Computer Simulation:
A Methodology to Improve the Efficiency in the Brooke Army Medical Center Family Care Clinic

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Abstract
The executive leadership at Brooke Army Medical Center (BAMC) believes there are inefficiencies, characterized by poor access, high patient total time in the clinic, high patient wait time, and inappropriate resource utilization in the BAMC primary care clinics. The tool of computer simulation was selected to assist in reengineering the primary care clinics at BAMC to improve efficiency and patient satisfaction. This study focused specifically on the BAMC Family Care Clinic (FCC). The purpose of this study was to describe the current system and to evaluate the potential impact of process and resource changes in patient wait times, access, and resource utilization at the BAMC FCC. Base models were developed to replicate current FCC operations and tested for validity before creating all alternate models. The base models were utilized to compare results of proposed process and resource changes (alternate models). Alternate models were compared to the base model for the time the patient waits for the PCPs (Primary Care Providers), the total time a patient is in the clinic, and resource utilization (e.g., PCPs, LVNs [Licensed Vocational Nurse], and exam rooms). Comparison of model outputs revealed that two alternate models generated lower patient wait times in the clinic than the base model. These alternate models' resources were individually changed to determine the effect on the models outputs. Ultimately, these alternate models' multiple resources were optimized at 110, 120, and 130 percent of FY99 FCC visits to ascertain the best process and resource mix to improve access and patient wait times in the FCC.

Introduction
Background
Brooke Army Medical Center (BAMC), located at Fort Sam Houston in San Antonio Texas, serves 185,000 TRICARE beneficiaries in cooperation with nearby Wilford Hall Medical Center (Noyes and Harben 1998). BAMC's staff provides inpatient/outpatient care, level-one trauma, and graduate medical education in a modern, state-of-the-art, 450-bed healthcare facility.

Because of healthcare advances and cost-containment pressures, BAMC, like other major healthcare facilities, has shifted its focus from inpatient to outpatient care. BAMC has 58 outpatient specialty clinics, which recorded over 353,000 patient visits for fiscal year 1999 (FY99), and seven outpatient primary care clinics, which recorded over 276,000 patient visits for FY99 (Noyes and Harben, 1998; Composite Health Care System [CHCS], October 1999). Only five BAMC primary care clinics enroll TRICARE beneficiaries (BAMC's TRICARE primary care clinics). Three of these primary care clinics are located in the main BAMC building: Pediatrics/Adolescent Medicine, Internal Medicine, and the Adult Primary Care Network Clinic. The other two BAMC's TRICARE primary care clinics, General Medicine Clinic (for active duty only) and the Family Care Clinic (FCC), are located two miles away from the main BAMC building at the McWethy Troop Medical Clinic.

Traditionally, BAMC's TRICARE primary care clinics provided primary care to active duty personnel and their family members, military retirees under the age of 65 and their families, and eligible beneficiaries over 65. Currently, in addition to providing care for these aforementioned healthcare recipients, these clinics have recently expanded their capabilities to support the primary care workload of an enrolled elderly population of TRICARE Senior Prime (TSP) beneficiaries. These TSP beneficiaries usually have ailments related to chronic conditions, which increase their potential to consume more healthcare resources. Overall, these increases in patient load and severity mix have had a significant impact on the efficiency of operations in the primary care clinics (DeMouy, Rozowski, Rusing 1999).

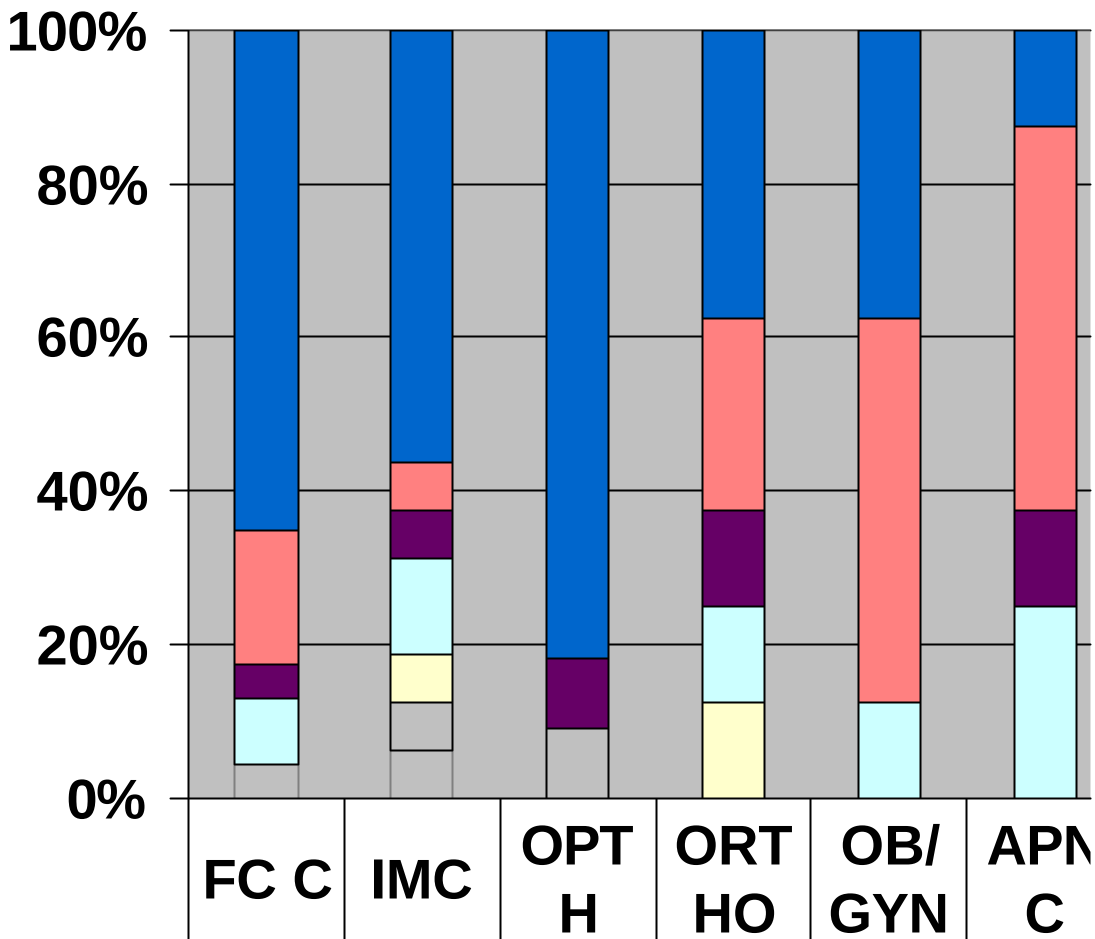
BAMC's TRICARE primary care clinics provide care for an enrolled beneficiary population of 34,936 (CHCS, August 1999). The BAMC FCC provides primary care services to an enrolled beneficiary population of 9,800 (3,279 active duty family members, 2,166 retirees and their 2,968 family members, and 1,387 TSP members under its current configuration) (CHCS, August 1999). BAMC FCC's nine primary care providers (PCPs) had over 44,200 patient visits for FY99 (CHCS, October 1999; Dr. Sauri 1999). The PCPs were military personnel, federal employees, and contracted care providers who represented various levels of healthcare providers ranging from family practitioners, general medical officers, physician assistants, and nurse practitioners (Dr. Sauri 1999).

