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Designing Selection Tests for the Future National Airspace System Architecture

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16. Abstract

Empirical data describing the mix of human abilities required to operate and maintain the future National Airspace System (NAS) architecture are presently lacking. A research program is proposed to develop the scientific tools and collect data to describe and assess the mix of abilities likely to be required of future Federal Aviation Administration air traffic control specialists, electronics technicians, and transportation system specialists. The first phase of the proposed research program is to develop a baseline profile describing the skills, abilities, and knowledge required to use, operate, and maintain the current NAS architecture. The second phase of the program is to develop and apply scientific tools to identify changes in personnel selection requirements in parallel with air traffic control and maintenance systems development. The third step in the research program is to develop, validate, and deliver new personnel selection technologies to reflect the human ability and performance needs of the future NAS architecture. The research program is designed to provide agency managers with the selection tools needed to manage personnel costs, inevitable generational change in the technical workforces, and technological innovation in air traffic control and maintenance systems.

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Designing Selection Tests for the Future National Airspace System Architecture

What abilities will be required of controllers to operate and maintain the air traffic control/management (ATC/M) systems of the future? Cole suggested that the ATC/M systems of the future "will require individuals with a different mix of abilities than what is needed today" (1995, p. 47). Similarly, the National Research Council recently suggested that different abilities, or a different weighting of abilities, might be required under different forms of future automation (Wickens, Mavor, & McGee, 1997, p. 68). However, empirical data are presently lacking to describe the mix of abilities required to operate and maintain the emerging National Airspace System (NAS) architecture, as described in the *National Airspace Architecture version 2.0* (FAA, 1996). The goal of the Civil Aeromedical Institute (CAMI) Training and Organizational Research Laboratory's future selection research program is to develop scientific tools and collect data to describe and assess the mix of abilities likely to be required of future controllers, technicians, and systems specialists.

This development of the tools and data to identify and assess abilities required to operate and maintain the future NAS architecture is needed to maintain a high quality workforce in the FAA's safety-related occupations. The development of these tools will occur within the context of three important trends. First, as noted in the *National Airpsace Architecture version 2.0*, "Personnel costs are the main drivers of O&M (Operations and Maintenance) funding" (p. 2-89). For example, personnel costs account for the bulk of expected O&M funding from 1998 through 2015 (Figure 2.2.4-3, "Proposed architecture O&M costs and expected available O&M funding," p. 2-11). Personnel will account for almost 100% of the available Office of Management and Budget (OMB) expected passback of about $4 billion for O&M by the year 2015, according to the NAS architecture document. Cumulative personnel costs between 1998 and 2015 may well exceed $50 billion, dwarfing total investment in procuring the hardware, software, and services comprising the NAS. Putting the right people into the jobs of using, operating, and maintaining the NAS through efficient and effective personnel selection is one relatively inexpensive management tool for maximizing the agency's return on what may well be a significant national investment.

Second, there will be a generational change in the ranks of controllers, technicians, and systems specialists as current employees reach retirement eligibility and are replaced by a new generation. That process has already started in the ranks of field maintenance technicians, as shown in Figure 1. By the year 2002, according to available Airway Facilities demographic data (Airway Facilities, 1992), about 46% of the current field maintenance workforce will be eligible for retirement; reasonably one would expect an even greater proportion of the current generation to reach retirement eligibility beyond 2002. Even with staffing reductions and reorganization, significant numbers of new technicians will likely be required. This demographic trend is echoed in the ranks of controllers, as the post-strike generation begins to reach retirement eligibility starting around 2005 (Figure 1). By the year 2020, approximately 80% of the post-strike generation of controllers will be eligible for retirement. As a consequence, the agency will need reasonable and job-related tools to select the few from among the many applicants who have the "right stuff" to become the operators, maintainers, and managers of the emerging NAS architecture.

