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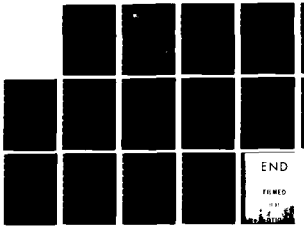

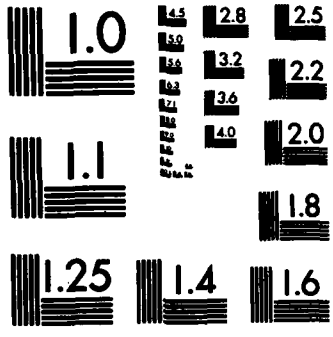


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# AUTOMATED DENTAL EPIDEMIOLOGY SYSTEM: II. SYSTEMS ANALYSIS AND FUNCTIONAL DESIGN

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# AUTOMATED DENTAL EPIDEMIOLOGY SYSTEM: II. SYSTEMS ANALYSIS AND FUNCTIONAL DESIGN

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**Approved and released by:**

**G. E. CLARK**
**Captain, Dental Corps,**
**United States Navy**
**Commanding Officer**

## BACKGROUND

The Navy Dental Corps has been tasked as the lead agency of the Department of Defense to conduct research in oral diseases and dental emergencies (1). Such research has the potential for considerable benefit to the Navy through reduction of dental morbidity levels, especially by reducing the dental emergency experience in operational naval units. Another likely product of such research is the reduction of time and expense required for dental treatment and a minimization of patient time lost from military duties. Navy dentistry can thus be expected to become more cost effective and make a greater contribution to enhanced operational efficiency, readiness and mission performance. To accomplish this, however, will require considerable information which accurately reflects the status of oral health and the nature of dental disease through the naval population.

Developing this kind of information requires extensive use of dental epidemiology. The incidence of caries and periodontal disease continues to be of concern to the Navy Dental Corps. Comprehensive epidemiology information is needed to intelligently plan, direct and evaluate Navy Dental Corps efforts toward reducing the incidence and detrimental effects of caries and periodontal disease in the field and afloat. In this regard, dental epidemiology can be especially valuable for evaluating and improving the Navy preventive dentistry program. It has been recommended that the Navy conduct research in these areas since comprehensive, large scale epidemiology studies are not possible in smaller, non-military populations (2).

A preliminary investigation conducted by the Naval Dental Research Institute found that a fully automated dental epidemiology information system is feasible using presently available technology (3). In this study, the effects of dental emergencies in military forces were summarized, and the potential uses for timely, comprehensive epidemiology information were determined. A review of civilian and military developments in automated data processing applications to dentistry and dental epidemiology was performed. Alternative means to improve military dental epidemiology techniques and information uses were compared.

This preliminary study determined that reports developed on a routine basis would be valuable for local dental clinic management and for regional administration. On a larger scale, the information developed by this system would likewise be valuable to the Navy Dental Corps administration for service planning and evaluation. The information produced by an automated dental epidemiology system, if implemented throughout the Navy, would provide long term treatment information on a large population to evaluate dental materials, devices and treatment techniques. Such information, useful for the advancement of the entire dental profession, would be available to a degree of comprehensiveness and on a scale not obtainable in the civilian sector. An automated dental epidemiology system would also be an excellent data source for a dental management information system (MIS) supporting the Navy Dental Corps in the supply, fiscal, maintenance and personnel areas of administration.

This present study will address the analysis and preliminary design of an automated dental epidemiology system. Systems analysis is a methodical approach to problem solving (4-9). It identifies and evaluates all relevant facets of the organization being studied in terms of impact on operations and performance. The systems analysis method involves the identification and evaluation of

potential improvements through information gathering, consolidation and analytical steps. Once these aspects are understood, the criteria for an optimum automated approach are described as a system requirements specification. The final phase of this study describes a computerized functional design. This is a conceptual overview, or blueprint of the computerized approach which appears to best satisfy the requirements specification. This report will procede from clinically pertinent information in the systems analysis, to a more technically oriented data processing description in the requirements specification and functional design.

A systems analysis was conducted at the Naval Dental Clinic (NDC), Great Lakes, during the first half of FY83. The objective of this analysis was to gather sufficient information to enable a flexible, user-oriented automated information system to be designed and implemented at NDC Great Lakes facilities. Guidelines for the analysis were established by the preliminary investigation. Though intended to be developed within the existing structure and operations of NDC Great Lakes, it was considered appropriate to produce a design that would permit implementation at similar Dental Corps facilities without a major redesign effort. It was deemed imperative that system implementation not adversely affect NDC operations.

The scope of this analysis and design effort was defined by the preliminary investigation to include only those administrative and managerial functions that directly support dental care delivery. Those aspects providing general administrative support, in areas such as finance and supply, are a primary function of a dental management information system (MIS) and are outside the scope of an oral epidemiology information system. Where possible, priority development would be undertaken of those specific applications requested by NDC personnel to directly assist clinical management and operations.

## SYSTEM ANALYSIS METHODS

In this project, conventional systems analysis methods were employed in four phases: information gathering, consolidation and analysis, system requirements specification, and functional design development (4-9).

### 1. Information Gathering

Information was obtained by interview and discussion, direct observation, participation in clinical operations, and review of appropriate documents (5,6,9). Extensive use was made of information obtained in previous data processing projects (10,11). These projects developed specific requests from dental personnel in various operational environments. Input from non-dental personnel in the line community was especially valuable since it represented the desires of the ultimate beneficiaries of improved dental service. Technical assistance was provided by personnel from the Navy Data Automation Facility (NAVDAF), Great Lakes, and from various data processing equipment and service vendors on an as-required basis.

Personnel targeted for interview at NDC Great Lakes included command administrators, clinical managers, key senior enlisted personnel and numerous treatment providers. Both formal and informal interviews and discussions were undertaken, using both structured and unstructured format (8,9,12). The participative, open nature of the unstructured interview and discussion was preferred.

Observations were conducted to characterize clinical and managerial procedures. Information was elicited from those personnel directly performing the procedure, personnel in direct control, and those personnel responsible for performance but not in immediate proximity of the actual operation. Suggestions for improvement of both procedures and information flow were continuously elicited from all personnel. Participatory exercises were performed in the NDC Inprocessing Clinic to obtain an insight into screening examination procedures from the clinician's perspective.

Documents pertaining to clinical operations were gathered prior to and during observations (5,8,9). These documents were used to develop an understanding of clinical and administrative procedures. Extensive reference documentation was maintained. Notes were taken in conjunction with all aspects of information gathering to minimize selective bias and distortion through reliance on memory (8,9,12). Information obtained informally was recorded at the first available opportunity.