Three of BAMC's TRICARE primary care clinics were among the top six areas of patient complaints for BAMC for the month of September 1999 (see Figure 1) (BAMC Patient Representative Log 1999). The high number of complaints in the BAMC FCC in particular, in conjunction with the recent enrollment of TSP members, have prompted the executive leadership to request a study that focused on improving efficiency and patient satisfaction at the FCC.

Statement of the Problem

The BAMC leadership believes that inefficiencies exist in the present configurations of the primary care clinics. These inefficiencies are characterized by poor access, high total patient time in the clinic, high patient wait time, and inappropriate resource utilization. These inefficiencies were created when BAMC shifted its primary focus from graduate medical education to primary care under TRICARE without changing its current organizational structure. Because the greatest number of complaints pertain to BAMC FCC, this study focused on the FCC. If resource inefficiencies do exist in the FCC, this study will aid in identifying where they exist. Additionally, BAMC currently has no standard management tool to accurately predict the effect of resource allocation changes within the organization. Building a computer simulation model of the current FCC will allow the BAMC executive leadership to evaluate future proposed changes in the clinic in a less expensive, less disruptive, and more timely manner.

Figure 1: BAMC Top Six Areas of Patient Complaints (for September 1999)
Note: Figure adapted from BAMC's "Patient Representative Report." 1999.



	FC C	IMC	OPT H	ORT HO	OB/ GYN	APN C
Access	15	9	9	3	3	1
Admin	4	1	0	2	4	4
Staff/Courtesy	1	1	1	1	0	1
Quality Care	2	2	0	1	1	2
Waiting	0	1	0	1	0	0
Telephone	0	1	1	0	0	0
Misc	1	1	0	0	0	0

Misc Telephone Waiting
Quality Care Staff/Courtesy Admin
Access

Literature Review

The Department of Defense initiated the transition into managed care in the Military Health Service (MHS) on October 1, 1993. The overall goals of the program, called TRICARE, are to improve beneficiary access, ensure quality of care, and control healthcare costs (Department of Defense 1994). According to the current Army Surgeon General, LTG Blanck:

> "managed care" means managing the healthcare of each patient so that the right level of care is provided at the right time and at the right place…. Often managed care means caring for patients on an outpatient basis as opposed to inpatient status when there is no difference in quality of outcome (Blanck 1997).

Primary care is key to the success of the MHS under TRICARE. Primary care is defined as the first level of care accessed by the patient (White 1996). Comprehensive primary care also focuses on the elements of prevention, early intervention, and wellness programs (Gapenski 1996). The key player in the success of managed care is the patient care manager. In the MHS, the PCP is the patient care manager. The ideal PCP not only provides comprehensive (i.e., broad range of services-acute and chronic disease management), coordinated (i.e., awareness of patient's entire list of problems), and continuous and accountable care, but it is also accessible to the patient (White 1996). The PCP coordinates care for the patient throughout the MHS. Family practice/general medicine, internal medicine, pediatrics, emergency medicine, and obstetrics/gynecology are provider categories generally defined as primary care (Kongstvedt 1997; Booz, Allen, and Hamilton 1998).

The appropriate staffing level for PCPs varies depending on the supported population demographics, utilization patterns, and the overall mission of the health system. Based on research in 1995, in health systems with less than 80,000 members, the weighted mean PCP staffing ratio was 0.89:1,000 (1 PCP per 1,124 members) with a standard deviation of 0.68. For systems greater than 80,000 members the weighted mean PCP was 0.66:1,000 (1 PCP per 1,515) with a standard deviation of 0.51 (Kongstvedt 1997). The AMEDD Fort Campbell Staffing Study and the Automated Staffing Assessment Model (ASAM) both consider provider nonpatient time in developing their staffing ratios. Both of these systems found that Department of Defense (DoD) PCPs are unavailable for patient services approximately 10 percent of the time because of specific organizational requirements of the MHS (Booz, Allen, and Hamilton 1998). While MHS PCP's time available for patient care is lower than their civilian counterparts, patient utilization rates are significantly higher (as much as 40 percent increase in demand factor) in MHS than in a civilian system because of the availability of "free care" (Newhouse 1993).

In addition to enrollee demographics and utilization, a particular clinic's processes and activities can have an enormous effect on the required staffing and overall effectiveness of the clinic. Improving the overall process of patients moving through a clinic can reduce patient wait time and increase the overall access to a clinic. However, managers rarely have the time or resources to experiment with such process changes.

Computer simulation offers managers an accessible, less expensive, less disruptive, and more timely means of evaluation (Benneyan 1997). Simulation is one of the most widely used methods to evaluate, improve, and optimize many types of processes. Simulation is an imitation of an actual process over time (Levy, Watford, and Owen 1989; Gogg and Mott 1993; Benneyan, Horowitz, and Terceiro 1994; Benneyan 1997). Simulation models imitate a system's behavior, referred to as "baselining," and are then used to evaluate possible changes in its structure, environment, or underlying assumptions in the form of "what-if-analysis" (Benneyan, Horowitz, and Terceiro 1994; Bateman et al. 1997).

Nonhealthcare industries often employ simulation software to assist managers in decision making. Similarly, the advantages of simulation are receiving increased attention within the healthcare industry. The literature consistently notes that simulation of patient flow provides invaluable information for senior and mid-level managers in problem-solving activities (Benussi et al. 1990; Mahacheck 1992; Benneyan, Horowitz, and Terceiro 1994; Benneyan 1997). Benneyan, Horowitz, and Terceiro (1994) recommend using computer simulation to test process and resource changes in an organization.