Third, new ATC/M technological innovations will be entering service in the NAS at about the same time this generational change is occuring, as shown in Figure 2. For example, the consolidation of Airway Facilities Maintenance Control Centers (MCCs) into 9 Operations Control Centers (OCCs) under the National Infrastructure Management Systems (NIMS)

Figure 1
Estimated proportion of FAA
technical workforce reaching retirement eligibility

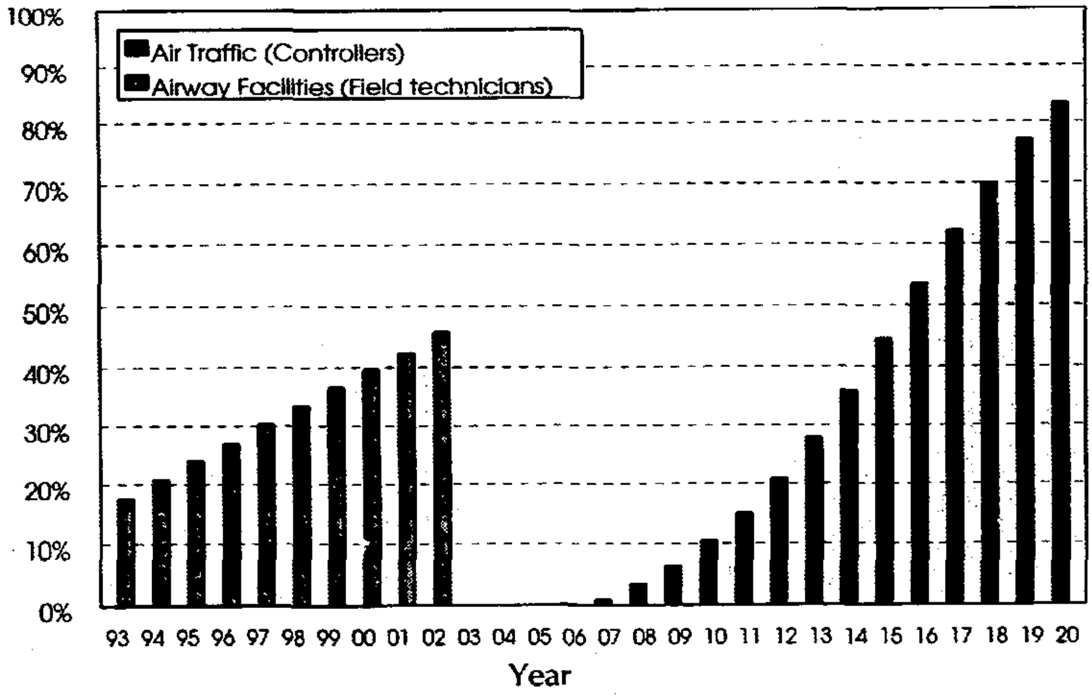
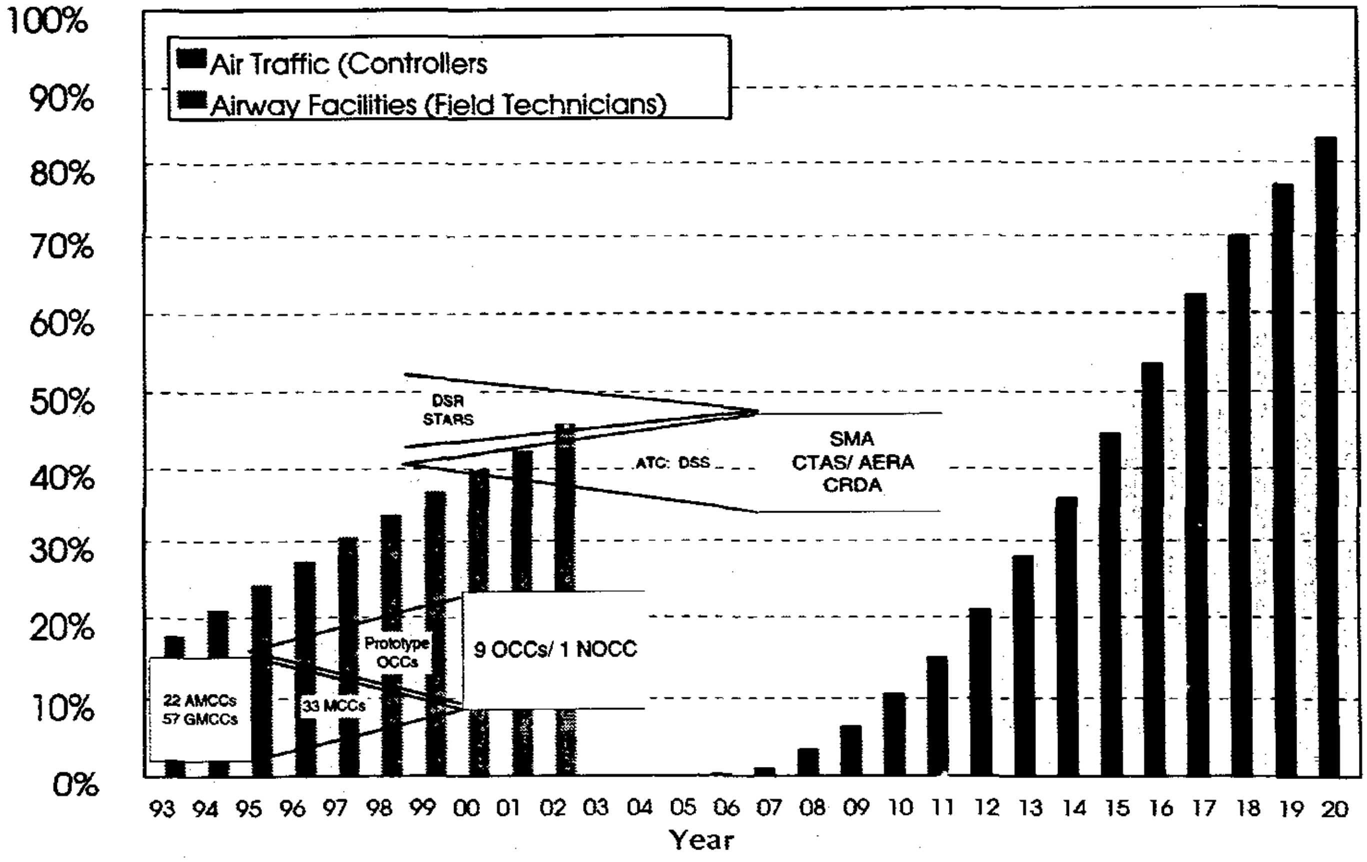


