now information systems developed for civilian hospitals primarily serve to accumulate charges for patients. This matter is largely irrelevant for military hospitals.

- All hospitals operate as part of a larger system of health care, but in military hospitals this factor is more pronounced because military personnel are transferred so frequently. With regard to patients, this means that whatever innovations in record systems are introduced, they must produce hard copies for records when personnel are transferred.

- Another effect of the same circumstance in military hospitals is to increase the value of making procedures routine, as computer systems tend to do. Because tours of duty in a military hospital are usually only two or three years, and sometimes even less, staff members do not get to know one another well, and the "structure" to procedures must lie mainly in rules rather than in personal working relationships.

- One obstacle which has stood in the way of developing workable hospital information systems in civilian hospitals has been the resistance of physicians who have little motivation to learn the proper procedures or to tolerate the flaws and delays characteristic of most systems under development.[2] Coupled with the fragmentation of authority and responsibility in civilian hospitals, this has been a potent force impeding development and acceptance of hospital information systems.

The same problem will arise, of course, in military hospitals, but the command structure in these institutions can minimize its effect.

- Whatever developments are undertaken by the Department of Defense, their costs are spread over many hospitals. The costs of computer developments are substantial, and most private hospitals are unable to underwrite them.

7.5.7. RECOMMENDED PROGRAM FOR AUTOMATION OF CLINICAL DATA SYSTEM

Although there are few demonstrable savings that would help to offset the cost of a computerized communication system for clinical data, we believe that the Department of Defense cannot afford to neglect this area. Initial installations must be regarded as experimental, and one of the major goals must be evaluation of the installation.

It would be unwise to try to develop at the outset a system which embraced all computerizable functions in a single computer. Instead, we would advise the development (as stand-alones) of a computer in the pharmacy for outpatient prescriptions (Section 7.3) and another in the laboratory to permit the use of fast analyzers (Section 7.6).

Functions such as history-taking, computer-aided diagnosis (Section 7.7), and report composition need further development, not of the hardware or technical software, but of specifications for questions to be included; the problems lie in the medical field, not the computer field. This development need not be done in the prototype hospital, though it could be. Whenever development is done, it should include installation of a computer and CRT terminals in an operating military hospital, so that the programs can be tested in a realistic environment.

We have been impressed by the simplicity and consequent ruggedness of the Medelco system and believe that it deserves consideration for military hospitals. Since the prototype hospital will be the testing ground for more advanced systems, a Medelco system should be tried in some other hospital, if DOD elects to evaluate it.

For the prototype hospital, we recommend installation and evaluation of a system like those offered by NDC, Lockheed, or Spectra. Such a system would embrace the following functions:

- Recording data on admissions and patient transfers and maintaining a bed census;
- Recording and forwarding to the laboratory all test requests, and generating specimen collection schedules and lab work plans;
- Recording lab results, either automatically from automatic equipment or manually from nonautomated equipment (excluding, of course, those performed on fast analyzers, as discussed in Section 7.6) and maintaining cumulative records of results for a week;
- Recording and forwarding to the pharmacy all inpatient prescriptions printing labels and other data for drug deliveries from the pharmacy, and providing drug administration worksheets for nurses;
- Recording requests and scheduling appointments in radiology and accepting results, including free text recorded and entered by a stenographer;
- Recording all nursing orders from physicians and providing a care plan for each inpatient;
- Issuing reminders to nurses, lab personnel, etc., for work not completed and recorded after specified intervals, and reminders of medications or other actions due;
- Recording schedules for outpatient visits to clinics and generating appointment schedules for each physician in the clinic;
- Generating a shift summary of nursing notes for nurses' signatures and a 24-hour summary of nursing notes for each inpatient;
- Logging dispatch and receipt of record folders and X-rays, using an optical or magnetic reader of special labels on each such folder; and

- Generating a discharge summary from internal records at time of patient discharge.

All the functions enumerated (except for record folder logging) are now performed by at least one of the existing systems and could be made part of a new system.

Existing systems seem to be standardizing on one CRT terminal in each nursing ward, with a printer for every ten or so beds; this number is based upon the amount of time users (physicians and nurses) need to spend at the consoles entering and retrieving data. Whether this number is adequate depends upon the response time of the system and the amount it is used; present experience is insufficient to supply a conclusive answer, but a cursory analysis suggests that more consoles are probably needed.

From a physician's point of view, written records are better than those displayed on a CRT, because they are readily accessible, can be prepared or modified at bedside, and are easily authenticated; therefore, we are inclined to believe that computerized systems will not be fully accepted by physicians until there is a console for every bed (or for every room). This would appear to be an expensive requirement, since system cost is directly affected by the number of terminals; however, the cost of CRT terminals and matrix printers has fallen rapidly in the last few years, and still further reductions are likely in the next five years. We do not think an experimental system will get a fair trial unless it provides sufficient consoles. (To test this assertion in the prototype hospital, one ward could be equipped with one console per bed and other wards could have less.)

The question of whether the central computer should be on-site or off has supporters on both sides. As we have remarked, REACH was orginally conceived with an on-site computer tied to a larger off-site computer, but, as it has worked out, virtually all computations are done on-site. Lockheed's MIS will use off-site computers at regional centers connected to the terminals by wideband telephone lines. The presumable advantage is that costs can be somewhat lower because fewer personnel are needed to tend one computer than to tend several in several hospitals. This cost reduction is offset to a degree by the cost of the lines, and reliability may be somewhat less. Experience is insufficient to show which alternative is preferable, but in the prototype hospital the computer should be on-site to facilitate experimentation.

7.5.8. TELEVISION FOR REMOTE CONSULTATION

Several pilot programs utilizing closed-circuit TV to link patients with physicians have been undertaken in the United States. There is no question about technical feasibility of "telemedicine"; the major problem is the cost (about $100,000 if the stations are sufficiently far apart to require transmission towers or long runs of coaxial cable).

In practice, TV can be used in several different ways. These should be distinguished, because they are applicable to different aspects of medical practice.

- Telediagnosis. In this mode, a physician at one end of the TV link diagnoses a patient attended by a nurse or corpsman at a remote location. It has been used with some success, especially for emergency cases, at Logan Airport in Boston, which is linked to Massachusetts General Hospital. With such an arrangement the physician can ask the patient or a medically trained attendant to change positions, to report on coloring, to use a stethoscope, and to perform other simple tests which aid diagnosis.
- Teleconsultation. A physician specialist at one end of a TV link can advise another physician, or a nurse or corpsman, when the problem is beyond the competence of the person attending the patient. This technique has been used with some success at the VA Hospital in Bedford, Massachusetts, which is linked to Massachusetts General Hospital. As a rule, such consultations are arranged by schedule and are no different from referral to a specialist, except that the need for the patient or the specialist to travel is eliminated.
- Telecounseling. In this mode a psychiatrist, psychologist or social worker at one end of the link counsels a patient at a remote location. Operationally, it is

no different from other modes. However, telecounseling may be valuable for treating an emergency patient, such as one undergoing an adverse LSD reaction, when no trained assistance is available at the remote location. Also, it is said that some patients, especially adolescents, prefer the impersonality of a TV screen to the intimacy of a face-to-face encounter.

- Teleinterpretation of X-rays. A radiologist or physician can often interpret X-rays by television from a remote location. The feasibility of the technique depends upon the X-ray, but when it can be done, the delay in shipping X-rays for interpretation is eliminated. The radiologist can request that the camera be focused on particular regions of the film, or he can ask the attendant about the presence or absence of subtle features.
- Education. TV links expand the opportunities for instructing medical personnel or training patients with disorders (such as aphasia) which require extended therapy. In cases where travel, by either the patient or the specialist, is an impediment, TV may be useful.

In addition to cost, there are some other problems. Obviously, television contact is less satisfactory than face-to-face contact, except perhaps in the case of counseling. Therefore, it makes sense mainly when the alternative is no contact with a specialist at all, or contact with a specialist only with significant inconvenience or expense. Television images are imperfect, and the absence of detail and color are impediments in some situations. Color TV does not reproduce colors with sufficient fidelity to warrant the additional expense. However, color information is not wholly lacking with black and white TV, because the specialist can always ask the attendant about coloring, which may be important in some situations such as dermatological diagnosis.

More significant problems lie in organizing procedures at both ends of the TV link and in gaining acceptance of the idea. The stations at Massachusetts General Hospital mentioned above are said to have worked reasonably well. Physician acceptance was low at first, but now the stations are in use about four hours per day.

Of all the modes for telemedicine, teleconsultation is the one which makes most sense for military hospitals. The advantage offered is that travel by the patient or physician is eliminated and less time is lost.* By providing the opportunity for convenient consultation with a specialist, teleconsultation increases the feasibility of using paramedical personnel for primary care in ambulatory care facilities.

Simply providing a TV link between a dispensary and the main hospital is insufficient to assure its usefulness. It should be part of an experimental program to extend the ability of nonphysicians to provide high-quality care as part of a team, as described in Section 2.4. No formal evaluations of telemedicine in the experimental set-ups at Massachusetts General Hospital have been completed, but success has been sufficient for the program to be expanded and continued.

Viewed solely from a financial aspect, a TV link involves an expense of about $20,000 per year (amortizing the capital expenditure over five years). The savings appear in reduced travel time for patients - referral to the main hospital from a dispensary on a military base typically takes at least half a day of the patient's time - and in extending the scope of a nonphysician's activities, thus taking advantage of the lower salaries of nonphysicians. If two physicians can be saved, then the cost of the system is justified. Even more important than the cost of physicians' services is the shortage of physicians.

Accordingly, an experimental TV link between the base hospital and at least one of the dispensaries should be installed in the prototype hospital. Its principal mode of use will be teleconsultation, with specialists on an appointment basis and with other physicians in emergencies or when the dispensary physician is absent.

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*A possibility outside the scope of this study is to link hospitals on military bases with referral hospitals such as Walter Reed or Bethesda. Transport of patients to these centers is now a significant expense.

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7.6. AUTOMATION IN THE CLINICAL LABORATORY

7.6.1. INTRODUCTION

Expenditures for labor, reagents, equipment, and other supplies for clinical laboratories amount to about 5% of the operating budgets of DOD hospitals. Furthermore, this segment of hospital activity has been growing rapidly as new tests have become possible and physicians have become familiar with their significance. For the most part, lab tests performed manually must be done sample by sample and test by test. Thus, doubling the workload implies doubling the staff and the equipment, and doubling the budget, for there is little opportunity for economies of scale when tests are performed manually.

One potential way out of the route to increased costs, as laboratory workloads increase, is automation of the test procedures. There is an enormous variety of such equipment available, and it holds promise of reducing costs and improving accuracy of laboratory determinations. Most of this instrumentation has been designed for the clinical chemistry area, although there are also instruments used in hematology, serology, and microbiology. Here, automation has replaced single functions of a technician or whole chains of linearly related procedures.

Despite the promise, in practice the saving (in time and dollars) which this instrumentation produces is often not realized because of improper selection of instrumentation for particular laboratories. The wrong automated instrumentation can prove to be more expensive than having no automation at all. The current fad of installing a Technicon SMA 12/60 (Sequential Multiple Analyzer) indiscriminately in hospital laboratories is a case in point.

Aside from cost, there are other reasons for introducing automation. Automated equipment may be more precise, in that the amounts of reagents added and the reaction times allowed are controlled more accurately by machine than by hand. (Accuracy is not usually at issue, since any acceptable device meets acceptable standards.) Secondly, automation may offer some advantages with respect to reliability and liability to large error. Another reason is that most automated equipment can perform large numbers of tests faster than a technician. This, of course, does not apply to STAT (immediate) tests, which are almost always performed as single determinations, but it does bear on many of the tests performed commonly and routinely.

Automated instrumentation may make it possible to perform tests for which technicians are not available. Tests which cannot be performed or can only be performed with great delay or great annoyance at any time are not requested by physicians; therefore, the present workload should be regarded a lower boundary. Usually, when automation is introduced, a greater demand is revealed. As remarked above, the fulfilled demand has been growing rapidly and probably would do so even in the absence of automation. Thus, if the present shortage of trained technicians were aggravated, automation would appear even more desirable.

Finally, the concept of making a large number of determinations without specific orders from a physician, in the expectation that the results may be needed or may reveal unsuspected abnormalities, has gained acceptance. With automated equipment, it is usually easier to perform a standard series of tests instead of a set tailored to each patient. Multichannel blood analyzers allow the performance of many determinations with a small investment in labor. Such determinations can be performed on presumably healthy individuals, on all hospital admittances, or on select patients as a part of routine diagnosis. The usefulness of such an approach is still debated. What is important to keep in mind is that an unassailable justification for laboratory automation occurs when the equipment rapidly and accurately performs large volume work which the laboratory must do. If, in addition, it can do other determinations without significant additional work, then that should be regarded as a benefit though not a justification. For a time, people attempted to justify machines that performed a large number of tests on the basis of discovery of occult disease, but the yield has been poor and the justification doubtful.