Numerous studies proclaim the advantages of simulation in identifying peak workload requirements and adjusting staffing patterns to increase providers' efficiency and decrease patient wait times (Bell, Warner, and Cameron 1985; Ammari, Abu Zahra, and Dreesch 1991, Benneyan, Horowitz, and Terceiro 1994; Hashimoto and Bell 1996; Allen, Ballash, and Kimball 1997; Benneyan 1997). Simulation results typically identify that the largest single challenge facing outpatient facilities is the time patients spend waiting to see a healthcare provider. Asefdeh (1997) noted that medical facilities could take advantage of outpatients' waiting periods, once identified, to disseminate preventive and other cost-effective healthcare information. Additionally, studies that modified clinics' operational procedures by incorporating simulation results report statistically significant benefits. For example, by incorporating simulation results into clinic operation, Hashimoto and Bell (1996) observed a decreased total time for patients in the clinic from a mean of 75.4 minutes (sd 34.2) to a mean of 57.1 minutes (sd 30.2) ($p<.001$, T test).

Simulation offers a practical alternative approach to problem solving. Because simulation models evaluate outcomes without actually making changes in the system, simulation modeling can allow the consideration of several alternatives before any resources, especially human, are expended. Healthcare is a dynamic service industry with high human involvement, sporadic workflow, and high variability. Benneyan, Horowitz, and Terceiro (1994) points out that accountability for the variation of patient arrival times, staff shifts and breaks, and queuing and treatment times is vital for accurate statistical results in a process that is dominated by interaction between human beings. A healthcare simulation program, such as MedModel® version 4.2, is ideal for healthcare because its dynamic, stochastic (random) method can account for variability and randomness in a process over time and incorporate these attributes into the final analysis (ProModel® Corporation 1998a).

The appropriate level of detail in a model is extremely important in achieving useful results. The simulator must choose the appropriate level to answer the objective (ProModel® Corporation 1998a). As the model becomes more complex, it requires additional data and continuous verification; a simulator must understand the inverse relationship between model complexity and utility (ProModel® Corporation 1998a). Once an appropriate simulation model is built, it repeats the process for the researcher to observe. Because simulation focuses on objective measures of the process, researcher bias decreases on the results of the study.

The amount of literature that describes simulation applications to healthcare and patient scheduling is increasing substantially (Kalton et al. 1997; Benneyan, 1997). The use of simulation as a technique for evaluating military primary care facilities, such as BAMC FCC, is also gaining momentum. In 1994, Reese developed a computer simulation to assess the effects of proposed changes on Martin Army Community Hospital emergency department. Two years later, an animated simulation was used to determine the optimal staffing and process configuration for the Heidelberg Medical Department Activity Family Practice Clinic (Ledlow 1996; Ledlow and Bradshaw 1999). In 1998, Fay used simulation to compare three Ireland Army Community Hospital Primary Care Clinics and ultimately recommended process and staffing changes. Similarly, computer simulation has been used to analyze staff utilization and patient waits to modify processes of Fort Monroe Health Clinic prior to facility occupation (Duray 1998). Fulton (1998) developed an outpatient model to assist in reengineering Bayne-Jones Army Community Hospital.

Purpose
The purpose of this study is to describe the current system and through the development of a simulation model to evaluate the potential impact of process and resource changes on patient wait times, access, and resource utilization on the BAMC FCC. Additionally, building a computer simulation model of the current FCC provides the FCC leadership the capability to evaluate future proposed changes in the clinic in a more timely and less resource-intensive manner. The terminal objective of this project is to determine resource levels and processes for the FCC that will improve operational efficiency. Efficiency for this study is defined as decreased patient total time in clinic, increased patient access (i.e. increased number of available appointments), and appropriate resource utilization.

Limitations and Assumptions
As with any study, certain limitations and assumptions must be identified. The primary limitation of this study is that the simulation model can not replicate every variable or occurrence of the FCC system. The complexity of such a detailed model would actually decrease its utility. The major assumption governing this study was that a one-month time study of the FCC was sufficient to attain an accurate representation of the current system. A second assumption was that all data collected relating to workload and appointment scheduling were accurate. The following Department of Defense databases were utilized for data collection: Ambulatory Data System (ADS) and the Composite Health Care System (CHCS).

Method and Procedures
Even though each simulation is unique, past studies have shown a series of steps that lead to a successful simulation model. Steps common to successful simulation are

- establish goals and objectives of the simulation;
- formulate and define the model;

- collect data;
- build, verify, and validate the model; and
- experiment, analyze, and present results (ProModel® 1998c; Benneyan 1997).

This graduate management project followed the above format. Figure 2 is provided to illustrate the interrelationships between these steps.

Figure 2: Steps in a Simulation Study

Steps in a simulation study

- Problem formulation
- Set Objectives and Make Plan
- Model Conceptualization
- Data Collection
- Model Translation
- Verification
- Validation
- Experimental Design
- Production Runs and Analysis
- More Runs?
- Documentation and Reporting
- Implementation

Note: Figure adapted from R. Bateman, R. Bowden, T. Gogg, C. Harrel, and J. Mott (eds.). 1997. *System Improvement Using Simulation, Fifth Edition*. Orem, Utah: ProModel® Corporation.

For a better graphic representation of this figure, please call (312) 424-9473. It will be faxed to you.

Goals and Objectives
The goal of this simulation was to generate information that can be used by the BAMC leadership to make appropriate decisions that will result in increased operational efficiency in the FCC. To attain this goal, the following objectives were established:
1. Describe the current system
2. Evaluate the impact of process and resource changes on patient wait times, access, and resource utilization
3. Design an improved system for the FCC.

The development of a MedModel® simulation model aided in achieving these objectives. Additionally, building a computer simulation model of the current FCC provided the FCC leadership the capability to evaluate future proposed changes in the clinic in a more timely and less resource-intensive manner.

Model Formulation and Planning

Once the modeler and the FCC leadership agreed on the simulation objectives, the next step was to determine a conceptual framework of the model. The first step in understanding a system, such as the FCC, was to chart the flow of patients through the facility (Mahachek 1992). The framework for the FCC model was developed through a patient flow diagram. The patient flow diagram was confirmed with the chief, FCC, the head nurse, and the department of Primary Care and Community Medicine (see Figure 3).