2. Consolidation and Analysis

A source information file was developed as the primary analysis resource. Initial material for this file included information developed from previous dental clinic automation projects (10,11). Information obtained during interview, discussion, observation and participation was transcribed and used to continuously update this file. Anecdotal information (that obtained through casual conversation) was included in this file and noted as such. The information in this file was carefully evaluated and updated as subsequent information was obtained (5,6,8,9).

For analysis, the information contained in the consolidated file was organized into a hierarchy according to the precedence:

1. interview/discussion information
2. participatory exercise
3. procedural observation
4. anecdotal information

A comparison of this information versus a review of documentation was then conducted.

Dental service in each of the three main NDC clinics was characterized as groups of procedures, each composed of a group or sequence of individual tasks. Relationships among procedures and tasks within and between clinical facilities were determined. Work distribution, time expenditure and personnel requirements were determined for those existing procedures and tasks within the immediate scope of this analysis. Existing administrative and operational methods were examined to identify the specific improvements desired.

Inprocessing dental examinations were evaluated by timing the component procedures of dental officers during random observations conducted over the course of three months. Screening examination mean times and standard deviations were determined for each task within the examination procedure. A comparison of total examination time was made with that required for the examinations performed in the participatory exercise.

### 3. Requirements Specification

The essential features and operational characteristics for this system were specified as system requirements (7-9). System constraints were determined: these are the mandatory or inflexible processes and functions necessary for clinical operations or the administration of the NDC. Both operational and managerial requirements were determined. The specific categories of operational requirements which were determined included system output, input, data processing functions and the resources needed (8). An additional requirement was established to experimentally test a variety of data entry devices and remote data processing concepts, to simulate remote system operation using intermittent data communications (e.g., afloat and underway).

Attributes were established: these are criteria for the evaluation of the viability of the potential system designs (7-9). These design evaluation parameters were identified and ranked in order of relative importance. A secondary set of attributes was determined as system features which would be desirable if cost-effective.

### 4. Functional Design

The functional design was constructed to provide a conceptual overview of the system. A structured design process was selected to facilitate system design. The overall system concept was established and major component modules were identified. System modules were then arranged to provide a logical progression of information processing from input through output. A functional design was subsequently developed by matching data processing technology to these system modules (4-9).

Sequences of procedures and their component tasks were arranged to handle data flow within the system and to process the desired output information from system input. Types of equipment components available in current data processing technology were evaluated for potential application to the tasks within each identified procedure. Combinations of these component categories were then selected by successive elimination of incompatible or inefficient alternatives (8). The results were sets of system architectures, each being an adequate solution to the problems previously identified.

All of these system architectures were screened using the previously established system requirements. Those designs falling short of specification were discarded. Those selected were then rated according to the established attributes. This rating by attribute listed all architectures in descending order in which the top of the sequence would represent the optimal functional design (7,8).

## SYSTEMS ANALYSIS RESULTS

Background information obtained during the current and previous studies was gathered from Navy dental and line community personnel through interview and discussion (3,10,11). Discussions were undertaken with numerous personnel to develop a broadly based and thorough understanding of the performance desired of an automated dental support system. It was deemed most important to determine what was required of dental service by the operational units, and

then to explore means by which computerization could aid the Dental Corps to better meet those needs. Appendix A lists specific requests, determined through personal interview and discussion with both line and dental personnel, as compiled from the systems analysis consolidated file.

A reference file detailing numerous civilian medical and dental computerized clinical and management systems was assembled (9). This file established current trends in computer applications which are being used to meet the needs of dental service in the civilian community. Additional background information was previously gathered for comparison through discussions with U.S. Army and Air Force dental personnel in Europe, tours of their facilities, and through informal discussions about dental data processing developments with military dental officers from Holland, Germany and Great Britain.*

For the current study, the functional organization of the NDC facilities on board the Naval Base, Great Lakes, is illustrated in Figure 1. These facilities comprise a headquarters building, three large clinics and a prosthetic laboratory with clinical spaces. Dental personnel at the Inprocessing Clinic conduct daily screening examinations, usually on two to four naval recruit companies. Dental treatment for recruits is provided principally at the Recruit Clinic, with some initial treatment provided at the Inprocessing Clinic. Base staff and service school students receive dental treatment at the Mainside Clinic. Prosthetic support for the NDC is provided by the laboratory facilities, where prosthetic specialty care is also provided by the dental officer in charge in a small clinic. Though outside of the scope of this study, dental treatment including oral surgery support is available from the dental service of the Naval Hospital at Great Lakes.

1. The Inprocessing Clinic (Building 1523)

Naval recruit inprocessing examinations, both medical and dental, occur at the start of the recruit training period. All recruits being inprocessed receive a dental screening examination, except those excluded for medical reasons, i.e., active, serious disease such as hepatitis or VD, or other serious medical problem. Typically less than one to two percent of the recruits do not receive their dental inprocessing examination at this time. These recruits usually receive the screening examination at subsequent dental treatment, pending successful resolution of the medical problem. Figure 2 illustrates the general information flow through the inprocessing clinic.

Recruit companies number from 70 to 100 personnel. Companies are usually paired for inprocessing, and with such a group, approximately two and one half hours is required to complete the entire screening procedure. Currently, five dental officers conduct screening examinations. Although there are an additional five examination stations available if needed, experience from past peak inprocessing periods indicates only one additional station is required to meet the higher inprocessing load. Peak inprocessing is usually experienced during the summer months; this amounts to four companies daily, totalling approximately 350 recruits. No increase in this level is currently foreseen.

Dental records are assembled in a preparation room prior to the recruit companies reporting for examination. Standardized record jackets, forms and procedures are used (13,14). A listing of personnel for each company is forwarded

*Discussions with foreign military dental officers at USAREUR and 7th Army Dental Training Conferences 1980-1981, Garmisch, Germany.

to the Inprocessing Clinic from the Recruit Training Command (RTC). This listing is a copy of the computer printout of the recruit company Convening Roster, and contains information subject to the Privacy Act of 1974. This roster is used to identify personnel in the priority treatment groups and to assist records assembly. The standardized dental record form, SF-603, is received from RTC as a continuous form with computer printed recruit identifier information: name, social security number, and other data. Adhesive labels containing personnel identification information are also supplied by RTC to identify radiographs, forms and records. The data used to develop the Convening Roster is key entered at a separate facility into the computerized military personnel system. This data is forwarded to the Navy Data Automation Facility (NAVDAF), Great Lakes, on punched card where it is used to develop electronic files such as used in payroll records.