7.6.2. EQUIPMENT FOR LABORATORY AUTOMATION

Table 7.6.1 lists automated equipment for clinical laboratories, both existing (as of June, 1970) and shortly to be available. Here we have defined automated equipment as that in which an electromechanical function eliminates a technician function. Thus, the table does not include automatic pipettes, which reduce the time of a technician function but do not eliminate it, nor the reagent kits, which eliminate a function but are not electromechanical. These exclusions are not important in this discussion, because they represent little in the way of conceptual advances and even less in terms of capital budget outlay. We have also not included the more exotic instrumentation, such as amino acid analyzers, which would find very little application in clinical laboratories in military hospitals. The table also does not include histology instruments, such as the Auto-Technicon, nor desk calculators, which may be used in any clinical laboratory, since these represent automated instruments which have existed and been used historically for a longer period of time. The serology instruments listed can usually be used in a virology laboratory as well. The urinalysis, parasitology, and cytology laboratories are not included in this table because they do not utilize automated instrumentation (by our definition) except in procedures similar to those used in histology.

While the listing is intended to be exhaustive, it almost certainly falls short of this goal. What it does show is the enormous variety of automated instrumentation available. Even if the list were exhaustive today, it would be out of date tomorrow. We suggest later on an innovation which can achieve almost instantaneous turn-around, which will prove valuable, mainly for blood chemistry tests, which are already automated with longer turn-arounds. The next stage of development is probably in automatic pattern recognition of disease states in microscopic samples, on which a good deal of work is currently in progress.*

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*Subsequent to compilation of Table 7.6.1 the Technicon Hemolab D differential white cell counter was announced.

TABLE 7.6.1a AUTOMATED INSTI

Manufacturer	Model	Cost	Description
Advanced Instruments	Cryomatic Multiple		Freezing Point Osmometer
AGA**	Autochemist	$450,000	Discrete sample robot chemist
American Optical	Robot Chemist	21,700+	Discrete sample robot chemist
Aminco+	Assayomat	50,000	Robot chemist
Aminco	Rotochem	77,000	Centrifugal colorimeter
Aminco	4-7395		Fluoro-microphotometer
Atago	Automatic 36	2,800	Discrete sample colorimeter
Bausch & Lomb	Zymat 340	9,850	Enzyme rate analyzer
Bausch & Lomb	System 400	8,700	Discrete sample robot chemist
Bausch & Lomb+	Spectrophor I	9,875	Spectrophotometer
Beckman	DSA-560	17,175	Discrete sample robot chemist
Beckman	ERA-2001		Glucose analyzer
Beckman	Three models	5-8,000	Atomic absorption
Canalco Pacific	TOA Data Converter	3,500	Printing analog computer
Carlo Erba+	CL A 1510	3,680	Discrete sample robot chemist
Cecil Instruments	CE 404 System	1,625	Discrete sample colorimeter
Dynacon	LC-172	1,452	Linearizing analog computer
DuPont	ACA	65,000	Discrete sample robot chemist
Electro-Nucleonics	GeMSAEC	11,675	Centrifugal colorimeter
Farrand	ATS	4,800	Spectrofluorometer
Fiske	Osmatic		Automatic osmometer
Gilford	Phase II System		Flow-through colorimeter
Hewlett Packard	7670	2,850	GLC automatic sampler
Hilger & Watts	Atomspek	4,250	Atomic absorption
Hycel	Mark X	65,000*	Discrete sample robot chemist
Joyce Loebl+	Mecolab	13,000	Robot chemist
Joyce Loebl+	Mark II Mecolab	14,000	Robot chemist
Joyce Loebl	Microbio Mecolab		Discrete sample robot chemist
Joyce Loebl	Enzymat		Enzyme rate analyzer
Lab-Line	Clino-Mak	9,250	Discrete sample robot chemist
LKB	8600	7,500	Enzyme rate analyzer
LKB	7400	9,500	Calculating absorptiometer
Luft Instruments+	77	895	Enzyme analyzer
N.I.L.	Digital		Flame photometer
Orion	Ionalyzer	150-250	Specific ion electrodes

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ED INSTRUMENTATION -- CHEMISTRY

	Samples Handled Unattended	Maximum Procedures Per Sample	Comments
r	29	1	Specific application only
hemist		24	Greatest flexibility
hemist	100	1	Too generalized for hospital. Off the market.
	33		Spectrophotometric
		1	Not yet on market
	20	1	Can be used with Autoanalyzer
eter	36	1	Uses specific filters; includes recorder
	47	1	340 mμ light source
nemist	45	1	Can run rate reactions
	16		Electrometric
nemist	40	2	Analog $2,500. Protein-free filtrate
	1	1	Glucose in plasma, serum, or urine
	20-200	1	Accessories for flame emission
:	1	1	Uses Autoanalyzer output
nemist		1	30 or 60 samples/hour
:ter	30	1	Recorder extra
ter	1	1	Uses Autoanalyzer output. Must be linear
emist	Varies	30	Designed for stats. Not yet on market
	16	1	Analog $5,280 extra. Roto-loader $3,000 extra
	16	1	Designed for clinical batch analysis
	24	1	Fully automatic
	1	1	Used with Autoanalyzer for digital printout
	36	1	Gas chromatograph extra
	40	1	Sample changer extra
emist	60	10	Only 10 specific tests possible
	15	1	Photometric. No UV
	15	1	Spectrophotometric
emist	40	1	Specifically for vitamin tests
	15	1	340 mm and higher light source
emist	90	1	With cuvette washer and recorder
	100	1	340 mμ light source
er	100	1	Visible range only. Printer $1,050 extra
	52	1	Necessary modules are above base price
	30	2	Includes diluter. Printer $750 extra
	1	many	Readout instrument extra

Manufacturer	Model	Cost	Description
Perkin-Elmer	C4	$ 25,000*	Discrete sample robot chemist
Perkin-Elmer	4A	15,725	Atomic absorption
Philips Electronic Inst.	4		Flame emission and absorption
Phoenix Instrument +	B9000	19,600	Discrete sample robot chemist
Scientific Industries	MSAS/360	9,000**	Solid phase sample analyzer
Sherwood	Digecon	10,525	Enzyme rate analyzer
Shimadzu	Double 40S	9,700	Enzyme rate analyzer
Smith, Kline	Eskalab Flowthrough	4,375	Flowthrough spectrophotometer
Technicon	Autoanalyzer	6,500	Flowthrough robot chemist
Technicon	Autoanalyzer II		Flowthrough robot chemist
	1 channel	9,000	
	2 channel	11,000	
Technicon	Electrolyte System	20,000	Flowthrough robot chemist
Technicon	SMA 6/60	31,750	Flowthrough robot chemist
Technicon	SMA 12	--	Flowthrough robot chemist
Technicon	SMA 12/60	70,000	Flowthrough robot chemist
Technicon	SMA 12/Jr	60,000	Flowthrough robot chemist
Technicon	SMA 12/Micro	70,000	Flowthrough robot chemist
(Other Technicon instruments include the IDee and T40 sample identification systems, the Technilogger tabulator, Fluorometer II, PBI System, Kjeldahl System, Urinary Estrogen Sy			
Unicam	AC60	25,000*	Discrete sample robot chemist
Unicam	SP90	4,340	Atomic absorption
Unicam	SP800	6,990	UV and visible spectrophotometer
Union Carbide	CentrifiChem	21,500	Centrifugal colorimeter
Varian Techtron	AA-120		Atomic absorption
Vickers	Multi-Channel 300	(23,000)	Modular robot chemist
Zeiss	PL 4 or PM 4		Flowthrough spectrophotometer

All information is from manufacturers' literature except when noted otherwise as below:

* Indicates hearsay information or a nonquotable source
\+ Indicates 11/20/69 Industrial Research Magazine as source
** ADL Service to Investors Report 10/7/68

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ED INSTRUMENTATION -- CHEMISTRY (Cont'd.)

	Samples Handled Unattended	Maximum Procedures Per Sample	Comments
chemist	60	4	Sample identification system
	100	1	Fully automated (dilution to printout)
sorption	25	4	Simultaneous Na, K, Ca, and Mg
chemist	36	1	Spectrophotometric
alyzer	30	1	Not yet on market
	1	1	High precision. Digital output
	5	1	Variable dwell and cycling times
otometer	50	1	Not yet on market
nist	40	1	Multiple channel also available
nist	40	1	Less reagent and smaller samples; $3000 add'l for digital readout $5000 add'l for digital readout
nist	40	4	Na, K, Cl, CO_2 only
nist	40	6	Glucose, BUN, Na, K, Cl, CO_2 only
nist	40	12	Off the market
nist	40	12	Variety of procedures to choose from
nist	40	12	$2,180 more for Hospital Model
nist	40	12	0.2 ml for 12 tests
ems, Estrogen System)			
chemist	120	1	Highly flexible
	32	1	Recorder extra
photometer	50	1	Sample changer and printer extra
r	30	1	Digital printout. Not yet on market
	60	1	Uses ASC-50 sample changer and DP-32 printer
	60	20	Different configurations of basic unit
tometer	50	1	Modular unit

TABLE 7.6.1b AUTOMATED INSTRU

Manufacturer	Model	Cost	Description
Bio-Medical System	Thrombo Wheel	$ 385	Clotting timer
Coulter	Many models		Impedance blood cell counters
Coulter	S	35,000	Cell counter and Hb analyzer
Coulter	Hemoglobinometer	1,300	Hemoglobin concentration
Fisher	Autocytometer II	3,800	Optical blood cell counter
Fisher	Hem-alyzer	17,100	Cell counter and Hb analyzer
Fisher	Hemophotometer		Hemoglobin concentration
General Science	Haema-Count	845	Blood Cell Counter
Hyland	Clotek		Clotting timer
Kalmedic Instrument	Fragiligraph		Osmotic fragility
Medical Automation*	Electra 500		PT and partial thromboplastin time
Shick			Clotting timer
Technicon	Cell Counting System		Optical blood cell counter
Technicon*	SMA 4A	17,325	Cell, Hb and HCT analyzer
Technicon*	SMA 7A	19,950	Cell, Hb and HCT analyzer
Technicon	Platelet Counter		Flowthrough counter

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OMATED INSTRUMENTATION -- HEMATOLOGY

	Samples Handled Unattended	Maximum Procedures Per Sample	Comments
	1	1	Very simple instrument
nters	1	1	RBC, WBC. Platelet count adapter
yzer	1	3	Dilutes, counts, prints out 7 values
	1	1	Flowthrough colorimeter
er	1	1	Digital display readout
yzer	48	3	Fully automated
	1	1	Flowthrough colorimeter
	1	1	Not yet use-tested
	1	1	Not yet use-tested
	1	1	Cumulative fragility or derivative
astin time			New instrument. Characteristics unknown
	1	1	Not yet on market
er	40	1	Off the market
:	40	4	Replaces SMA 4 and 7
:	40	4	Also calculates MCV, MCH, MCHC
	40	1	Can also be used for RBC's or WBC's

TABLE 7.6.1c AUTOMATED INSTRUMENTATION -- SE

Manufacturer	Model	Cost	Description
SEROLOGY			
Canalco	Autotiter II	$ 3,685	Serial dilutor
Fisher	SeroMatic	15,000	Syphilis slide preparer
Technicon*	ART		Syphilis screen
Technicon	Hemaglutination Sys.	6,089	Hemagg and complement fixat:
BLOOD BANKING			
Technicon	Typing Auto Analyzer	20,000*	Direct and indirect typing
Technicon	Auto Typer	8,400*	Direct and indirect typing
MICROBIOLOGY			
DuPont	Luminescence Biometer	5,500	ATP detector
Millipore	piMC	25,000	Particle Counter

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:NTATION -- SEROLOGY, BLOOD BANKING, AND MICROBIOLOGY

ption	Samples Handled Unattended	Maximum Procedures Per Sample	Comments
	8	1	Includes blotting, washing and flaming
preparer	40	1	Performs Aerojet-General FTA-ABS test
n		1	Performs reagin test
plement fixation	40	1	Two-channel system $9,620
irect typing	200	8-15	Not yet accepted by NIH
irect typing	40	10-12	Paper strip output contains aggregates
	1	1	Specifically to diagnose bacteriuria
er	1	varies	Microscope-computer-television system

In each case, following the manufacturer and model, we have listed the cost of the equipment, a description of its function, the number of samples which can be loaded at one time, the maximum number of procedures per sample, and any brief comments about the device. This information will be used as the basis for discussion of the issue of automation of clinical laboratories in military hospitals. It will be seen that it is not possible to be categorical about particular items. Instead, the only reasonable way to proceed is to examine automation of laboratories in particular hospitals on the merits of the particular situation. This we have done in the context of the laboratories at Fort Dix and Jacksonville. We did not carry out this scheme at March AFB, because data available on the laboratory workload do not itemize the kinds of tests; instead, records of the workload are maintained only as aggregates of all procedures. However, the two examples will serve to illustrate quite adequately the reasoning which should lie behind selection of automated equipment for clinical laboratories.