Figure 3: BAMC FCC Patient Flow

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The FCC patient flow process can be summarized as follows:

1. A patient checks in with the receptionist and/or records clerk and then waits in the waiting area.
2. screener escorts each patient to a screening room where vitals and general patient information are taken (e.g., height/weight and reason for appointment).
3. After screening, the patient is directed back to the waiting area.
4. Once the primary provider is available, the PCP directs the patient to his or her exam room/office.
5. After the appointment is complete, the PCP directs the patient to the discharge area or to other ancillary care (e.g., medic for basic procedure, laboratory, x-rays, or pharmacy) depending on the situation.
6. A civilian nurse who is responsible for final coordination of patient treatments (e.g., discussing doctor treatment procedures, setting follow-up appointments, and discharging the patient) staffs the discharge area. If this individual is not available the patient may wait for the discharger, get prescriptions filled, or go to the laboratory.

At the FCC, appointments are conducted from 0730 to 1900 hours, Monday and Thursday, and from 0730 to 1600 on Tuesday, Wednesday, and Friday. Physician appointments begin between 0730 and 0900 and are scheduled for 15 minutes to 40 minutes, depending on the type of appointment and patient. Most providers take a short lunch break around 1200. Primary care appointments begin again for the majority of the providers at 1300 hours. Most provider appointments continue until 1600. On Monday and Thursday, two providers' appointments continue until 1900.

Creation of a flowchart assisted in the development of decision variables in the FCC process. To develop these models, certain process decision variables (variables that management has control over) as well as uncontrollable variables, such as patient timeliness, had to be collected. Table 1 lists the primary "inputs" included in the FCC model.

Table 1: Process Variables and Simulation "Inputs"

Number of:	Distribution of time for:
· Receptionists	· Patient arrival

· Screeners	· Patient to check-in
· Screening rooms	· Screener to screen patient
· Providers	· Provider to examine patient
· Total appointments	· Discharger to discharge patient
· Total exam rooms	
· Dischargers	General Facility Layout
· 91Bs	
· Education nurses	

Table 2 lists the "output" performance measures that were collected from the FCC model. However, the modeler in conjunction with the FCC leadership determined the output performance measures in bold were the most relevant to increasing efficiency defined in this study. Therefore, only the output performance measures in bold were analyzed.

Table 2: Simulation "Output" Performance Measures

Patient waits:	Location and number of patients:
· Total patient wait	· Waiting to check-in
· Wait for receptionists	· Checking-in
· Wait for screening room	· In waiting room
· Wait for screeners	· Waiting for screener
· Wait for exam room	· Being screened
· Wait for provider	· Waiting for provider
· Wait for discharger	· Being examined
· Total time until seen by provider	· Waiting for discharger
· Total time in FCC	· Being discharged (follow-up appt arranged)
Resource utilization:	Total number of patients:
· Receptionist idle time and utilization	· Arrived
· Screener idle time and utilization	· In FCC
· Provider idle time and utilization	**· Departed**
· Waiting room utilization	
· Screening room utilization	
· Exam room utilization location and number of patients	

Data Collection
Several ongoing methods were used to collect data for input variables of the model throughout the study. A time study was initiated on October 1, 1999 (see Appendix A). Observations and personal interviews began in October and continued throughout the project. Interviews with the staff provided important information on daily work hours, personnel shifts, and lunch breaks.

Historical data on clinic visits were collected from BAMC database systems-ADS and CHCS-but the primary source was CHCS. Adhoc CHCS reports provided information for model inputs such as the number of patients seen in the clinic by appointment type per month and the number of patients seen/appointments scheduled for each physician per month. To gather the needed data, Adhoc CHCS reports were run for BAMC FCC for Fiscal Year 1999 (see Appendix B).

The collected data was matched to an appropriate frequency distribution by using Stat:Fit®, a curve-fitting program in MedModel® version 4.2. These frequency distributions were placed into MedModel® to represent patient inter-arrival times, process duration times, and probabilities of occurrences.

Model Development, Verification, Validation, and Reliability
The models were built using version 4.2 of the MedModel® simulation software bought from ProModelÒ Corporation. MedModel® is a computerized simulation software specifically designed to model medical processes. Six elements common to any MedModel® simulation model include entities, locations, arrivals, pathways, processes, and resources. Entities are objects that have actions performed on them (e.g., patients, medical charts, lab samples, x-ray, etc). Locations are the places where the activities associated with entities occur (e.g., treatment rooms). Arrivals describe patterns (e.g., frequency and time) related to when and how entities enter the system. Pathways represent the route entities take as they travel through the system (pathways can differ based on the type of entity-e.g., child vs. adult-and the actions performed on the entity). Processes are actions done to an entity (e.g., what action is performed, rules for prioritizing which entity is acted on, who performs the action, how long it takes, and what happens to the entity when the action is completed). Resources perform processes on entities (e.g., physicians, nurse, etc.); resources limit the capacity of the system (ProModel® 1998a, 1998c). Through MedModel®, the modeler converted the actual workings of the system, shown in Figure 2, to these different elements to simulate actual FCC operations.

The head nurse of the department of Primary Care and Community Medicine provided the original floor plan of the McWethy TMC. This version was edited in Microsoft Paint© to reflect the present layout of the TMC (see Appendix C). The programmer then imported the image to MedModel® simulation software and sized the image using the grid setting option to accurately depict the correct relative square footage of the TMC.

The actual development of the simulation was incremental, with process detail and complexity added in a stepwise fashion. After each process was modeled, it was debugged (reconciled) and verified before the next process was added. Ultimately, two BAMC FCC status quo models evolved to sufficiently meet the study's first objective. One model simulated Monday and Thursday extended day operations, while the other model simulated Tuesday, Wednesday, and Friday normal day operations.

A model is verified when it processes data as intended by the modeler and has the ability to generate output information that can satisfy the objectives of a study (Mahachek 1992; Gogg and Mott 1993; Bateman et al. 1997; ProModel® 1998a). The flow of the patient (entity) in the BAMC FCC status quo models were traced to verify the accuracy of the process, routing, and frequency distributions; when an inconsistency was identified it was debugged. This verification process was continued throughout the study.