Preliminary medical history, oral hygiene and oral surgery screening precede radiographs and preventive dentistry instruction. Gross scaling is performed as needed, and recruits are advised of the availability of orthognathic surgery service as appropriate to individual cases. Dental radiographs are taken as determined necessary by the dental officer in charge or the dental officer performing the screening examination. Following the preventive dentistry instruction, the recruits receive a dental screening examination, subsequent diagnostic radiographs as required, and then return to the staging area. The screening examination includes a charting of the patient's existing dental condition on the dental record form SF-603, Figure 3, and making a preliminary treatment plan. The extent of dental caries is noted by classifying the lesion as "A" (minimal), "B", "C", or "U" (urgent) with increasing proximity of caries to the dental pulp.

Following completion of the examinations on the entire recruit company (or pair of companies), patient radiographs and entries on the dental record are reviewed by the examining dentist in a separate treatment planning room. All records are updated as necessary and, as completed, are signed off. Dental records for each recruit company are then sorted, released and forwarded to the Recruit Clinic records area.

Dental treatment is available in the Inprocessing Clinic. Four to five dental officers provide specific dental care in a separate mini-clinic within the inprocessing building. Treatment provided is characterized as general dental care, and is targeted on high priority groups such as recruits destined to enter the nuclear field or submarine service. Patients are selected from those companies just completing inprocessing, or are referred from the Recruit Clinic. The five additional examination operatories are frequently used for gross scaling and dental prophylaxis. With additional staffing and logistical preparation, these could be made available for screening examination or treatment delivery.

Eight dental officers were observed conducting screening examinations. Observations were performed at random times over a three-month period. Each dental officer was found to adapt examination procedures according to professional judgement within established guidelines. In general, the screening examination consisted of the following tasks:

1. review of patient medical history
2. review of radiographs
3. evaluation of overall dental health, recording section 4 of the SF-603
4. examination for dental pathology, recording section 5 of the SF-603

5. citing and recording remarks on the SF-603
6. noting the extent of lesions on a locally generated treatment planning form

Most of the dental officers observed combined several of these tasks into single operations and all performed the actual dental examination as a radiograph review, examination of existing conditions, examination for pathology and remarks. This examination sequence involves two duplicate observations of the dental arches. This method appears to be dictated by convenience in preparation of the two-part format of the SF-603.

The Inprocessing Clinic observations were conducted in two phases. A general observation was accomplished and an informal, open-ended discussion was held while observing the conduct of several screening examinations by each dental officer. When the dental officer and technician were observed to be relaxed in the presence of the observer, timing measurements were performed on three consecutive screening examinations. Table I relates the procedural times required for these examinations; the time ranges, means and standard deviations for each of the component tasks is noted. For comparison, there is also a similar analysis of total examination times as determined by participatory exercise. During interview and discussion, most of these dental officers estimated three and one half minutes were required to conduct a screening examination.

Dental officers regarded the occurrence of error in examination and data entry to be the main cause of time delay in the screening examination process. Errors entered on the SF-603 are typically corrected by the technician at chairside by an application of a white liquid masking agent over the error, with the new examination entry subsequently recorded. Including drying time for the masking agent, time to correct a single error appears to be slightly more than one minute. The technician often procedes and then returns to note the correction -- occasionally requiring the dental officer to return to that tooth to re-examine and call the observation. Dental officers estimated that there was an error rate of at least one event per examination per ten patient sittings. During the 24 timed observations, three examinations exhibited such error corrections. During the participatory exercise, similar errors were detected and corrected in seven of fifty-five examinations. These error rates are comparable to the ten percent rate cited by Pieper, et al. in previous work (13).

In 18 of the 24 timed examinations there were events where error correction was made prior to transcription; this rapid discovery and correction appeared due to a free interaction between the dental officer and the recording dental technician. These dental officers also indicated that during the record review process, there was a 20 to 30 percent change rate for charting entries. For the participatory exercise, entries on 12 of 55 dental records were changed during review, for a 22 percent change rate.

## 2. The Dental Treatment Clinics

### a. Recruit Clinic (Building 1017)

Naval recruits typically receive the greatest amount of specific dental treatment at the Recruit Clinic, midway through the second week of training. There are multiple objectives for this treatment. It is desired that the maximum number of patients receive dental treatment. Furthermore, it is required that

recruits destined to receive nuclear field training or those entering the submarine service complete their course of dental treatment prior to entry into those demanding Service School training programs. These priority patients generally have their dental treatment completed during recruit training. It is mandatory that high quality dental care be provided, especially to prevent future pulpal involvement or debilitating soft tissue pathology (e.g., pericoronitis or periodontal abscess). Therefore it is desired that urgently needed treatment procedures, such as restoration of "U" lesion caries, be accomplished in a timely fashion. Less critical lesions are generally restored concomitantly with those urgently needed, as in quadrant restorative practice.

When received from the Inprocessing Clinic, dental records are sorted, grouped by recruit company, and filed according to the standardized terminal digit practice (14). Prior to the recruit company reporting on board for treatment, the dental officer in charge of the records area reviews each case and establishes a tentative treatment plan. With this triage step complete, recruit dental records are prepared for distribution to the first treatment provider.

Recruits who receive treatment may typically expect from one to three treatment sittings. A higher number of treatment sittings may occur in exceptional or extensive cases, or during non-peak recruit training periods. Recruits generally return their own dental records to the records filing area after completion of treatment. Upon completion of the course of treatment for the company, the recruits are dismissed enmasse to RTC personnel. Dental records are reviewed by the triaging dental officer as a treatment monitoring and verification process for procedural audit control. Patients requiring a recall visit are identified and arrangements made for their subsequent return to the clinic.

b. Mainside Clinic (Building 237)

The principal difference in clinical operations between the Recruit Clinic and the Mainside Clinic is the method of pre-treatment patient management. Where the Recruit Clinic processes patients to treatment as multiple small groups, patients at the Mainside Clinic are scheduled for individual appointments. Both clinics provide comprehensive dental care and provide service to walk-in patients for dental sick call. The Mainside Clinic also operates an extensive preventive dentistry program, with numerous dental screening and annual recall examinations, plus examinations for replacement records, reenlistment, release from active duty and sick-call examinations.

Apart from these differences, patient treatment and information flow through both clinics can be characterized as shown in Figure 4. Thirty-six dental officers are normally assigned to the Recruit Clinic, while typical staffing at the Mainside Clinic is thirty dental officers. Typical treatment times range from 25 to 75 minutes. Some procedures such as extensive periodontal surgery may require more time. Most routine restorative treatment can be accomplished in less than 30 minutes for single restorations. Multiple routine restorations as in quadrant dentistry, or extensive single procedures, e.g., a pin-retained amalgam restoration, are typically completed in 45 minutes to one hour.