7.6.3. CRITERIA FOR SELECTION

The size of Table 7.6.1 indicates the diversity of automated equipment available for the clinical laboratory. It would be ideal for decision-making if each of these instruments had a particular and distinctive niche in which it performed most effectively, to the exclusion of all others. This is not the case. Instead, the capabilities of the instruments overlap in various ways. Nevertheless, a number of specific criteria for deciding on an instrument in a particular laboratory situation do exist. Beyond the question of costs (for staff, equipment, and reagents) there are four important criteria:

(1) Turn-around time. The importance of decreasing the amount of time spent between receiving the sample in the laboratory and obtaining the results is, in fact, not as critical as is sometimes considered in contemporary laboratory practice. Specific laboratory situations may exist, however, in which this factor does have an effect in selecting an instrument.

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(2) Number of tests. Although it is impossible to make a universal correlation between the number of tests which are performed and the need for a particular piece of equipment, certain numerical plateaus may be established. It is desirable to shift to an instrument of greater automation once the number of tests passes certain plateaus.

(3) Test diversity. Especially when considering the tests performed in the clinical chemistry laboratory, it is important to remember that many tests require totally distinct instrumentation, and that if there is a wide variety of tests in the laboratory, automation is less desirable.

(4) Suitability for interfacing to automated information systems. An obvious element of an automated medical information system is one which assembles orders for laboratory tests and records the results of those tests. In some systems the interface to the activities in the laboratory is simply a teletypewriter or some other terminal where requests are printed and results typed in. However, it is also possible to let the computer specify the order in which samples are to be loaded in automated equipment and to record the results directly from an automated instrument.

To make the four considerations above explicit, we have specified certain of the selection criteria by imagining that we were undertaking automation of the laboratories at Walson Army Hospital and Jacksonville Naval Hospital under the workload currently observable at those locations. Both these laboratories, as well as the laboratory at March AFB, currently employ a certain amount of automated test equipment.

7.6.3.1. Turn-around Time

With regard to turn-around time (that is, the time which elapses from the request for a test at bedside in a ward until the result is returned to bedside) we consider two possibilities: eight hours and one hour. In current DOD hospital practice, an eight-hour turn-around time is employed so that the results from samples drawn in the morning are posted that evening. Depending upon when the doctor makes his rounds, the practical result is usually a 24-hour turn-around time. The one-hour turn-around time occurs with emergency tests and sometimes with STAT tests. It is included here since it is possible and it leads to some speculations for new developments permitting even shorter turn-arounds.

7.6.3.2. Number of Tests

To have a specific basis for discussion, we will use in our analysis the number of tests currently being performed in the clinical laboratories at WAH and JNH. We shall focus on chemistry tests, since that is where the diversity is most apparent and where there is the greatest choice of automated equipment, but we shall also consider hematology, serology, microbiology, and blood banking. For the second quarter of 1969 the number of tests performed at each hospital is shown in Table 7.6.2. It will be noted that the major candidates for automation, chemistry and hematology, account for about a third of the total workload. Thus, even if it is possible to make major gains through automation, the total gain is not likely to be large.

7.6.3.3. Diversity of Tests

As we have mentioned, automation makes sense only when a sufficient number of tests of one kind have to be performed daily. A rule of thumb, which corresponds with our experience, is that automation should be considered when seven or more tests of one kind are required each day[1]. In Table 7.6.3 we present a list of the chemistry tests for which there are seven or more requests daily at WAH and JNH. Taking 42 tests per week as the critical level, 16 tests are performed at WAH with sufficient frequency to justify considering automation, and 11 at JNH.

7.6.3.4. Suitability for Interfacing to an Automated Information System

As we have discussed in Section 7./ on Computer Systems, information systems cannot be justified on the strength of cost savings. They must still be considered experimental. Therefore, in the discussion to follow we have considered the suitability of automated test equipment for interfacing with an information system as a benefit but not as a justification.

TABLE 7.6.2
CLINICAL LABORATORY WORKLOADS
(Second Quarter, 1969)

Type of Test	WAH	JNH	MAFH**
Chemistry	41,210	28,167	14,000
Hematology	47,638	20,470	10,000
Serology	21,192	9,334	5,000
Microbiology	40,988	11,452	7,000
Blood bank	60,639	4,422	1,500
All other	45,125	82,048	37,500
Total lab procedures*	256,792	155,893	75,000

Data in this table (except as noted below) represent actual workloads as reported by the laboratories. More complete data are given in Volume 8, Survey of Military Base Hospitals. The April-June quarter is typical.

*A procedure is a single test or single determination; in some reports value scores are used,which give different weights to procedures according to their difficulty.

**Since these data are not reported at March AFB,estimates based upon a comparison with data for JNH have been provided.

TABLE 7.6.3
CHEMISTRY PROCEDURES PERFORMED MORE THAN 42 TIMES PER WEEK
(Data for an Average Week in the Second Quarter, 1969)

Test name	WAH	JNH
Albumin	68	-
Bilirubin	195	114
Calcium	53	-
Chloride	118	80
Cholesterol	-	45
Creatinine	98	-
Enzyme, lactic dehydrogenase	96	-
Enzyme, phosphatase	201	81
Enzyme, transaminase	317	131
Gases, carbon dioxide	118	80
Glucose, quantitative	464	306
Phosphorus	53	-
Potassium	108	101
Protein, total	82	-
Sodium	108	101
Urea nitrogen	367	306
Uric acid	98	43
Total	2,444	1,388

7.6.4. EXAMPLES OF SELECTION OF AUTOMATED TEST EQUIPMENT FOR CLINICAL CHEMISTRY LABORATORIES

7.6.4.1. An Eight-Hour Turn-around in a Large Hospital

It is clear from the test mix in Table 7.6.3 for WAH that the automation of such a laboratory should begin with more than an assemblage of single channel instruments such as the Lab-Line Clinomak or the Unicam AC-60. However, the frequency of testing does not justify the purchase of an AGA Autochemist, which costs about $450,000. Thus, one would consider as the basis for automation in such a laboratory a Technicon, Hycel, Perkin-Elmer, or similar multichannel instrument. The Hycel instrument has the advantage of saving reagents. However, the Hycel Mark X is not especially suitable for this particular situation, because among the ten tests which it performs are cholesterol, globulin, and PBI, none of which is performed in sufficient quantity at WAH to justify automation. Most of the other multichannel instruments do not perform simultaneously enough determinations to be used in a laboratory where 16 tests are to be automated.

The most attractive possibility is the new Technicon SMA 12/Jr Survey Model. This model analyzes for calcium, phosphate, glucose, urea nitrogen, uric acid, cholesterol, total protein, albumin, total bilirubin, alkaline phosphatase, lactic dehydrogenase, and glutamate-oxaloacetate transaminase. If one were to substitute a creatinine test for the unneeded cholesterol test (which can be done when ordering at a moderate additional cost), it would then be possible with the addition of the Technicon Electrolyte System (which measures chloride, carbon dioxide, potassium and sodium) to take care of all of the procedures which should be automated at WAH.

Although such instrumentation would be efficient on the basis of getting results out in an eight-hour turn-around, this combination is relatively inefficient in terms of reagent use. Many requests are made of the laboratory for only a quantitative glucose determination or for a glucose plus urea nitrogen determination. Such samples, if processed through the SMA 12/Jr, would require unnecessary reagent use in the other ten channels. It would therefore be better to provide as well an instrument to measure both glucose and urea nitrogen alone. For this purpose, any of the flow-through or discrete sample robot chemists listed in Table 7.6.1 which can quantify results colorimetrically or spectrophotometrically is applicable. Maximal efficiency is obtained with a dual-channel instrument. The Beckman DSA-560 (Discrete Sample Analyzer), Perkin-Elmer C-4, the Vickers Multi-Channel 300, or the Technicon Autoanalyzer adapted for dual-channel operation are all candidates. On the basis of cost, we would favor the Technicon Autoanalyzer.

The argument applied to tests for glucose and urea nitrogen does not apply to the transaminase determinations, although these are also performed more often than most other tests at WAH. When transaminase is measured in serum, it is almost always accompanied by measurements of other blood constituents. Thus, a single- or dual-channel instrument for measuring transaminase levels is not desirable. One difficulty which does arise with the transaminase determination, however, is that there are two different transaminases which are routinely measured. These are SGOT and SGPT (serum glutamate oxaloacetate transaminase and serum glutamate pyruvate transaminase). Using the SMA 12/Jr Survey Model as suggested, it would be possible to measure only SGOT. Conceivably this is a drawback, since SGPT tests may be done and reported as enzyme transaminase procedures.

If the number of cholesterol determinations performed at Walson continues to grow, these will be the next procedures to consider automating. At present, an average of six cholesterol determinations are performed per day. If the cholesterol tests were to be automated, the standard SMA 12/Jr Survey Model would be applicable without replacement of the cholesterol channel with a creatinine as discussed above. In that case, a single-channel instrument would be required to perform the creatinine procedure. Such an instrument might be the Lab-Line Clinomak, the Unicam AC-60, the Technicon Autoanalyzer, the Bausch and Lomb system 400, the Joyce Loebl Mecolab, or some other. There is no important difference among these choices, although convenience in obtaining maintenance assistance suggests the Technicon, since then all automated equipment would come from one manufacturer.

There remains the question of automating STAT tests. In some cases, single automated tests require more time than the manual procedure. With most procedures, the time required to use a single-channel Technical Autoanalyzer is about the same as that required to do the test by hand.

Other automated equipment, such as atomic absorption spectrophotometers, flame photometers, and osmometers, are not necessary at WAH because of the small number of tests requiring such special instrumentation. This also applies to enzyme rate analyzers. However, automatic colorimeters or spectrophotometers might be useful in automating what would otherwise be completely manual methods, both STAT and routine. Any of the instruments listed in Table 7.6.1 and useful for this purpose (such as the Atago, Gilford, LKB, or Zeiss) would be acceptable. The cost of such instruments is not excessive, and modifications of this kind of device appear frequently. In addition, such items as automatic diluters, rapid sampling spectrophotometers (such as the Gilford 240 equipped with the Model 2443 vacuum sampler), tube shakers, and so on, none of which were considered automated instrumentation, can decrease the time required for STAT tests.

7.6.4.2. An Eight-Hour Turn-around in a Smaller Hospital

It is evident from Table 7.6.3 that the number and mix of tests performed in the JNH clinical chemistry laboratory are quite different from those at WAH. Most noticeable is the large number of quantitative glucose and urea nitrogen tests performed in relation to other test procedures. In this situation, the most efficient way by far is to perform these tests on a dual-channel Technicon Autoanalyzer (as is, in fact, the practice). Those serum samples on which multiple tests, aside from glucose and urea nitrogen, are desired can be integrated into some other instrument. Performing multiple tests on all samples including those for which only a glucose and a BUN are required, would be a great waste of reagents and too expensive.

In this laboratory it might also be useful to analyze for chloride, carbon dioxide, potassium, and sodium using a Technicon Electrolyte System as at WAH. Another possibility is to utilize a Hycel Mark X, which performs glucose, urea nitrogen, globulin, total protein, cholesterol, uric acid, phosphatase, phosphorus, total bilirubin, and PBI. There are two drawbacks: the globulin results obtained are not often needed, and this would waste one channel of the machine; and the transaminase procedure, which is needed, cannot be performed by this machine. However, one benefit is that the Hycel

Mark X performs PBI determinations. This can be especially important, since the effort expended in conducting a PBI test manually is considerable - the manual test is given a weighting of seven, contrasted with the automated test, which is given a weighting of one. At JNH more than six PBI determinations are performed daily. Although this falls below the level we have established for considering automation, its automation does make sense. One difficulty in using the Hycel instrument for this purpose, however, is that many clinical investigators do not trust the chemical determination of PBI (as performed by the Mark X). Also, the same information as the PBI test yields is now being obtained using the T3 or T4 test in the nuclear medicine area, and this trend is expected to increase.

A possible alternative to the Hycel Mark X is the SMA 12/Jr Hospital Model. This instrument determines calcium, glucose, urea nitrogen, total protein, albumin, total bilirubin, alkaline phosphatase, SGOT, sodium, potassium, carbon dioxide, and chloride. It would be necessary to substitute cholesterol and uric acid channels for the glucose and urea nitrogen channels. The albumin values obtained by the Hospital Model would remain as excess data. The choice is not entirely clear-cut, as this discussion has shown, but we are inclined to prefer the Hycel Mark X, although purchase should await results of use-testing now going on in other laboratories.