"Model validation establishes credibility in the model" (Gogg and Mott 1993). A valid model behaves like the actual system in a manner sufficient to address the stated problem (Bateman et al. 1997; ProModel® 1998a). Validation was accomplished in a stepwise manner, with each model segment tested and validated before starting the next. When complete models were constructed, these aggregate FCC status quo models' outputs were validated through statistical analysis that compared model outputs with data gathered through previous observations of the clinic. In past studies Z and T tests were used to determine if a significant statistical difference existed between the aggregate model outputs and previous empirical observations of clinic operations (Lowery and Martin 1992; Ledlow 1996; Duray 1998; Fay 1998). Likewise, a Z test was utilized to determine if the total time until seen by a PCP and total time in clinic produced from the FCC status quo models had a statistically significant difference from empirical wait times for October 1999. Additionally a T test was employed to determine if total patient visits produced from the FCC status quo models had a statistically significant difference from the total patient visits in the FCC in October 1999. Table 3 shows the results of these statistical validations. Similarly, a Z test was used to validate the FCC status quo models in FY99. The FY99 models' processes were based on the BAMC FCC status quo models in October 1999).

The only variation in these models was that their arrival patterns were based on yearly data (FY99) instead of monthly data (October 1999). The FY99 models were not validated on wait times because of lack of yearly wait time data. Appendix E demonstrates the processes and numbers utilized for all statistical validation results. The alpha level for statistical significance for these tests was .05. For validation purposes, a statistically significant difference should not exist between the empirical patient wait times and those obtained in the simulation models. From the results of these Z and T tests, and from conferring with Dr. Sauri, the modeler determined that no statistically significant or practical difference exists between the model and real patient wait times in the FCC.

Table 3: Validation Results of BAMC Status Quo Models (October 1999)

PATIENT	MEAN		SAMPLE SIZE		RESULTS	
Total	Empirical	Model	Empirical	Model	Test	
In Clinic (time)	65.24	67.99	135	1382	1.22(z)	No statistically significant difference
Waiting for Provider (time)	21.44	18.19	146	1382	-0.074(z)	No statistically significant difference

Patients	117	124.99	21	21	1.47(t)	No statistically significant difference

Reliability is the ability of the model to consistently measure what it is designed to measure (Cooper and Schindler 1998). Reliability looks at the variance of outputs produced from the model over time (see Appendix D). The modeler ran the simulation for different iterations to determine the reliability of the model. Also the modeler changed the streams (i.e., sequences of independently cycling, random numbers used in conjunction with distributions [ProModel® 1998c]) of the model and compared the results of different streams with Z tests to establish reliability of the model (see Appendix D). From the results of the Z tests, the modeler determined that the BAMC FCC status quo models were reliable.

Ethical Considerations

Confidentiality and privacy are significant considerations when performing healthcare research. The Privacy Act and other patient protection policies require extreme diligence. Throughout this study, patient information was examined. All patient information involved in this study was collected in aggregate and only summary statistics were presented. Anonymity of all participants (patients and interviewees) was protected and used only with expressed permission. Appropriate recognition and source quotes are provided in all cases.

Model Experimentation, Analyses, and Results

The model experimentation and analyses of results are provided to answer the objectives of this study, one of which is to increase operational efficiency. Efficiency for this study is defined as decreased patient total time in clinic, increased patient access (i.e. increased number of available appointments), and ensure appropriate resource utilization. To accomplish these efficiencies, a review of current operations was completed.

Current FCC System

The average time a patient waits to see a provider and the overall patient time in the current FCC system are 24.8 and 80.59 minutes, respectively. The utilization of PCPs, LVNs, and exam rooms are 78.54, 49.67, and 46.41 percent of available time, respectively. Appendix B provides FCC patient information, and Table 4 summarizes the FY99 FCC utilization by patient category.

Table 4: FY99 FCC Utilization

Enrollment Category	Number Enrolled	Visits	Utilization (Visits per year)
Tricare Prime	7,850	25,973	3.0308
Tricare Senior Prime	1,485	8,829	5.9495
Space A	0	7,396	4.0108
Active Duty	13	6	0.4615
Other Clinic	0	1,584	2.6893

TOTAL	9,348	43,788	3.9369

Note: Numbers based on end of FY99 enrollment; therefore, patients may be enrolled during visit but not enrolled at end of FY99 and will be shown as Space A. Enrollment data are provided by Foundation Health; while visit data are provided by CHCS.

Impact of Resource Changes

The modeler then examined some preliminary what-if (imagineering) factors that may affect patients access, wait time, and resource utilization (see Table 5).

Table 5: Simulation Factors Examined by the Modeler

- Number of exam rooms
- Number of screeners (LVNs) and providers
- Number of appointments
- Various combinations of above

The actual number and type of what-if analysis performed was constantly adjusted as needed to achieve the study objectives. Table 6 describes the different models used in the what-if analysis. What-if simulation outputs were tested for statistical significance (using Z tests) as well as for overall practicality (i.e., decreased overall time in clinic and minimal resource consumption). As suggested by Gogg and Mott (1993) and Bateman et al. (1997), overall analysis was designed to maximize the usefulness of the information produced from simulation runs while minimizing the effort. Table 7 lists the major statistical analyses performed for the status quo and what-if models.

Table 6: Description of Models Used in What-If Analysis

Models	Description
Alternative-One Models	Combine the FCC and APNC resources at the TMC (10 PCPs, 2 interns, 20 exam rooms, 2 receptionists, 2 91Bs, 2 education nurses, and 1 discharger) for 100 percent of FY99 FCC visits.
Alternative-Two Models	Replicate one team (6 PCPs and 1 intern) with the support of the rest of the FCC resources (15 exam rooms, 2 receptionists, 2 91Bs, 2 education nurses, and 1 discharger) for 50 percent of FY99 FCC visits.
Alternative-Three Models	Replicate one team (6 PCPs and 1 intern) with the support of the rest of the FCC resources (15 exam rooms, 2 receptionists, 2 91Bs, 2 education nurses, and 1

	discharger) with no screening rooms (process changed to accomplish screenings in exam rooms) for 50 percent of FY99 FCC visits.
Alternative-Four Models	Combine the FCC and APNC resources at the TMC with no screening rooms (process changed to accomplish screenings in exam rooms) for 100 percent of FY99 FCC visits.

Note: For each model types, two models were built. One model simulated Monday and Thursday extended day operations, while the other model simulated Tuesday, Wednesday, and Friday normal day operations. All models replicated current FCC staff shift schedules.