3. Information Management

Patient dental records are maintained in centralized files for both clinics. As in many Dental Corps facilities, central record files, scheduling areas and

appointment desks are not located in close proximity to all treatment operatories. In the Recruit Clinic, several passageways and a stairway separate the record files area from convenient access to most clinical spaces.

Upon conclusion of the treatment visit, the treatment procedures are recorded in the patient's dental record. The patient then either proceeds to subsequent dental service or is dismissed for the day. Records are returned to the central files either by the patient upon completion of service for that day, or by the dental officer or technician at various times throughout the day. All records, except when held in charge by the patient, return to and are maintained at the central file area.

Permanent, legible entries using standard notation to describe the services provided are specified for section 17, "Services Rendered", of the patient's SF-603 (15). Handwritten entries made by dental officers, or by technicians at the direction of dental officers, do not always meet these criteria. Considerable variance was observed among dental record entries made prior to and during this study. Typical of such entries are nonstandard notations: using "EXTR" for pulp extirpation, being confused for extraction; "AMAL" for amalgam instead of the standard "AM"; or "REP" for "replaced" where this is standard for "repair". Use of nonstandard surface designations such as "B", "BU", or "BUC" for a facial surface is not infrequently observed. Similar variation was noted among dental officers in the calls made in, and the technician recording of dental examination observations ... typically relating to the morphology of caries or restorations.

Dental record entries are to be made in black or blue-black permanent ink (15). Though use of Federal stock ballpoint pens is widespread, many record entries are made using felt-tipped, cartridge, or fountain pens. Felt-tipped pen entries, as reported by one dental officer during the discussions, were found to "spread" to the point of being illegible when exposed to continuous high humidity as is often found in tropical locations. Entries made using non-waterproof ink are often obliterated with an accidental water spillage on the record sheet.

In visits to dental clinics of the other armed services, use of typewritten entries made by specially trained clerical personnel were observed as a means to obtain legibility and uniformity of record entries. This approach appeared to be most efficient in the single-dentist clinic, where the record entry could be made immediately upon completion of treatment. In larger clinics, especially in those having six or more dental officers, this process is logistically difficult and accounts for considerable delay. Dental officers in these situations are obliged to sign-off their entries early in the day following overnight treatment entry transcription. This procedure increases the potential for missing records. Erroneous, incomplete or missing treatment entry is possible, especially if the dental officer does not clearly remember the specific case from the previous day.

In addition to the treatment entry made on the SF-603, NDC Great Lakes procedure calls for treatment-provided information to be transcribed onto a locally generated daily procedural worksheet. Such worksheets list treatment procedures according to Dental Information Retrieval System (DIRS) codes (16). Entries on the worksheet are listed by patient identification, compiled at the end of the day and used to prepare the DIRS mark-sense document used for procedural reporting (17). Similar procedures are used by dental clinics throughout the Navy.

The fourth item required for daily preparation by the dental officer/technician team is the Uniform Staffing Methodologies (USM) time study source document (18). This worksheet is submitted through the NDC administrative chain for report preparation purposes.

All of these documents are used by the regional administration to provide both an audit trail and as an information source for service evaluation. Such local practices were established in response to the need for more timely, useable and comprehensive information than that available through the DIRS. To accomplish these tasks, a senior enlisted supervisor monitors two dental technicians performing the required data handling tasks on a full time basis. NDC administration makes extensive use of two word processors for this information analysis and for routine office functions.

## SYSTEM REQUIREMENTS SPECIFICATION

The essential features required of this system are derived from its fundamental objectives. These are to provide dental information to clinical managers, regional administrators and scientists. As an adjunct, the system is also required to reduce the load of clerical tasks faced by the dental professional, thus making more time available for treatment delivery. The number of source documents required to be prepared by clinicians is to be reduced to a maximum of two. Information which is to be developed by this system should be produced in a timely manner, i.e., within a brief enough time to enable optimum use in service planning and in command and control functions. For service planning at the Recruit Clinic, a two-week lead time to evaluate comprehensive treatment needs reports from the inprocessing screening examination is to be provided. Overall the information produced should be useful for both short and long range dental service planning and evaluation.

The specific constraints that were identified are:

1. that the system not interfere with the primary mission of the NDC,
2. that no additional personnel be required to operate the system beyond those already performing equivalent manual tasks, and
3. that there be no negative impact on clinical operations during installation, testing or system operation.

System operational characteristics center around the production of user-specified printed reports: these documents to serve managerial, administrative and scientific purposes. Input for this system includes dental examination findings, records of dental service, personnel demographic information and user demands. Data processing functions include data capture, processing and output, and the long-term maintenance of patient data and treatment chronology files. System resource characteristics are moderate on-line and off-line data storage capacity (for the immediate application), efficient processing capabilities for handling approximately 25,000 individual dental records (especially for sort, merge and direct file access functions), and input and output device speeds according to the demands of specific applications. There must also be efficient, reliable and cost-effective data communications, again to be determined according to specific application.

The output requirement for the system is to produce the following:

1. individual, specialized reports on demand
2. low volume, routinely generated reports, e.g., group treatment needs
3. high volume, specialized documents such as dental examination findings, and
4. on-line video display in response to individual record query at selected clinic sites.

The system will therefore require high-speed printers where routine, high volume printed output is needed, and low-speed printers where intermittent or low volume printed reports are to be generated. Printed output should be limited to an 8 1/2 by 11 inch format.

Video terminals, where a high degree of system responsiveness to user demand is needed, are required to have the following characteristics:

1. a monochromatic, diffused light intensity display to reduce screen glare
2. a non-fatiguing screen color
3. a screen that is user-adjustable for viewing angle and position, to be ergonomic and glare-resistant
4. an 80 character by 24 line display
5. easily readable characters on a flicker-free screen
6. a screen image adjustable for both intensity and contrast
7. ability to highlight and/or invert individual characters, words and phrases, and
8. a bell or other sound indicator.

Data input requirements are governed by efficiency and cost-effectiveness, and by the experimental objective to evaluate various data capture devices in a simulated remote operational environment. The primary requirement for data input is to permit a minimum of errors from human action to enter the system. Therefore, the input devices and methods are required to limit the potential for human error, and have a provision for making immediate, on-line error correction. Typewriter keyboard devices will be specified only where required for system control, administrative query or epidemiologic usage. Alternate devices are to be examined experimentally for general data input. All data entry work stations are to have acceptable tamper-proof safeguards for system, equipment and information security. NDC command and administrative personnel are required to have complete access to all facets of the system.