Figure 2
ATC/M technology programs overlaid
on top of FAA technical workforce retirement eligibility trends



project will occur just as the proportion of retirement eligible field technicians reaches about 46%. A new *ATC/M infrastructure will be developed through the* ARTCC Display System Replacement (DSR) and terminal Standard Tower Automation Replacement System (STARS) programs through the turn of the century. New ATC/M decision support systems (DSS) will be developed during the same time period, as the post-strike generation of controllers continues to age. Controller retirement eligibility will begin to rise at about 2005, just as these new DSSs are supposed to be integrated with the DSR/STARS infrastructure (Figure 2). The operational concept known as "Free Flight" will frame these technological changes. Selecting the next generation of controllers and systems specialists to operate and manage the new ATC/M systems in the Free Flight environment will be an important management task that will have profound effects on the safety and efficiency of the future NAS. The tools and processes to be used by agency managers to select the future NAS workforce must reflect the human ability and performance requirements of the emerging ATC/M architecture.

These three trends — the overwhelming cost of staffing the NAS, the inevitable generational changes in controller and technician workforces, and the continuing introduction of new ATC/M technologies to support the "Free Flight" concept of operations — define a research requirement to identify the personnel selection requirements associated with the evolving NAS architecture. That is, these inescapable facts of cost, generational change, and technological innovation, force the agency to confront the question, "What is the mix of abilities required to operate and maintain the emerging NAS architecture?" The Civil Aeromedical Institute's (CAMI) Training and Organizational Research Laboratory research program on future selection proposes to address these issues in three phases.

First, the FAA's research program will develop a baseline profile describing the abilities required to use, operate, and maintain the current NAS. Second, the research program will develop and apply scientific tools to identify changes in selection requirements in parallel with ATC/M systems development. Third, the research program will develop, validate, and deliver new personnel selection technologies to reflect the human ability and performance requirements of the emerging NAS architecture.

Current baseline

A baseline profile of abilities required of controllers to operate the current NAS was developed by the job analysis phase of the Separation and Control Hiring Assessment (SACHA) procurement in late 1994 (Nickels, Bobko, Blair, Sands, & Tartak, 1995). That analysis of the terminal, en route, and flight service air traffic control specialist (ATCS; GS-2152) job described baseline en route Host Computer System (HCS), terminal Area Radar Terminal Service (ARTS), and Model I Automated Flight Service Station (AFSS) job duties and functions. The SACHA job analysis also identified the abilities required for successful performance in each environment.