The BAMC leadership recently directed the combination of the FCC and the APNC. This decision led to the first what-if-analysis, which studied the effects of the consolidation of these clinics. The Alternative-One Models were developed to represent the new allocation of resources in the McWethy Troop Medical Clinic. Overall, the Alternative-One Models show that the combination of the FCC and the APNC will have a positive impact on efficiency with regard to patient wait times (see Appendix D-6). The average time a patient waits for a PCP and the overall time in the clinic will decrease 4.52 and 7.24 minutes, respectively, from the current FCC system (see Table 7).

Table 7: Summary of Statistical Analyses

	Empirical (OCT) Total Wait Time to See PCP	Empirical (OCT) Overall Time in Clinic	Empirical (Oct) Total Patient Visits	Empirical FY99 FCC Total Patient Visits	OCT99 FCC Status Quo Models Patients' Wait Time to See the PCP and Overall Time in Clinic	FY99 FCC Status Quo Models Patients' Wait for PCP (Model processes based on Oct99 Model with yearly patient load)	FY99 FCC Status Quo Models Patients' Overall Time in Clinic (Model processes based on Oct99 Model with yearly patient load)	Alternative-One Models [Directed Change]	Alternative-One Models [Directed Change]	% Util PCPs	% Util LVNs	% Util Exam Rooms
Model												
Oct99 FCC Status Quo	No Statistical Significant Difference Appendix D-1	No Statistical Significant Difference Appendix D-1	No Statistical Significant Difference Appendix D-1									
FY99 FCC Status Quo Models (Model Processes Based on Oct99 model with				No Statistical Significant Difference Appendix D-3		24.8	80.59			78.54	49.67	46.41

yearly patient load)												
FY99 FCC Status Quo Models (Change in Streams)				No Statistical Significant Difference Appendix D-4								
FY99 FCC Status Quo Models (Change in # of Iterations)				No Statistical Significant Difference Appendix D-5								
Alternative-One Models [Directed Change]						Positive Statistical Significant Difference (5.52 minute decrease in wait) Appendix D-6	Positive Statistical Significant Difference (8.24 minute decrease in wait) Appendix D-6			77.85	53.74	43.07
Alternative-Two Models [Team Concept]						Positive Statistical Significant Difference (10.36 minute decrease in wait) Appendix D-7	Positive Statistical Significant Difference (7.13 minute decrease in wait) Appendix D-7			68.44	24.49	19.6
Alternative-Three Models [Process Change with a Team Concept]						Negative Statistical Significant Difference (3.92 minute increase in wait) Appendix D-8	Positive Statistical Significant Difference (21.06 minute decrease in wait) Appendix D-8	Negative Statistical Significant Difference (1.6 minute increase in wait) Appendix D-9	Positive Statistical Significant Difference (12.82 minute decrease in wait) Appendix D-9	65.46	35.29	29.32
Alternative-Four Models [Process Change]						Negative Statistical Significant Difference (3.07 minute increase in wait) Appendix D-10	Positive Statistical Significant Difference (8.82 minute decrease in wait) Appendix D-10	Negative Statistical Significant Difference (8.59 minute increase in wait) Appendix D-11	Positive Statistical Significant Difference (.58 minute decrease in wait) Appendix D-11	66.22	68.87	46.34

Note: Level of Significance = .05; Patient Visits exclude telephone consults; Utilization percentages only account for utilization in patient related activities and do not encompass all patient care activities because of the impracticality of the models to replicate all activities.

Because the FCC staff was contemplating developing teams in the new FCC system, the modeler developed Alternative-Two Models to determine the effects of the team concept. This model replicated the work of only one team (six PCPs and one intern) with the support of the rest of the

FCC resources (fifteen exam rooms, two receptionists, two 91Bs, two education nurses, and one discharger). The Alternative-Two Models reveal the team concept will have a positive impact on efficiency in regards to patient wait times when compared to the current FCC system (see Appendix D-7). The average time a patient waits for a PCP and the overall time in the clinic will decrease 10.36 and 7.13 minutes, respectively, from the current FCC system. However, the team concept does not improve the overall efficiency of the combined FCC/APNC, Alternative-One Models (see Table 7).

To reiterate the terminal objective of this project was to determine resource levels and processes for the FCC that will improve efficiency. The modeler did some imagineering in an attempt to determine the optimal FCC structure. The modeler, after discussion with PCPs, developed the Alternative-Three Models that apply the same concepts as the Alternative-Two Models. However in the Alternative-Three Models, the present duties of the screeners (LVNs) changed to include preparing the patient for the PCPs in the exam rooms, which enables the PCPs to concentrate more on treating the patient and eliminates the use of a screening room for most patients. The Alternative-Three Models demonstrate that increasing the responsibilities of the LVNs will have a positive impact on efficiency in regards to patient wait times (see Appendix D-8) when compared to the current FCC system. The average time a patient waits for a PCP and the overall time in the clinic will decrease 3.92 and 21.06 minutes, respectively, from the current FCC system. The Alternative-Three Models also improved efficiency in regards to wait times when compared to the Alternative-One Models. The average overall time a patient is in the clinic will decrease 12.82 minutes from the combined FCC/APNC system (see Appendix D-9). The Alternative-Three Models gained efficiency in patient time in the clinic would allow the FCC to increase appointments by at least 30 percent before the patient time in clinic would reach the same level as the proposed combined FCC/APNC system (Alternative-One Models). Even though the Alternative-Three Models system would allow the clinic to increase patient appointments, it may be impractical because of the additional staff required to support this team system with budgetary constraints.

Therefore, the Alternative-Four Models were designed to determine the true effects of changing the screening process without increasing staff requirements. These models are based on the processes of the Alternative-One Models except with the change in the screening process. The present duties of the screeners (LVNs) changed to include preparing the patient for the PCPs in the exam rooms, which enables the PCPs to concentrate more on treating the patient and eliminates the use of a screening room for most patients. The Alternative-Four Models demonstrate that increasing the responsibilities of the LVNs will have a positive impact on efficiency in regards to patient wait times when compared to the current FCC system (see Table 7). The average overall time a patient is in the clinic will decrease 8.82 minutes from the current FCC system (see Appendix D-10). However, increasing the responsibility of the LVNs does not significantly improve the overall efficiency of the combined FCC/APNC (Alternative-One Models) in respect to the total time in clinic, a decrease of only .82 minutes (see Appendix D-11).