7.6.4.3. A One-Hour Turn-around in a Large Hospital

As we have said, consideration of a one-hour turn-around is of interest because it is achievable with available equipment. We discuss it partly to show its limitations and partly to lead into a discussion of some major improvements which we believe are possible. The most applicable equipment on the basis of speed is the new line of centrifugal analyzers, resulting from the work of Dr. Norman Anderson of Oak Ridge. Although both Aminco and Union Carbide have prototypes of such an instrument, only Electro-Nucleonics presently has one on the market. Two of these Electro-Nucleonics GeMSAEC (National Institute of General Medical Sciences, Atomic Energy Commission) instruments might be used in a laboratory requiring a one-hour turn-around time. One instrument would process the 76 glucose tests performed per day and could then be used for bilirubin determinations. The other GeMSAEC instrument could perform urea nitrogen tests as well as transaminase determinations, phosphatase, and lactic dehydrogenase assays. In fact, transaminase determinations can be performed with this instrument in the same run as lactic dehydrogenase assays. The instrument is especially useful for performing enzyme tests.

The determination of chloride, carbon dioxide, potassium, and sodium would, once again, be performed using the Technicon Electrolyte System. However, to save time in computation, it would be desirable to couple an analog computer such as the Dynacon LC-172 or the Canalco/Pacific TOA Data Converter, so as to allow automatic conversion of the measurements into concentration units.

The remaining six procedures would be performed using robot chemists. Any of the models listed in Table 7.6.1 are applicable, but the Technicon Autoanalyzer is favored, again based on cost. It is desirable, wherever possible, to perform multiple determinations on each sample. The Chicago Hospital Council Study[1] shows that each additional test on an Autoanalyzer adds less than 10% of additional time. With this in mind, we would choose three dual-channel Autoanalyzers to handle the remaining procedures. They would be arranged so that one handled calcium and phosphorus, a second creatinine and uric acid, and the third albumin and protein. We would also use analog conversion equipment with these instruments to produce concentrations directly.

7.6.4.4. A One-Hour Turn-around in a Smaller Hospital

In the smaller hospital, it still appears that two Electro-Nucleonic GeMSAEC machines would be most useful. More than 50 glucose and urea nitrogen determinations are performed each day, and in order to get these results in less than an hour the speed of the centrifugal analyzer is necessary. The deployment of the instruments could be the same as for the large hospital. Thus, one GeMSAEC machine could handle glucose and bilirubin procedures and the other could perform urea nitrogen, transaminase, and phosphatase assays. As in the larger hospital, an Electrolyte System could handily perform chloride, carbon dioxide, potassium, and sodium determinations necessary in a one-hour turn-around time. The data from the Electrolyte System could be calculated through an analog computer interface. This would leave the cholesterol and uric acid determinations to be performed on one dual-channel instrument. At the rate of seven determinations per day, automatic conversion is not necessary.

7.6.4.5. Automation in Other Laboratories

At WAH over 1000 leucocyte counts are performed each week. With this large number of tests, automation is a necessity. The decision, however, as to which of the many automated cell-counting systems appearing in Table 7.6.1 Part B (Hematology) should be employed in the laboratory is more difficult to make. Most of the cell-counters listed use an optical determination of cell count. This has been shown not to be as accurate as the impedance method employed in the Coulter Counters, which are the most popular blood-cell counters found in automated hematology laboratories, although they are expensive. However, a new device, put out by General Science, called the Haema-Count, counts both red and white cells by impedance, with a minimum of technician time, at much lower cost. Although this instrument has not yet been proven in the laboratory, it seems ideal for dealing with the requirements in hematology laboratories in military hospitals. The automation of other procedures, such as cell fragility and thrombus formation, are less important because of the smaller requirements for these tests.

Automation of the serology laboratory (Table 7.6.1 Part C) has limited influence on time and money savings. The Canalco Autotyper might prove useful in eliminating certain handwork, but it does not directly yield any results. The low number of confirmatory syphilis tests (not including qualitative flocculation tests) performed in the DOD hospitals limits the usefulness of either the Fisher SeroMatic or the Technicon ART (Automated Reagin Test) instruments. The low volume of requests for specific agglutination and complement fixation tests likewise limits the applicability of the Technicon Hemagglutination System. Automation of tests in the serology laboratory is not justifiable at this time.

The Technicon Autotyper Systems for blood banking have not yet been approved (or disapproved) by the National Institutes of Health, Division of

Biological Standards, and that has perhaps retarded their field acceptance. Although these instruments are not designed for pre-transfusion crossmatching, a recent paper by C.E. Shields[2] from the Army Medical Research Laboratory at Fort Knox indicates that the Technicon eight-channel and fifteen-channel instruments can be useful in reducing error in large-scale blood-type identification programs if blood is processed within one or two days after collection. Since some of the DOD hospitals have significant involvement in such identification programs as Armed Services Whole Blood Plasma Laboratory (ASWBPL), investigation of such instruments for use in these blood banking laboratories would be worthwhile.

The automated instruments available in the microbiology laboratory are limited and not applicable in base-level military hospitals. The DuPont Luminescence Biometer may eventually become part of routine bacteriological practice for the early diagnosis of bacteriuria, but the elaborate particle counters will probably remain as research instruments. New developments in the microbiology area, however, are expected to have the greatest future impact in terms of decreasing technician time and increasing efficiency.

7.6.5. EVALUATION OF THE IMPACT OF AUTOMATION

As the discussion of automation shows, wholesale automation of the clinical laboratory is not possible within the current state of the art. Most automated equipment which performs the routine tests encountered in base level military hospitals is confined to the chemistry laboratory, which accounts for about one sixth of the total workload (see Table 7.6.2), and to a lesser degree to the hematology laboratory, which accounts for about the same proportion of workload. Therefore, automation at best affects only about a third of the workload, and no spectacular gains can be expected.

Of the military hospitals we visited, all had already introduced some automation, so we are dealing with only marginal improvements. Nevertheless, there are some gains to be made, and as a general policy automation should be encouraged. Not only does it offer some savings in costs for technician time, but it reduces the number of technicians required. The services are already hard pressed to train a sufficient number of technicians, and, since civilian demand will keep the retention rate low, any improvement which reduces the number of technicians required is desirable.

To compute the reduced workload attributable to automation in the chemistry laboratory, we make use of the weighting factors published by the Veterans Administration[3]. This booklet compares the relative work required for various tests performed manually or with automated equipment. The work units for relevant tests are given in Table 7.6.4. By multiplying number of tests of each kind by the appropriate number of work units, the total quarterly load which is potentially automatable at WAH and JNH can be derived. This is given in Table 7.6.5.

We have less data on the hematology laboratory, so we have assumed that cell counters can reduce the workload by comparable amounts - namely, 19% at WAH and 23% at JNH. As remarked above, these two laboratories account for about a third of the total workload; additional automation would reduce workload by about 6% at WAH and 8% at JNH. Thus, the gains to be made in reducing costs by this route are not large. From Volume 8, Survey of Military Hospitals, we find the staffing for the laboratories at WAH and JNH. Additional equipment discussed could allow a reduction of the professional staff (excluding pathologists) from 79 to 75 at WAH and from 22 to 20 at JNH. This would represent a savings in salaries of $24,000 at WAH and $13,700 at JNH. In addition, the automated equipment uses more reagents, estimated at $12,000 per year at WAH and $6,000 per year at JNH. The remaining savings ($12,000 per year at WAH and $7,700 at JNH) are comparable to expected expenses for maintenance. Thus, dollar savings, as we have remarked, do not provide the justification for automation.

In Table 7.6.6 we have listed the automated equipment referred to in our discussion. For the usual eight-hour turn-around we have suggested automated equipment beyond that already employed, costing $83,600 at WAH and $68,645 at JNH. If we take a ten-year life for the equipment and discount future savings at 10% per year*, the present value of those savings is 6.77 times the annual rate, that is, $81,200 at WAH and $52,000 at JNH. Thus the balance between current capital investment and discounted value of

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*See Section 1.5. for a discussion of discounting.

TABLE 7.6.4
COMPARATIVE WORK OF PERFORMING CLINICAL LABORATORY TEST BY AUTOMATED AND NONAUTOMATED METHODS

Test Name	Work Units Automated	Work Units Nonautomated
Chemistry		
Albumin	1	3
Bilirubin	1	3
Calcium	1	4
Chloride	1	2
Cholesterol, total	1	4
Cholesterol esters	1	4
Creatinine	1	2
Enzyme, amylase	1	3
Enzyme, phosphatase, acid or alkaline	1	4
Enzyme, transaminase (SGPT or SGOT)	1	4
Enzyme, other tests	1	3
Gas, carbon dioxide	1	2
Glucose, quantitative	1	3
Hormone, iodine, protein-bound (PBI)	1	7
Phenylalanine, quantitative	1	6
Phosphorus	1	3
Potassium	1	2
Protein, total	1	2
Sodium	1	2
Urea nitrogen	1	3
Uric acid	1	2
Hematology		
Cell count, erythrocyte	1	2
Cell count, leucocyte	1	2
Count, platelet	1	3

Source: Reference 3.

TABLE 7.6.5
REDUCTION IN WORKLOAD THROUGH
ADDITIONAL AUTOMATION OF CHEMISTRY LABORATORY
(Based on Data for Second Quarter, 1969)

		WAH	JNH
1.	Workload - potentially automatable procedures	31,772	18,044
2.	Workload - nonautomatable procedures	9,438	10,123
3.	Total workload (sum of 1 and 2)	41,210	28,167
4.	Work unit value - potentially automatable procedures not automated	94,549	52,208
5.	Work unit value - potentially automatable procedures automated	31,772	18,044
6.	Work unit value - nonautomatable procedures*	18,876	20,246
7.	Work unit value - total, without automation (sum of 4 and 6)	113,425	72,454
8.	Work unit value - total, with automation (sum of 5 and 6)	50,648	38,290
9.	Work unit value - current degree of automation**	62,903	50,000
10.	Percent reduction in work units through additional automation	19%	23%

*This number assumes a value of 2 work units for each of the non-automatable tests.

**In the case of WAH, this number is computed by the laboratory; in the case of JNH it was estimated by comparing the degree of automation with that at WAH.

TABLE 7.6.6
CAPITAL COSTS FOR AUTOMATED
LABORATORY EQUIPMENT

Walson Army Hospital - 8-hour turn-around	
1 Technicon SMA 12/Jr	$60,000
1 Technicon Electrolyte	20,000
1 Technicon Autoanalyzer - dual channel	11,000
1 Technicon Autoanalyzer - single channel	9,000
1 Atago Automatic 36 Colorimeter	2,800
1 General Science Blood Cell Counter	845
	$103,645
Jacksonville Naval Hospital - 8-hour turn-around	
1 Technicon Autoanalyzer - dual channel	$11,000
1 Hycel Mark X	65,000
1 Atago Automatic 36 Colorimeter	2,800
1 General Science Blood Cell Counter	845
	$79,645
Walson Army Hospital - 1-hour turn-around	
2 Electro-Nucleonics GeMSAEC	$23,350
1 Technicon Electrolyte	20,000
4 Dynacon Converters	5,908
3 Technicon Autoanalyzers - dual channel	33,000
	$131,358
Jacksonville Naval Hospital - 1-hour turn-around	
2 Electro-Nucleonics GeMSAEC	$23,350
1 Technicon Electrolyte	20,000
1 Dynacon Converter	1,452
1 Technicon Autoanalyzer - dual channel	11,000
	$55,802

future savings is almost an exact stand-off. We have not included the cost of training technicians, nor have we included likely wage increases. For these reasons, we believe our estimates are conservative and that laboratory automation to the degree we have outlined is desirable.

Alternatively, we can reflect the capital expenditure in operating costs but amortizing the value of the equipment. Using a 10-year lifetime, we reach the same conclusion, that the savings in operating expenses just about equal the amortized annual expense of the equipment.

When we turn our attention to equipment to permit a one-hour turn-around in the chemistry laboratory, we discover that the high-speed GeMSAEC machines are no more expensive than the slow machines they replace. However, the drawback with the present GeMSAEC machines is that, although they produce determinations very rapidly, they make only one test per sample at a time.

Loading the machines is an exacting procedure, and to aid in loading Electro-Nucleonics supplies a device called a Roto-loader, which measures appropriate amounts of specimens and reagents. Using a Roto-loader, it is claimed that 300 samples per hour can be processed. To achieve this rate requires reloading the machine every three minutes with a new batch of 15 samples. Thus one technician is kept fully occupied loading the machine. In contrast, a 12-channel Technicon can produce 12 different determinations every minute (or 720 per hour) with only one technician during loading and none during a forty-minute run. Because of their high manpower requirement, the GeMSAEC machines cannot realize their full potential unless the laboratory has a requirement for very many identical tests, and this circumstance does not arise often in military hospitals; for example, the most common test is a quantitative glucose, which at WAH is requested about 80 times per day.

A more important consideration with regard to a one-hour turn-around is the question of how the rest of the hospital would organize to produce such a requirement. STAT tests, which do require a rapid turn-around, occur sporadically and are usually best dealt with as single tests. In the case of inpatients, there are often large batches of identical tests to be run following the morning collection of specimens, but the physician requesting the tests is not likely to see the patient or to concern him-self with the test results until the next morning, when he makes rounds again. Thus the situation in which a one-hour turn-around can be achieved is just that in which it is not needed.