Data processing will be limited to clinical dental applications and those directly supporting clinical managerial functions. The system is required to construct and maintain patient files detailing dental health status. Chronologic files containing dental service provided information are to be developed and maintained. A common file structure is to be used as required for all related applications programs. A commonly used, well standardized, high level data processing language, such as ANS COBOL, is required for the applications programs. These applications programs are to be written in a modular manner, using a structured approach, to enable ease of program maintenance and general comprehension by non-data processing personnel. Where possible, existing and well-proven techniques and algorithms will be incorporated. Extensive statistical analysis and other highly mathematical applications are to be custom written for and performed on self-standing equipment at NDRI.

Electrical utilities for the system are required to be 120 VAC, 60 hz, for all clinical installations. Equipment for these installations must not require environmental control such as air conditioning. Printers are to use readily available 8 1/2 by 11 inches, continuous form paper. Specific applications will require pre-printed forms and/or adhesive labels having a maximum size of 8 1/2 by 11 inches. Synchronous data communications are required; these are to be conducted over common carrier land lines. Where cost-effective for high volume usage, dedicated or private lines operating at 9600 baud (data trasmission rate) are to be used. Keyed switch and password security measures are to be employed for system access.

Hardware (equipment) and software (program) acquisitions are to be limited to well-tested and proven items. Low cost, mature systems are preferred to elegant, "threshold of technology" equipment. Equipment is to be obtained from reputable, stable vendors which can provide highly responsive maintenance. Where critical, high usage equipment is employed, maintenance response within four hours of service request is required. Back-up manual systems are to be kept available in case of need.

There are two primary managerial requirements. First, there is to be a timely availability of information in the form of routine reports and documents prepared on demand. The second requirement is that the system cost less than the value of enhanced dental service made possible by system operation. System life cycle is defined as five years and the system selected should reach a break-even point (BEP) at or before two and one half years.

The primary attributes for the system were determined by ranking the system parameters as:

1. modular equipment organization
2. ease of equipment and program use
3. equipment reliability and serviceability
4. ease of system expansion, and
5. availability of compatible equipment.

Modularity allows for flexible equipment arrangement without detriment to system operation. System expandability allows for potential adaptation to other users and Dental Corps facilities.

Secondary attributes, those to be included in the design if cost-effective, were determined to be:

1. potential for on-line data processing for all input-output stations
2. ability to accept data entry points for individual treatment providers
3. self-contained application program library to allow local program customization, and
4. use of high capacity on-line memory for all applications.

Considering the evolution of technology, the system should be designed to permit easy future inclusion of newly developed features, as they reach maturity and their relative cost decreases to the point of being cost-effective for this system.

## FUNCTIONAL DESIGN

For this system, the overall design concept was established as: a means to obtain a wide variety of dental epidemiology information useable for both service planning, evaluation and clinical management, using both dental examination and service provided data. In this light, several major component modules were identified, following the conventional "input-processing-output" pattern. These modules are the principal functioning units in the system. The major input modules were determined to be an inprocessing examination module, a subsequent examination module, and a treatment provided module. Two major output modules were established as a dental epidemiology reporter, and a custom data reporter. The master processing module would perform the required data handling tasks. Figure 5 illustrates the interrelationship of these modules. Information flow through this system is one-way, from input to output, except for the interactive, bidirectional information flow of the custom reporter.

Numerous combinations of data processing technologies were matched to these modules. The specific approaches which resulted were:

1. on-line multiprocessing via the local data automation facility
2. an on-line microcomputer network
3. numerous independent microcomputer installations
4. multiprocessing using a "top end" microcomputer and terminal network
5. multiprocessing using a minicomputer and terminal network, and
6. contracted service through a commercial local area network.

Various possible architectures for each of the alternatives were devised by selecting appropriate, compatible equipment assemblies. Inefficient and non-cost effective alternatives were excluded.

Several possible architectures for the minicomputer and terminal network were evaluated. All of these alternatives were very costly, ranging from $80,000 to $200,000. For all of these alternatives, a high degree of system responsiveness to user demand was noted, especially in the high volume in-processing examination module. Most of these architectures, however, possessed far more capability than needed by this system; though efficient, these architectures did not appear to be cost-effective.

Contracted service through a commercial local area network, such as Ethernet or Cybernet, was evaluated. Since these networks have no applications programs appropriate for system use, custom program design would be required at an inconvenient location removed from actual operational sites. The programs once developed, would be difficult to conveniently modify as needed for future adaptation. Costs for service, program development and data storage are much higher than that of other alternatives. For this system there also are difficulties in the system control and security areas.

Various networks of on-line microcomputers were evaluated. These machines included various types of personal computers (e.g., Apple, TRS-80, etc.) and small business computers (e.g., Altos). This approach initially appeared promising and much previous developmental work was performed on like equipment (11). This equipment uses the industry standard RS-232 serial interface for data communication through direct connection or by modem operation over telephone lines. Vendor claims for multiprocessing capability were examined. Although

all systems function with the vendor-specified number of users, system response to any single user rapidly diminishes as the numbers of users is increased. These networks are, therefore, inefficient for the workload anticipated in the inprocessing examination module.

By adding considerable expense to the microcomputer network, data acquisition would become more efficient. Such equipment uses a higher capability microprocessor which is able to perform data handling operations at a much greater speed. Microcomputers of this type (e.g., the TRS-80 Model 12 or 16, or the Cromemco System I) can more efficiently handle simultaneous data entry from multiple work stations. These work stations may use microcomputers or terminals for data entry. These units, like the smaller microcomputers, have the drawback of being unable to efficiently process the files containing the large volumes of data expected to be developed by the inprocessing module, in particular, file sorts, merges and direct file access provisions.

The system architecture using terminals and multiprocessing from a large "main frame" computer at the Great Lakes Data Automation Facility meet all system requirements. By using bi-synchronous data communication, response time for data entry operations appears to be satisfactory for the demands of the inprocessing module. All system processing tasks are easily managed by this architecture. For the experimental requirement to evaluate remote data entry devices and techniques, stand alone microcomputer stations having limited data communication to the main computer appear adequate. Likewise, the use of a "top end" microcomputer, installed at NDRI, appears capable of the scientific and epidemiology applications anticipated for this system. Figure 6 illustrates the resultant functional design of the proposed system.

This design provides both tangible and intangible benefits to NDC, Great Lakes, and hence, to the Dental Corps. Estimates of tangible benefits to the Dental Clinic derived from this system are principally the potential for increase in dental treatment productivity and the ability to reassign dental technicians from manual service evaluation tasks to other functions. An economic analysis for this functional system design was conducted (20) and is to be presented as a separate report. This analysis indicates the system break-even point (BEP) will occur approximately one-half year after full implementation. This BEP reflects the point in the system lifetime where the total cumulative dollar value for the tangible benefits of the system, the potential for increased productivity, equals the total cumulative cost of system installation and operation. It is emphasized that this measure is "potential for increased productivity"; this system is expected only to make more treatment time available, not mandate that increased productivity will occur. This break-even point was conservatively determined, using a 20-day work month, a high estimate of system costs, a low-range dollar value for the two-surface amalgam restoration (the productivity standard), and the ability to exploit approximately one-third of the expected increase in available treatment time. Only the value of restorative dental treatment was considered; if the potential productivity increase for other treatment areas is included and the other elements considered more favorably, the BEP analysis becomes even more attractive.