The Alternative-One Models and the Alternative-Four Models were further analyzed to determine if changing the number of PCPs, LVNs, exam rooms, or the number of appointments would increase the efficiency of either system. Appendix E-1 not only confirms the conceptual inverse relationship between the individual number of PCPs, LVNs, or exam rooms and the total time a patient spends in the clinic but also illustrates that patient generally spends less time in clinic with the Alternative-Four Models. Appendix E-2 verifies the theoretical inverse relationship between the number of PCPs, LVNs or exam rooms and utilization of these resources. Appendix E-2 also demonstrates that Alternative-One Models have higher levels of PCPs utilization and lower levels of LVN and exam room utilization when compared to Alternative-Four Models. Appendices E-3 and E-4 confirm the direct relationship between increasing the amount of appointments and total time a patient is in the clinic and utilization of resources.

Designing an Improved System (Optimization)
Because this study was designed to improve the access in the FCC (see Figure 1), the modeler used MedModel SimRunner2!® to attempt to improve the access and efficiency of both models. SimRunner2!® conducts various what-if analyses to determine the best way to perform operations (i.e. optimization). SimRunner2!® enables the modeler to optimize multiple factors simultaneously (ProModel® 1998b). Because the modeler desired to increase access to the FCC, the modeler ran optimizations on the Alternative-One Models and Alternative-Four Models with increased appointments from FY99 (110, 120, and 130 percent). The modeler used the same input factors that were studied individually in Appendix E (i.e., 12-20 PCPs, 4-12 LVNs, and 20-32 exam rooms) to determine the optimal combinations of these multiple factors (resources) to attain the desired efficiencies. To maintain or preferably decrease the overall time the patient spent in the clinic, the modeler elected to minimize the average total time a patient is in the clinic as the optimization models' output. To accurately predict the objective function difference of 1.25 minutes with a statistical confidence level of 95 percent, the modeler ran 30 iterations of each potential combination of resources tested in SimRunner2!®. The modeler used Statistical Advantage, a component of SimRunner2!®, to determine the accuracy of SimRunner2!® objective function (average overall time a patient is in the clinic).

Table 8 summarizes the optimization results. The modeler determined the optimal solution from SimRunners2!® optimization results for each model by using the following practical significance criteria:
1. Acceptable results must have an overall patient time in clinic of less than 70.59 minutes (a ten-minute decrease in time from current FCC operations).
2. The lowest number of the PCPs utilized, the better the solution (the most expensive resource).
3. The lowest number of LVNs and exam rooms with the lowest PCPs and an acceptable overall time in clinic patient is the optimal solution.

Table 8: Optimization Results

	Time Patient is in the Clinic	# of PCPs/ Utilization	# of LVNs/ Utilization	# of Exam Rooms/ Utilization
Alternative-Four Models 1.1 Appendix F-1	66.27	12/68.79%	7/38.95%	20/50.46%
Alternative-One	69.86	14/65.26%	8/24.19%	26/29.43%

Models 1.1 Appendix F-1				
Alternative-Four Models 1.2 Appendix F-2	70.52	12/74.49%	12/23.03%	21/54.55%
Alternative-One Models 1.2 Appendix F-2	No Acceptable Results			
Alternative-Four Models 1.3 Appendix F-3	69.79	16/57.24%	12/24.72%	28/40.63%
Alternative-One Models 1.3 Appendix F-3	No Acceptable Results			

Note: Acceptable results must have an overall average patient time in clinic < 70.59 minutes. Overall average patient time in clinic has a +/- variance of 1.25 minutes with a confidence level of 95 percent. 1.1, 1.2, and 1.3 refer to the models simulating 110 percent, 120 percent, and 130 percent of FY99 FCC visits, respectively.

Discussion

Interpretation of Results

According to FCC PCP Time Study (2000), only 79 percent of a PCPs' time is available for any type of patient care; therefore, any increase in direct patient care and decrease in indirect patient care time is crucial. Even though desirable, a 100 percent utilization rate of PCPs is not practical. Literature states a utilization rate of 70-80 percent of available time for patient care is as good as one could expect (Dawson et al. 1994; Ditch 1997). Because the models do not account for all indirect patient care (e.g. reading charts, coordinating with other providers, etc.), the modeler reduced available patient care time by 5 percent of the PCPs time for indirect patient care, decreasing the desired appropriate utilization in the FCC models for the PCPs to 65-75 percent. Even though the modeler desired to maintain an approximate 65-75 percent PCP utilization rate in all models, the modeler was not able to achieve this rate with a 30 percent increase in patient visits in the Alternative-Four Models. However, the modeler still listed this scenario as a valid combination of resources because of the model's ability to increase visits by 30 percent and still decrease overall patient time in clinic by ten minutes. Because the PCPs are the most expensive human resource, the appropriate LVN and exam room utilization rates were based on the highest rate that enabled the system to achieve a PCP utilization of 65-75 percent.

Table 9: Comparison of Optimization Models to Base Models

	FY99 FCC (Current)	Alternative-One Models	Alternative-Four Models	Alternative-One Models 1.1	Alternative-Four Models 1.1	Alternative-Four Models 1.2	Alternative-Four Models 1.3

		(Directed Change)	(Process Change)				
Average Daily Patient Census	146	146	146	161	161	175	190
Average Overall Time in Clinic	80.59	72.35	71.77	69.86	66.27	70.52	69.79
# of PCPs/ Utilization	11/76%	12/78%	12/66%	14/65%	12/69%	12/74%	16/57%
# of LVNs/ Utilization	4/50%	4/54%	4/69%	8/24%	7/39%	12/23%	12/25%
# of Exam Rooms/ Utilization	15/46%	20/43%	20/46%	26/29%	20/50%	21/55%	28/41%
Ratio of LVNs To PCPs	.36	.33	.33	.57	.58	1.0	.75
Ratio of Exam Rooms To PCPs	1.36	1.67	1.67	1.86	1.67	1.75	1.75

Note: Overall average patient time in clinic has a +/- variance of 1.25 minutes with a confidence level of 95 percent. 1.1, 1.2, and 1.3 refer to the models simulating 110 percent, 120 percent, and 130 percent of FY99 FCC visits, respectively.