For outpatients, the schedule at which the patients are seen (generally one every 15 minutes by each doctor in the clinics) does not give rise to batches of identical tests but rather to a fluctuating continuous demand. Waiting until a batch has accumulated keeps the early patients waiting so long that the advantage of the high-speed machine is vitiated. For these reasons we cannot visualize a practical testing scheme which would take advantage in any important way of a one-hour turn-around.

However, a re-examination of the principles of the GeMSAEC analyzers has led us to conclude that they hold more promise than has thus far been realized. In the succeeding three sections we discuss the GeMSAEC analyzers and possible improvements to them in more detail.

7.6.6. OPERATING PRINCIPLES OF FAST ANALYZERS

The basic principles of the GeMSAEC analyzers, or fast analyzers as they are sometimes called, are described by Anderson[4]. A flat rotor is arranged to spin about a vertical axis. Arranged along each of from 15 to 40 radial paths are several depressions and a chamber open toward the axis with glass top and bottom, called a cuvette. In separate depressions are placed measured volumes of sample and reagent. While the rotor is at rest the sample and reagent do not mix, but when the rotor is spun up, the liquids move out radially, mixing together and coming to rest in the cuvette, as shown in Figure 7.6.1. The time since mixing is accurately known, and a fixed phototube illuminated by a lamp shining through the mixture can measure the transmittance of the mixture, from which the property of the sample being tested for can be inferred. The rotation of the rotor allows scanning of all the samples.

The output of the phototube is a series of pulses as each sample passes. Obviously, reading data at the speed with which samples pass (typically one sample every 50 milliseconds) requires electronic instrumentation, an oscilloscope or a computer. It is simple to devise circuitry which recognizes

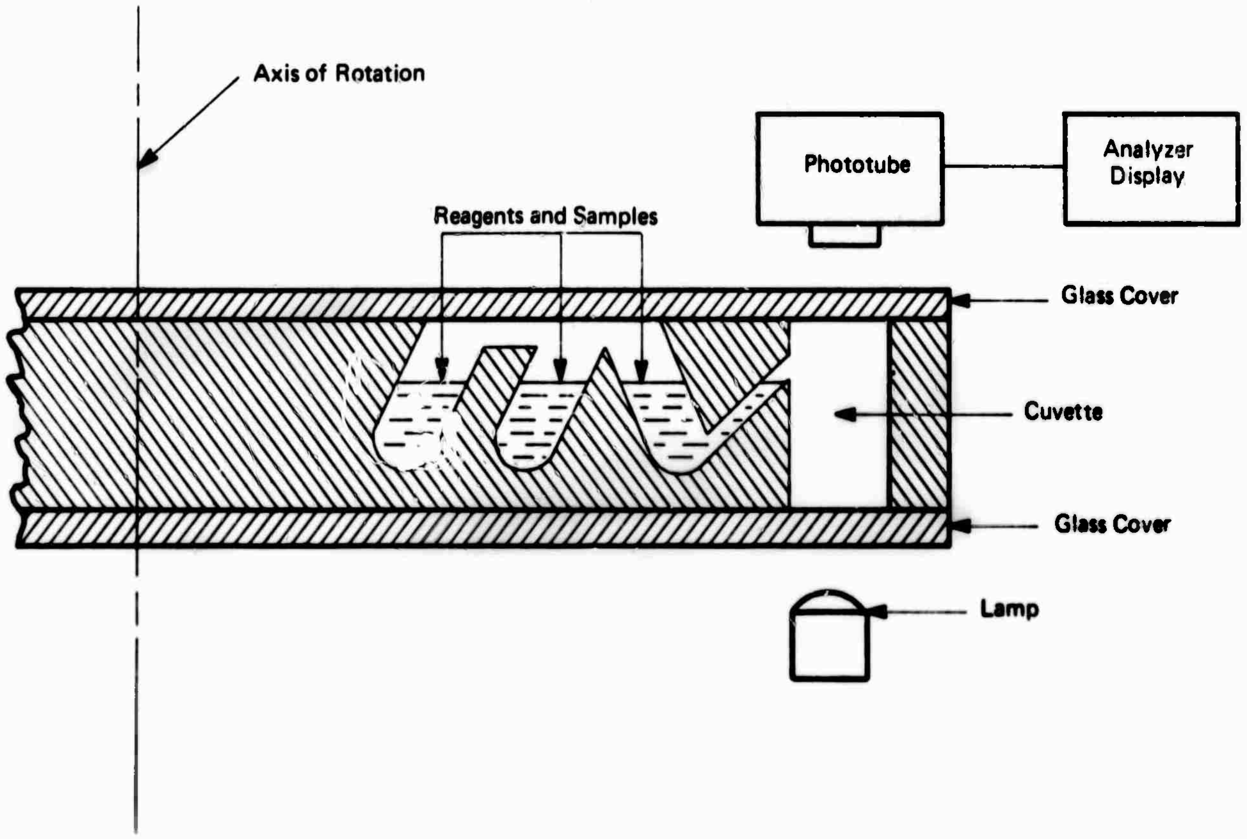

FIGURE 7.6.1 (Adapted from Reference 5) THE PRINCIPLES OF OPERATION OF FAST ANALYZERS. The three depressions hold samples or reagents. When the rotor is spun up, all the fluids move into the third chamber, and ultimately into the cuvette where they have become mixed and can be analyzed optically.

the first sample (for example, by putting a double space between the last and the first cuvette on the rotor) and which keeps track of which pulse comes from which sample. It is very convenient to include blank samples or calibration samples interspersed among test samples, and these are read at almost the same time as the test samples, thus virtually eliminating problems of drift. The digital computer can make suitable calculations to convert transmittance to concentrations, taking into account timing, temperature, and dilution as revealed from calibration samples, and it can print results in any desired format.

The high forces in a centrifugal field produce many desirable effects. The meniscus is flattened so that in certain configurations very accurate volume measurements can be made. Suspended solids settle out rapidly. Air bubbles are forced out.

Despite these virtues, fast analyzers are not widely used, and they possess certain drawbacks. Those now commercially available are simple and perform only one determination on each of the samples loaded. While the time for loading is not long - it is said to take about three minutes to load a rotor with 15 samples using a special metering device - and the time to make the determination following loading is only several seconds, making multiple determinations requires the full attention of an operator for as many multiples of three minutes as there are determinations per sample. For this reason the effective speed of the fast analyzers is not as great as the spin-up and scanning speeds might lead one to expect. Furthermore, they require the full attention of the operator for loading, which occupies most of the testing interval. On the other hand, the slow analyzers, typified by the equipment produced by Technicon, require no attention from the operator once they have been loaded, and multiple determinations are hardly more time-consuming from the operator's point of view than single determinations.

There have been many ingenious variations of the fast analyzer principle, but so far they seem to have been largely confined to development laboratories. Fast analyzers are winning only slow acceptance, partly because of the drawbacks cited, and partly because there are still problems with accuracy and reliability, particularly if novel reagents are used.

Nevertheless, there appear to be no significant barriers, not even economic ones, to achieving required accuracy and reliability.

Furthermore, it is easy to conceive many extensions to the fast analyzer principle. For example, there is the so-called Z-path rotor, in which the mixed sample and reagent first come to rest in a cup which has an opening at the bottom placed radially inside the inner edge of the mixture. (Figure 7.6.2). Thus during the first spin-up the mixture stays in the first cup. When the rotor is stopped, the mixture flows through the opening into a second chamber. One use of this arrangement is to remove precipitates formed by the reagent; the solids remain deposited on the side of the first cup while the liquid drains away to a cuvette when the rotor stops. The liquid can then be scanned for transmittance when the rotor is spun up again.

It is possible to fill cups of cuvettes with reagents while the rotor is spinning, simply by squirting the reagent through a fixed tube arranged to discharge the fluid radially outward. Because of the flattened meniscus, it is easy to devise accurate measuring methods based on the Z-path rotor in which the liquid beyond the required amount overflows the first cuvette. It is also possible to imagine Z-path rotors stacked one upon the other or cascaded outward along a radius. In addition, rotors may be of different diameters so that multiple illuminating sources and phototubes could operate simultaneously on samples mixed with different reagents. Cuvette belts made of plastic and disposable after use have been proposed.

When a digital computer is part of the system, a number of other possibilities that take advantage of the computer's flexibility also come to mind. For example, repeated determinations on the same sample can be used to enhance reliability. (Since the phototube scans each sample once per revolution, many scans are available on each mixture, and the computer can compute averages, ranges, standard deviations, or any other statistical properties of the differences in scanning.) It is conceivable that the label identifying a sample can be coded magnetically so that the computer keeps track of the sample's identity. Spin-up and slow-down can easily be placed under computer control.

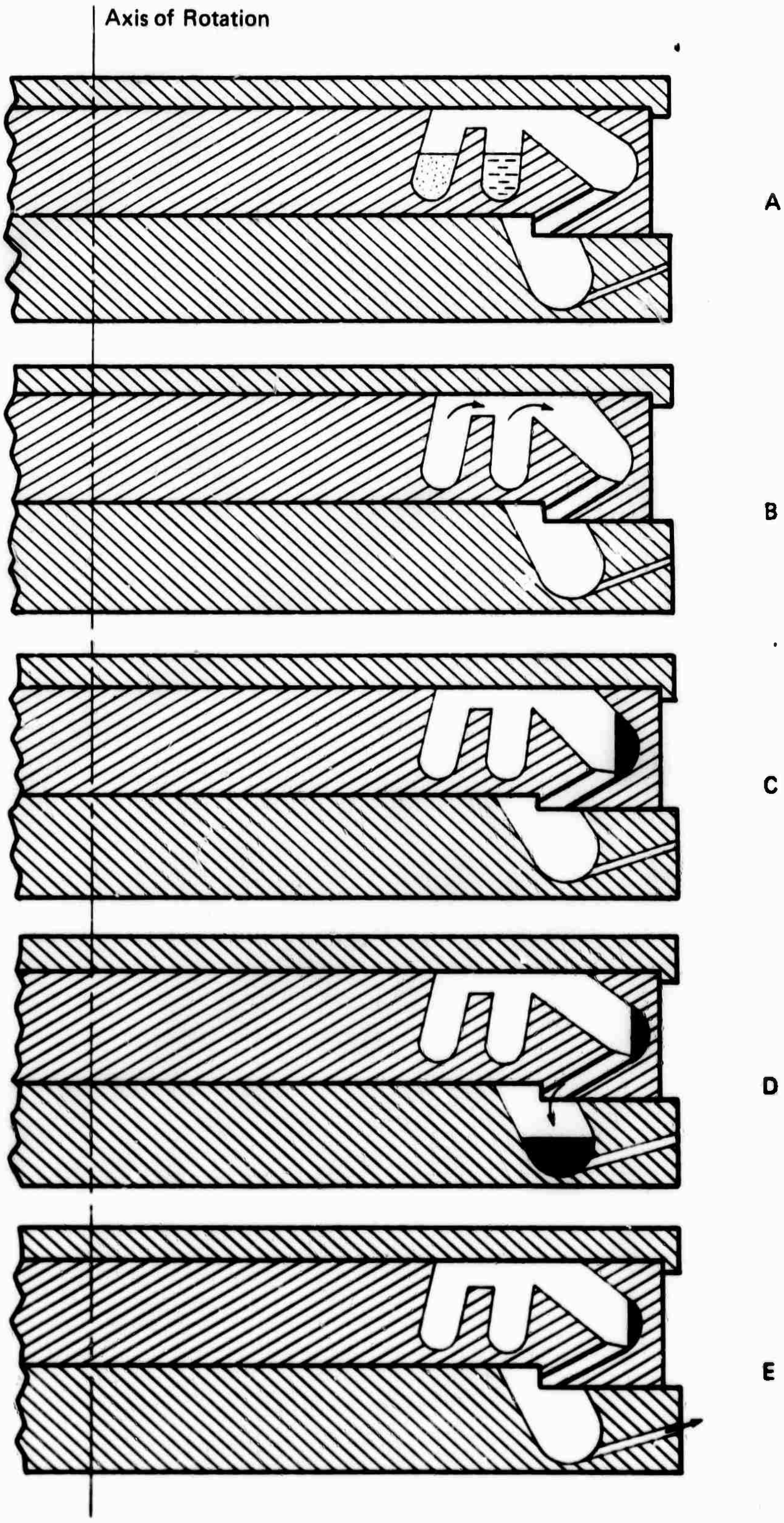

FIGURE 7.6.2 (Adapted from Reference 5) OPERATION OF A Z-PATH ROTOR.
The reagent and sample originally are in the two upper depressions, as in A. On spin-up they move outward, as in B to the cup where they react depositing a precipitate, as in C. When the rotor is stopped the precipitate remains but the fluid drains away to the lower cup, as in D. Upon respinning, the supernatant flows outward for measurement or discard, as in E.