Development of a baseline profile of Electronic Technician (ET; FG-0856) and Transportation Systems Specialist (TSS; FG-2101) job duties, functions, ands abilities has been proposed for FY 1997 using FAA research, engineering, and development (RE&D) human factors funds. Booz, Allen, Hamilton conducted an analysis of the ET knowledges and skills required to maintain specific NAS equipment and systems in 1993. However, that analysis did not describe the ET or TSS jobs as a whole in a way technically or legally suitable to support the development of personnel selection procedures under the **Uniform Guidelines on Employee Selection Procedures** (29 CFR 1607). A new baseline analysis will provide a starting point for identifying changes in, or new, ability and performance requirements associated with programs such as the National Infrastructure Management System (NIMS).

Identifying changes

The next element of CAMI's Training and Organizational Research Laboratory selection program is to identify changes in job duties and human performance requirements. The continuing research, development, and introduction of new technologies into the ATC/M environment creates an impression of rapid change in the job. Some technologies being introduced, such as the planned Display System Replacement (DSR) seem largely incremental in nature, and appear unlikely to dramatically change the nature, structure, or activities of the controller's job. Other technologies, such as the User Request Evaluation Tool (URET), Center-Terminal Automation System (CTAS), Automated Enroute ATC (AERA), and other decision support systems may substantially change the nature, structure, and activities of the controller job. The development and implementation of the Operational Control Center (OCC) concept for management of the NAS infrastructure may similarly have a profound effect on the nature, structure, and ability requirements of the technician and system specialist job.

Given the 2 to 3 year lead time between selection and certification of a person as a full performance level (FPL) controller, technician, or systems specialist, the agency cannot wait for these new ATC/M technologies to emerge from the RE&D cycle to develop and field new selection tests. FAA tests should be fielded prior to implementation of the new technologies to assure a flow of qualified personnel into the training and development pipeline. The analyses to identify changes in, or new, predictors and criteria should be conducted in parallel with systems development.

To support the early development of new selection instruments, a methodology for analyzing the selection-oriented requirements of ATC/M systems in various stages of the acquisition cycle is needed. As one might expect, the type, amount, and quality of information available about a proposed system varies directly with the system's developmental stage. For example, the only information available early in the acquisition cycle might be a high-level requirements analysis and the relatively global concept of operations for fulfilling those requirements. Specific technological solutions might be developed in successive iterations. Information available with each iteration of the systems design process might include more detailed functional requirements, data specifications, human-computer interface and interaction specifications, system integration plans, and implementation/transition plans. Cognitive and other task analyses may be developed as part of the iterative systems development cycle. It may be possible to develop a model of how a proposed ATC/M system will be incorporated into the controller, technician, or system specialist job on the basis of these documents as the system moves through the development cycle.

Practical methods do not currently exist in the selection psychologist's tool kit for analyzing systems under development to forecast their human KSAO requirements. Most, if not all, currently available job analysis techniques used in applied settings to support personnel selection test development and validation are intended for use with relatively stable jobs that incumbents are already performing. Available methods are ill-suited for analysis of the requirements of new systems (Schneider & Konz, 1989). Methods such as "strategic job analysis" (Schneider & Konz) have not found wide application because they have been difficult to use in applied settings. Also, they may yield less information than is desirable for designing new selection systems (Manning & Broach, 1992). Factors such as the amount of information available about the new ATC/M system and compositon of subject matter expert (SME) panels appear to significantly influence the results obtained from a "strategic job analysis."

Traditional job analysis methods are focused on discrete tasks, rather than on business processes as the unit of analysis (Cascio, 1995). Moreover, traditional job analysis methods do not typically take into account team work requirements (Salas, Dickinson, Converse, & Tannenbaum, 1992; see also Dieterly (1988) for a review on team-oriented job analysis). Traditional job analysis techniques are also poorly suited to the description of the covert, cognitive, or information processing-based elements of jobs (Hogan, Broach, & Salas, 1991). Finally, job analysis has typically been a "one-shot" affair. Rarely, if ever, are job requirements evaluated on an iterative basis to determine if there are any important changes in either the profile of abilities underlying successful performance or the definition of successful performance. The "shelflife" of a competently done selection test validation study is about five years (Lefkowitz & Gebbia, 1995), suggesting a requirement to reevaluate job requirements on an iterative basis. A job analytic methodology that can be used iteratively in parallel with ATC/M system design, development, and operational evaluation, is required to meet the three challenges of cost management, generational change, and new technologies. This methodology should identify changes in, and new, controller KSAO requirements as the basis for future selection systems. Such an analytic methodology would take into account the continuous process nature of the controller and systems specialist functions as well as team work requirements.