Although the intangible benefits of the system are nearly impossible to accurately quantify, they are expected to have greater long-term impact on and have a much higher qualitative value to the Dental Corps. The foremost intangible benefit is enhanced quality of dental service. By itself, this benefit may likely

outweigh the typical costs of system implementation. Though no dollar value can be assigned to the increased ability to accurately plan dental service well in advance, the benefits of enhanced capability in this area are apparent. By enabling a highly responsive allocation of limited resources to meet the treatment demands of a highly mobile population, this system has the potential for considerable contribution of enhanced dental care for the naval personnel at Great Lakes. Thus NDC professionals can have an expectation to more effectively plan and provide dental service to naval personnel than is possible using current conventional methods.

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Table I. Time Analysis for Dental Inprocessing Examinations
(time in seconds)

| Task | Range | Mean | Standard Deviation |
|---|---|---|---|
| Evaluate radiographs | 8 - 56 | 26 | 14 |
| Gross examination and complete SF-603 section 4. "Missing teeth and existing restorations" | 15 - 272 | 81 | 49 |
| Complete SF-603 section 5. "Diseases, Abnormalities and X-rays" | 25 - 164 | 88 | 45 |
| Complete SF-603 Remarks | 0 - 23 | 13 | 7 |
| Total times for observed examinations. N = 24 (8 groups of 3) | 126 - 445 | 208 | 68 |
| Total times for participatory exercise examinations. N = 55 | 132 - 426 | 212 | 41 |

APPENDIX A: A Compilation of Dental ADP Support Desired by Naval Personnel

## Dental Corps Treatment Providers

1. Treatment efficacy: to improve professional service, e.g., examining the success rates of various treatment methods and techniques.

2. Identification of potential state/regional dental board examination patients.

3. Relative productivity and service efficiency of various treatment areas and techniques for self-improvement.

4. Follow-up of specialty board patients: an interactive "recall on demand", so cases do not become lost.

5. Cephalometric and occlusal analysis methods.

6. Aid to the design of prosthetic devices, e.g., computerized design of removable partial denture frameworks.

7. Patient education, preventive dentistry and hygiene maintenance, automated PCI techniques.

8. Identify possible medication-treatment interactions.

9. Simple means to enter routine treatment, i.e., a single code for often-occurring procedures such as "T/3 Exam, PCI".

10. Aids for forensic identification of human remains.

11. Reduction of the time spent in administrative, non-patient treatment chores, e.g., routine record tasks.

## Dental Corps Clinic Managers and Administrators

12. Provide dental treatment required information:

    a. treatment needs by groups, including priority groups (e.g., nuclear field and submariners)

    b. service planning aid for clinic staffing

    c. treatment needs in terms of time-in-chair requirements

13. Treatment planning for individual patients:

    a. specific treatment needs

    b. health history review and precautions (e.g., rheumatic fever history)

14. Treatment impact on dental health:

    a. for individuals, groups and the occurrence of specific pathologic conditions (e.g., the "U" lesion)

b. changes in dental health profiles (by dental class) for both individuals and naval units served

15. Post-treatment recall by a variable time period specified by dental officer, both short and long term recall.

16. Uniform, standardized coding of all dental treatment provided information.

17. Readily available duplicate dental record, eliminating lost information, for forensic identification when original records are destroyed.

18. A completely electronic dental records system:

a. master record maintained by unit personnel department

b. electronic record maintained by dental personnel

c. individuals on leave or in transit given a "brief sheet" describing current dental status

d. completely standardized system for recording dental conditions for forensics

19. Computer storage of dental radiographs in digital format.

20. Prosthetic service productivity and laboratory output on semi-annual or annual basis.

21. Clinical criteria for interceptive treatment of potentially pathologic conditions (e.g., partially erupted mandibular third molars) to prevent future dental emergencies.

22. A dental sick call profile, listing diagnosis, etiology, and treatment provided information, to improve preventive measures and treatment technique, and prevent emergencies.

23. A means to match appointment time to individual dental officer skills.

24. A uniform means to interpret and evaluate treatment procedures for all treatment providers.

25. A means to obtain a single, clear audit trail, completely secure and free from errors.

26. An individualized dental recall notification.

27. Daily or weekly summary of clinic utilization to enable responsive control:

a. patients appointed

b. failed appointments and late cancellations

c. stand-by patients treated

d. include items like dental officer time lost to leave, training, administrative duties, etc.

28. Dental treatment productivity as a comprehensive report by dental officer, clinic and region on a monthly or quarterly basis:

a. numbers of patients appointed

b. numbers of patients treated

c. types and numbers of procedures accomplished

d. treatment provided valuation (DIRS equivalent)

29. A method to determine supply expenditures per amount of treatment provided, to use as a planning aid for the region and for individual clinics.

30. Dental productivity as a function of the availability of chairside support personnel.

31. A summary monthly report of cumulative productivity for clinics, e.g., fiscal year to date.

Navy Line Community

32. Advisement about personnel who may negatively affect mission performance:

a. personnel in urgent need of treatment

b. personnel undergoing long term treatment where deployment may cause complications

33. Identify personnel that may jeopardize mission:

a. immediate post-dental treatment condition (third molar extraction)

b. possible dental emergency

34. A deployment and mission planning aid:

a. identify personnel in treatment or in need of treatment

b. summary or dental profile of units

35. Target critical skill or reliability personnel and maintain them in top dental health, free from distraction or incapacitation from dental problems (command, key tactical, nuclear weapons, aviation and submarine personnel).

36. Identify personnel needing treatment early, prior to deployment preparation phase so required treatment will not interfere with military duties, and all post-treatment problems will be resolved prior to deployment.