Although the fast analyzers are not as far developed as the slow analyzers, there do not appear to be any important barriers to devising machines which achieve similar results at comparable cost in much less time. The question will be whether or not the time-saving potentially available from the fast analyzers can be put to good use. In the next section we discuss some configurations for a multichannel, multisample fast analyzer which is, as far as we know, new. In the succeeding section we discuss the operational use of a multichannel fast analyzer.

7.6.7. SOME NOVEL CONFIGURATIONS FOR FAST ANALYZERS

In connection with exploring technology applicable to the "new generation" of military hospitals, we have been led to consider the possibilites of a real-time analyzer which could routinely return the results of laboratory tests in a few minutes. While there is need for further development, the concept appears feasible and worthwhile. Basically, the idea is to use a fast analyzer utilizing the principles discussed above, with the rotor sets and suitable sensing devices at many locations, all relying upon a central computer for computations and for formatting output messages.

We believe that it is possible to build a multichannel fast analyzer which need be no more expensive than the single-channel device, which eliminates the exacting measurements in loading, which could be built so that with interchange of only a few parts a normal run could consist of as few as two samples or as many as ten*, which could do many of the clinical chemistry tests in a minute or so, and which would be easy to clean and keep clean.

To convert a single-channel fast analyzer to multiple channels, one makes use of the Z-path configuration described earlier, cascading the Z's one after the other along a radius for each sample, as shown in Figure 7.6.3. Here we have shown a three-channel analyzer. An amount of the sample fluid adequate for three tests - the amount need not be exact, only sufficient - is placed

*It will be se... that it is possible to devise a machine to process more than ten samples at a time, but since results are returned within a minute or so, there is no need for larger rotors.

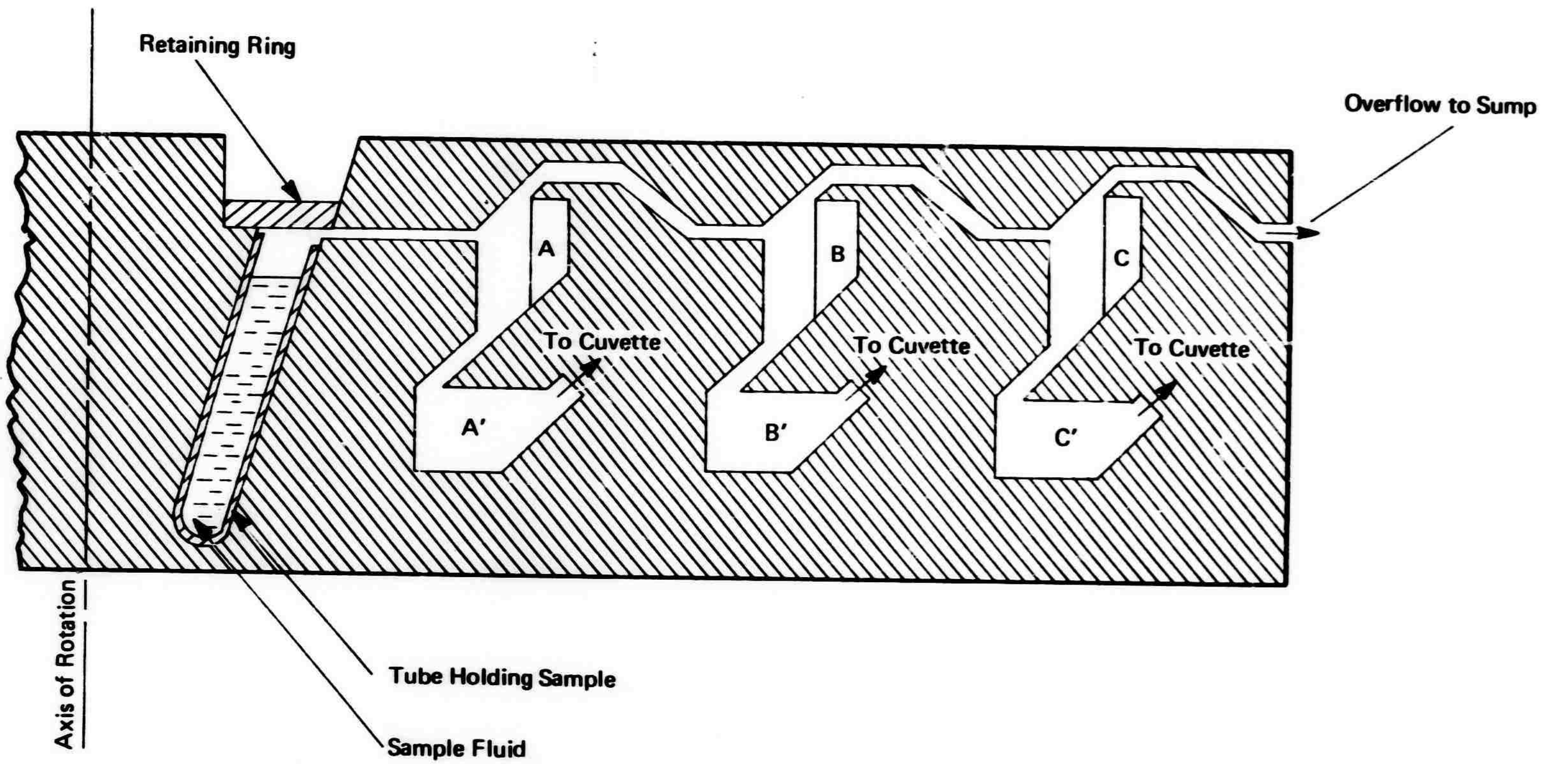

FIGURE 7.6.3 **CROSS-SECTION OF A THREE-TEST ROTOR SHOWING Z-PATHS FOR METERING THE SAMPLE.** The cross section lies along a radius. When the rotor is spun up, the fluid moves out of the tube and is caught in precisely metered amounts at A, B, and C. The overflow is discarded to a sump. When the rotor stops, the fluid runs down to A', B', and C', and upon respinning the fluid is transferred to cuvettes which lie out of the plane of the Z-paths.

in the inner cup. When the rotor is spun up, the fluid is caught in the first cup (A) until it overflows, after which it is caught in the second cup (B) until it overflows, after which it is caught in the third whose overflow is thrown outward to a sump. This spin-up serves to obtain three exactly measured portions of the sample. The fact that the centrifugal field is very strong means that the meniscus is flattened and all air is driven out, thus assuring accurate measure.

When the rotor is stopped, the metered samples flow down the diagonal of the Z into the lower cups (A', B', C'). Respinning the rotor causes the metered samples to move into a cuvette, where they become mixed with reagent, metered in a similar way along its own path as described below, and the mixture can be read optically in the fashion described for fast analyzers. Since the mixed samples are spaced at three different radii, three separate illuminating sources and phototubes can be used to give results for three separate tests. Obviously, this scheme can be extended to more than three tests, and there do not appear to be essential barriers to perhaps twelve tests.

Since the samples for each test are distributed radially, the problem with the reagents is to distribute them circumferentially. One way that this could be done is shown in Figure 7.6.4. Here we have shown a four-sample rotor. The reagents are placed in three annular channels whose outer walls have been distorted so that radial motion of the fluid causes it to collect at four overflow vents spaced equally around the annulus. These vents are the entrance to Z-paths, which are essentially the same as those for the samples. These Z-paths would be equidistant from the axis with the Z-paths for the samples, but displaced tangentially so that the two paths would not meet until the fluids were flowing into the cuvettes on the second spin-up. On the first spin-up the reagent moves into its Z-path and is metered in the upper cup just as the sample is. The overflow leads to a sump. Just as with the samples, the amount of reagent originally placed in the annulus need not be measured exactly - there need be only an amount sufficient for four tests.

When the rotor is stopped, the reagent flows down the diagonal of the Z into the lower cup. On the second spin-up the reagent is mixed with the sample in the cuvette. In the example we have given, there would be twelve

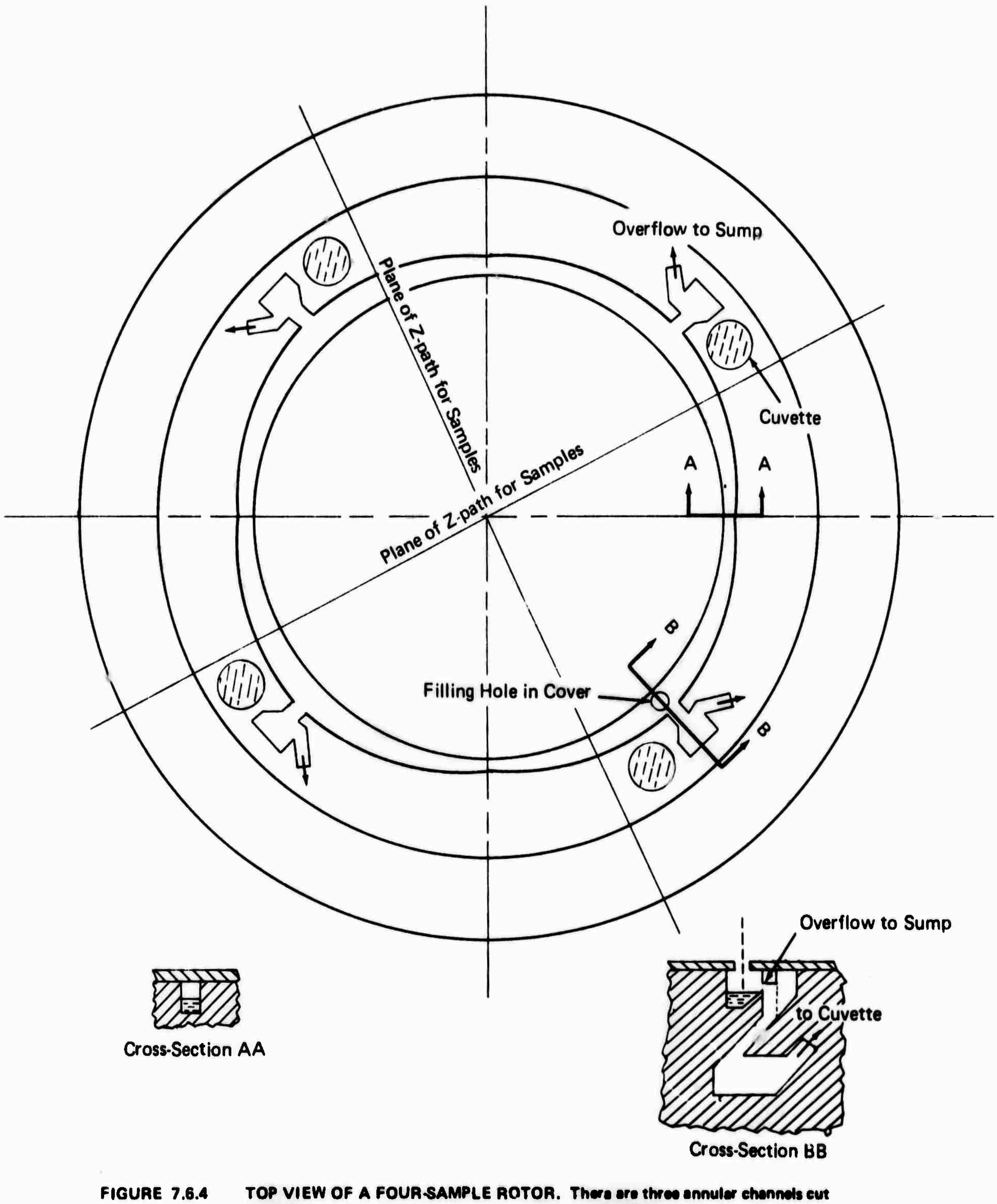

FIGURE 7.6.4 TOP VIEW OF A FOUR-SAMPLE ROTOR. There are three annular channels cut in the top of the rotor and covered by a circular glass plate. Only one of the channels has been drawn in detail. The outer wall is not circular but is arranged so that centrifugal force will cause the fluid to flow out through the four radial vents. The vents are the entrance to Z-paths whose upper cups have overflows so that the reagent is metered when the rotor is spun up. When the rotor is stopped the metered reagent flows to the bottom of the Z, from which it flows to the cuvette, where it is mixed with the sample, when the rotor is spun up a second time.

cuvettes, equally spaced in fours in three rings. The various radial channels we have described would run through the parts of the rotor between the cuvettes. Multiple reagents can be added to any sample simply by providing more annular storage channels and additional Z-paths.

Although the paths through the rotor present at first glance a machinist's nightmare, the problems are not so formidable. The rotor can be built up out of layers sandwiched between glass plates which form the top and bottom windows of the cuvettes, and the many hidden holes shown in Figure 7.6.3 become accessible when the layers are separated.

The number of samples per rotor needs some discussion. Since results are obtained so quickly, there is no need to wait until a large number of samples have been obtained to start testing. In certain applications, such as an analyzer in a military dispensary, so few patients require lab tests that it is reasonable to contemplate a rotor with space for only two samples, one a sample to be tested, and the other a standard. Rotors with space for larger numbers of samples, up to eight or ten and possibly more, are easy to imagine. There is no reason, of course, why every space needs to be filled; the consequence of running with empty spaces is simply wasted reagents. It would probably be too expensive to equip every terminal with multiple rotors accepting different number of samples to be selected on the basis of the workload at the moment. Instead we imagine that some locations, such as dispensaries, would have two-sample rotors; others, such as medical wards, would have five-sample rotors; still others, such as the chemistry laboratory, would have ten-sample rotors. However, if the workload at a station changed, there would be no significant problem in trading rotors.