Table 9 compares the optimization models to base models. All models developed in this study demonstrated the importance of having the appropriate amount and type of resources (i.e., PCPs and the appropriate ratio of exam rooms and LVNs to support the PCPs). The current FCC configuration has inappropriate resources to gain efficiency. Efficiency for this study was defined as decreased patient overall time in clinic, increased patient access (i.e., increased number of available appointments at the 110, 120, and 130 percent level), and appropriate resource utilization (i.e., 65-75 percent of PCPs available time). As seen in Table 9, additional PCPs and an appropriate number of exam rooms and LVNs supporting the PCPs are needed to gain optimal performance in the FCC. The BAMC leadership recently directed change of combining the FCC and the APNC will increase the number of PCPs and exam rooms, which consequently will decrease the overall time a patient is in the FCC at McWethy Troop Medical Clinic. Nonetheless, to realize greater efficiencies (i.e. increasing the number of patients that the

PCP can see and to reduce the overall time a patient is in the clinic), the number of LVNs supporting the PCPs must also be increased. The FCC could gain even more efficiencies if the present duties of the screeners (LVNs) are changed to include preparing the patient in the exam rooms for the PCPs (enabling the PCPs to concentrate more on treating the patient and eliminating the use of a screening room for most patients).

Using the ratios listed in Table 9, the BAMC leadership has a method to determine the appropriate mix of resources to gain operational efficiency in the BAMC FCC with a constrained resource of PCPs, LVNs, or exam rooms. For example, if the leadership wants to increase the FCC's capability up to 30 percent and changes the screening process (but has a constrained resource of only 15 PCPs available), the FCC would need 25-26 exam rooms and 9-15 LVNs (i.e., exam rooms = (# of PCPs) x (ratio of exam rooms to PCPs at a 10 percent to 30 percent increase); LVNs = (# of PCPs) x (ratio of LVNs to PCPs at a 10 percent to 30 percent increase). Likewise if the constraining resource is the number of available exam rooms, the leadership can determine the appropriate amount of PCPs and LVNs (i.e. PCPs = (# of exam rooms) x ((ratio of exam rooms to PCPs at a 10 percent to 30 percent increase)-1); LVNs = (# of PCPs determined in above formula) x (ratio of LVNs to PCPs at a 10 percent to 30 percent increase).

The results of optimization demonstrate, when varying the combination of multiple resources (PCPs, LVNs, and exam rooms), that the Alternative-Four Models are consistently more efficient than the Alternative-One Models (see Appendix F). In all cases (110, 120, and 130 percent of FY99 FCC visits), the Alternative-Four Models used fewer PCPs to achieve an acceptable time in the clinic for the patient (see Table 8). These models used the PCPs more efficiently because the process was changed to increase the responsibilities of the LVNs to include preparing the patient in the exam room for the PCPs. This change in process will enable the PCPs to use more of their time in direct patient care (actual examination of the patient) and less time in preparing the patient for the exam.

Under all the Alternative-Four Models (i.e., 1.1,1.2, and 1.3), the exam rooms would have to be equipped to enable LVNs to screen patients in them. With this additional equipment and only three additional LVNs, the Alternative-Four Models 1.1 demonstrate that changing the screening process would enable the FCC to have an average of 15 more visits daily and to decrease the overall time a patient is in the clinic by an average of 14 minutes from the current FCC configuration.

One finding that emerged in the study, albeit not via the project's design, was that increasing the number of exam rooms does not necessarily increase the productivity of PCPs. The actual location of these rooms is more essential to productivity. Increasing the number of exam rooms not in the proximity to the provider can decrease the productivity of the provider and decrease the efficiency of the system. Therefore, the location of resources used by the PCP are key for the productivity of the provider and the efficiency of the system.

Presentation of Results

The modeler presented these results in a team fashion to key decision makers and to personnel who may be affected by the results. In the presentations, the following was addressed with references to technical, operational, and financial concerns: (1) project objectives, (2) problem solved, (3) project methodology, (4) pros/cons of proposed solution, and (5) rejected alternatives and reasons (Gogg and Mott 1993).

Conclusions and Recommendations

The models developed identified the need for one to five additional PCPs, four to eight LVNs, and five to thirteen exam rooms, depending on the target capability and processes selected (see Table 9). The anticipated directed consolidation of the FCC and the APNC will provide only one PCP and five exam rooms. Therefore, to gain the delta in resources needed to achieve optimal performance in the FCC, the BAMC leadership needs to examine the possibility of allocating more resources to the FCC (i.e., PCPs, LVNs, and exam rooms). Because of the military's resource-constrained environment, the BAMC leadership may need to redirect resources, initiate resource sharing agreements, or limit enrollment in the FCC to gain efficiency.

As stated earlier, the terminal objectives of this project were to determine resource levels and processes for the FCC that will improve efficiency. Efficiency for this study was defined as decreased patient overall time in clinic, increased patient access (i.e., increased number of available appointments at the 110, 120, and 130 percent level), and appropriate resource utilization (i.e., 65-75 percent of PCPs available time).

As anticipated, the study findings identified several methods to improve the operational efficiency of BAMC FCC, specifically in the areas of access, patient wait times, and resource utilization. By implementing the proposed process and resource changes of the Alternative-Four Models, the FCC can increase patient visits up to 30 percent, decrease patient total time in clinic by ten minutes, and increase PCPs' direct patient care utilization. In turn, these resources and process changes are anticipated to improve the satisfaction of patients with BAMC FCC.

Before this study, BAMC did not have any standard management tool to determine the effect of changes of resource allocation in the FCC. The computer simulation models developed in this study will allow the BAMC executive leadership to evaluate future proposed changes in the clinic in a less expensive, less disruptive, and more timely manner. We recommend that these models be used to further analyze the effect of increasing the number of exam rooms and to evaluate other proposed process changes to increase the use of PCPs for direct patient care and to increase LVNs' responsibilities in the clinic. Likewise the procedures in this study can be used as a guide for completion of future studies of a similar nature in other BAMC TRICARE primary care clinics.

Overall, we recommend BAMC leadership to continue to support the use of computer simulation analysis. The ability of computer simulation to do "what-if" analyses without disrupting present processes and resources is invaluable. However, simulation is a resource intensive process that cannot be accomplished in a haphazard fashion. To effectively use computer simulation as a management decision-making tool, appropriate resources in the form of trained modelers, as well as allocation of time, must be specifically provided to the project under study. Additionally, we strongly recommend that individuals selected for training should be available to conduct simulation studies as a primary duty.

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