37. Determine the amount of time personnel need for treatment, to plan daily assignments and watch bills, and to optimally schedule service school students

38. "I want NONE of my people to blow a mission or miss any duty because of a dental problem which could have been treated earlier." -- an air squadron Executive Officer

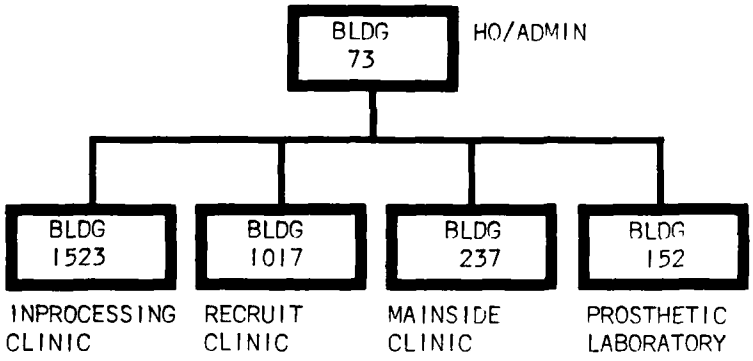



**FIGURE 1. Functional Organization of NDC Great Lakes**

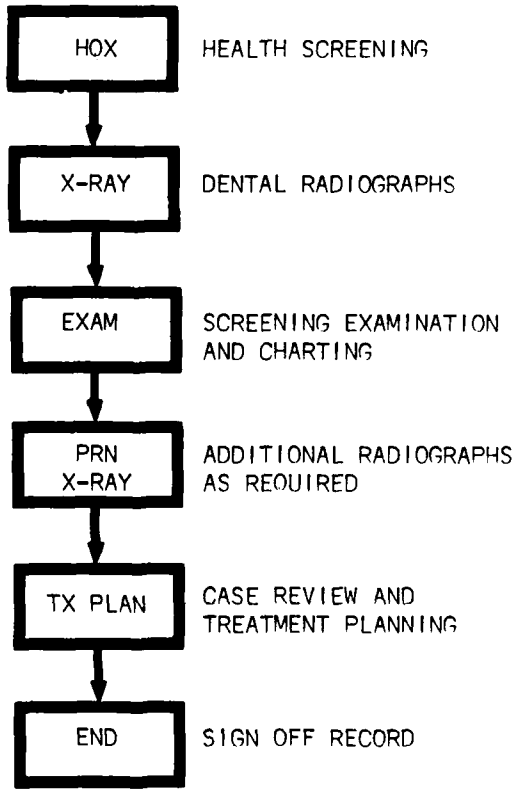



**FIGURE 2. Patient-Information Flow through Dental Inprocessing**

# FIGURE 3. Standard Dental Examination Form

**HEALTH RECORD** | **DENTAL**

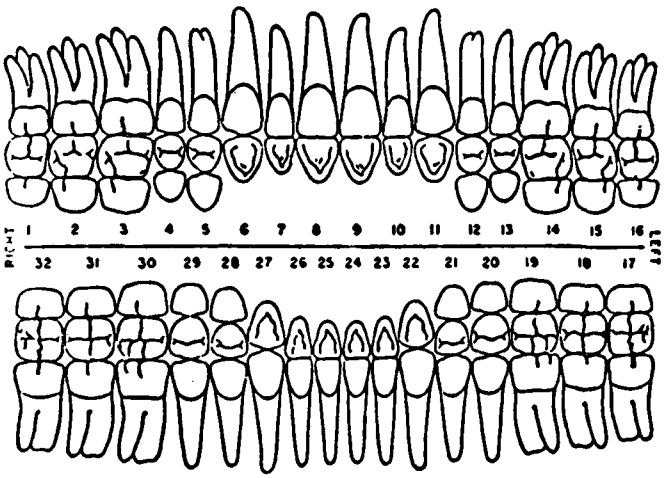
## SECTION I. DENTAL EXAMINATION

1. PURPOSE OF EXAMINATION: INITIAL | SEPARATION | OTHER (Specify)

2. TYPE OF EXAM: 1 | 2 | 3 | 4

3. DENTAL CLASSIFICATION: 1 | 2 | 3 | 4 | 5

4. MISSING TEETH AND EXISTING RESTORATIONS

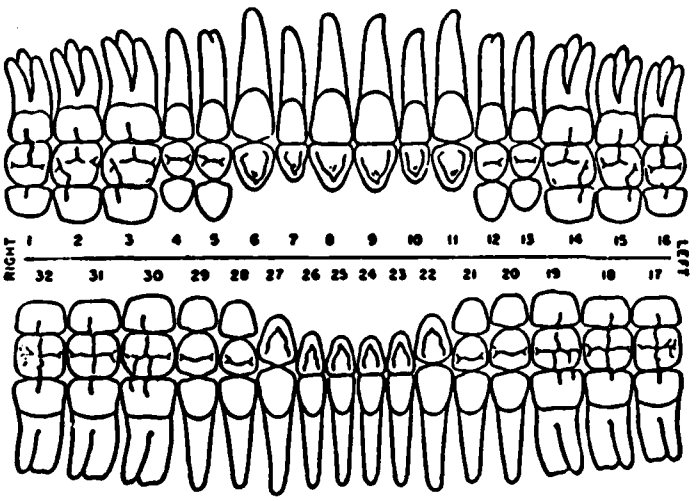



REMARKS

PLACE OF EXAMINATION | DATE

SIGNATURE OF DENTIST COMPLETING THIS SECTION

5. DISEASES, ABNORMALITIES, AND X-RAYS




A. CALCULUS: SLIGHT | MODERATE | HEAVY

B. PERIODONTOCLASIA: LOCAL | GENERAL; INCIPIENT | MODERATE | SEVERE

C. STOMATITIS (Specify)

GINGIVITIS | VINCENT'S

D. DENTURES NEEDED (Include dentures needed after indicated extractions)

| FULL | | PARTIAL | |
|---|---|---|---|
| U | L | U | L |

ABNORMALITIES OF OCCLUSION—REMARKS

E. INDICATE X-RAYS USED IN THIS EXAMINATION

FULL MOUTH PERIAPICAL | POSTERIOR BITE-WINGS | OTHER (Specify)

DATE | PLACE OF EXAMINATION

SIGNATURE OF DENTIST COMPLETING THIS SECTION

## SECTION II. PATIENT DATA

| 6. SEX | 7. RACE | 8. GRADE, RATING, OR POSITION | 9. ORGANIZATION UNIT | 10. COMPONENT OR BRANCH | 11. SERVICE, DEPT., OR AGENCY |
|---|---|---|---|---|---|
| | | | | | |

| 12. PATIENT'S LAST NAME–FIRST NAME–MIDDLE NAME | 13. DATE OF BIRTH (DAY-MONTH-YEAR) | 14. IDENTIFICATION NO. |
|---|---|---|
| | | |

DENTAL
Standard Form 603
603–102–01

M-2498-A (3/69)