Anderson reports the possibility of using amounts of fluid for each test as small as a microliter. However, to achieve satisfactory results with these small amounts of reagents requires that all transfers occur in the strong centrifugal field. Since the Z-paths we have described require transfer under the comparatively weak gravitational field, when the rotor is stopped between the first and second spin-ups, it will not be possible to use such small amounts. Under gravitational forces, viscosity and surface tension can both supply forces strong enough to hinder or stop the motion of small amounts of fluid. For this reason, we imagine that the metered amounts should be on the order of 500 microliters.

The potential problem of transferring the liquids down the diagonal of the Z under gravitational forces suggests the possibility of a different transfer mode. If the Z-path were laid out in a nearly horizontal plane instead of a vertical plane as we have described it, then the transfer could be effected by decelerating the rotor so rapidly that the deceleration forces exceeded the centrifugal forces enough to drive the fluid centripetally along the diagonal of the Z. Putting the Z so that its plane sloped downward somewhat, instead of being exactly horizontal, would insure that the fluid stayed in the lower cup if the rotor were brought to rest. This same scheme can be used to empty the cuvettes following completion of a determination.

Because the scheme outlined always transfers fluids under the high centrifugal or deceleration fields, there should be little problem with residual fluid causing contamination of subsequent runs. However, this matter will require further investigation. If contamination is a problem, then it is possible to conceive schemes, probably under computer control, which flush water through the chambers along the same paths followed by samples and reagents.

Filling the rotor to begin a run could be done as follows. As we have remarked, there is no need to measure accurately the fluids put in; they need only be sufficient. The samples, all of which are initially placed near the axis of the rotor, could be simply small, open-mouthed tubes, shaped like test tubes, which would be placed in holes in the rotor and secured by a ring which would keep them in place as shown in Figure 7.6.3. Filling the annuli with reagents could be done from overhead tanks connected by tubes to a spacing beam which would hold the tubes in position for the filling holes, as shown in Figure 7.6.5.

For reading the results, it might be advantageous to stagger the cuvettes by bending the fluid paths so that they are not precisely radial. In this way the cuvettes could be arranged so that only one was reading at a time.

However, this scheme is likely to become impractical if there are many channels. It therefore seems preferable to treat the output from each phototube as a separate channel and to rely on the electronics rather than the mechanics to separate signals.

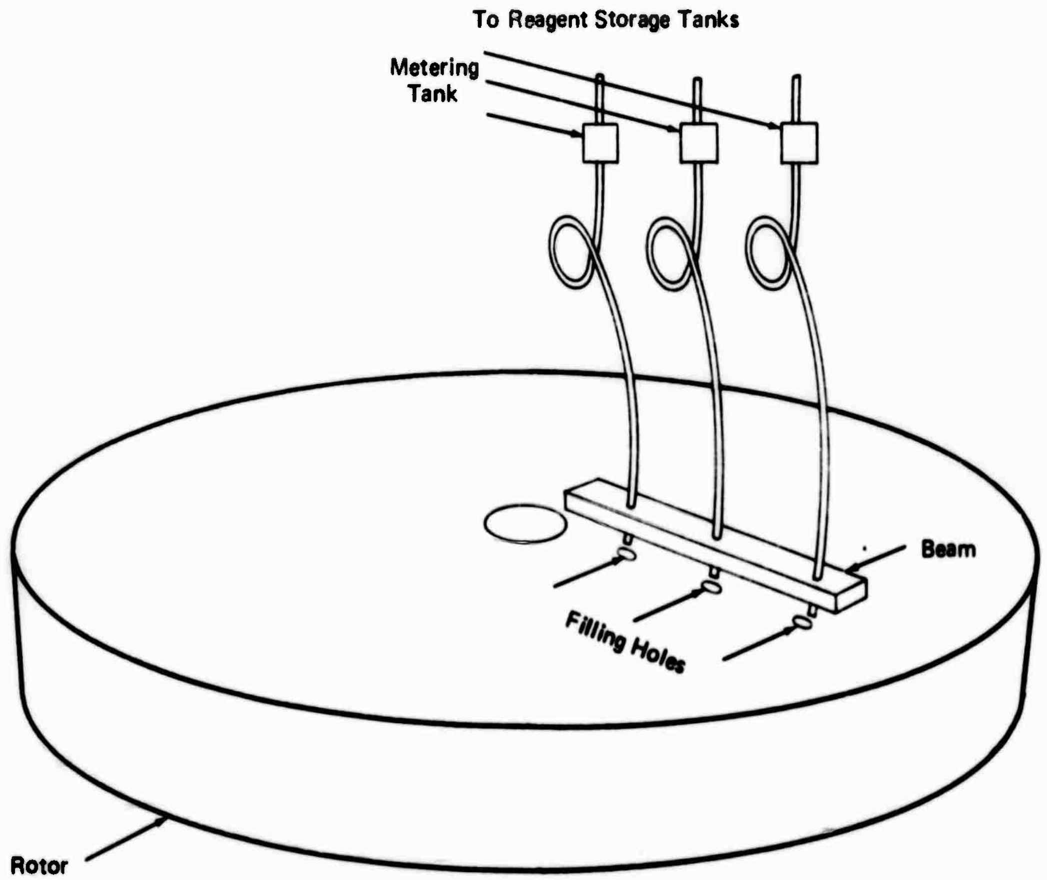

FIGURE 7.6.5 POSSIBLE ARRANGEMENT FOR FILLING ANNULAR CHANNELS HOLDING REAGENT. The reagent is stored in tanks and flow is by gravity while the rotor is stopped. The beam maintains spacing and facilitates placing tubes in filling holes. Metering tanks assure that the right amount of reagent is added; high accuracy is unnecessary. It is also possible to conceive automatic methods for this same operation.

The analog signal on each channel from the phototube is a series of pulses, generated as each cuvette passes by the illuminating source. Following amplification and filtering to remove high frequency noise, the analog signal would be digitized. Anderson reports that resolution to one part in 1000 (10 bits) is satisfactory. The digital signal would be used to drive a sample-and-hold circuit which would detect peaks. These values would then be stored in registers, one for each cuvette. Additional computational circuitry would allow continual revision of the average and standard deviation on the signals from a given cuvette over a number of revolutions of the rotor.

We are inclined to think that these operations should be done with special-purpose digital circuitry which is part of each fast analyzer. The contents of various registers could be displayed on request on a digital readout at the analyzer. The advantages of this procedure are several. An important one is reliability. We have been imagining that a central processor controls further manipulation of the measured quantities to provide output in a convenient format. Should the processor fail or the communication links fail, the circuitry we have described allows the operator to obtain results, although in a manual mode (which is somewhat less cumbersome than the present readout on an oscilloscope).

Another advantage is that the registers not only accumulate results but act as buffers for transmission to the central processor. Having a buffer store is important if results are transmitted over voice-grade lines (band width of 5000 hertz), as we believe they should be. They are also important if the number of samples and number of tests is large. For instance, if there were 12 tests on eight samples, 96 readings would be taken with each revolution of the rotor, which takes about 100 milliseconds; transmitting a reading of ten bits each millisecond cannot be done over voice-grade lines. However, the buffer registers allow data to be sent at any desired rate.

The central processor would interpret the raw readings, apply corrections derived from the calibration samples, format the output, and transmit the results back to the analyzer station. We imagine that results could be provided conveniently on a teletypewriter. The electronic equipment for these purposes is shown in Figure 7.6.6.

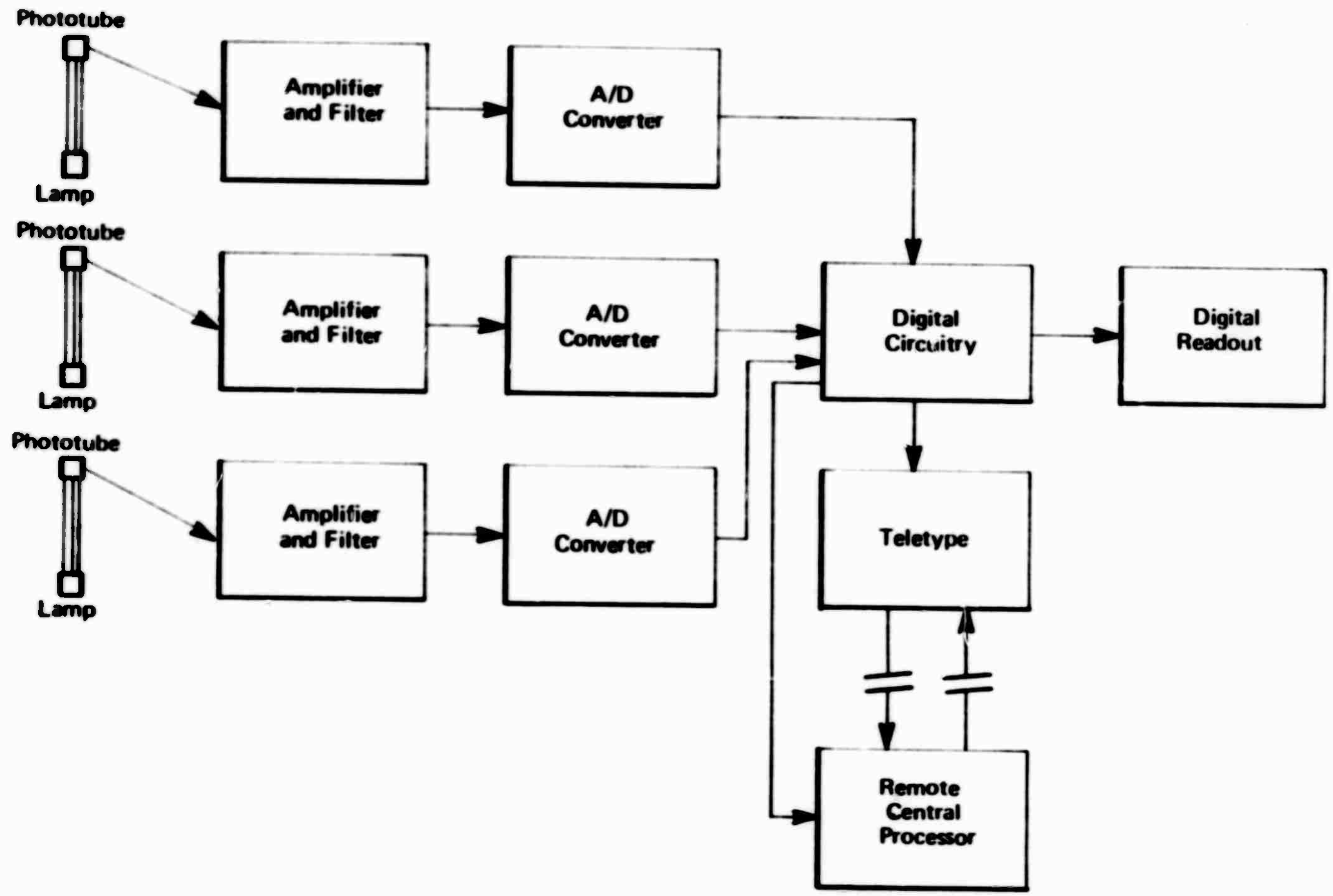

FIGURE 7.6.6 ELECTRONIC ELEMENTS OF A FAST ANALYZER SYSTEM. Each channel of the analyzer has its own lamp and phototube, whose output is amplified, filtered to remove high frequency noise, and digitized. The special purpose digital circuitry accumulates raw data and transmits it to a remote central processor over telephone lines. Results are returned on teletypewriter. The digital readout allows operation in a manual mode and aids troubleshooting.

7.6.8. UTILIZATION OF FAST ANALYZERS

If, as we have suggested, a really fast multichannel analyzer with a turn-around time of a minute or so can be built, then it becomes reasonable to expect a patient or a physician to wait for results. With such rapid response, the times to collect a sample, write out the request, transport it to the laboratory, record results, and transmit results back to the originator dominate the time to perform the test. As we have implied, very fast analyzers make sense only if the times to perform the other operations can be reduced, and this suggests that there must be multiple terminals at which a sample can be analyzed.

We believe that it is technically feasible to build a system with perhaps a dozen or so terminals, located at dispensaries, in clinics, and in wards. If that is so, then there are two other important considerations. One is whether it would be possible to provide adequate training, discipline, and supervision for the dozen operators at a dozen locations. Obviously, there is no categorical answer to this question; the answer depends upon how rugged and foolproof a machine can be devised. The other is whether the cost of such a system would be reasonable.