CAMI initiated the first phase of the development of a tool or methodology for strategic job analysis at the beginning of FY 1997 (see Caliber Associates, 1996). The prototype methodology is expected to be available by the end of FY 1997. The selection research program then calls for testing and refining the strategic job analysis tool on selected systems at various stages in the development cycle (concept, prototype, and operational test and evaluation) in FY98. The goal is to then apply the methodology to other systems described in the *National Airspace System Architecture version 2.0* (FAA, 1996), in parallel with the evolution of the NAS. From those iterative analyses, new, changed, and continuing selection requirements can be identified to serve as the basis for the evolution of agency recruitment and selection programs.

Developing future tests

The final major component of the FAA's selection research program is the development and validation of the actual tests, criteria, and procedures for selecting the next generation of controllers, technicians, and systems specialists. Flexible, living, and dynamic, data-driven recruitment and selection systems are envisioned, rather than the static, monolithic processes of the past. New tests will capitalize on the open systems architecture and multimedia capabilities of personal computers and networks. New testing technologies currently under development by CAMI include (a) variable-item generation for knowledge and skill-based tests, (b) simulation-based assessment of ability, and (c) simulation-based assessments of team work.

The research on variable-item generation addresses the issue of test security. The objective is to develop a process to generate multiple versions of any single test item, within defined parameters, in such a way that each examinee is presented with a unique item. This technology can be coupled with computerized item banking and scoring to support computer-adaptive testing. In computer-adaptive testing, items are drawn from a pre-calibrated pool in just sufficient numbers to accurately assess the candidate's knowledge or skill in a specified domain. Rather than all examinees getting the exact same number of items, some may get more or fewer items, based on mathematical algorithms for estimating ability from item responses. A test using both technologies would present each examinee with the minimum number of unique examplars of a class of items just sufficient to accurately assess the candidate's knowledge in that area. The end product of the technology development is a secure, cost- and time-efficient test.

The second testing technology under development by the FAA is based on the use of work samples as simulation-based assessments of abilities. The first generation of simulation-based tests for air traffic control selection included the Multiplex Controller Aptitude Test (MCAT) and the FAA Academy ATCS Nonradar Screen. The second generation of performance-based aptitude testing was represented by the computerized work sample known as the Air Traffic Scenario Test (ATST; Broach & Brecht-Clark, 1993). Issues of measurement reliability, construct representation and nomothetic span in complex work samples such as the ATST need to be researched to draw meaningful inferences from scores generated by this class of performance-based tests. Other research issues that need to be addressed include the identification of what aspects of the job are to be represented in the work sample or simulation, the influences of previous computer and video game experience, training, and performance strategies.

The third testing technology under development by CAMI is based on the use of simulation to assess teamwork. Teamwork has only recently been recognized as an important aspect of human performance in the NAS (FAA, 1995). For example, coordination was cited as a causal factor in 15% of 1,038 low-to-moderate severity operational errors in the NAS between 1988 and 1991 (Rodgers & Nye, 1994). Coordination errors were cited as causal factors in operational errors of greater severity more often than other causal factors such as misuse of displayed radar data (Rodgers & Nye). A recent evaluation of operational errors across the 21 ARTCCs in the contintental

United States pointed toward other teamwork failures as contributing factors in the recent operational error rate trends (Kirk, Mayberry, & Lesko, 1996; Mayberry, Kropp, Kirk, Breitler, & Wei, 1995).

There is a significant gap in the general and ATC/M human factors scientific literature and data concerning team behaviors and their impact on system safety and efficiency. Moreover, the team or group performance literature is both large and fragmented, with many idosyncratic definitions and operational representations of "team," "team performance," and "team work" (Driskell, Hogan, & Salas, 1987; Driskell, Salas, & Hogan, 1987). Teamwork is a very active area of scientific research, with no standardized methodology for the assessment of behaviors. Many of the assessment instruments currently available to assess "team work" (however defined) were developed more on the basis of the researcher's intuition, rather than formal empirical analysis (Michaelson & Baker, 1995). The majority of studies in the "team" literature focus on describing teams and attitudes toward teams rather than behavior within the team (Michaelson & Baker).