AM 333-A

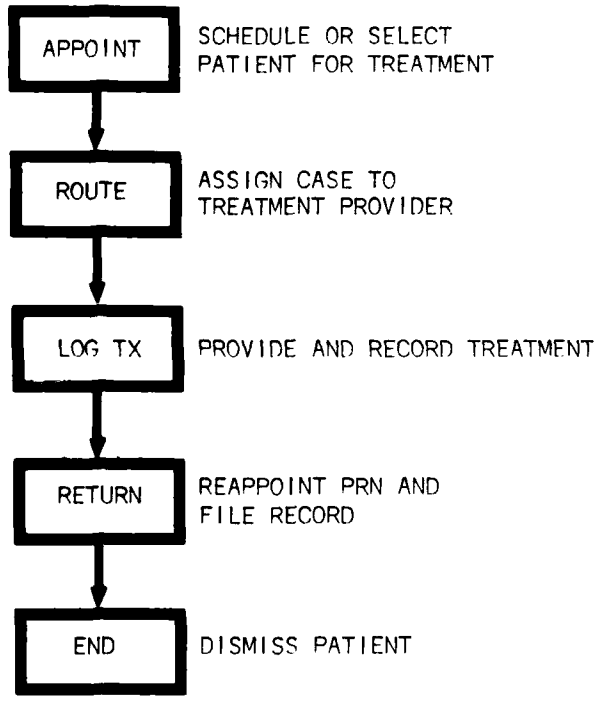



**FIGURE 4. Information Flow During Dental Appointment**

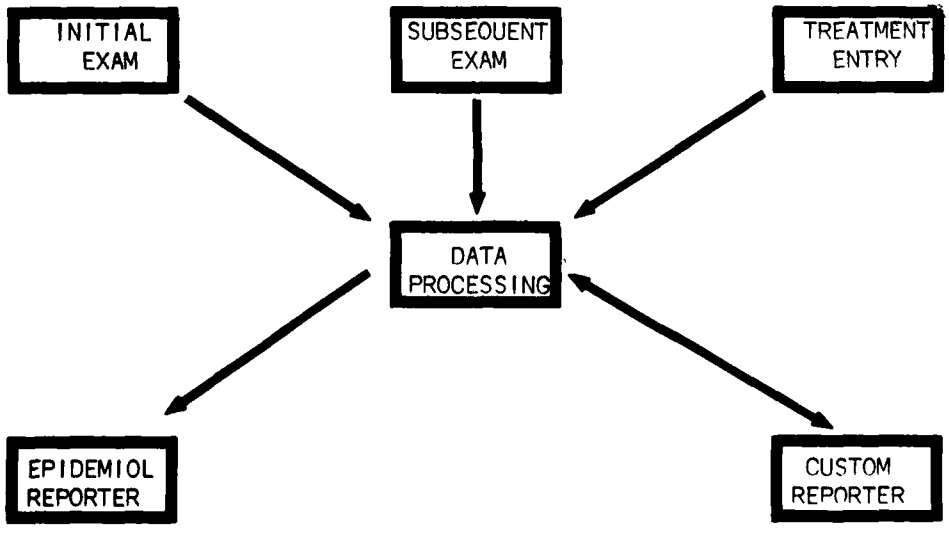



**FIGURE 5. Main System Modules**

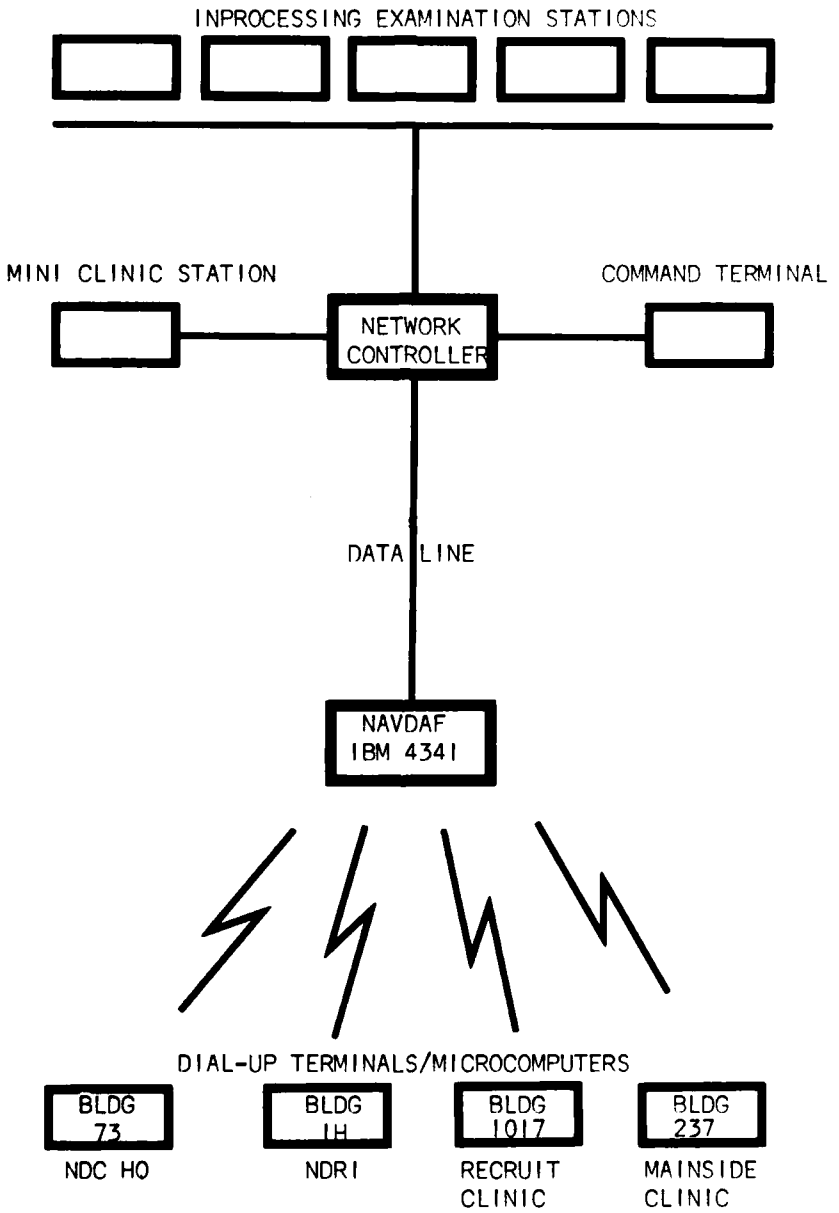



**FIGURE 6. NDC-NDRI Great Lakes Dental Epidemiology System Functional Design**

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A systems analysis was performed to enable the design and implementation of a dental epidemiology information system at the Great Lakes dental facilities. Appropriate information was obtained from Dental Corps command and staff personnel, consolidated and analyzed. Systems requirements were specified and a functional design was developed. This system design included a remote terminal network at the recruit inprocessing facility and sufficient stand-alone microcomputers to provide follow-up dental treatment information. A preliminary economic analysis indicated a break even point for this approach.

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