For the sake of comparison, the GeMSAEC machines produced by Electro-Nucleonics sell for $11,675. They will do but one test on up to 16 samples on each run. The output is presented in analog form on an oscilloscope to be recorded manually. Electro-Nucleonics also sells a computer for $14,700, to be connected to its single-channel fast analyzer, which computes concentrations, corrects for calibration errors, and formats the output messages. In addition, because of the exacting measurements required for loading, a special device known as a Roto-loader, costing about $3000, is highly desirable though not absolutely necessary. However, it is only with the Roto-loader that the three-minute loading time referred to above can be realized. Thus a single-channel fast analyzer with a computer would cost $29,375. Union Carbide's centrifugal colorimeter, which includes a small digital computer, is expected to sell for $21,500. It can handle 30 samples and has but one channel.

The rotor we have described is a good deal more complex than those in either Electro-Nucleonics' or Union Carbide's machines, and therefore might be presumed to cost more. The digital circuitry we have described presumably would cost about $10,000 on the basis of what these two companies charge, though a cursory analysis suggests it should be cheaper. There is some reason to believe that, since fast analyzers are not yet widely used or widely known, the prices are appropriate to experimental equipment and somewhat on the high side. We expect that an analyzer terminal of the kind we have described could be sold for $20,000.

The central processor and its various peripherals, including teletypewriters at each terminal, would cost between $100,000 and $150,000. These figures are based upon the costs of the Clindata Systems sold and serviced by Berkeley Scientific Laboratories, Berkeley, California[5,6]. Their systems were originally developed under contract with the National Institutes of Health, so the original software is in the public domain. This fact is mentioned not to suggest that the software is applicable (though conceivably some of it may be), but to point out that the price of their systems ($100,000 to $200,000) excludes the cost of original software development but includes tailoring (typically three or four months) to a particular installation. The computers which BSL supplies are either the PDP-12 or the LINC-8, both built by Digital Equipment Corporation, Maynard, Massachusetts.

Our rough estimates on the cost to develop a very fast multichannel analyzer (which, as we have seen, would be applicable to perhaps a third of the laboratory's workload) are $200,000 for hardware development and $150,000 for software development.

If such a system were operating, then a physician could obtain results for either inpatients or outpatients almost immediately. It is well known, though we have no specific figures to support this view, that a number of repeat outpatient visits or extra days in the hospital are occasioned only by the need to obtain laboratory results. Trips from a dispensary to the hospital for laboratory tests typically use up half a day or more of an enlisted man's time. On the strength of these benefits, the possibilities of a very fast analyzer should be pursued further.

7.6.9. COMPUTER SYSTEMS IN THE CLINICAL LABORATORY

As we have discussed in Section 7.5., we remain skeptical of the current practicality of a hospital-wide (or base-wide, including dispensaries) medical information system. In any event we believe that any medical information system must be constructed in a logically modular form if not in a physically modular form. With this in mind we propose to discuss a computer system for the clinical laboratory without regard to information from activities other than the laboratory and those who request and use its results. Since the problems in developing full-scale systems are formidable enough to be uncertain of when they will be successful, each element of what can become a full-scale medical information system should be justified on its own merits, at least for now.

There are a large number of computer installations in clinical laboratories throughout the country which are summarized in Reference 5. Development is far along in the file maintenance programs of Berkeley Scientific, Spear, Inc., IBM, and Digital Equipment Corporation. Most of the laboratory computer systems cost between $100,000 and $200,000, including software, and comprise a medium-size computer (such as the PDP-12, the CDC 3200, or the IBM 360/40), teletypewriters, card readers, and interface equipment for automated test devices, such as those discussed in Section 7.6.2. Except for data obtained from the automated devices, all data are entered either from a card reader or a teletypewriter. The systems organize test requests (that is, specify the order in which samples are to be loaded), receive and verify results, make necessary conversions on raw measurements, and format and print the output.

From available data we have no basis for cost-benefit analysis. Our examinations of justifications for existing installations before the facts have shown that personnel expected to be saved in fact were not. For one thing, operations of the computer has proved to provide a bigger workload than anticipated, and for another the number of tests requested has gone up. We do not believe that computers can be justified on the basis of personnel saved, at least in the current state of the art.

On the other hand, there are undeniable benefits in the quality of results and in quality control. They arise from the ease with which additional standards can be run, from the strict adherence to routine demanded by computer systems, and from the fact that systems do not degrade from fatigue.

For these reasons, in addition to the requirements of the rapid-turnaround fast analyzer described in Sections 7.6.7. and 7.6.8., a computer system in the clinical laboratory appears desirable.

With the exception of the fast analyzer terminals, there is no reason to enter requests from remote terminals because in any event the sample must be transported from the terminal, and it is better not to separate the request from the sample. However, it is worthwhile to print out results at remote terminals near the origin of the request (at nurses' stations, dispensaries, or clinics), and this can be done using teletypewriters or alphanumeric CRT displays. We have discussed this matter in Section 7.5.

7.6.10. REFERENCES

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7.7. OTHER COMPUTER APPLICATIONS

7.7.1. INTRODUCTION

In earlier sections in this volume we have discussed various non-accounting uses for computers in military hospitals. These have included applications in the pharmacy (Section 7.3), in the clinical laboratory (Section 7.6), and in a variety of areas where clinical data originate or are used (Section 7.5). In this section we briefly describe and comment on a number of other applications of potential value to military hospitals.

As with most computer applications to clinical practice, these developments are too new for their benefits to be proven or their costs clearly established. Most of them are promising enough so that the Department of Defense should investigate them further and, in some cases, consider participating in their development, as indeed DOD already has in matters such as the Automated Military Outpatient System (AMOS) and the Modernization of Routine Physical Examinations (MORPE).

7.7.2. HISTORY TAKING

Computer systems and software for taking medical histories are available from several vendors. Some have a relatively rigid repertory of questions, conceptually comparable to a mechanization of the standard government form (No. 89). A very simple way of mechanizing such questionnaires is to print each question in a form which can be answered yes or no on a computer card; punched for identification of the question, one question to a card. Patients are asked to sort the cards into two groups, and those to which the patient answered "yes" are read by a card reader providing input to a computer which formats a report of the responses. This method is used to obtain histories in the Kaiser multiphasic clinics.

Other systems and software have a more complete set of questions and are designed for evolution and flexibility. These systems proceed through a branching set of questions, new questions depending on the response to previous questions, much as a physician proceeds in taking histories; for example, if the response is positive to a question about pain in the chest, the program will shift to questions about frequency, locale, and duration of the pain; otherwise the program proceeds to questions about other matters. This kind of system is typified by that offered by Meditech, which uses a CRT display for the questions and a keyboard for the patient's responses. After a brief explanation by an aide, the patient operates the console, although the aide remains available to answer questions or provide further guidance. Many patients find the computer system a pleasant challenge, though some dislike its impersonality or its apparent complexity. In Meditech's system the computer is off-site and time-shared among many users. The report is provided on a printer, formatted as a narrative history and expressed in appropriate technical terms. (Such terms are avoided in the original questions answered by the patients.)

Meditech has expended a great deal of effort in making its system easy to change and therefore easy to tailor to any user's special requirements. Inserting or deleting questions is technically simple, although this in no way alleviates the problem of conceiving the right questions. To develop or adapt a set of questions appropriate to each of the various medical specialties in military hospitals would require professional commitment from military doctors.

Automated history-taking would be useful for several purposes:

- As a substitute for a handwritten record such as Form 89 or a more detailed history which might be taken by a specialist at the time of a particular complaint;
- As a convenient way to increase the comprehensiveness of histories without expending extra physician time;
- As a way to obtain uniformly structured histories in a machine-retrievable form for analysis, summarization, or investigative purposes; and
- As input to a system for computer-aided diagnosis (discussed in Section 7.7.3.).

On the other hand, if viewed simply as a substitute for the manual version, automated history-taking offers only modest benefits (legibility, structure, and perhaps greater comprehensiveness) for the costs involved.

Whether such programs will be acceptable to military physicians who are treating patients for serious ailments is problematical. Acceptance of programs utilizing questions written by someone else is by no means guaranteed. The physicians must have faith that the questions are well conceived, complete, and sufficiently redundant so that they can trust the resulting reports. Meditech has faced this problem by allowing each user to make changes in the questions as he wishes.

There is some didactic value for physicians in computerized history taking. Developing suitable programs forces developers to be explicit about plans, procedures, and purposes, and this has been one of the most important benefits of the computer revolution. One can learn much about history-taking from a well conceived program for history-taking. The development of these programs poses a significant challenge; DOD might consider this work -- particularly for specialties of unusual importance to DOD, such as neuropsychiatric disorders -- as professional stimulation for its physicians.

On balance, however, we do not believe that there are adequate benefits from automated history-taking to warrant the expense. Nevertheless, as with all our negative conclusions, the Department of Defense should stay abreast of developments in this field and should review the conclusion from time to time.

7.7.3. COMPUTER-AIDED DIAGNOSIS

Numerous efforts are under way to develop programs for computer-aided diagnosis. Although they are all in the experimental stage, we know of one which is available commercially through Mead-Johnson. This program is essentially a compilation of an enormous amount of data from the literature in pediatric medicine. The system uses a CRT terminal connected to a remote time-shared computer and a book of codes. The physician enters codes for symptoms, observations and laboratory findings, and the system displays a list of all diagnoses compatible with the data entered as well as lists of additional data required for further discrimination.

The developers carefully point out that the system does not diagnose but only aids in diagnosis. What is lacking, of course, is any measure of the weight to be given to each of the input data and the weight to be given to each of the sources of diagnostic data embodied in the routines. On the other hand, because programs such as this may suggest unusual diagnoses which might otherwise be overlooked, they have some didactic value as well as clinical value.

For the most part, however, computer-aided diagnosis is still in its infancy, and it will be years before such programs are sufficiently developed to gain widespread use. As a professional challenge to its physicians, DOD may wish to consider engaging in some development in this area; but for the time being, computer-aided diagnosis does not have much to offer in military hospitals.

7.7.4. ELECTROCARDIOGRAPHIC ANALYSIS

Programs for computer analysis of electrocardiograms have been in use for some time, and further evolution can be expected. Possibilities range from small hard-wired devices to moderately complex interpretive programs. There are two conceivable justifications for automating EKG analysis: saving the time of the cardiologist, and saving the time of technicians or others who must transcribe findings. Neither of these benefits seems adequate for DOD to expend much effort in this direction.

7.7.5. APPOINTMENT SCHEDULING

Computer systems to keep records of appointments (as opposed to generating schedules) are available from vendors such as Meditech. They do nothing more than keep track of blocks of time available from physicians in outpatient clinics or from the X-ray department. However, because computers can easily reorder data, they can also produce worksheets for service units, like X-ray, and reminder notices for inpatients (and, conceivably, if the mails or telephone were used, for outpatients).

A computerized system offers no important benefits over a well-run clerical activity to arrange appointments, except that the system can be interrogated from any point where there is a display. Thus, for example, a nurse wishing to schedule an appointment in radiology for an inpatient can see what times are available without telephoning, and an operator can do the same thing for an outpatient.

In our observation of outpatient scheduling in military hospitals, practices were uneven. Some appeared to be well run and efficient; some did not. In this application a computer makes only a modest contribution to efficiency. By itself, a computerized scheduling system is hard to justify. However, as part of a hospital information system, it does seem worthwhile as a way to cut down on telephoning. (Although we made no measurement of this, telephoning for information can be surprisingly wasteful of staff time, since it ties up both of the people involved.)

7.7.6. NURSE DUTY SCHEDULING

A perennial problem in hospitals, including military hospitals, is the scheduling of duty periods for nurses, shift by shift, or day by day. Chief nurses in charge of scheduling must consider a variety of factors:

- Current patient needs,
- Nursing specialties,
- Prior duty assignments,
- Personnel conflicts, and
- Personal constraints or preferences.

On top of this, the chief nurse should avoid showing favoritism.

It is possible to devise computer programs which take into account in a reasonable way all of the above factors. One such program is available commercially from General Electrics's Medinet. There is no reason to suppose that a computer can do much better than a competent administrative chief, but is does relieve her of some criticism.

Such programs require as input a rating of each patient for the relative amount of care he requires, a list of available nurses, a specification of constraints on their availability, and a specification of their preference or requirements for assignment. The computer then generates a figure for each ward for the aggregate of patient care needs, and computes the ratio between this figure and the number of nurses available for the ward and normally assigned to it. Wards with high ratios are understaffed, so the program reassigns nurses from more heavily staffed wards and from lists of "floaters" to make the ratios for all wards equal. It then prints the assignments. How far ahead such assignments can be projected depends upon how reliably the input data can be estimated.

In our visits to military hospitals we heard many complaints about duty scheduling from the nurses, and occasionally from the chiefs of nursing. There was no reason to believe that this was more than normal grousing, but it was a recurring complaint. A computer can be accused of ignorance but not of bias, and it might be a considerable help in making assignments that are perceived as equitable.

Developing such a program or adapting an existing one would require only a modest effort, which we believe would be worthwhile.

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