The focus of CAMI's Controller Teamwork Evaluation and Assessment Methodology (CTEAM) research task is to develop a prototype computerized tool for the assessment of team work behaviors (Bailey, Broach, & Enos, 1997). CTEAM provides a simulated multi-player radar-based ATC environment that requires cooperation and coordination between players to accomplish the goal of getting the aircraft within the scenario to their destinations safely and efficiently. However, that simulated multi-player environment also may provide a basis for constructing a process or procedure for the selection of persons who work well in teams. Moreover, the general model of CTEAM may be translated into the collaborative, shared decision-making environment characterizing the emerging Operations Control Center (OCC) concept.

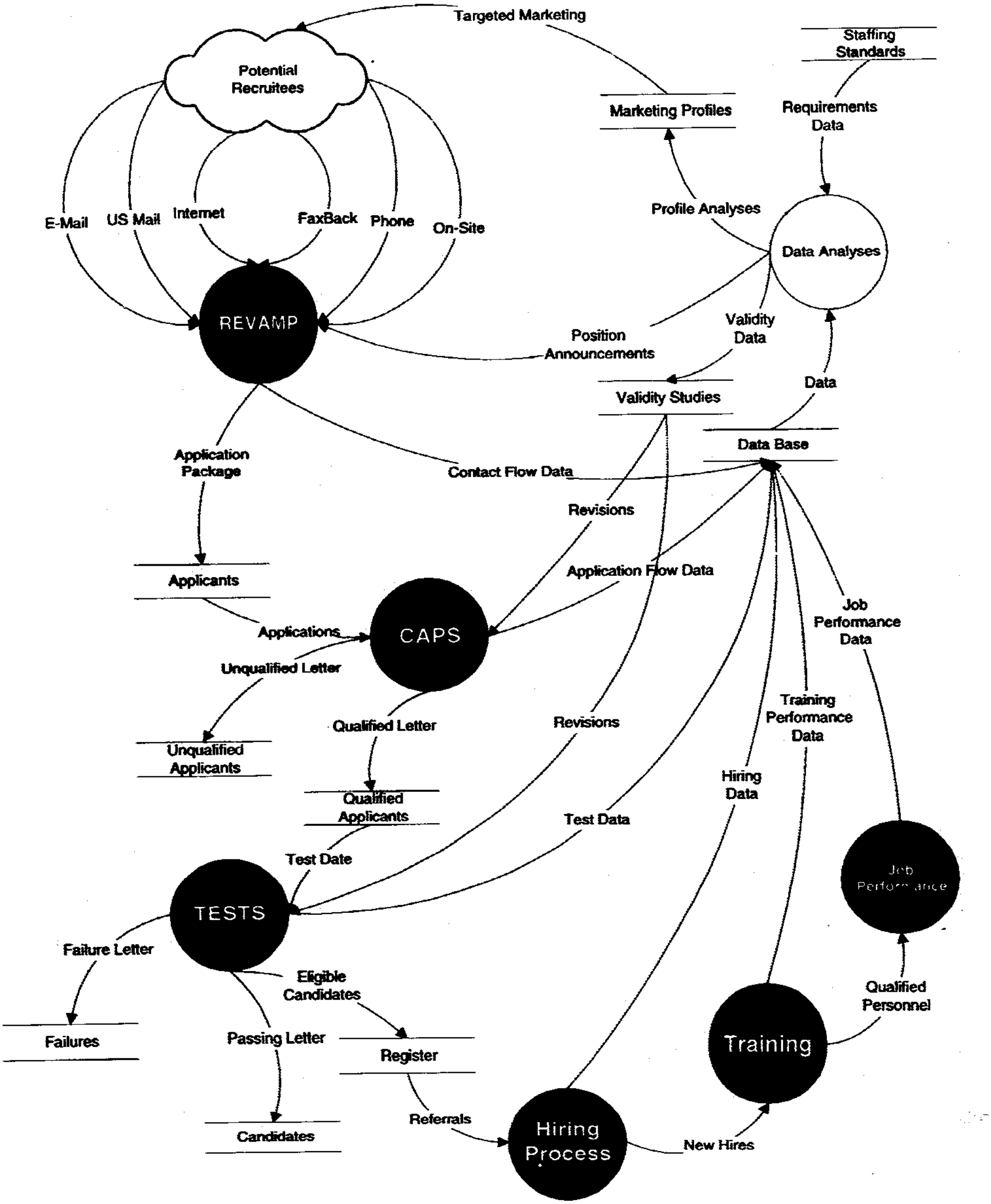
Planned work by CAMI will focus on the extension and elaboration of these three basic concepts — secure and efficient knowledge and skill tests, simulation-based assessment of abilities, and performance- or simulation-based assessments of team work — to support development of new modules to add to the controller, technician, and systems specialist selection processes. Other personnel selection technologies such as automated training, education, and experience rating and ranking algorithms, as prototyped in FY 1996 for the FG-0856 [Electronics Technician] occupation, will also continue to be refined and extended.

Implementation

These new selection technologies will be developed within a framework analogous to the "plug and play" model for adding hardware to a personal computer under Windows 95®. That is, new test modules will be developed under a common software interface so that the modules can be easily added to the assessment system to reflect new or changed knowledge, skill, ability, or performance requirements in an occupation. At the same time, new measures of job performance would be developed to serve as validation criteria for the new tests. Rather than mammoth, painful validation studies involving hundreds of controllers, smaller, more focused validation studies relating specific tests to specific criteria might be conducted using sophisticated statistical techniques such as bootstrapping and/or resampling where technically and legally feasible. The focus would then shift to longer-term evaluation of the relationship between predictors and job performance measures over time, to identify those measures that are most efficient and useful, and those whose predictive utility is declining as the occupation changes.

This approach requires the creation of an integrated recruitment, selection, training, and job performance data collection and analysis system. One possible configuration is presented in Figure 3 as an example of the kinds of data linkages needed to support the development of selection systems by evolution, rather than revolution. In this integrated system, potential recruitees use the Remote Vacancy Announcement for Merit Promotion (REVAMP) system to obtain information about job vacancies in the FAA, via any one of several information channels, such as the Internet, phone, and on-site recruitment visits. REVAMP generates an application package as requested. The applicant then submits the application to the Computerized Applicant Pools (CAPS) system for initial evaluation and screening. CAPS provides an automated rating of training, education, and experience, and ranks candidates relative to the require-

Figure 3
Example integrated recruitment and selection process



ments of the position to be filled. Qualified applicants receive the appropriate letter, and if required, notification of the procedure, date, and location for formal occupational testing. For example, an applicant for the GS-2152 ATCS occupation might be screened for basic qualifications under CAPS and told to report for further testing at a local facility or contract testing site, such as a junior college. Candidates passing any formal tests would then be placed on a centralized register under personnel reform for referral to hiring authorities. New hires would then be scheduled for required training (advanced placement examinations might be used to place new hires into "true need" training only). From there, the trained personnel would move on to the job.

A key piece of this infrastructure would be a data base to track contacts, application data, and examinee scheduling and test scores for equal employment opportunity (EEO), validation, cost, and other management purposes. Hiring, training, and job performance data would also be tracked in the data base to support a variety of data analyses. Analyses might include application and testing validation studies to identify revisions to employment criteria. They could also include analyses of the background, ability, training, education, and experience profiles of successful candidates at each stage of the recruitment-selection-training-job pipeline to develop targeted recruitment profiles. Development and implementation of such a comprehensive feedback system is absolutely critical to the management of the three challenges of workforce generational change, technological innovation, and fiscal constraints after the turn of the century.

SUMMARY

The FAA is pursuing a three-phase approach to identifying the human abilities and performance requirements of the emerging NAS architecuture under the Selection and Training thrust described by the 1995 *National Plan for Civil Aviation Human Factors: An Initiative for Research and Application* (FAA, 1995). The first phase is to develop a baseline model of the jobs of our technical workforce in the current NAS architecture. The second phase is to develop and apply tools for identifying changes in or new human ability and performance requirements in parallel with ATC/M systems development. The third phase is to develop, validate, and deliver innovative personnel selection instruments that reflect the human ability and performance requirements of the future NAS. The program is designed to provide agency managers with the selection tools needed to assure a high quality workforce and to manage personnel costs, generational change in the technical workforce, and technological innovation.

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